THE EFFECTS OF INBREEDING ON THE SOCIAL BEHAVIOR OF CHICKENS

by

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B. S., Kansas State University
of Agriculture and Applied Science, 1960

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Poultry Science

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1963

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INTRODUCTION

Social organization within flocks of chickens has recently been the subject of many investigations. Recent changes in management and more effective skills and techniques in poultry breeding have centered interest in poultry behavior. Reports show that certain aspects of social behavior influence egg production. Undesirable types might be unintentionally produced; for example, strains might be highly combative or have such a low sex drive as to influence fertility.

Methods for studying the social organization of small flocks of chickens have been devised and are reported in the literature. The basis of these methods for determining social organization is the aggressive behavior of the birds composing the flock. Birds display this behavior by pecking, threatening, or avoiding other birds in paired interactions. The birds may be arranged in an order according to the number of birds pecked. This ranking of despotism forms a dominance order or peck-order. A number of factors may be involved in success or failure resulting from encounters between two birds. Some of these factors are the weight, age, familiarity of environment and state of health of the bird.

The purpose of this study was to determine the effect of inbreeding on the development of aggressive behavior in chickens. It is known that inbreeding has a general depressing effect on the development of traits of fitness. Experiments were designed to study the effects of inbreeding on the development of aggressive behavior and possible associations with certain other traits. The variables studied in males were the number of encounters won, encounters initiated, encounters with no outcome, and age at sexual maturity. In females the characteristics studied were percentile social rank, age at sexual maturity and percentage hen-day egg production.

REVIEW OF LITERATURE

Inbreeding and its Effects

Lush (1945) defines inbreeding as "the mating of animals more closely related to each other than the average relationship within the population concerned". Such matings tend to increase the homozygosity of the offspring. The increase in homozygosity is best measured by the inbreeding coefficient F. It was first defined by Wright (1922a) as "the correlation between uniting gametes". Lerner (1958) defines this "constant" as an expression of the probability that the two alleles at a locus which enter the zygote are derived from a common ancestral allele, ar as measuring the proportionate decline in the average number of heterozygous loci carried by a randomly chosen individual in the population. "The degree of relationship expressed in the inbreeding coefficient is essentially a comparison between the population in question and some specified or implied base population," as defined by Falconer (1960). All genes present in the base population are regarded as independent or not identical by descent.

The theory that inbreeding does have effects likely to bring about a selective disadvantage depends essentially on dominance. Fisher (1949) stated that without dominance, the only effect of inbreeding is to increase the frequency of the two kinds of homozygote equally at the expense of the frequency of the heterozygote. When factors showing dominance are present in the inbred material, the direction of the change is toward the recessive alleles. Fisher (1930) gives some account of the theory that deleterious alleles are maintained in all species by rare mutations and that natural selection will constantly favor modifying factors which tends to render the disadvantageous mutant more recessive. Lush (1945) points out that because inbreeding uncovers many recessive genes which would otherwise remain concealed by their dominant alleles, there is usually some degeneration in average individual merit when inbreeding is practiced.

The earlier investigators expressed diverse opinions as to the effects of inbreeding on plants and animals. King (1918a, 1918b) reported that her inbred albino rats were as a rule heavier than the stock albino rats after 15 generations of brother-sister matings. After 25 generations of the same series, the constitutional vigor of these rats was apparently not impaired to any extent by inbreeding. East and Jones (1919) working with maize concluded that inbreeding had but one demonstrable effect, the isolation of homozygous types. They concluded that inbreeding was not injurious by reason of the consanguinity. The only injury proceeding from inbreeding came from the inheritance received. The constitution of the individuals resulting from the process of inbreeding depended upon the chance distribution of traits existing in the stock before inbreeding was started. Contrary to the findings by King and East and Jones, Wright (1922b) reported results indicating an average decline in vigor in age of maturity, fertility, rate of growth and mortality among young during the course of 13 years of inbreeding of quinea pigs, brother with sister.

Further investigations showing the effects of inbreeding in various traits in different species have been made. In general, the closer the character is related to fitness, the more it is subject to inbreeding depression. Cole and Halpin (1922) inbred Rhode Island Red chickens for eight years. There was a particularly noticeable decline in vitality as measured by hatchability of the eggs. Egg production was also affected to some extent. McPhee, et al. (1931) attempting to establish an inbred strain of Poland China swine by brother-sister mating, failed in the second generation due to a decrease in fertility and high mortality. In the second generation, the litter size became reduced and vigor of the pigs greatly decreased. Bradford et al. (1958) observed a decrease of pigs farrowed per litter, pigs raised per litter, individual pig weight and total litter weight in five inbred lines tested during an 8 year period. In a study of three separate experiments of Friesian dairy cattle, Robertson (1949) noted a general decrease in birth weight, size, and milk and fat production among individuals of more intensive inbreeding.

Certain traits do not show depression effects due to inbreeding. Wright (1922a) found no difference between inbreds and controls in the sex ratio yield of guinea pigs. He found also that certain colors and patterns tended to become fixed automatically in each line of descent. Studies of inbred lines of chickens by Waters and Lambert (1936) and Shoffner (1948) indicated that inbreeding did not materially decrease the mature body weight of the bird nor affect the average egg size. Waters (1945a) observed little change in the mean egg weight of different inbred lines from generation to generation.

