Production performance, use of nest box, and external appearance of two strains of laying hens kept in conventional and enriched cages[1]

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ABSTRACT The aim of this study was to investigate the differences in production performance, use of nest box, and external appearance of 2 strains of laying hens kept in conventional and enriched cages. Lohmann Brown Classic (LB, n = 532) and Lohmann LSL Classic (LW, n = 532) hens were housed from 16 to 73 wk in either conventional cages or enriched cages. Enriched cages had a nesting area, scratch pad, perch, and nail shortener. Body weight (BW), hen-day egg production, egg weight, feed intake, feed conversion ratio (FCR), cracked and dirty eggs, use of nest box for lay, and external appearance were determined. Laying period influenced the hen-day egg production, egg weight, feed intake, and feed conversion ratio. Cage type affected the hen-day egg production and feed conversion ratio, while strain affected the egg weight, feed intake, and feed conversion ratio. Laying period × cage type and laying period × strain interactions affected egg production, egg weight, and feed conversion ratio. Both strains preferred to lay in the nest box. Percentages of cracked and dirty eggs of LW hens in enriched cages were higher than that in conventional cages. Most of the dirty eggs laid by both strains were found outside of the nest box. The LW hens laid more dirty eggs than the LB hens. Cage type and cage type × strain interaction were important for total feather score. Final claw length was affected by cage type, strain, and cage type × strain interaction. This study suggests that cage type, strain, and also cage type × strain and period × strain interactions should be considered when alternative housing systems are used.

Key words: Laying hens, strain, cage, performance, nest box use

2015 Poultry Science 94:559–564
http://dx.doi.org/10.3382/ps/pev009

INTRODUCTION

The use and development of different housing systems for layers have been changing in the world. Concerns about the welfare of hens prompted an industry-wide search for a better system of housing (Tauson, 2005; Tactacan et al., 2009). Conventional cages are controversial because they are without furnishings such as perches, nests, and scratch pads. Thus, conventional cages do not allow hens to express certain behaviors and provide a barren environment for the hens with little space (Tauson, 2005; Lay et al., 2011). Conventional cages were banned in many countries. However, the switching cost of enriched cage systems is very high for farmers. Alternative systems for laying hens must be designed to balance the health, hen's production, hen's welfare, food safety, and consumer preferences (Singh et al., 2009; Sumner et al., 2011). Enriched cages are gaining importance due to the consumers' demands. The aim of this cage is to enable laying hens to display natural behavior and increase the hen's welfare. Different strains are used in egg production and their productive performance has a genetic basis and varies between strains of hens (Silversides et al., 2006; Singh et al., 2009). However, research about strain and cage system interaction effects on production and welfare parameters is limited. Also the relative economy of different systems is country-specific. Many factors affect the production cost and they can change in different countries (Tauson, 2005).

This study was undertaken to evaluate the differences in egg laying performance, use of nest box for lay, and external appearance of two strains of laying hens kept in conventional and enriched cages.

MATERIALS AND METHODS

A total of 532 beak-trimmed Lohmann Brown Classic (**LB**) and 532 beak trimmed Lohmann LSL Classic (**LW**) pullets (16 wk age) were used in this study. Two caging systems, conventional and enriched,

Received July 15, 2014.
Accepted November 16, 2014.
[1]This study was supported by Ankara University (Grant No. BAP-10A3338005).
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Table 1. Composition and analysis of experimental diets.

	Laying periods (wk)				
Ingredient, %	16 to 17	18 to 31	32 to 45	46 to 59	60 to 73
Corn	51.60	52.00	53.40	54.00	54.80
Wheat	7.60	7.80	6.80	6.90	6.90
Soyabean meal, 47%	17.37	17.27	17.30	17.05	16.20
Fullfat soya	8.00	6.52	6.09	4.34	4.10
Sunflower seed meal	5.50	5.70	5.10	6.20	6.40
Limestone	8.00	8.50	9.10	9.40	9.60
Dicalcium phosphate	1.20	1.50	1.50	1.40	1.30
Salt	0.21	0.21	0.21	0.21	0.21
DL-Methionine	0.17	0.15	0.15	0.15	0.14
Vitamin mineral premixes[1]	0.25	0.25	0.25	0.25	0.25
Sodium bicarbonate	0.10	0.10	0.10	0.10	0.10
Analyzed value					
ME[2], kcal/kg	2,760	2,730	2,725	2,700	2,700
CP, %	17.75	17.30	16.95	16.60	16.20
Ca, %	3.40	3.70	3.95	4.05	4.12
Total P, %	0.58	0.61	0.60	0.58	0.55
Calculated analysis					
Methionine, %	0.44	0.41	0.41	0.41	0.39
Lysine, %	0.87	0.84	0.83	0.80	0.77

