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Research Article

Effects of Cage Density and Cage Position on Performance of Commercial Layer Pullets from Four Genotypes

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Abstract: This study was carried out to determine the effects of genotype, cage density and position on the pullet performance of commercial layer chicks housed in cages.

Two thousand 1-day-old chicks of Lohman Brown, Lohman White, Isa Brown and Bowans White genotype were housed at 3 cage densities (105.9, 134.8, 185.3 cm^2/bird from day 1 to 4 weeks of age; 211.8, 274.5 and 370.6 cm^2/bird at 4 to 16 weeks of age) and 3 cage positions (top, middle and bottom rows of the battery).

Brown egg layer genotypes were heavier, more uniform and gained more weight with less feed. White egg layers were more sensitive to the effects of treatment. The pullets at the highest density realized optimal final body weight and uniformity with less feed consumption, excluding one genotype. Although the pullets were heavier and most uniform in weight in the bottom row, the feed conversion rate of these pullets was not favorable. Cage density and cage position treatments produced different responses in the different genotypes. It was concluded that if the layer chicks are housed according to their known responses to cage density and position, pullet welfare improves, resulting in better performance.

Key Words: Layer pullet, genotype, cage density, cage position, pullet performance

Kafes Sıklığı ve Kafes Pozisyonunun Dört Yumurtacı Genotipten Piliçlerin Performansı Üzerine Etkileri

Özet: Bu araştırma kafeste büyütülen ticari yumurtacı piliçlerin performansına genotip, sıklık ve pozisyonun etkilerini araştırmak için yapılmıştır.

Lohman Brown, Lohman White, Isa Brown ve Bowans White genotiplerine ait 1 günlük yaşta toplam 2000 adet civciv üç kafes sıklığında (1 günlük - 4 haftalık yaş döneminde 105,9, 134,8, 185,3 cm^2/piliç; 4 - 16 kaftalık yaş döneminde 211,8, 274,5 and 370,6 cm^2/piliç) ve üç kafes pozisyonunda (kafes bataryasının üst, orta ve alt sıralarında) büyütülmüştür.

Kahverengi yumurtacı genotipler daha ağırdılar, daha birörnektiler ve daha az yemle daha çok canlı ağırlık kazandılar. Beyaz yumurtacı genotipler uygulamaların etkilerine karşı daha hassastılar. Bir genotip hariç, en yüksek sıklıkta büyütülen piliçler daha az yem ile optimum bitiş canlı ağırlığı ve üniformitesi gösterdiler. Alt sıradaki kafeslerde bulunan piliçler daha ağır ve daha yüksek birörnekliğe sahip olmalarına rağmen bu piliçlerin yemden yararlanmaları yeterli değildi. Kafes sıklığı ve pozisyonu uygulamaları farklı genotiplerce farklı yanıtlandı. Eğer yumurtacı civcivler kafes sıklığı ve pozisyonuna verdikleri yanıtlara göre kümese yerleştirilir ise piliç refahının yükseltilebileceği ve bunun sonucunda da piliç performansının arttırılabilceği sonucuna varılmıştır.

Anahtar Sözcükler: Yumurtacı piliç, genotip, kafes sıklığı, kafes pozisyonu, piliç performansı

Introduction

Because of the growing concern for animal welfare, it is essential that researchers continue to look for ways to enhance the well being of animals, while keeping production and profits at a high level (1-5). In fact, the well being of chicks has been shown to play a significant role in their pullet and laying performances. What determines an animal's welfare is unique to its genotype and the environment in which it is raised, and can be assessed by monitoring the mental and physical state of the animal (6-9).

It is a common rearing practice to house layer chicks in multiple-deck cage systems at high densities in order to meet demand for pullets (10,11). Cage density is one component of the environment that plays a critical role in determining the well being of a bird (12-14,). Several studies have measured the impact of cage density on bird performance (15-18). Carey et al. (17) reported that greater stocking densities significantly reduced feed intake and 18-week body weight, and that mortality up to 20 weeks was higher among birds reared at 222 cm^2 per bird, in a comparison of animals reared at 311, 259, and 222 cm^2. Carmichael et al. (15) observed that behaviors that decreased in incidence with crowding included standing, moving, foraging and dust-bathing.

Although it has been reported that the performance of caged layers is also influenced by cage position and genotype x environment interactions, more research is needed in this area (19-21). The main objective of this study was to determine the effects of cage density and cage position on the well being and performance of commercial layer pullets of 4 different genotypes.

Materials and Methods

Rearing conditions and experimental design

This study was performed at the Poultry Department, Afyon Yem Sanaayi A.Ş., Afyon Turkey. The experiment was conducted as a randomized complete block design with a 4 x 3 x 3 factorial arrangement of treatments.