Numerous results of inbreeding in fowls have been reported in the literature. The effect of inbreeding on hatchability has been reported by Cole and Halpin (1922), Dunn (1923), Hays (1929), Jull (1929, 1933) Waters and Lambert (1936), Waters (1945b), Knox (1946), Shoffner (1948), Wilson (1948b), Duzgunes (1950) and Bernier et al. (1951). In general, hatchability decreases as the intensity of inbreeding increases. Cole and Halpin and Waters and

Lambert demonstrated that it is possible to maintain a reasonably "safe" level for hatchability under an intense breeding system, but there has to be a very rigid selection for high hatchability.

A decrease in egg production as a result of inbreeding has been observed by Cole and Halpin (1922), Dunn (1923), Goodale (1927), Hays (1924, 1929), Jull (1933), Shoffner (1948), Wilson (1948a) and Stephenson _et al_. (1953). Shoffner found that an increase of ten per cent in inbreeding resulted in a decline of about nine eggs.

A delay in attainment of sexual maturity was observed by Dunn (1923), Hays (1924), Dunkerly (1930), Jull (1933), Waters and Lambert (1936), and Shoffner (1948). Waters (1945c) found that little change in the mean age at sexual maturity had occurred between generations within 11 of the inbred lines while four other lines showed an increase during the two most recent generations only. Shoffner found on the average an increase to maturity of six days for every ten per cent increase in inbreeding.

An increase in chick and pullet mortality was found by Dunn (1923), Dumon (1930), Dunkerly (1930), Wilson (1945b) and Duzgunes (1950). Jull (1933) found viability of chicks was not materially affected by inbreeding. Wilson suggests that heredity influences mortality prior to eight weeks more than mortality after eight weeks.

Inbreeding has been observed to result in a decrease in fertility by Hays (1924), Goodale (1927), Dunkerly (1931), Jull (1930, 1933), Knox (1946) and Bernier _et al_. (1951) while Cole and Halpin (1922), Waters and Lambert (1936) and Wilson (1948a) observed no change in fertility following inbreeding. Bernier _et al_. demonstrated that inbreeding did not influence fertility directly. However, they concluded that the breeding system responsible for the production of females has an effect on their fertility. Thus, hens of an inbred origin are definitely less fertile than those of an outbred origin.

Social Behavior in the Domestic Chicken

Recognition of the existence of a definite social organization within flocks of chickens dates from the observations of Schjelderup-Ebbe (1922; cited by Guhl, 1953). Certain conditions of despotism on which the peck-order is founded were later summarized by Schjelderup-Ebbe (1935). Early American workers, Sanctuary (1932; cited by Guhl, 1953) and Masure and Allee (1934), substantiated Schjelderup-Ebbe's observations on the domestic chicken. They observed that peck-order position had an effect on the individuals' behavior and items of productivity. High ranking hens have priority for food, nests, roosting areas and tend to produce more eggs than hens low in the peck-order.

Social organization is based primarily on the outcome of individual pair-contests. When strange birds are placed in a pen, fights occur by twos, until each bird has engaged all the other birds. The winner of each paired contest thereafter has the right to peck the loser. Some individuals give way without a fight, while others may challenge the winner again before dominance relations are settled. After subsequent meetings where one member of a pair pecks or threatens the other, dominance-subordination relationships are settled and the peck-order is established (Guhl, 1953).

Collias (1950) stated that the contagiousness of chick behavior facilitates aggregation and socialization. Guhl (1958) observed that in the development of social organization of the chick, certain behavior patterns tended to appear in the following sequence: escape reactions, frolicking, sparring, aggressive pecking, avoiding reactions and fighting. Males established dominance-subordination relationships, peck-rights, and a peck-order earlier than females.

Guhl and Allee (1944) reported some difference between socially organized flocks of common hens and similar flocks under constant reorganization. The comparisons indicated that after an initial period of adjustment, the alternating hens in the flocks that were undergoing reorganization, pecked each other more than did members of the organized control flocks. Douglis (1948) observed that it was possible for a hen to become an assimilated member of as many as five different flocks and simultaneously maintain a different status in the hierarchy of each. She observed also that it was possible for a hen to recognize and react according to a rank to a total of 27 other individuals which may not be the upper limit. Guhl (1953) found evidence of a peck-order in a flock of 96 pullets, but in such a large flock the peck-order tended to be less stable due to the large number of individuals each bird must learn to recognize, either as a superior or a subordinate.

Factors which make for success or failure in initial pair-contests were given by Schjelderup-Ebbe (1935), Allee _et al_. (1939) and Collias (1943). Among these are:

1. Sex - the males usually being dominant over females.
2. Familiarity with the surroundings - a bird fights best in its home territory and among flock mates.
3. Body weight and general state of health - the heavier, healthier birds having a better chance to win.
4. State of molt - molting birds tend to be less aggressive in initial encounters.

5. The physiological condition of the bird as regards to male hormones - the size of the comb being used as an indicator of the amount of androgens present in the body.
6. Psychology of success - the social rank of the bird in its home flock is indicative of its chance of dominating its opponent.