[1]Supplied per kg of diet: 3.6 mg retinol, 0.06 mg cholecalciferol, 30 mg DL-α-tocopherol acetate, 2.5 mg menadione dimethylpyrimidinol bisulfite, 2.5 mg thiamin, 6 mg riboflavin, 4 mg pyridoxol, 20 μg cobalamin, 25 mg niacin, 8 mg calcium-D-panthotenate, 1 mg folic acid, 50 mg ascorbic acid, 50 μg D-biotin, 150 mg choline chloride, 1.5 mg canthaxanthin, 0.5 mg apo carotenoic acid esther, 80 mg Mn, 60 mg Zn, 60 mg Fe, 5 mg Cu, 1 mg I, 0.5 mg Co, and 0.15 mg Se.

[2]Estimated using the equation of Carpenter and Clegg (1956).

were installed in the same building. Each system consisted of 3 rows. Conventional cages were designed to house 20 hens with dimensions measuring 192 cm in width, 62.5 cm in depth, and 57 in cm height. Nipple-type drinkers (8 nipples/cage) were used. The experimental unit was 28 cages with 20 hens/cage. The enriched cages were designed to house 18 hens with dimensions measuring 240 cm in width, 62.5 cm in depth, and 57 cm in height. Enriched cages included nest area (48 cm in width × 62.5 cm in depth), scratch-pad area (35 cm in width × 35 cm in length), perch, and embossed nail shortener (12 cm in width × 3 cm in length). The nesting area was separated from the other areas by a blue curtain composed of plastic strips. Two plastic perches, 190 and 137 cm in length, ran parallel to the feed trough in the perch area. Scratch-pad areas were green plastic mesh. Nipple drinkers were used (8 nipples/cage). The experimental unit was 28 cages with 18 hens/cage. At 16 wk age all pullets were weighed. Then, 252 and 280 pullets each of LW and LB strains were housed in to the conventional cages and enriched cages, respectively. The ingredients and the nutrient compositions of the diets by period are reported in Table 1. Nutrient compositions of the diets were determined with Associaton of Analytical Chemists (AOAC) methods (AOAC, 2000). Calcium (Farese et al., 1967) and total phosphorus (ADAS, 1981) were determined after ashing the samples in a muffle furnace. Metabolizable energy levels of samples were estimated using the equation of Carpenter and Clegg (1956). The lighting program was 16:8 L:D during the laying period. Eggs from each cage type and strain were collected daily from 18 to 73 wk age. Egg production was calculated on a hen-day basis. Eggs laid in each cage were visually examined to record the number of cracked and dirty eggs daily from 47 to 73 wk. Also in enriched cages, the locations of cracked and dirty eggs were determined in regards to the nest boxes. All eggs were weighed on 1d/wk, and egg mass was calculated from egg production and egg weight. The feed conversion ratio (**FCR**) was calculated by dividing the feed intake by the egg mass. Hen-day egg production, egg weight, feed intake, and feed conversion ratio were calculated for 4 equal periods and are shown in Table 2. External appearance traits, including plumage condition and claw length, were measured at 16 and 73 wk age. Hens were individually taken out of their cage and examined for feather score (Onbaşılar and Aksoy, 2005). A score (graduated from 1 = very poor plumage to 4 = intact plumage) was assigned for feather condition for each area of the body (neck, breast, back, wings, and tail). The length of the right middle claw was measured with compass. At 73 wk age all hens were weighed.

Statistical Analysis

Statistical analyses were performed using the software package SPSS for Windows (SPSS, Chicago, IL). Data were tested for distribution normality and homogeneity of variance. Data set showed normality. Repeated measures of analysis of variance (**ANOVA**) was used to determine the differences among laying period, cage type, and strain groups as well as their interactions with respect to the egg production, egg weight, feed intake, and feed conversion ratio, and 2-way ANOVA was used to determine the differences between feather score

Table 2. Hen-day egg production, egg weight, feed intake, and feed conversion ratio of two different strains kept in conventional and enriched cages.

