EFFECTS OF REARING RELATIONSHIP, CAGE SIZE, AND BIRD DENSITY ON PERFORMANCE OF TWO COMMERCIAL STRAINS OF EGG-TYPE CHICKENS

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TABLE OF CONTENTS

INTRODUCTION

The development of the cage system to lower housing costs per bird along with other advantages has led to the use of colony cages for rearing of replacement pullets (Hibbard, 1970). It is a common practice to disregard group organization when moving replacement pullets from growing to laying cages. This results in a number of birds being placed in the same cage that are strangers to each other. Choudary and Craig (1972) found pullets housed as strangers at 19 weeks of age showed increased agonistic behavior from 19 to about 26 to 30 weeks of age. An increase in agonistic interactions along with high bird densities and cage size, which are characteristics of colony cages, may contribute to social stress.

According to Siegel and Siegel (1961) male chickens placed as a minority in pens of strangers had heavier left adrenals than birds remaining in their own flock, indicating that strangeness is stressful. Several studies have shown that agonistic interactions increase with a regrouping of members as compared to undisturbed flocks (Guhl and Allee 1944; Guhl 1953; and Craig et al. 1969). Although an increase in agonistic behavior results from unstable group membership, an adverse effect on production was not detected by Craig and Toth (1969) and Choudary and Craig (1972). This was contradicted by Guhl and Allee (1944) and McBride and Foenander (1962) who found unstable alternating flocks laid fewer eggs than socially organized control flocks.

Effects of cage size and bird density on performance of egg-producing birds have been widely studied. Adams and Jackson (1970) reported on a study involving birds housed at densities of 700 and 350 $cm.^2$ of cage floor area per bird in large (71.1 x 81.3 cm.) and small (30.5 x 45.7 cm.) cages. They found that birds housed in small cages at low density laid the most eggs, and had the lowest mortality and highest Haugh unit values. Similar results were obtained by Lowe and Heywang (1964); Moore *et al.* (1965); Marr *et al.* (1967); Champion and Zindel (1968); Ruszler and Quisenberry (1969); Biswas and Craig (1970) and Mather and Gleaves (1970). Ten birds per cage gave the best results according to Tower *et al.* (1967) when compared with 2, 5, and 20 birds per cage at a constant density of 0.625 square feet per bird. Dorminey and Arscott (1971) found no significant effect of density on egg production.

The following study was conducted to test the effect of two commercial strains of replacement pullets housed as penmates or intermingled as strangers in two sizes of cages at two densities on subsequent performance. It was hypothesized that the stress on birds of forming a new group organization could be reduced and performance increased if birds that were reared together were kept together during the laying period.

EXPERIMENTAL METHODS

Day-old, female chicks of 2 commercial egg-laying strains of White Leghorn type from 2 different hatcheries were received at the Kansas State University (KSU) Avery Research Center on May 17 and 18, 1971, respectively. The chicks were wing banded, dubbed, and vaccinated for infectious bronchitis, Newcastle and Marek's diseases.

Each strain was allotted at random to 6 floor pens, 3.06 x 5.5 m., in a combination brooding-rearing house. KSU 20 and 18 percent protein all-mash rations were fed *ad libitum* from 0 to 8 and 8 to 12 weeks, respectively. Chicks were debeaked at 4 weeks of age. Light equal to natural day length was provided for the first 10 weeks.

At 10 weeks of age the birds were moved to a 36.5 x 11 m. cage house. It was an environmentally modified, fan ventilated, windowless type with three rows of stretched wire cages. Each side of each row had two sizes of cages, 72 x 82 and 41 x 41 cm. Twenty pullets were housed in each large cage, none in small cages. Two trigger-type plastic cup waterers in each large cage and one in each small cage supplied water *ad libitum*. The birds were allowed 12 hours of light a day during the balance of rearing period. The KSU 14 percent protein growing ration was supplied *ad libitum* from 12 to 21 weeks of age.

At 21 weeks of age all birds were relocated among cages within the house; half of the large and small cages with birds reared in the same cages (penmates) and half with birds reared in separate cages (intermingled). The two strains were randomly distributed in cages throughout the house but were not mixed. Moderate culling was practiced. Details of the treatments are given in Table 1.