The presence of male hormone is a potential source of aggressiveness. Cocks are more aggressive than hens or capons; also cocks have larger combs. Domm (1939) reported that capons lose much of their aggressiveness and have very small combs. Allee et al. (1939) found that low ranking hens injected with testosterone propionate moved upward in social status and eventually occupied the top position in each flock. Results obtained by Allee and Collias (1940) indicated a contrast in the action of testosterone propionate and estradiol as measured by the social behavior of hens. Hens treated with a heavy dosage of estradiol displayed lowered aggressiveness and decreased sizes of head furnishings. Allee et al. (1940) found that thyroxin produced no change in social status of treated hens unless the dosage initiated molting and the associated conditions. Allee and Foreman (1955) injected testosterone propionate into low ranking hens. They reported that the 14 socially mobile hens won 60 reversals in social rank. In contrast, 37 hens without added androgen showed only 5 reversals during the same period.

Two methods frequently used for measuring level of aggressiveness are the rank in peck-order and the number of initial pair-contests won, Allee et al. (1939) and Collias (1943). When determining the level of aggressiveness in a large flock, the disadvantages of the peck-order method are evident. The investigator may be unable to observe all pair interactions or the peck-order may not necessarily reflect the potentialities of the individuals. Guhl (1953) discussed the merits of both methods. He indicated that initial pair-contests may be more reliable, because some of the environmental factors which make for dominance can be controlled. Collias devised a technique for staging initial pair-contests between pairs of hens by placing them simultaneously in a neutral pen to settle their dominance relationships. Each hen was allowed to meet a number of strange hens and a score was obtained which gave a measure of the relative aggressiveness of the birds tested.

The initial pair-contest method may be subdivided into two additional methods. One method is the caged method, described by Eaton (1949) and Guhl (1953). Birds were isolated in individual cages. After two weeks of separation the birds were placed in a neutral area for initial pair-contests. Each bird met each of the other birds to settle dominance relationships. The other method is the inter-pen method described by Guhl (1953). A group of birds were divided into two pens and pair-contests arranged so that each bird in one pen met each bird in the other pen. A modification of this method is described by McBride (1958). His method was to measure aggressiveness by scoring against a standard panel of birds under controlled conditions. Panel scores tended to be highly repeatable. Siegel (1960) has reported another modification of the inter-pen method. An equal number of cockerels were placed into two pens, visually isolated from each other. Individuals from each of the two flocks were then selected at random and placed in a neutral pen to settle dominance relationships. Each bird was engaged in eight randomly paired contests. Highly significant correlations between rank in the home flock and a number of initial paired contests won against test cockerels were obtained. This method eliminates the necessity of conducting numerous initial pair-contests or determination of peck-orders when large numbers of chickens are used.

Evidence of breed differences in aggressiveness was observed by Potter (1949) and Holabird (1955). Potter found White Leghorns to be the most dominant of seven breeds observed. Holabird reported Light Brahmas displayed a lower level of aggressiveness toward other breeds by losing dominance once won. Both workers observed small numbers of birds.

Selection for an aggressive and unaggressive strain was described by Eaton (1949). His results indicated that strain differences were not conclusive after two years of selection for aggressive and unaggressive lines. Tindell and Craig (1959) found significant differences among six strains of four breeds of chickens. Inter-strain competition appeared to result in higher performance levels for the more aggressive, whereas the less aggressive strains tended to mature later, lay at a lower rate and have poorer livability. Siegel (1959) and McDaniel and Craig (1959) found a correlation between levels of aggressiveness and courtship displays and between aggressiveness and completed matings in cocks. Guhl _et al_. (1960) found that strains differing in relative aggressiveness may be obtained by selective breeding. Two different strains of White Leghorns were produced and selection was carried to the F_4 generation. Beginning with the F_2 generation the two lines showed significant differences in the percentage of pair-contests won or lost as well as in high or low ranks in the peck-order. Heritability estimates of 0.22 and 0.18 were obtained when based on the percentages of contests won and individuals dominated, respectively.

Komai _et al_. (1959) determined heritability and repeatability of social aggressiveness in the domestic chicken. Percentile social ranks of daughters and dams within six strains and four breeds were used to estimate the heritability for aggressiveness. The intra-strain mean heritability estimates were 0.30 and 0.34. The social status of the six strains studied had a high repeatability of 0.857.

Bellah (1957) obtained evidence suggesting that the age at which different strains become mature may be a factor in social rank obtained. All the strains in the multistrain flock under study were reared together. King and Bray (1959) compared strains of chickens reared in separate and intermingled flocks. They reported that subsequent effects of productivity due to method of rearing were so small in size that they were of only indefinite biological importance.

MATERIALS AND METHODS

The noninbred stock used for this study consisted of Regional NC-47 Cornell randombred control White Leghorns obtained from the Northcentral Regional Poultry Breeding Laboratory, Lafayette, Indiana. In the development of the Cornell randombred control population as described by King _et al_. (1959), at least four different White Leghorn strains were represented in every chicken hatched in the first generation forming a wide genetic background. Since the original parental matings in 1955, the Cornell randombred control population has been closed to introduction of new genetic material. A restriction imposed upon the randomness of matings is that no sib or half-sib matings are made.

The inbred lines were derived from the same control population of White Leghorns imported into the South Dakota station in 1958. The inbreds used in this study were obtained by close matings and without artificial selection for productivity. The noninbred strain obtained from the Regional Laboratory, Lafayette, served as the control group in the experiment. Hatching eggs from the two sources were set concurrently in the same incubator. All chicks hatched March 4, 1960, were wingbanded, dubbed and vaccinated for Newcastle and bronchitis disease. The chicks were placed in rearing batteries, separating the inbreds from the noninbreds. At 17 days of age all birds were debeaked. During the fourth week of age the birds were transferred to floor pens in a brooder house, still separated as inbred and noninbred groups. At nine weeks of age, they were sexed, vaccinated for Newcastle and fowlpox disease and the males were dewattled. The birds were then subdivided into four groups consisting of inbred males, inbred females, noninbred males and noninbred females. All groups were housed in similar pens and handled in a similar manner.