Laying period (wk)	Cage type	Strain[1]	Hen-day egg production (%)	Egg weight (g)	Feed intake (g)	Feed conversion ratio (g feed/g egg)
18 to 31			81.26^{d}	56.09^{c}	106.32^{c}	2.34^{a}
32 to 45			94.87^{a}	63.40^{b}	112.86^{a}	1.88^{b}
46 to 59			92.01^{b}	66.39^{a}	113.30^{a}	1.86^{b}
60 to 73			88.96^{c}	66.48^{a}	110.70^{b}	1.88^{b}
	Conventional		88.61^{n}	63.03	111.04	2.02^{n}
	Enriched		89.94^{m}	63.15	110.55	1.96^{m}
		LB	89.49	63.50^{x}	113.79^{x}	2.03^{x}
		LW	89.06	62.68^{y}	107.79^{y}	1.95^{y}
	Conventional	LB	88.89	63.37	114.20	2.06
		LW	88.33	62.69	107.88	1.97
	Enriched	LB	90.10	63.63	113.39	1.99
		LW	89.79	62.67	107.71	1.93
Pool SEM			0.31	0.09	0.31	0.01
Tests of between-subject effects (P-value)						
Cage type			0.036	0.523	0.438	0.003
Strain			0.492	<0.001	<0.001	<0.001
Cage type × strain			0.840	0.463	0.605	0.452
Tests of within-subjects contrasts (P-value)						
Laying period			<0.001	<0.001	<0.001	<0.001
Laying period × cage type × strain			0.031	0.995	0.985	0.111

[1]LB: Lohmann Brown Classic, LW: Lohmann LSL Classic.

[a,d]Means among laying periods in a same column not sharing a common superscript are different ($P < 0.05$).

[m,n]Means between cage type in a same column not sharing a common superscript are different ($P < 0.05$).

[x,y]Means between strains in a same column not sharing a common superscript are different ($P < 0.05$).

and claw length. Claw length at 73 wk age was adjusted to initial claw length. Comparisons among means were made by the Tukey test. Significance of differences in percentages of eggs laid in nest box and percentages of cracked and dirty eggs were done by the Chi-square test. A value of $P < 0.05$ was considered statistically significant (Dawson and Trapp, 2001).

RESULTS AND DISCUSSION

At 16 wk, body weight (**BW**) of LB hens, 1,285 g, was greater than that of LW hens, 1,109 g ($P < 0.001$). Laying period ($P < 0.001$), cage type ($P = 0.036$), and laying period × cage type × strain interaction ($P = 0.031$) was found for hen-day egg production as shown in Table 2. As expected, hen-day egg production changed throughout the laying period. In enriched cages, laying hens produced more eggs than hens in conventional cages. The rate of lay in LB strains, over the period of 18 to 73 wk, ranged from 77.09 to 91.27% in conventional cages and ranged from 82.11 to 89.79% in enriched cages. The rate of lay in LW strains, over the period of 18 to 73 wk, ranged from 81.08 to 85.92% in conventional cages and ranged from 84.77 to 88.85% in enriched cages (Figure 1). However, Tactacan et al. (2009) observed that only difference between their treatments was observed in the last period, in which birds in conventional cages had higher hen-day egg production than birds in the enriched cages. In the current study, LW strains had higher hen-day egg production than LB strains in the first period. However, after this period this situation changed and LB strains produced more eggs than LW strains. Total egg production did not differ between the 2 strains. Also, Singh et al. (2009) reported that egg production of white and brown egg commercial hens were similar, likely because intensive selection of commercial brown egg layer has brought their production to similar levels as those of white egg strains. Cage type × strain interaction was not different in egg production in this study.