Two thousand 1-day-old layer chicks were used in this study, 500 each of the following 4 genotypes: Lohman Brown (LB), Isa Brown (IB), Lohman White (LW) and Bowans White (BW). The chicks were placed in the cages with 5 nipple drinkers per 109 x 68 x 39 cm (in width, depth and height, respectively) cage at 3 cage densities, which included 70, 55, and 40 pullet chicks per cage providing 105.9, 134.8, and 185.3 cm^2 per bird, respectively, from day 1 to 4 weeks of age, as previously described by Patterson and Siegel (16). Each of these cage density groups had 3 replicates for each genotype, and they were randomly distributed to the cage units in the middle row of the battery (into 36 cages). Linear feeder space was 109 cm per cage or 1.56, 1.98, and 2.73 cm per bird at the 70, 55, and 40 birds per cage density, respectively. At 4 weeks, the first replicates and second replicates were randomly moved to cages at the top and the second replicates of the bottom rows, and the third replicates remained in the middle row. Immediately afterwards, half of the remaining chicks in the replicates were moved to a nearby empty cage, thereby doubling the number of replicate cages and reducing bird density to 35, 27, and 20 birds per cage (into 72 cages total). Thus, cage space was increased to 211.8, 274.5, and 370.6 cm^2 per bird, and feeder space increased to 3.11, 4.04, and 5.45 cm per bird from 4 to 16 weeks.

Brooding temperatures and light were maintained at 33 ºC during the first day and 24 h/day during the first 2 days; then temperature and light were reduced gradually and maintained at 21 ºC and 13 h/day thereafter (22-25).

Day 1 to 8 weeks, 9-14 and 15-16 week periods used the starter, grower and developer diets, which contained 20%, 17% and 14% CP and 2800, 2750 and 2750 kcal ME/kg, respectively. Feed and water were provided ad libitum and pullets were fed twice per day at approximately 09.00 and 15.00 h. The compositions of the diets used in the experiments and nutrients amounts of the diets are given in Table 1. Individual body weights were measured in all groups on day 1 and at weeks 2, 4, 8, 12, and 16. Feed consumption was measured each week from 3 and 2 replicate cages at 1 to 4 weeks and 4 to 16 weeks (from each row), respectively. Dead chicks were replaced to maintain the treatments (from spare groups at similar densities) through week 2 only; thereafter, no birds were replaced.

Statistics

A 3-factor by 4 genotype (G), 3 cage density (D) and 3 cage position (P) factorial arrangement of randomized design was used. Factors were examined for their main effects and their interactions. Response variables included viability, body weight, body weight gain, feed intake (FI) and feed conversion ratio (FCR). Independent variables (genotype, density, and cage position) were analyzed using 2 statistical models (26) for day 1 to 4 weeks (model 1) and for 4 to 16 weeks (model 2) and these were

$$Y_{ijk} = \mu + S_i + D_j + SD_{ij} + e_{ijk} \qquad \text{[Model 1]}$$

$$Y_{ijk} = \mu + S_i + D_j + L_k + SD_{ij} + SL_{ik} + DL_{jk} + SDL_{ijk} + e_{ij}k \qquad \text{[Model 2]}$$

Table 1. Ingredients and nutrient composition of experimental diets.

Ingredients	Diets		
	Starter	Grower	Developer
	%		
Corn	30	20	20.7
Wheat	27	34	40
Barley	0	15	15
Sunflower meal	13.6	17.5	18.5
Corn bran	6.5	2.75	0
Soybean meal	20.8	5.4	0
Cotton seed meal	0	2.5	2.5
Limestone	0.50	1.2	1.64
DCP	0.7	0.7	0.7
Salt (NaCl)	0.35	0.35	0.30
Vitamin premix[1]	0.25	0	0
Vitamin premix[2]	0	0.25	0.25
Mineral premix[3]	0.1	0.1	0.1
DL-Methionine	0.07	0	0.02
Lysine	0.02	0.14	0.18
Natuphos[4]	0.06	0.06	0.06
Natugren blend[5]	0.05	0.05	0.05
Calculated analysis			
Dry matter %	88.16	88.32	88.36
Crude Protein, %	20.0	17.0	14.0
Crude cellulose %	5.0	6.2	6.0
Crude ash %	5.7	6.0	6.0
Metabolizable energy (ME), kcal/kg	2800	2750	2750
Calcium, %	0.75	1.1	1.4
Total phosphorus, %	0.72	0.71	0.71
Sodium, %	0.16	0.16	0.16
Chloride, %	0.28	0.30	0.28
Potassium, %	0.85	0.74	0.68
Methionine %	0.4	0.28	0.28
Methionine + cystine, %	0.7	0.57	0.55
Lysine, %	0.86	0.70	0.60
Tryptophan, %	0.23	0.19	0.17

[1] Rovimix 121-L, Provided per 2.5 kg of diet: vitamin A 12,000,00 IU; vitamin D_3 2,500,000 IU; Vitamin E 20,000 mg; Vitamin K_3 4000 mg; vitamin B_1 3000 mg; vitamin B_2 6000 mg; vitamin B_6 5000 mg; vitamin B_{12} 20 mg; niacin, 25,000 mg, Ca-D-Pantotenate, 6000 mg; folic acid, 750 mg; choline chloride, 250,000 mg.