At 14 weeks of age the 40 inbred males with the highest coefficients of inbreeding and 40 randomly selected noninbred males were leg banded and placed in individual cages. Sixty inbred females with the highest coefficients of inbreeding and 60 randomly selected noninbred females were also selected at this time. All hens were identified by pairs of numbered wing badges. The inbred females were assigned to 6 lots, each lot containing as near as possible, equal numbers of hens having the same inbreeding coefficients. F_x will hereafter be used to denote Wright's (1922a) coefficient of inbreeding.

Measurements on Males

The lot of 40 inbred males consisted of 15 individuals with an F_x of 37.5 percent, 8 males with an F_x of 18.8 percent and 17 males with an F_x of 15.6 percent. For convenience in analysis and since a difference of 3.2 percent in inbreeding with such limited numbers is of small significance, the inbred males were therefore considered as two groups with F_x's of 37.5 and 16.6 percent respectively.

Each inbred male was tested for level of aggressiveness in six initial pair-contests with randomly selected noninbred males at 16, 20, 24, 28, 32 and 39 weeks of age. An inbred male was tested with the same six noninbred males at each age. A circular pen with a diameter of 42 inches was used for conducting the initial pair-contests. Pairs of males were released simultaneously by hand to start the contests. All pair-contests were limited to a 10 minute period.

A male could win a contest by a fight, peck or threat. Credit was also given to the male initiating the contest either by a peck or threat. The contest was called a "no contest" when neither male displayed an aggressive response toward the other during the 10 minute period. If one or both males displayed aggressive responses toward each other, but a winner could not be determined, it was called a "no decision". The total number of contests won, contests initiated and number of contests with no outcome (includes no contest and no decision) were tabulated for the noninbred males (designated the zero level) and the 16.6 and 37.5 percent inbred males. A male was declared sexually mature if a sample of his semen could be obtained by an ejaculation containing spermatozoa when observed under a microscope. Males were artificially stimulated for semen collection at weekly intervals until all males were sexually mature.

Measurements on Females

Each inbred female lot of 10 hens consisted of two or three hens with an F_x of 37.5 percent, one or two with an F_x of 18.8 percent, two or three hens with an F_x of 15.6 percent and four or five hens with an F_x of 12.5 percent.

At 14 weeks of age, 10 inbred females and 10 noninbred females were placed in individual cages. After two weeks separation (individuals separated for two weeks lose recognition of former penmates, Schjelderup-Ebbe, 1935) these females were then placed in a floor pen as a mixed flock. All females making up a mixed flock were released at the same time so that none of the females would gain advantages of being longest on the floor of the pen, Guhl (1953). When this procedure is followed, the peck-order method is believed to be relatively reliable in determining dominance relationships. Subsequently at 20, 24, 28, 32 and 36 weeks similar lots of 10 inbred and 10 noninbred females were also placed in floor pens after two weeks semi-isolation in individual cages. After the females were placed in a pen, they were observed to determine peck-rights. The procedure was to wait several days for a peck-order to become established, then observe the birds during feeding time in the morning. The birds were fed in a trough type feeder in direct view of the observer. The mash was wetted to induce more social interactions, Guhl (1953). All pens were observed for a total of 10 to 12 hours and were handled in a similar manner.

Sexual maturity of the females was measured by the days of age at first egg. Percentage hen-day egg production was calculated from day of first egg until the end of the period or until death. All hens were trap-nested three days a week. Hens with no egg records were omitted from the study. There was evidence of floor laying, therefore all zero egg record hens were considered floor layers. Percentage hen-day egg production was not calculated if less than 10 trap days were included. The study was terminated when the hens were 270 days of age.

Statistical Analysis

The partitioning of chi-square analysis as described by Snedecor (1956) was used to test the hypothesis of no difference between the inbred and non-inbred males for contests won and contests initiated. The chi-square test for independence, also described by Snedecor (1956), was used to test frequencies of the number of contests won and contests initiated when the outcome was determined by a fight.

The measurements of aggressiveness were suspected of having a non-normal distribution, therefore Spearman rank correlation coefficients (r_s) were calculated, as illustrated by Siegel (1956). The variables correlated were number of contests won, contests initiated, unsettled contests and age at sexual maturity for each level of inbreeding.

Fisher's chi-square method of "r to z" transformation was used to test for heterogeneity between the levels of inbreeding for the correlated variables, Snedecor (1956). As suggested by Fieller _et. al._ (1957), the invariance for each sample were estimated by $(n-3)/1.06$. When no evidence of heterogeneity was found, pooled rank correlation coefficients were calculated. The differences between "z" values were tested for significance, according to Snedecor (1956), when the test for heterogeneity resulted in a significant chi-square value.

After all observed peck-rights were tabulated for each pen of females, it was evident that not all the possible dominance combinations had been observed. Therefore, a modified method reported by Tindell and Craig (1959) and Komai et. al. (1959) was used to determine the percentile social status of an individual within a pen. This method is based on the following:

> Percentile social status = (A plus B)/2, where A = the percentage of birds that X dominated, and B = 100% minus the percentage of birds dominating X.