Egg weight did not differ between the 2 cage types. This agrees with the study of Tactacan et al. (2009) comparing average egg weight of laying hen housed in conventional and enriched cages ($P < 0.001$). Also, Applebely et al. (1992) reported that perches in laying cages didn't affect the egg weight. Laying period and strain affected ($P < 0.001$) the egg weight. As expected, increase in egg weight throughout the duration of the production cycle was observed due to the increased hen age. The egg weight of LB hens was heavier than that of LW hens. As known, body weight and egg weight are positively correlated (Siegel, 1962); therefore, LB laying hens were heavier and laid larger eggs. Laying period × cage type × strain interaction was not different for egg weight in this study.

Laying period and strain influenced ($P < 0.001$) the daily feed intake. In the first period hens ate less feed than the other periods ($P < 0.001$). LB hens consumed more feed than LW hens due to the difference of body weight. EFSA (2005) reported that hens resting on perches could result in energy savings. Also some studies show that perching in cages reduces feed usage (Tauson and Abrahamsson, 1994; Hester et al., 2013).

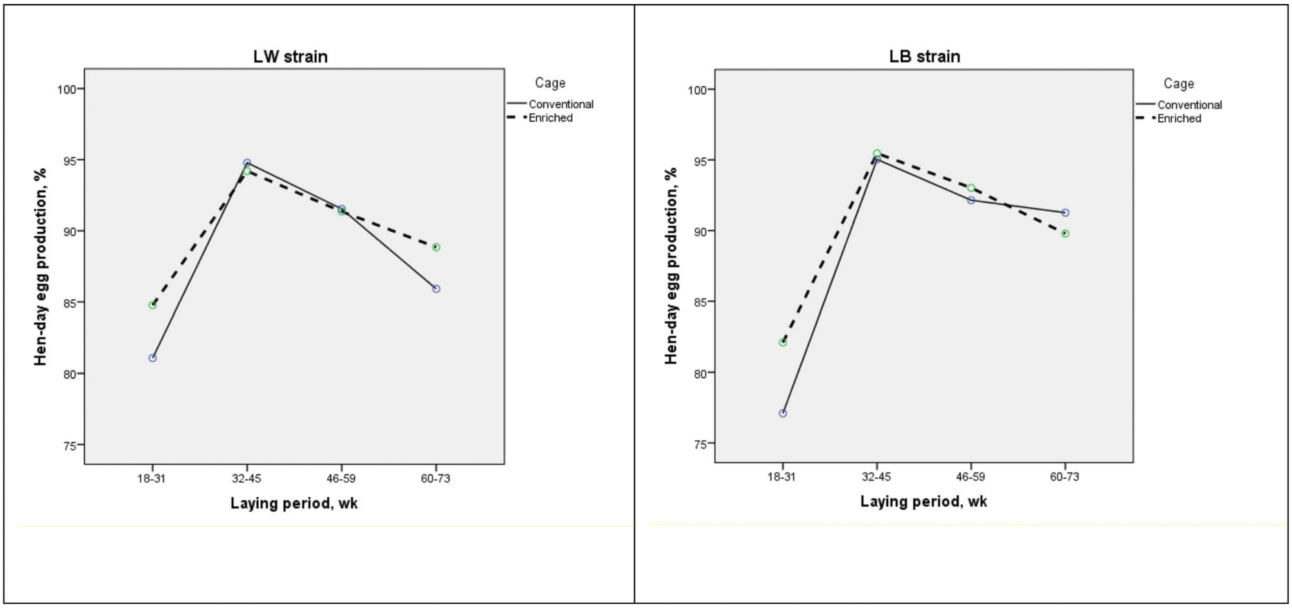

Figure 1. Hen-day egg production of different cage type and hybrid groups according to laying period.

Table 3. Percentages of eggs laid in nest box by different genotype in enriched cages.

Genotype[1]	Percentages of eggs laid in nest box
LB	86.2^{m}
LW	82.9^{n}
P-value	<0.001

[1]LB: Lohmann Brown Classic, LW: Lohmann LSL Classic.

^{m,n}Means in a same column not sharing a common superscript are different ($P < 0.05$).

Table 4. Percentages of cracked and dirty eggs of 2 different strains kept in conventional and enriched cages.

Genotype[1]	Egg shell traits	Conventional cage	Enriched cage	P-value
LB	Cracked	1.02	1.38	0.213
LW	Cracked	0.80^{y}	2.44^{x}	<0.001
P-value		0.810	0.830	
LB	Dirty	0.83	0.80^{n}	0.815
LW	Dirty	0.83^{y}	$1.94^{x,m}$	<0.001
P-value		0.977	0.001	

[1]LB: Lohmann Brown Classic, LW: Lohmann LSL Classic.