Table 1. Treatments used with 2 strain of White Leghorn-type pullets

Treatments	Housing method	Cage size	No. birds/ cage	Cage floor area/bird	No. of birds/ treatment/ strain[1]
		(cm.)		(cm.^{2})	
1	Intermingled	72 x 82	18	328	324
2	Intermingled	72 x 82	10	590	180
3	Penmates	72 x 82	18	328	324
4	Penmates	72 x 82	10	590	180
5	Intermingled	41 x 41	5	336	90
6	Intermingled	41 x 41	3	560	54
7	Penmates	41 x 41	5	336	90
8	Penmates	41 x 41	3	560	54
			Total birds per strain		1296

[1]Eighteen cages per treatment, 6 per row.

A minimum of 14 hours of light per day was supplied by artificial light throughout the laying period. KSU all-mash rations calculated to contain 18 and 16 percent protein were fed from 21 to 40 and 40 to 52 weeks of age, respectively. Only birds that died were removed and none were replaced.

Records on egg production and mortality were maintained from 24 to 52 weeks of age. Eggs laid per cage were recorded three days each week and mortality daily. The total 28-week production period was divided into seven 4-week periods. Egg quality was measured at preselected times (210, 240, 300, and 360 days of age) during the laying period. Eggs equal to 33 percent of the number of birds in each cage were collected for 2 consecutive days from 3 replications on a side of each row for each treatment. After sampling, the eggs were placed in a cooler, weighed and broken for albumen measurements the next day. A total of 288 birds; 6 birds per treatment, row and strain, were weighed at 21, 35, and 52 weeks of age to determine changes in body weight.

Hen-housed production was calculated on the basis of number of pullets housed per cage. Hen-day production was calculated on the basis of number of birds present in each 3-day recording period per week for each strain-treatment-row-cage subclass. Rate of lay was calculated from the age of sexual maturity to 52 weeks of age. Age at sexual maturity was estimated using the age when the first week of the first two weeks each respective cage laid at 50% or more on a hen-day basis.

Hen-housed, hen-day, and rate of survival were analyzed by 4-week periods. Analysis of variance for a mixed model using a split plot design (Snedecor and Cochran, 1967) was used with all effects fixed. The model contained the effect of period, row, strain, cage size, density, and housing method plus their two and three-way interactions and the four-way interactions on row, strain, cage size, density and housing method.

Rate of lay, sexual maturity, percent change in body weight and egg quality data were analyzed with a model with all effects fixed. The model contained the effect of row, strain, cage size, density, and housing method plus their two and three-way interactions. The means were tested for significant differences using Duncan's New Multiple Range Test (Duncan, 1955).

RESULTS

Analysis of variance of the data analyzed by period for mortality, hen-day production and hen-housed production are presented in Tables 2 and 3. Analysis of variance of data for rate of lay, sexual maturity, and percent change in body weight are presented in Table 4.

Mortality - The average percent mortality of the birds in the various treatments is shown in Table 5. The analysis of variance showed none of the parameters studied had a significant effect on mortality (Tables 2 and 3).

Egg production - Hen-day and hen-housed egg production averages are shown in Tables 6 and 7, respectively. Although there were no significant housing method effects, with the exception of periods 1 and 7, the birds housed as penmates out-produced those housed on an intermingled basis (Table 8). The data show cage size and density had a highly significant ($P < 0.005$) effect on hen-day and hen-housed production (Table 2). Birds in small cages laid at 3.3% and 2.7% higher hen-day and hen-housed rates, respectively, than did those in large cages. Birds housed at high density laid at lower rates (3.9% hen-day, 3.7% hen-housed basis) than those housed at low density.

Cage size x density effect on hen-day egg production was significant ($P < 0.05$). Hen-housed egg production was significantly ($P < 0.01$) affected by cage size x density. Best egg production was from the birds housed in small cages at low density; poorest from the birds in large cages at high density.