Spearman rank correlation coefficients were used to analyze measurements on the females. These measurements were also suspected of having non-normal distributions. Level of inbreeding was tested for correlation with percentile social status, age of sexual maturity and percentage hen-day egg production. Similar analytical procedures to those described above were used.

Regression coefficients, as described by Snedecor (1956), were calculated for level of inbreeding and percentile social status, age at sexual maturity and percentage hen-day egg production, respectively. This was to determine the effect of inbreeding on the social behavior and productivity of the females. The regression coefficients were tested by first computing the sample standard deviation then computing a "t" value, Snedecor (1956).

RESULTS

Effect of Inbreeding on Male Social Aggressiveness

At the beginning of this study, it was assumed that each lot of males had an equal chance of winning half of the paired contests. However, if level of aggressiveness is related to maturity, it is also reasonable to assume that the later maturing inbred males would win fewer contests at the beginning but eventually reach the 50 percent level as all the inbred males became sexually mature. Percentages of paired contests won by the inbred males at the different ages are presented in Table 1. A definite trend is apparent. As age increases the percentage of paired contests won by the inbred males asymptotically approaches a level well below 50 percent. Table 2 shows the percentage of contests initiated by the inbred males at different ages. A clear trend is again apparent with an increase in percentage of paired contests initiated as age increases, but the incidence remains well below 50 percent. These two tables also show that the top of an age curve is lower for the more highly inbred males. It was of interest to determine if the incidence of unsettled paired contests would change as age and length of time spent in individual cages increased. Table 3 gives the percentages of unsettled paired contests at the different ages. No pattern emerges for this measurement.

Table 1. Percentage of paired contests between inbreds and noninbreds won by inbred males.1/

Coefficient of Inbreeding	No. of males	Age in weeks 16	20	24	28	32	39	All ages
16.6	25	15.1	24.0	25.6	33.3	37.0	35.7	27.9
37.5	15	4.5	12.7	21.9	10.0	23.1	25.8	17.4
Pooled	40	11.0	19.5	24.3	28.2	32.5	32.2	24.0

1/ "No decisions" (both aggressive and passive behavior displayed, winner indeterminable) and "no contests" (no aggressive behavior displayed) were excluded from the computations.

Table 2. Percentage of paired contests between inbreds and noninbreds initiated by inbred males.1/

Coefficient of Inbreeding	No. of males	Age in weeks 16	20	24	28	32	39	All ages
16.6	25	14.1	27.3	27.1	33.3	38.3	39.6	29.6
37.5	15	9.0	11.4	21.9	21.7	23.1	30.6	18.9
Pooled	40	12.1	21.0	25.2	28.8	33.3	36.7	25.7

1/ As before in Table 1.

Table 3. Percentage of unsettled pair contests between inbreds and noninbreds.

Coefficient of Inbreeding	No. of males	Age in weeks 16	20	24	28	32	39	All ages
16.6	25	29.3	19.3	14.0	36.0	46.0	23.3	30.0
37.5	15	25.6	12.2	18.9	33.3	56.7	31.1	29.6
Pooled	40	27.9	16.7	15.8	35.0	50.0	26.0	28.6

Partitioning of chi-square analysis based on actual numbers of paired contests with definite outcomes was carried out to determine whether inbreeding affected paired contests won and paired contests initiated. The expected values on the null hypothesis were that half the paired contests would be won and the same number of paired contests would be initiated at each level of inbreeding by males at the different ages. The results are summarized in Tables 4 and 5. Significant chi-square values were found for ages and levels of inbreeding. The age by levels of F_x interaction value lacked significance. The fact that age had a significant effect indicates that such an interaction did exist; not between the 16.6 and 37.5 percent inbred levels at the six ages but rather between the zero level and any level of inbreeding at the six ages.

Table 4. Chi-square analysis for effects of level of inbreeding and age of inbreds on paired contests won.

	Degrees of freedom	Chi-square
Sum of 12 chi-squares	12	310.82**
Pooled	1	277.39**
Ages	5	22.68**
Levels of F_x	1	10.69**
Heterogeneity after ages and levels of F_x	5	.06

**Significant at the .01 level.

Table 5. Chi-square analysis for effects of level of inbreeding and age of inbreds on paired contests initiated.

	Degrees of freedom	Chi-square
Sum of 12 chi-squares	12	281.30**
Pooled	1	243.19**
Ages	5	26.53**
Levels of F_x	1	10.93**
Heterogeneity after ages and levels of F_x	5	.65

**Significant at the .01 level.

Spearman rank correlation coefficients were calculated for paired contests initiated with paired contests won within each level of inbreeding, Table 6. A test of heterogeneity resulted in a chi-square value of 1.969 which lacked significance, therefore a pooled correlation was calculated. All correlations were highly significant indicating that males initiating paired contests won a high percentage of them. A chi-square test for independence for fights only resulted in a nonsignificant value of .507. This indicates that the number of fights initiated was independent of fights won by inbred males, when both males were aggressive. When the outcome was decided by a peck or threat, the male with the initiative automatically won.

Table 6. Rank correlation coefficients of paired contests initiated and paired contests won for males within levels of inbreeding.