^{m,n}Means in a same column not sharing a common superscript are different ($P < 0.05$).

^{x,y}Means in a same row not sharing a common superscript are different ($P < 0.05$).

Table 5. Percentages of cracked and dirty eggs were laid in different location of 2 different strains kept in enriched cages.

Genotype[1]	Egg shell traits	In the nest box	Outside the nest box	P-value
LB	Cracked	1.52^{n}	0.49	0.101
LW	Cracked	2.61^{m}	1.64	0.218
P-value		0.009	0.107	
LB	Dirty	0.64^{y}	$2.51^{x,n}$	<0.001
LW	Dirty	0.84^{y}	$7.61^{x,m}$	<0.001
P-value		0.403	0.001	

[1]LB: Lohmann Brown Classic, LW: Lohmann LSL Classic.

^{m,n}Means in a same column not sharing a common superscript are different ($P < 0.05$).

^{x,y}Means in a same row not sharing a common superscript are different ($P < 0.05$).

Feed conversion ratio changed from Period 1 to 4 ($P < 0.001$). Cage type influenced the feed conversion ratio ($P = 0.003$) was observed. The feed conversion ratio in enriched cages was better than in conventional cages, possibly because of hen-day egg production differences. Also, the feed conversion ratio was better for LW hens due to the low body weight and low feed intake. In this study, there was no interaction among laying period × cage type × strain.

Ekstrand and Keeling (1994) reported that nest box usage was important for laying hens. In the current study, laying hens in enriched cages preferred to lay in nest boxes (Table 3). LB and LW hens laid 86.2 and 82.9% of their eggs in the nest boxes, respectively ($P < 0.001$).

Percentages of cracked ($P < 0.001$) and dirty ($P < 0.001$) eggs statistically differed only in the LW hens between different cage types (Table 4). Percentages of cracked and dirty eggs of LW hens in enriched cages were higher than those in conventional cages. In enriched cages there was a trend for a higher number of cracked eggs found inside the nest boxes than outside the nest boxes (Table 5). Similarly, Wall et al. (2002) reported that percentage of cracked eggs in enriched cages was usually higher than that in conventional cages because the area where the more eggs are laid was the nest box. Such collisions can easily occur among eggs and egg shells to cause damage. Cracked egg percentages of LW hens were higher than that of LB hens in the

Table 6. Feather score of 2 different strains kept in conventional and enriched cages at 73 wk age.

Cage type	Strain[1]	Body region: Neck	Breast	Back	Wings	Tail	Total feather score[2]
Conventional	LB	2.43[a]	2.93[a]	2.90[c]	3.10[b]	3.22[a]	14.6[b]
	LW	2.03[b]	2.74[b,c]	3.12[b]	3.11[b]	2.85[b]	13.9[c]
Enriched	LB	2.40[a]	2.64[c]	3.21[b]	3.18[b]	3.30[a]	14.7[b]
	LW	2.40[a]	2.82[a,b]	3.72[a]	3.54[a]	3.23[a]	15.7[a]
Conventional		2.23[n]	2.84[n]	3.01[n]	3.11[n]	3.03[n]	14.2[n]
Enriched		2.40[m]	2.73[m]	3.46[m]	3.36[m]	3.27[m]	15.2[m]
	LB	2.42[x]	2.79	3.06[y]	3.14[y]	3.26[x]	14.7
	LW	2.22[y]	2.78	3.42[x]	3.33[x]	3.04[y]	14.8
Pool SEM		0.017	0.023	0.024	0.019	0.019	0.073
P-value							
Cage type		<0.001	0.024	<0.001	<0.001	<0.001	<0.001
Strain		<0.001	0.906	<0.001	<0.001	<0.001	0.384
Cage type × strain		<0.001	<0.001	0.002	<0.001	<0.001	<0.001

[1]LB: Lohmann Brown Classic, LW: Lohmann LSL Classic.

[2]Score (graduated from 1 = very poor plumage to 4 = intact plumage) was assigned for feather condition for each area of the body (neck, breast, back, wings and tail).

[a,c]Means between cage type and strain interaction in a same column not sharing a common superscript are different ($P < 0.05$).