[2] Rovimix 122-E, Provided per kg of diet: Vitamin A:10,000,000 IU, vitamin D_3 1,000,000 IU, vitamin E: 25,000 mg, vitamin K: 3000 mg, vitamin B1: 2000 mg, vitamin B2: 25,000 mg, Niacin: 20,000 mg, Calcium D-pantothenate 8000 mg, Vitamin B6: 4000 mg, Vitamin B12: 15 mg, Folic acid: 800 mg, Choline Chloride: 300,000 mg.

[3] Remineral S provided per 2.5 kg of diet: Mn, 40,000 mg; Fe, 60,000 mg; Zn, 5000 mg; Cu, 500 mg; Co, 2000 mg; Se, 150 mg; Ca, 223,905 mg.

[4] Natugrain Blend Provided per 1000 g: Endo-xylanase: 11,000,000 U, Beta –Glucanase: 240,000 U.

[5] Natuphos Provided per 1000 g: Phytase 500,000 U.

where Y_{ijk} is the observation per cage; μ is the overall mean; S_i is the bird genotype effect; D_j is the cage density effect; L_k is the cage position; SD_{ij}, SL_{ik}, DL_{jk}, SDL_{ijk} are subsequent interactions; and eijk is the random error. Data were subjected to statistical analysis using the general linear models procedure of SPSS (27), and differences among the means were partitioned using Duncan's multiple range procedure (26). Significance level was set at $P < 0.05$.

Results

The results on viability rates of layer pullets at different ages, densities and locations are presented in Table 2. The genotype and position effects were significant ($P < 0.01$, $P < 0.05$) There were higher viability rates for the LB and IB and middle row position groups. There were significant G x D, D x P, G x P and G x D x P interactions in the experiment (Table 2).

As shown in Table 3, body weight was affected significantly by genotype, density and cage position ($P < 0.01$). From 4 weeks of age, the brown-egg layer pullets were evidently heavier than the white-egg layer pullets. Cage density impacted mean body weight at all weighing periods ($P < 0.01$) (Table 3). The birds housed at 20 birds per cage were heavier than pullets housed at other densities. The heaviest birds were at the top, middle and bottom rows at 4, 8 and 12 weeks of age, respectively, and the cage position effects were not significant at 16 weeks of age.

For body weight, there were significant G x D, G x P interactions at all weighing periods (except for the second week) and P x D interactions at 8 and 16 weeks of age (Table 3).

The mean, maximum and minimum body weights and standard deviation, coefficients of variation and flock uniformity results as functions of genotype, density and

Table 2. Viability of layer pullet genotypes at different ages, densities and positions.

Treatments			Viability	
Genotype	Density[1]	Position[2]	Day 1 to 4 weeks	4 to16 weeks
			(%)	
Lohman Brown			99.43 [a]	96.28 [a]
Isa Brown			97.08 [b]	95.03 [a]
Lohman White			95.85 [b]	91.87 [b]
Bowans White			93.02 [b]	89.72 [c]
	70 to 35		96.36	93.16
	55 to 27		96.21	92.97
	40 to 20		96.46	93.54
		Top		92.40 [b]
		Middle		94.58 [a]
		Bottom		92.70 [b]
ANOVA			Probability	
Genotype (G)			**	**
Density (D)			N.S.	N.S.
Position (P)			N.S.	*
G x D			**	**
G x P			N.S.	**
D x P			N.S.	**
G x D x P			N.S.	**
SEM			0.22	0.33
R^2			0.69	0.84

[a-c] Means in a column and treatment variable with no common superscript differ significantly (($P < 0.05$)

[1] Cage density was reduced at 4 weeks of age from 70, 55 and 40 birds per cage to 35, 27 and 20 birds per cage by randomly dividing birds between 2 cages.

[2] Cage position was made by 1 group of birds for each density and birds genotype.

* $P < 0.05$, ** $P < 0.01$, N.S.: Non-significant

Table 3. Body weight of layer pullet genotypes at different ages, cage densities and positions.