Level of Inbreeding	d.f.	"r_s"
0	38	.986**
16.6	23	.992**
37.5	13	.980**
Pooled	78	.987**

**Significant at the .01 level.

Social Behavior as Related to Sexual Maturity in the Males

The correlation coefficients were determined for age at sexual maturity with total paired contests won and total unsettled paired contests. Table 7 gives the rank correlation coefficients of total paired contests won and age at sexual maturity. The test of heterogeneity resulted in a chi-square value of 1.787 which lacked significance. Nonsignificant correlations indicated the two variables were independent.

Table 7. Rank correlation coefficients of total paired contests won and age at sexual maturity for males within levels of inbreeding.

Level of Inbreeding	d.f.	"r_s"
0	38	.012
16.6	23	-.344
37.5	13	.012
Pooled	78	-.056

Table 8 presents the correlations of total unsettled paired contests and age at sexual maturity. A nonsignificant chi-square value of .454 resulted from the test of heterogeneity. The correlations were found to lack significance which indicates the variables were independent.

Table 8. Rank correlation coefficients of total unsettled paired contests and age at sexual maturity for males within levels of inbreeding.

Level of Inbreeding	d.f.	"r_s"
0	38	.028
16.6	23	-.140
37.5	13	.099
Pooled	78	-.014

Effect of Inbreeding on Social Behavior and Productivity of Females

One aspect of this study was to determine the effect of age on the social behavior of the females when assembled at different ages. There is evidence that inbreeding increases the age to sexual maturity (Shoffner, 1948, and others). As sexual maturity and social behavior are related, the hypothesis was made that as the inbred females became sexually mature there would be an increase in the percentage of all females dominated by the inbred females at each older age of assembly until the inbred females were dominating about half of all the females in each flock. The percentage of females dominated by the inbred females within each flock is presented in Table 9. These percentages were calculated from known paired interactions only. As the results indicate, no trend is evident in this measurement.

Table 9. Percentage of all females dominated by inbred females within each pen (all known interactions).

	Age in weeks when flock assembled					
	16	20	24	28	32	36
Percent dominated	37.5	38.6	19.7	19.5	37.2	30.9

The within flock averages of age at sexual maturity and percentage hen-day egg production for the inbred and noninbred females were calculated to show the effect of inbreeding on these traits. Table 10 gives these averages. The pooled averages over all ages show the inbred females were later maturing and the percentage hen-day egg production was less than that of the noninbred females. These results agree with those of Shoffner (1948) and others.

Table 10. Effects of inbreeding on age at sexual maturity and percentage hen-day egg production.

	Age in weeks when flock assembled						
	16	20	24	28	32	36	Pooled
Age at Sexual Maturity (in days)							
Inbreds	176	196	174	188	186	215	188
Noninbreds	174	169	171	171	194	179	177
Percentage Hen-day Egg Production							
Inbreds	61.2	72.8	50.1	52.9	56.5	56.6	57.3
Noninbreds	66.2	70.4	60.0	63.4	58.7	63.2	63.3

Level of inbreeding was correlated with percentile social status to determine if inbreeding affected the aggressive behavior of the females, Table 11. A test of heterogeneity for age at assembly resulted in a chi-square value of 8.411 which lacked significance. The negative pooled rank correlation coefficient was highly significant which indicates the higher the percentile social status the lower the level of inbreeding.

Table 11. Rank correlation coefficients of level of inbreeding and percentile social staus for females at different ages of flock assembly.

Age at Assembly	d.f.	"r_s"
16 Weeks	18	-.435
20 weeks	18	-.646**
24 weeks	18	-.840**
28 weeks	18	-.843**
32 weeks	18	-.376
36 weeks	18	-.662**
Pooled all ages	118	-.634**

**Significant at the .01 level.

Rank correlation coefficients of level of inbreeding with age at sexual maturity are given in Table 12. The test of heterogeneity for age at assembly differences resulted in a chi-square value of 8.619 which was nonsignificant. The pooled rank correlation coefficient was highly significant. This indicates that within a higher level of inbreeding, age at sexual maturity is greater. When the level of inbreeding with percentage hen-day egg production rank correlation coefficients (Table 13) were tested for age at assembly differences, a nonsignificant chi-square value of 2.483 was found. The negative pooled rank correlation coefficient was highly significant. This shows that as level of inbreeding increases, percentage hen-day egg production decreases.

Table 12. Rank correlation coefficients of level of inbreeding and age of sexual maturity for females at different ages of flock assembly.

Age at Assembly	d.f.	"r_s"
16 Weeks	16	.172
20 weeks	9	.803**
24 weeks	16	.146
28 weeks	16	.470*
32 weeks	16	-.062
36 weeks	15	.503*
Pooled all ages	98	.262**

* Significant at the .05 level.
**Significant at the .01 level.

Table 13. Rank correlation coefficients of level of inbreeding and percentage hen-day egg production for females at different ages of flock assembly.

Age at Assembly	d.f.	"r_s"
16 Weeks	14	-.301
20 weeks	9	-.127
24 weeks	14	-.181
28 weeks	14	-.603*
32 weeks	12	-.175
36 weeks	10	-.349
Pooled all ages	83	-.318**

* Significant at the .05 level.
**Significant at the .01 level.

Regression coefficients were calculated for level of inbreeding with percentile social status and items of productivity. The regression coefficients, sample standard deviations and "t" values (tests for significance), are given in Table 14. All "t" values were found to be significant or highly significant indicating there were differences between the levels of inbreeding for all measurements studied. These results are in accord with the rank correlation coefficients found in the study, i.e. as the level of inbreeding increases, percentile social status decreases, age at sexual maturity is greater and percentage hen-day egg production decreases.