The row, strain and housing method interactions were not significant for hen-day or hen-housed production. The only significant interaction was strain x density x housing method for hen-housed egg production. A possible

Table 2. Analysis of variance for indicated traits

Source	d.f.	Mean Squares: Hen-day production	Mean Squares: Hen-housed production	Mean Squares: Mortality
Row (R)	2	.002	.012	.003
Strain (S)	1	.027	.086	.004
Cage (C)	1	.575***	.384***	.001
Density (D)	1	.800***	.666***	.001
Housing (H)	1	.010	.039	.001
RS	2	.005	.037	.002
RC	2	.054	.025	.001
RD	2	.051	.010	.002
RH	2	.045	.038	.000
SC	1	.029	.036	.000
DS	1	.041	.045	.000
SH	1	.050	.096	.002
CD	1	.187*	.248**	.000
CH	1	.003	.050	.002
DH	1	.010	.008	.001
RSC	2	.044	.070	.003
RSD	2	.082	.071	.004
RSH	2	.032	.010	.004
RCD	2	.008	.001	.001
RCH	2	.032	.033	.002
RDH	2	.055	.019	.000
SCD	1	.065	.078	.000
SCH	1	.008	.000	.005
SDH	1	.036	.168*	.007
CDH	1	.084	.063	.001
Error	11	.023	.026	.003
Total	47			

***Significant $P < 0.005$
**Significant $P < 0.01$
*Significant $P < 0.05$

Table 3. Analysis of variance for effect of 4-week periods on the indicated traits

Source	d.f.	Mean Squares		
		Hen-day production	Hen-housed production	Mortality
Period (P)	6	8.606***	7.773***	.001
RP[1/]	12	.015	.014	.001
SP	6	.073***	.089***	.002
CP	6	.010	.014	.002
DP	6	.009	.012	.001
HP	6	.006	.010	.002
RSP	12	.013	.018	.001
RCP	12	.014	.013	.001
RDP	12	.012	.018	.002
RHP	12	.003	.003	.001
SCP	6	.001	.001	.001
SDP	6	.006	.006	.001
SHP	6	.013	.010	.000
CDP	6	.045***	.039***	.001
CHP	6	.009	.011	.002
DHP	6	.012	.014	.002
Error	1842[2/]	.010	.011	.002
Total	2015			

[1/]The capital letters stand for the following: Row (R), Strain (S), Cage size (C), Density (D), and Housing method (H).

[2/]The error term includes the effects in Table 2 thus the degrees of freedom are a total of the two.

***Significant $P < 0.005$

Table 4. Analysis of variance for indicated traits

		Mean Squares			
		Rate of	Sexual	% change in body wt.	
Source	d.f.	lay	maturity	20 to 35 wk.	20 to 52 wk
Row (R)	2	.001	1.7	54.4	2.7
Strain (S)	1	.066***	19.5**	549.6*	358.4
Cage (C)	1	.110***	16.5**	4.0	75.7
Density (D)	1	.091***	0.2	0.3	7.3
Housing (H)	1	.007	0.1	180.8	64.5
RS	2	.010	0.7	4.4	13.0
RC	2	.005	3.4	50.4	56.8
RD	2	.000	2.5	152.0	63.9
RH	2	.003	4.3	20.2	35.3
SC	1	.003	1.5	83.1	205.7
SD	1	.002	1.0	57.8	171.3
SH	1	.003	1.3	23.0	17.6
CD	1	.005	41.3***	256.0	17.2
CH	1	.000	1.3	15.0	46.0
DH	1	.001	0.0	37.0	83.7
RSC	2	.018*	1.1	15.0	26.6
RSD	2	.019*	1.2	50.5	58.3
RSH	2	.002	1.3	30.6	12.6
RCD	2	.001	0.5	47.3	41.3
RCH	2	.001	7.4*	115.4	243.8
RDH	2	.006	4.9	31.0	30.2
SCD	1	.038**	0.0	5.0	209.9
SCH	1	.002	0.8	27.8	28.1
SDH	1	.002	3.3	207.9	373.2
CDH	1	.005	0.1	0.3	120.2
Error A[1/]	251	.005	2.1		
Total A	287				
Error B[2/]	11			88.5	103.6
Total B	47				

[1/] A is the error term for rate of lay and sexual maturity.

[2/] B is the error term for percent change in body weight.