Treatments			Body weight average					
Genotype1	Density2	Position3	Day 1	2 weeks	4 weeks	8 weeks	12 weeks	16 weeks
			(g)					
Lohman Brown			35.18^{b}	100.82^{a}	220.71^{a}	697.06^{a}	1075.56^{a}	1492.36^{a}
Isa Brown			36.61^{a}	95.46^{b}	204.57^{b}	679.45^{b}	1079.10^{a}	1438.07^{b}
Lohman White			36.55^{a}	97.68^{c}	220.71^{a}	636.18^{c}	963.31^{b}	1202.43^{c}
Bowans White			33.62^{c}	88.26^{d}	195.58^{c}	575.91^{d}	875.44^{c}	1115.45^{d}
	70 to 35		35.30^{b}	96.45^{a}	213.33^{a}	634.83^{b}	987.91^{b}	1275.34^{a}
	55 to 27		35.68^{a}	94.94^{b}	205.72^{b}	642.66^{b}	987.48^{b}	1340.35^{b}
	40 to 20		35.49^{ab}	95.28^{ab}	212.13^{a}	663.95^{a}	1019.66^{a}	1320.54^{c}
		Top	35.27^{b}	95.27	213.91^{a}	635.08^{a}	982.16^{a}	1305.58
		Middle	35.72^{a}	96.17	209.78^{b}	647.59^{b}	998.77^{b}	1314.86
		Bottom	35.48^{ab}	95.22	207.49^{b}	658.78^{c}	1014.12^{c}	1315.79
ANOVA			Probability					
Genotype (G)			**	*	**	**	**	**
Density (D)			**	**	**	**	**	**
Position (P)			*	N.S.	**	**	**	N.S.
G x D			**	N.S.	**	**	**	**
G x P			N.S.	**	**	**	*	*
D x P			N.S.	N.S.	N.S.	**	N.S.	*
G x D x P			N.S.	**	**	**	N.S.	*
SEM			0.06	0.26	0.69	1.67	3.39	3.16
R^2			0.20	0.18	0.22	0.35	0.44	0.70

[a-d] Means in a column and treatment variable with no common superscript differ significantly ($P < 0.05$)

* $P < 0.05$.** $P < 0.01$, N.S. : Non-significant.

[1] All birds in the groups were weighted at weighting periods.

[2] 70-35, 55-27 and 40-20 birds per cage 3: The top, middle and bottom rows of the battery.

cage position groups at 16 weeks are addressed together in Table 4.

The maximum and minimum body weight within each cage density and cage position group increased as mean values increased at 16 weeks of age. However, the body weight goals recommended by pullet management guides for LB, IB and LW and the mean body weight were 5% less for BW pullets. The best flock uniformity was obtained in the highest density for LB and LW pullets. The uniformity recommended by most pullet management guides is to produce 80% or more pullets within 10% of the mean. In this experiment the goal was realized by LB, IB, LW (93.9%, 81.5% and 88.9%) at highest density treatments (35 birds per cage) but the goal was not realized except for lowest density treatments (20 birds per cage) for BW pullets (88.8%). There were poorer uniformity rates for the top row. Better flock uniformity values were obtained for the highest density at all positions. The uniformity was poorer at the top row for average density and the sufficient uniformity was for only the bottom row for lowest density.

Body weight gain, FI, and FCR for day 1 to 4 weeks and 4 to 16 weeks are shown in Tables 5 and 6. The mean body weight gain, feed intake and feed conversion of pullets genotypes in relation to different cage densities and location are presented in Tables 7 and 8.

Table 4. Body weight statistics and uniformity values of layer pullet genotypes at 16 weeks of age and different cage densities and positions.

	Lohman Brown									Isa Brown								
	Birds Per cage									Birds Per cage								
	70 to 35			55 to 27			40 to 20			70 to 35			55 to 27			40 to 20		
Statistics	T	M	B	T	M	B	T	M	B	T	M	B	T	M	B	T	M	B
Mean, g	1.411	1.450	1.464	1.481	1.571	1.565	1.519	1.506	1.464	1.163	1.411	1.374	1.459	1.456	1.493	1.452	1.464	1.471
Maximum, g	1.563	1.683	1.602	1.811	1.869	1.819	1.803	1.768	1.690	1.535	1.619	1.541	1.615	1.823	1.805	1.692	1.721	1.889
Minimum, g	1.015	1.162	1.273	1.056	1.359	1.223	1.238	1.175	1.171	1.113	1.268	1.054	1.281	1.051	1.288	1.178	1.168	1.227
SD	105.1	114.9	78.0	167.9	128.1	115.0	140.7	132.5	113.7	101.9	96.4	116.3	89.00	148.8	114.1	119.3	119.7	131.1
CV, %	7.45	7.92	5.33	11.34	8.15	7.35	9.26	8.80	7.77	8.76	6.83	8.46	6.10	10.22	7.64	8.22	8.18	8.91
Uniformity, %	91.2	86.1	94.4	64.5	78.1	90.6	69.4	75.00	77.8	83.3	86.1	75.00	93.8	84.4	87.5	77.8	71.9	80.6