Table 14. Regression coefficients for level of inbreeding and various measurements.

Variable	d.f.	b	s_b	t
Percentile social status	118	-1.118	±.134	8.342**
Age at sexual maturity	98	.652	±.203	3.204**
Percentage hen-day egg production	83	- .259	±.121	2.132*

* Significant at the .05 level.
**Significant at the .01 level.

DISCUSSION

These results show that inbreeding is a factor affecting social agressiveness in chickens. Differences in the percentages of paired contests initiated and paired contests won were found between the inbred and noninbred males. These differences became smaller as age increased, i.e. the percentages of paired contests initiated and paired contests won by the inbred males increased. However equality of inbreds and noninbreds was not achieved as the percentages remained well below 50 percent for the inbreds. It was also shown that the top of the age curves were lower for the more highly inbred males.

Comparing the female data with the male data, it was found that no trend with age was indicated in the percentages of all the females dominated by the inbred females as compared with age trends found in the male data. The percentile social status was found to be affected by the level of inbreeding, i.e. the higher the percentile social status, the lower the level of inbreeding. Not only were differences in aggressiveness found to exist between the inbred and noninbred levels, but significant differences were found between the inbred levels. Although age at sexual maturity was greater for the inbreds, the age of the females when assembled in the different flocks was not an apparent factor.

A genetic basis for level of aggressiveness was clearly suggested by these data. These findings differ from those of Siegel (1959) who found one noninbred line of males winning a significantly larger percentage of paired contests with males from the other inbred and noninbred lines. In Siegel's study five lines were involved. Males were selected from each of three inbred lines and from each of two single crosses of the inbred lines included in the study and another inbred line. The levels of inbreeding represented were 34 and 22 percent. The inbred and noninbred lines used in this study were from the same original strain, but were from different flocks. A wider range in coefficients of inbreeding were represented. In this study 1440 paired contests were conducted compared to 190 paired contests in Siegel's study. Siegel's findings also indicated a genetic basis for level of aggressiveness.

The number of paired contests initiated and won by males was found to be highly correlated. These results were expected and even automatic when the outcome was decided by a peck or threat since in all of these the bird with initiative wins. It was found however that the variables were independent of each other when both birds were aggressive and the outcome was decided by a fight.

Significant differences were found for the level of inbreeding and age of inbreds on paired contests won and paired contests initiated (a measure of social rank of the males). It was found that an age by levels of inbreeding interaction existed between the zero level and any level of inbreeding at the different ages. Social status of the females was found also to be affected by level of inbreeding. Females with lower levels of inbreeding had higher social status. Age at sexual maturity and social status were found to be independent variables in the males. A significant negative correlation of age at sexual maturity and total paired contests won would have indicated that males reaching sexual maturity at an earlier age were winning more paired contests suggesting they were the more aggressive males. A significant positive correlation of age at sexual maturity and total unsettled paired contests would have suggested that the later maturing males were displaying more passive behavior by being involved in more unsettled paired contests. The level of inbreeding was found to affect age at sexual maturity of the females. The results indicated that with a higher level of inbreeding, age at sexual maturity was greater.

These findings are in accord with the investigations of Shoffner (1948), Stephenson et.al. (1953) and others showing that as the level of inbreeding increases, egg production decreases. Social status also affects egg production. Investigations by Sanctuary (1932), Guhl (1953) and Tindell and Craig (1959) show that high ranking individuals produce more eggs than low ranking individuals. The question arises, would inbreds perform any differently in competition with noninbreds as compared to competition with other inbreds. Tindell and Craig (1959) observed a tendency for the more aggressive strains to do better in interstrain competitions than in pure strain flocks. Contrarily, less aggressive strains performed at relatively lower levels when in competition with more aggressive strains than when placed in pure strain flocks.

A question raised from the studies of Guhl, Craig and Mueller (1960) is whether the pair contest method measures more than aggressiveness. For example, aggressiveness and submissiveness may be independent factors rather than extremes of a gradient (Guhl, 1961). Another factor may be passive behavior. These results suggest an interesting aspect as to the development of aggressive behavior. When the number of paired contests won (a measure of aggressive behavior) and the number of unsettled paired contests (a measure of passive behavior) were independently correlated with age at sexual maturity, nonsignificant values resulted. This would indicate that the aggressive or passive behavior of the males did not significantly change after they became sexually mature. These results should be of value in further investigations of the effects of inbreeding on social aggressiveness of the chicken.

SUMMARY AND CONCLUSIONS

Inbred and noninbred stock consisting of Regional NC-47 Cornell randombred control White Leghorns was used to study the effects of inbreeding on social aggressiveness in chickens. Paired contests were conducted between inbreds and noninbreds at six different ages to measure aggressiveness in the males. Mixed flocks of inbred and noninbred females were placed in floor pens at six different ages. The peck-order in each flock was used to measure aggressiveness in the females.

Definite trends were apparent in the percentages of paired contests won and the percentages of paired contests initiated by the inbred males. As the age of the males increased the percentages of paired contests won and paired contests initiated by the inbred males asympotically approached a level well below 50 percent. No apparent trend was seen in the percentages of unsettled paired contests involving the inbred males at the different ages.