***Significant $P < 0.005$
**Significant $P < 0.01$
*Significant $P < 0.05$

Table 5. Effect of strain, cage size, density, and housing method on mortality (%)[1/]

Strain	Cage size		Density		Housing method		Strain av.
	Small	Large	Low	High	Penmates	Intermingled	
1	4.69	4.20	4.97	3.92	4.90	4.06	4.48
2	7.28	5.53	6.65	6.23	5.25	7.56	6.37
Av.	6.02	4.90	5.81	5.11	5.11	5.81	
Dif.[2/]	1.11		0.70		0.70		

[1/]Average percent mortality from 24 to 52 weeks of age.

[2/]The differences were not significant at $P < 0.05$.

Table 6. Effect of strain, cage size, density, and housing method on hen-day production[1/] (%)

Strain	Cage size		Density		Housing method		Strain av.
	Small	Large	Low	High	Penmates	Intermingled	
1	69.8	67.2	70.9	66.1	68.2	68.8	68.5
2	69.8	65.7	69.3	66.2	68.5	67.0	67.8
Av.	69.8	66.5	70.1	66.2	68.3	67.9	
Dif.	3.3[2/]		3.9[2/]		0.4		

[1/]Hen-day production is based on the number of birds present during the period.

[2/]Significant $P < 0.005$

Table 7. Effect of strain, cage size, density, and housing method on hen-housed production[1] (%)

Strain	Cage size		Density		Housing method		Strain av.
	Small	Large	Low	High	Penmates	Intermingled	
1	67.8	65.9	69.2	64.6	66.6	67.1	66.9
2	67.4	63.8	66.9	64.2	66.7	64.4	65.6
Av.	67.6	64.9	68.1	64.4	66.7	65.9	
Dif.	2.7[2]		3.7[2]		0.8		

[1]Hen-housed production was based on the number of birds present at housing.

[2]Significant $P < 0.005$

explanation for this interaction is that in every instance the birds housed at low density produced at a higher rate than the combinations containing birds housed at high density.

The seven 4-week periods were highly significantly different for hen-day and hen-housed egg production, but this was expected because of the normal change in an egg production curve over time (Table 3). Other highly significant ($P < 0.005$) effects were observed for strain x period, and cage size x density x period interactions. All other effects were non-significant. The strain x period interaction resulted from strain 1 starting out at a lower egg production rate (period 1) but laying at a higher rate (periods 3, 4, and 5) than strain 2 (Table 8).

Rate of lay averages are shown in Table 9. Strain, cage size, and density had a significant ($P < 0.005$) effect on rate of lay (Table 4). Strain 1 laid

Table 8. Effect of four-week periods on hen-day and hen-housed production (%)

Period	Strain		Cage size		Density		Housing method	
	1	2	Small	Large	Low	High	Penmates	Intermingled
Hen-day production								
1	28.1	31.5	31.0	28.6	31.9	27.7	29.3	30.4
2	64.9	69.0	69.2	64.7	69.7	64.2	67.3	66.6
3	77.6	76.1	79.5	74.2	79.1	74.6	77.2	76.5
4	79.5	76.3	79.7	76.1	80.1	75.7	78.2	77.6
5	78.9	75.3	78.8	75.4	78.0	76.1	77.9	76.3
6	74.7	72.9	75.0	72.6	75.5	72.1	74.3	73.3
7	75.9	73.2	75.6	73.5	76.5	72.6	74.3	74.8
Hen-housed production								
1	28.1	31.5	31.0	28.5	31.9	27.6	29.2	30.3
2	64.4	68.3	68.4	64.3	69.1	63.6	66.8	65.8
3	76.4	74.9	78.1	73.2	77.8	73.5	76.3	75.0
4	77.8	74.0	77.4	74.3	78.0	73.8	76.6	75.1
5	76.7	72.2	75.7	73.2	75.3	73.6	75.7	73.2
6	71.9	69.4	71.3	70.0	72.0	69.3	71.2	70.1
7	72.8	68.8	71.3	70.3	72.2	69.4	70.6	70.9

Table 9. Effect of strain, cage size, density and housing method on rate of lay (%)

Strain	Cage size		Density		Housing method		Strain av.
	Small	Large	Low	High	Penmates	Intermingled	
1	78.2	73.6	77.4	74.4	76.0	75.8	75.9[a][2/]
2	74.5	71.2	74.9	70.8	73.7	72.1	73.0[b]
Av.	76.4	72.4	76.2	72.6	74.9	74.0	
Dif.	4.0[1/]		3.6[1/]		0.9		

[1/] Significant $P < 0.005$

[2/] Means with different superscripts differ significantly at the $P < 0.005$ level.

at a higher rate than strain 2. Birds in large cages laid at a lower rate than those in smaller cages. Birds housed at low density laid at a higher rate than those housed at high density. There was no significant difference for rate of lay between the two housing methods.