	Lohman White									Bowans White								
	Birds Per cage									Birds Per cage								
	70 to 35			55 to 27			40 to 20			70 to 35			55 to 27			40 to 20		
Statistics	T	M	B	T	M	B	T	M	B	T	M	B	T	M	B	T	M	B
Mean, g	1.183	1.189	1.196	1.228	1.201	1.195	1.235	1.229	1.166	1.063	1.075	1.125	1.158	1.132	1.145	1.114	1.094	1.133
Maximum, g	1.352	1.359	1.400	1.447	1.368	1.484	1.534	1.454	1.319	1.196	1.210	1.276	1.383	1.312	1.372	1.265	1.238	1.341
Minimum, g	1.021	1.073	1.087	1.018	1.077	0.748	0.969	1.072	0.907	0.730	0.884	0.966	0.981	0.970	0.811	0.818	0.837	0.977
SD	84.4	79.9	68.2	122.2	72.6	138.4	120.4	105.6	92.00	99.8	81.7	75.9	102.6	91.2	112.1	84.8	76.9	79.5
CV, %	7.13	6.72	5.70	9.95	6.04	11.58	9.75	8.59	7.89	9.39	7.60	6.75	8.86	8.06	9.79	7.61	7.03	7.02
Uniformity, %	83.3	88.9	94.4	66.7	86.2	80.0	72.2	69.4	82.1	77.8	80.6	80.6	63.3	77.4	80.0	88.9	91.7	85.71

Uniformity = Percentage of the treatment population 10% from the mean body weight.

T: Top of the cage M: Middle of the cage B: Bottom of the cage

70 to 35: 211.8 cm^2/bird 55 to 27: 274.5 cm^2/bird 40 to 20: 370.6 cm^2/bird

Table 5. Body weight gain, feed intake, and feed conversion rate (feed intake:weight gain) of layer pullet genotypes at different ages and densities.

Treatments		Body weight gain		Feed intake[†]		Feed conversion rate	
Genotype[1]	Density[2]	Day 1 to 2 weeks	2 to 4 weeks	Day 1 to 2 weeks	2 to 4 weeks	Day 1 to 2 weeks	2 to 4 weeks
Lohman Brown		65.64 [a]	119.8 [a]	228.51 [ab]	285.51 [b]	3.49 [b]	3.31 [c]
Isa Brown		58.84 [b]	109.11[b]	196.23 [c]	283.61 [b]	3.34 [b]	3.42 [ab]
Lohman White		61.13 [b]	123.03 [a]	240.99 [a]	326.42 [a]	3.96 [a]	3.67 [bc]
Bowans White		54.64 [c]	107.32 [b]	217.73 [b]	291.05 [a]	4.01 [a]	3.81 [c]
	70 to 35	61.14	116.88	191.60 [c]	281.61 [b]	3.13 [c]	3.30 [c]
	55 to 27	59.26	110.78	214.13 [b]	285.39 [b]	3.64 [b]	3.54 [b]
	40 to 20	59.79	116.85	256.86 [a]	322.96 [a]	4.33 [a]	3.82 [a]
ANOVA		Probability					
Genotype (G)		**	**	**	*	**	**
Density (D)		N.S.	N.S.	**	**	**	**
G x D		N.S.	*	*	N.S.	*	**
SEM		0.47	1.29	2.18	5.30	0.05	0.05
R^2		0.76	0.68	0.91	0.57	0.86	0.74

a-c Means in a column and treatment variable with no common superscript differ significantly (P < 0.05)

[1]: n = 9, [2]: n = 3 (70-35, 55-27 and 40-20 birds per cage)

* P < 0.05, ** P < 0.01 N.S: Non-significant [†] : Feed intake was evaluated as g/bird/period

LB and LW chicks gained more weight at 2 to 4 weeks, and brown egg layer genotypes gained more weight than the white egg layers at 4-16 weeks. However, weight gain was not affected by cage density treatments before 12 weeks. The pullets housed at 55-27 birds per cage gained more weight than birds housed at other densities in the 12-16 weeks period. There were significant cage position effects only at 4-8 weeks. The FI were significantly affected by genotype and cage density (P < 0.01). Although the white egg layer pullets consumed more feed than the brown egg layer pullets in the first 4 weeks, the brown egg layer consumed more feed at 12-16 weeks. The higher the cage density, the lower the FI. The pullets in the top and bottom row cages ate more feed than the others in the middle row cages (P < 0.01) at 12 to 16 weeks. However, there were significant genotype effects for FCR throughout the experiment (P < 0.01). FCR was affected significantly by density and cage position in the 4 to 8 and 4 to 16 weeks (P < 0.01, P < 0.01 and P < 0.05).