Significant chi-square values were found for effects of level of inbreeding and age of inbreds for the number of paired contests won and the number of paired contests inititated. Although the age by levels of inbreeding interaction value lacked significance, the fact that age had a significant effect indicates that such an interaction did exist between the zero level and any level of inbreeding at the six ages.

Highly significant rank correlation coefficients were found indicating that males initiating paired contests won a high percentage of them, but these correlations were automatic when the outcome was decided by a peck or threat since in all these the bird with initiative wins. It was found however that the variables were independent of each other when both birds were aggressive and the outcome was decided by a fight.

When the age of sexual maturity was correlated with the number of paired contests won and the number of unsettled contests, nonsignificant rank correlation coefficients were found for the males within levels of inbreeding showing these variables to be independent.

No apparent trend was shown in the percentage of females dominated by the inbred females within each age. It was found that females with lower levels of inbreeding had higher social status. When all ages were pooled, the average age at sexual maturity and average percentage hen-day egg production showed the inbred females becoming sexually mature at a later age and having a smaller percentage hen-day egg production.

Negative, significant rank correlation coefficients were found to exist between the level of inbreeding and percentile social status and percentage hen-day egg production. A positive significant rank correlation coefficient was found between the level of inbreeding and age at sexual maturity. Regression coefficients were found between level of inbreeding and percentile social status, age at sexual maturity and percentage hen-day egg production.

These results show that as the level of inbreeding increases, the percentile social status decreases, percentage hen-day egg production decreases, and the age at sexual maturity is greater.

ACKNOWLEDGMENT

Sincere appreciation is expressed to Dr. J. V. Craig, major advisor and Poultry Geneticist who suggested this study, for his assistance, guidance, and consideration throughout this study.

Grateful acknowledgment is also expressed to Professor T. B. Avery, Head, Department of Poultry Science, for his encouragement during the period of study and for his constructive criticism of the thesis; Dr. A. M. Guhl, Professor of Zoology, for his suggestions and guidance concerning the behavior studies and to Dr. S. Wearden, Associate Professor of Statistics, for his statistical assistance in analyzing the data.

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THE EFFECTS OF INBREEDING ON THE SOCIAL BEHAVIOR OF CHICKENS

by

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B. S., Kansas State University
of Agriculture and Applied Science, 1960

AN ABSTRACT OF
A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Poultry Science

KANSAS STATE UNIVERSITY
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1963

Inbred and noninbred stock was used to study the effects of inbreeding on the development of aggressive behavior, age of sexual maturity and items of productivity in chickens.

The noninbreds were Regional NC-47 Cornell randombred control White Leghorns while the inbreds were derived from this control stock. Hatching eggs were obtained from two different supply flocks. Levels of inbreeding of zero, 16.6 percent (15.6 and 18.8 combined) and 37.5 percent were represented in the males. Zero, 12.5 percent, 15.6 percent, 18.8 percent and 37.5 percent levels of inbreeding were represented in the females.

Chicks representing all levels of inbreeding were hatched simultaneously in the same incubator. The chicks were raised in batteries until four weeks of age, then transferred to a brooder house being separated only as inbreds and noninbreds. At nine weeks of age the birds were then subdivided into four groups consisting of inbred males, inbred females, noninbred males and noninbred females.

Paired contests were used to measure aggressiveness in the males. At 16 weeks of age each of 40 inbred males was tested with six randomly selected noninbred males in paired contests. Each inbred male was tested with the same six noninbred males at 20, 24, 28, 32, and 39 weeks of age. A male could win a paired contest by a fight, peck or threat. If no winner could be determined at the end of a 10 minute period, the contest was considered a "no contest".

Mixed flocks of 10 inbred and 10 noninbred females were assembled and placed in floor pens at 16, 20, 24, 28, 32 and 36 weeks of age. Two weeks prior to assembly, the 20 females were placed in individual cages to erase the memory of former penmates. Peck-order observations were used to measure aggressiveness in the females. Each pen was observed for 10 to 12 hours and all pens were handled in a similar manner.

Definite trends were apparent in the percentages of paired contests won and the percentages of paired contests initiated by the inbred males. As the age of the males increased, the percentages of paired contests won and paired contests initiated asympotically approached a level well below 50 percent. No apparent trend was seen in the percentages of unsettled paired contests involving the inbred males at the different ages.

Significant chi-square values were found for effects of level of inbreeding and age of inbreds for the number of paired contests won and the number of paired contests initiated. Although the age by level of inbreeding interaction value lacked significance, the fact that age had a significant effect indicates that such an interaction did exist between the zero level and any level of inbreeding at the six ages.

Highly significant rank correlation coefficients were found indicating that males initiating paired contests won a high percentage of them. However these correlations were automatic when the outcome was decided by a peck or threat since in all these the bird with initiative wins. It was found however that the variables were independent of each other when both birds were aggressive and the outcome was decided by a fight.

Nonsignificant rank correlation coefficients were found when age at sexual maturity was correlated with the number of paired contests and the number of unsettled contests for males within levels of inbreeding indicating these variables to be independent.

No apparent trend was shown in the percentages of females dominated by the inbred females within each pen. It was found that females with lower levels of inbreeding had higher social status. When all ages were pooled, the average age at sexual maturity and average percentage hen-day egg production showed the inbred females becoming sexually mature at a later age and having a smaller percentage hen-day egg production.