The 3-way interactions of row x strain x cage size, row x strain x density, and strain x cage size x density were significant for rate of lay. The strain x cage size x density interaction was in favor of strain 1, small cage, and low density combination and the lowest rate was from strain 2, large cage and high density combination. This was indicated from Duncan's multiple range test. Although strain 1 produced at a higher rate than strain 2, both reacted in the same direction with regards to cage size, density, and housing method. The reason for the significant effect on the other interactions is not apparent. All other effects not mentioned were not significantly different.

Sexual maturity - Average ages at sexual maturity for the various treatments are shown in Table 10. There was a significant ($P < 0.01$) strain effect on age at sexual maturity (Table 4), with strain 2 maturing earlier than strain 1 (Table 10). Birds in small cages matured significantly ($P < 0.01$) earlier than did those in large cages. As shown in Table 4, except for cage size x density and row x cage size x housing method interactions, neither density, housing method, nor their interactions had a significant effect on age at sexual maturity. The highly significant cage size x density interaction was due to birds in large cages at high density maturing significantly ($P < 0.005$) later (8 days) than those in small cages at high density. Reasons are not apparent for a significant row x cage size x housing method interaction.

Table 10. Effect of strain, cage size, density, and housing method on sexual maturity[1/] (wk.)

Strain	Cage size		Density		Housing method		Strain av.
	Small	Large	Low	High	Penmates	Intermingled	
1	26.4	27.0	26.7	26.6	26.7	26.6	26.7[a3/]
2	26.0	26.3	26.1	26.2	26.1	26.2	26.2[b]
Av.	26.2	26.7	26.4	26.4	26.4	26.4	
Dif.	0.5[2/]		0.0		0.0		

[1/]Measured by determining the first week of the first two weeks the hens in each respective cage laid at 50 percent or more on a hen-day basis.

[2/]Significant $P < 0.01$

[3/]Means with different superscripts differ significantly at the $P < 0.01$ level.

<u>Percent change in body weight</u> - Body weight data are shown in Table 11. There was a significant ($P < 0.05$) strain effect on the percent change in body weight from 20 to 35 weeks (Table 4); strain 1 gaining significantly more weight than strain 2. All other parameters showed no significant differences.

<u>Egg quality</u> - Egg quality data are not shown since the only significant parameter was a strain effect, with strain 2 laying eggs that were significantly heavier but with lower Haugh unit values than those laid by strain 1.

Table 11. Effect of strain, cage size, density, and housing method on body weight

Source	Age (wk.) 20	35	52	% change in body wt. 20-35 wk.	20-52 wk.
	weight (gm.)				
Strain					
1	1133	1611	1697	42.9[a1/]	49.7
2	1218	1666	1760	36.2[b]	44.2
Cage size					
Small	1183	1644	1724	39.2	45.7
Large	1168	1633	1732	39.8	48.2
Density					
Low	1174	1635	1722	39.6	47.3
High	1176	1641	1734	39.5	46.5
Housing method					
Intermingled	1165	1645	1721	41.5	48.0
Penmates	1185	1631	1735	47.6	45.8

[1/] Means with different superscripts differ significantly at the $P < 0.05$ level.

DISCUSSION

Although housing method had no significant effect on egg production a trend was observed. In almost every instance the birds housed as penmates out performed those housed as intermingled (Tables 6 through 9). Guhl and Allee (1944) and Craig and Toth (1969) reported different results which may have been due to the different methods used. When establishing unstable flocks Guhl and Allee (1944) introduced one strange bird from isolated pens while Craig and Toth (1969) used a random scheme to intermingle flocks. Guhl and Allee (1944) reported lower production and increased agonistic behavior, indicating stress. Craig and Toth (1969) hypothesized from their results that frequent changes in group membership are beneficial to those individuals which would otherwise be at the bottom of the peck order in a stable group. Thus under a change in group membership they would have the opportunity to rise in the hierarchy whenever a new group was formed. The non-significant differences obtained in this study support this report, however the trend in favor of penmates may have an economical advantage.