Significant G x D interactions were observed for weight gain, feed intake and feed conversion, calculated at 2 to 4, day 1 to 2 weeks and day 1 to 4 weeks (P < 0.05, P < 0.05, P < 0.05 and P < 0.01). The G x D x P interactions were insignificant for all periods.

Discussion

Brown egg layer pullets were consistently within the viability values recommended by management. When LW pullets were housed at high density in top row cages, mortality was high. It was observed that the panic caused by sudden actions or sounds (especially in top row cages) may have been responsible for these deaths. Most of the deaths among BW pullets (6.98%) were observed at day 1 to 4 weeks. It was thought that deaths among the BW chicks were lower than among the others. Wyatt et al. (1) reported that small chicks are more sensitive to environmental conditions. Mortality was not impacted by the cage density treatments. This agrees with the findings reported by Patterson and Siegel (16), who examined the same stocking density (371.6 cm^2 per bird).

The brown-egg layer pullets were heavier than the white-egg layer pullets and they gained more weight. These results are expected because the brown-egg layer pullets are medium hybrids and white-egg layer hybrids

Table 6. Body weight gain, feed intake, and feed conversion rate (feed intake:weight gain) of layer pullet genotypes at different ages, densities1 and positions.

Treatments			Body weight gain			Feed intake[†]			Feed conversion rate		
Genotype[1]	Density[2]	Position[3]	4 to 8 weeks	8 to 12 weeks	12 to 16 weeks	4 to 8 weeks	8 to 12 weeks	12 to 16 weeks	4 to 8 weeks	8 to 12 weeks	12 to 16 weeks
			(g)								
Lohman Brown			485.76c	363.60 a	416.42 a	1278.71	1989.10 a	2999.31 a	2.66 b	5.71 ab	7.37 b
Isa Brown			469.76 c	399.71 b	358.63 a	1319.91	2044.46 a	2843.23 b	2.82 b	5.12 b	8.05 b
Lohman White			410.05 a	326.83 c	239.51 b	1331.21	1960.46 a	2805.20 b	3.24 a	6.02 a	11.93 a
Bowans White			375.34 b	300.21 c	183.85 b	1278.89	1827.25 b	2650.14 c	3.41 a	6.10 a	10.60 a
	70 to 35		427.41	341.69	287.44 b	1108.57 c	1829.44 b	2733.29 b	2.65 c	5.56	9.94
	55 to 27		431.94	345.17	352.19 a	1282.27 b	1900.60 b	2808.23 b	3.02 b	5.55	8.63
	40 to 20		446.34	355.91	259.17 b	1515.70 a	2135.90 a	2931.90 a	3.44 a	6.10	9.91
		Top	415.68 b	346.89	323.48	1310.44	1920.53	2834.97 a	3.18 a	5.57	9.54 ab
		Middle	432.44 b	351.74	274.00	1287.65	1959.25	2721.49 b	3.00 b	5.64	8.59 b
		Bottom	457.57 a	344.14	301.32	1308.45	1986.16	2916.96 a	2.92 b	6.00	10.35 a
ANOVA			Probability								
Genotype (G)			**	**	**	N.S.	**	**	**	*	**
Density (D)			N.S.	N.S.	*	**	**	**	**	N.S.	0.09
Position (P)			**	N.S.	N.S.	N.S.	N.S.	**	**	N.S.	*
G x D			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
G x P			N.S.	N.S.	N.S.	N.S.	N.S.	**	N.S.	N.S.	0.08
D x P			N.S.	N.S.	N.S.	N.S.	*	**	N.S.	N.S.	N.S.
G x D x P			N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
SEM			4.52	4.75	13.84	10.66	16.87	21.48	0.034	0.12	0.27
R^2			0.80	0.70	0.71	0.89	0.77	0.77	0.86	0.49	0.72

[a-c] Means in a column and treatment variable with no common superscript differ significantly ($P < 0.05$)

[1]n: 18 [2]n: 6 (70-35, 55-27 and 40-20 birds per cage) [3]n: 2 (The top, middle and bottom rows of the battery).

* $P < 0.05$, ** $P < 0.01$, N.S.: Non-significant [†]: Feed intake was evaluated as g/bird/period

Table 7. Body weight gain, feed intake and feed conversion rate of pullet genotypes in relation to different positions.

	Lohman Brown			Isa Brown			Lohman White			Bowans White		
	Position											
Traits	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Body weight gain(g)												
Day 1 to 2 weeks	65.3	66.6	65.1	59.9	59.7	56.8	59.1	60.2	64.1	55.7	55.3	53.0
2 to 4 weeks	122.5	118.3	118.9	119.9	107.9	99.5	119.6	122.2	127.4	112.6	106.1	103.3
4 to 8 weeks	463.9	472.5	520.9	436.2	482.8	490.4	401.9	410.5	417.6	360.7	364.0	401.4
8 to 12 weeks	354.8	384.3	351.8	386.2	401.1	411.9	332.3	329.1	319.2	314.3	292.6	293.8
12 to 16 weeks	422.3	426.9	400.2	380.6	350.5	344.8	260.6	241.8	216.1	230.4	240.4	244.3
Feed intake (g)												
Day 1 to 2 weeks	223.9	230.4	231.2	199.4	195.9	193.3	237.1	241.8	244.1	215.2	209.4	228.6
2 to 4 weeks	282.9	305.4	268.2	289.7	283.4	277.7	331.6	334.2	313.5	326.6	287.1	259.5
4 to 8 weeks	1266.1	1270.4	1299.6	1327.1	1329.7	1303.0	1334.1	1306.1	1353.5	1314.5	1244.4	1277.7
8 to 12 weeks	1952.3	2006.8	2008.2	2026.3	2038.9	2068.2	1851.0	2002.9	2027.6	1852.9	1788.4	1840.7
12 to 16 weeks	2905.6	2842.1	3250.2	2731.5	2876.6	2921.6	2894.9	2693.5	2827.2	2807.8	2473.8	1668.8
Feed conversion rate (g:g)												
Day 1 to 2 weeks	3.44	3.47	3.54	2.90	3.49	3.63	4.03	4.03	3.82	3.89	3.79	4.36
2 to 4 weeks	3.15	3.49	3.27	3.34	3.55	3.37	3.85	3.70	3.46	3.88	3.77	3.79
4 to 8 weeks	2.72	2.69	2.58	2.52	2.76	3.19	3.32	3.18	3.24	3.63	3.42	3.18
8 to 12 weeks	5.53	5.26	6.32	4.94	5.01	5.39	5.61	6.11	6.34	5.89	6.11	6.29
12 to 16 weeks	6.93	6.84	8.35	8.18	7.34	8.64	11.24	11.18	13.37	12.67	7.96	11.16
Viability Day 1-4 weeks %	99.0	99.6	99.6	96.7	97.2	97.3	96.3	97.5	93.8	92.3	94.7	92.0
4-16 weeks %	98.6	93.9	96.3	93.4	95.4	96.3	91.1	95.3	89.2	86.5	93.6	89.0

Table 8. Body weight gain, feed intake and feed conversion rate of pullet genotypes in relation to different cage densities.

	Lohman Brown			Isa Brown			Lohman White			Bowans White		
	Cage density											
Traits	70 - 35	55 - 27	40 - 20	70 - 35	55 - 27	40 - 20	70 - 35	55 - 27	40 - 20	70 - 35	55 - 27	40 - 20
Body weight gain(g)												
Day 1 to 2 weeks	66.5	64.4	65.9	58.5	58.1	59.9	63.7	60.6	60.0	56.9	53.9	53.3
2 to 4 weeks	135.7	108.4	115.5	105.9	107.5	113.9	119.3	122.1	127.6	106.6	105.3	110.3
4 to 8 weeks	496.5	470.5	490.2	446.2	480.9	482.1	400.6	404.0	425.5	366.3	372.2	387.5
8 to 12 weeks	347.6	371.3	371.9	386.6	385.2	427.4	329.6	324.9	326.0	303.0	299.2	298.4
12 to 16 weeks	354.0	483.1	412.1	343.9	395.9	336.0	234.9	254.1	229.5	216.9	275.6	222.6
Feed intake (g)												
Day 1 to 2 weeks	201.6	226.18	257.8	169.83	201.7	217.2	218.8	222.4	281.9	176.2	206.3	270.6
2 to 4 weeks	289.2	272.6	294.8	267.23	284.5	299.2	318.7	312.9	347.6	251.3	271.6	350.3
4 to 8 weeks	1120.8	1232.3	1483.1	1123.6	1305.7	1530.4	1093.9	1327.9	1571.8	1095.9	1263.3	1477.5
8 to 12 weeks	1804.6	1976.5	2186.2	1907.2	1928.9	2297.3	1841.6	1913.7	2126.1	1764.4	1783.3	1934.0
12 to 16 weeks	2911.9	2922.6	3163.5	2805.2	2869.8	2854.7	1650.4	2832.6	2932.6	2565.7	1607.9	2776.9
Feed conversion rate (g:g)												
Day 1 to 2 weeks	3.03	3.51	3.91	2.90	3.49	3.63	3.49	3.90	4.70	3.11	3.85	5.09
2 to 4 weeks	2.94	3.50	3.48	3.34	3.55	3.37	3.66	3.47	3.87	3.26	3.63	4.55
4 to 8 weeks	2.34	2.62	3.03	2.52	2.76	3.19	2.73	3.30	3.69	2.99	3.40	3.84
8 to 12 weeks	5.86	5.35	5.91	4.94	5.02	5.39	5.61	5.89	6.58	5.83	5.96	6.51
12 to 16 weeks	8.22	6.09	7.81	8.18	7.34	8.64	11.32	11.34	13.13	12.03	9.72	10.04
Viability Day 1-4 weeks %	98.3	100.0	100.0	98.6	95.2	97.5	95.7	95.2	96.7	92.9	94.5	91.7
4-16 weeks %	93.6	96.9	98.3	94.3	93.3	97.5	93.3	91.5	90.8	91.4	90.2	87.5