Lack of significant strain, cage size, density, and housing method effects on mortality are not consistent with previous reports. Lowe and Heywang (1964) reported high mortality, 76 percent of the total deaths caused by vent pecking, among 5 birds per cage compared to 2 or 1 birds per cage. Wilson _et al_. (1967) and Adams and Jackson (1970) indicated the possibility of a general stress effect along with cannibalism in high density cage housing.

The significant effect of cage size and density on egg production is in agreement with results published by Lowe and Heywang (1964), Wilson _et al_. (1967) and Adams and Jackson (1970), but does not agree with those by Tower _et al_. (1967), and Dorminey and Arscott (1971). This study showed significant cage size, density and cage size x density interactions. The best hen-day and hen-housed production rates 70 and 68 percent, were from birds housed in small cages and low density combination, respectively, and the lowest production rates, 64 and 62 percent, respectively, from those in large cages and high density combination. Cook and Dembnicke (1966) reported superior average egg production for birds housed in single cages, 32 and 59 egg advantage, over the production of the pullets in a double cage and colony cage,respectively. Adams and Jackson (1970) reported cage size and density had a significant effect on egg production but a cage size x density interaction was non-significant. They housed birds in similar sized cages but at lower densities than were used in this study, 700 vs 590 $cm.^2$ of floor area per bird for low density and 350 vs 328 $cm.^2$ of floor area per bird for high density. They suggested that cage size and density had separate but additive effects on egg production, as indicated by the large difference in production between best and poorest combinations.

Population size delayed sexual maturity as was shown by a cage size effect. It is not apparent why a significant density effect was not observed as reported by Adams and Jackson (1970). They stated that birds housed at a low density tended to mature earlier. Strain 2, which matured earlier than strain 1 laid more eggs early and peaked at a lower rate, suggesting that later maturing birds may peak at a higher rate of lay than those that mature earlier.

There was no significant effect on body weights by the various parameters studied. This is contrary to other reports by Dorminey and Arscott (1971) who found body weight to decrease as bird density increased. The non-significant effects of this study may have resulted from a large variation between the beginning weights as a result of the high density the birds were subjected to from 12 to 21 weeks of age.

The effects of the egg quality data are consistent with reports by Logan (1965); Cook and Dembnicke (1966); Wilson _et al_. (1967); and Adams and Jackson (1970). Egg weights and Haugh unit values differ significantly between strains but are not significantly affected by cage size or density.

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EFFECTS OF REARING RELATIONSHIP, CAGE SIZE, AND BIRD DENSITY ON PERFORMANCE OF TWO COMMERCIAL STRAINS OF EGG-TYPE CHICKENS

by

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Two commercial strains of White Leghorn-type pullets were reared in colony cages from 12 to 21 weeks of age. Then all birds were moved to different cages; half housed as penmates (reared in the same cage) and half as intermingled (reared in separate cages). Two cage sizes (72 x 82 and 41 x 41 cm.) and two densities (330 and 590 $cm.^2$ of cage floor area per bird) were used. Birds that died were not replaced. Traits measured were mortality, egg production, age of sexual maturity, and egg quality.

No significant differences were noted for the effect of the housing method on the parameters studied. However, there was a trend for the birds housed as penmates to out perform those housed as intermingled. This suggests that strangeness may have some small effect on performance. Mortality was not significantly affected by the parameters studied.

Egg production was significantly affected by strain, cage size and density. The highest rate of lay (78%) was from the small cage and low density combination, lowest rate of lay (70%) from the large cage and high density combination. A cage size x density interaction was observed for hen-day and hen-housed egg production which resulted from density differences being greater than cage size differences.

Birds housed in large cages matured later (4 days) than those in small cages. There was a cage size x density interaction with birds housed in large cages at high density maturing later (8 days) than those in small cages at high density.

Egg quality and bird weights were not affected by the parameters studied, except for a strain effect on egg quality.