are light hybrids derived primarily from White leghorns (5,8).

As cage space allowance increased, the birds became heavier up to 12 weeks of age, but the final body weights of these birds were lower than the groups kept at a density of 27 birds per cage as a control for density treatments. These findings agree with Carey et al. (17), who reported that lower densities allowed higher bird activity and caused them to use more energy for these activities, and these results seem also to be in compliance with the findings published by Carmichael et al. (15) and Lee and Moss (14), who observed that the behaviors that decreased in incidence with crowding included moving, foraging and dust-bathing. Our results showed that housing at low density may be good for bird welfare; however, this treatment is not so economical. The pullets raised at highest density were light, had good flock uniformity, consumed less feed, and they benefited from feed more and, except for BW-pullets, these birds reached the recommended body weights at 16 weeks of age (22-25). These results agree with reports by Anderson et al. (10) and Carey (12), and show that high stocking density does not lead to excessively poor bird welfare. The decreased feed intake, body weight and poorer FCR may be due to the restricted access to the nipple drinkers and feeders that occurs as animals are housed at high density, as reported by Patterson and Siegel (16), Leeson et al. (8) and Carey et al. (17).

The higher the bird density, the higher the flock uniformity, except in the case of BW pullets. These results indicated that genotype x environment interactions affected BW pullets more adversely than the other genotypes. Uniformity varies by genotype of birds, but uniformity also depends on the management of crowding, stress, and nutrition (4,10). These results were in agreement with the reports of Patterson and Siegel (16). The significant G x P interactions indicated that the restriction of activity may have had a significant role in determining body weight uniformity, especially for the brown egg layers. White egg layers are generally smaller than medium hybrids that lay brown eggs, and so that recommended space allowances seem more generous. However, light hybrids are more active than medium, especially before laying, and so the restriction of the cage environment may be more important (5,9).

In general, being located in the top row had adverse effects on pullet performance, and these effects became more clear when the pullets got older. One explanation is the higher light intensity at the top, which might be a stress on the birds housed there (7,19). It is much more difficult to provide uniformity of light intensity in cage operations, especially with multidecked cages. Nazlıgül et al. (20) reported significant cage row effects on layer performance, with the birds on top rows starting to lay early. Morris (2) reported different light intensity at different rows.

During the first 4 weeks, the white egg layer pullets consumed more feed than the brown egg layer pullets. These findings surprised us, and we thought at first that the chick feeders were somehow losing feed. Then, however, we observed that white egg layer chicks were more active. After 8 weeks of age, brown egg layers ate more feed. These results were not so surprising, because brown egg layers are heavier than the white egg layer pullets. As Prescott et al. (4) pointed out, heavy birds seem to consume more feed. The larger the bird, the greater the feed requirements for maintenance (3,9).

The more pullets there were in a cage, the less feed they consumed. Food intake may have been depressed because, at high bird density, access to the feeders and water is restricted. These results agree with reports by Carey (12). At 12-16 weeks the birds raised in the cages in the top and bottom rows showed 15% and 9% more weight gained and consumed on average 5% more feed, but they benefited less from the feed. The reason for this result was not clear, but it may be related to conditions associated with the row locations, such as ambient temperature, insufficient ventilation or other factors that create stress on the animals (13).

In conclusion, our results show that brown egg layer genotypes were heavier, more uniform and gained more weight with less feed. White egg layers were more sensitive to the effects of treatment. The pullets at highest density realized optimal final body weight and uniformity with less feed consumption, excluding BW pullets. Although the pullets were heavier and more uniform in the bottom row, the feed conversion rate of these pullets was not favorable. Cage density and cage position treatments gave different responses for different genotypes. If the layer chicks are housed in the rearing house according to their responses to cage density and position, pullet welfare will be enhanced, resulting in improved performance.

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