[m,n]Means between cage type in a same column not sharing a common superscript are different ($P < 0.05$).

[x,y]Means between strains in a same column not sharing a common superscript are different ($P < 0.05$).

nest box ($P = 0.009$). For both strains most of the dirty eggs were found outside the nest boxes ($P < 0.001$). The number of dirty eggs produced by LW hens was higher than the LB hens ($P = 0.001$). This can be largely attributed to eggs laid in the scratch pad area of the cage. Accumulating excreta in the scratch pad area resulted in an increase of dirty eggs. It is important that scratch pads be designed to be flush with the cage floor and the structure should allow the excretion to pass through to prevent dirty eggs. Scratch pad should be same flush with the cage floor and its structure should allow the excreta to be dropped.

At the age of 16 wk, when the first feather scoring was carried out, all of the birds were completely feathered. Feather score is important for hens' welfare and economic of production (Tauson and Svensson, 1980; Peguri and Coon, 1993). In this study (Table 6), cage type affected the feather score of each body regions and total feather score. Only feathers on the breast of hens kept in enriched cages were easier to remove than those of hens kept in conventional cages and may be explained by the hens resting on perches. However, the feather scores of other body parts and total feather score of hens kept in enriched cages were higher than those in conventional cages. Feather condition was strongly influenced by group size, with increasing feather damage being recorded in larger groups (Bilcik and Keeling, 1999). In the current study, 18 hens were kept in enriched cages, while 20 hens were kept in conventional cages. The strain did not affect the total feather score. However, cage type × strain interaction was important for feather score. In conventional cages, total feather score of LW hens was lower, while in enriched cages that of LW hens was higher ($P < 0.001$). Environmental enrichment affected the feather score of LW hens. However, feather score of LB hens was not changed by cage type.

Initial claw length of LW hens was longer than that of LB hens (Table 7). It may be claws of LW hens grow more or have a harder compound. Similar result was reported by Emous (2003). Excessive claw length can be a problem if hens do not have access to abrasive materials for trimming their claws (Roll et al., 2008; Hester, 2014). Cage type ($P < 0.001$) and strain ($P = 0.004$) were important for final claw length. Final claw length of hens was shorter in enriched cages due to

Table 7. Claw length (mm) of 2 different strains kept in conventional and enriched cages at 16 and 73 wk ages.

Cage type	Strain[1]	Claw length at 16 wk age	Claw length at 73 wk age[2]
Conventional	LB	14.89	26.47[b]
	LW	18.07	29.39[a]
Enriched	LB	14.91	25.06[c]
	LW	18.49	25.68[b,c]
Conventional		16.48	27.93[m]
Enriched		16.70	25.37[n]
	LB	14.90[y]	25.77[y]
	LW	18.28[x]	27.53[x]
Pool SEM		0.073	0.197
P-value			
Cage type		0.139	<0.001
Strain		<0.001	0.004
Cage type × strain		0.179	0.004

[1]LB: Lohmann Brown Classic, LW: Lohmann LSL Classic.

[2]Claw length at 73 wk age was adjusted to claw length at 16 wk age.

[a,c]Means between cage type and strain interaction in a same column not sharing a common superscript are different ($P < 0.05$).

[m,n]Means between cage type in a same column not sharing a common superscript are different ($P < 0.05$).

[x,y]Means between strains in a same column not sharing a common superscript are different ($P < 0.05$).

the use of nail shortener. Final claw length of LW hens was longer than that of LB hens. Cage type × strain interaction was found ($P = 0.004$), because difference of claw lengths between strains at 73 wk age was higher in conventional cages than in enriched cages. LW hens in enriched cages used the nail shortener more than LB hens, thus difference of claw lengths between strains at 73 wk age decreased in enriched cages.

Cage type ($P = 0.002$) and strain ($P < 0.001$) affected the final body weight. Body weights at 73 wk were 2,011 and 1,751 g, of LB and LW hens kept in conventional cages, respectively. Body weight of LB and LW hens kept in enriched cages, 2,049 and 1,818 g, respectively.

As a conclusion, hen-day egg production, feed conversion ratio, total feather score, and claw lengths were better for enriched cages. The percentage of dirty and cracked eggs was higher of hens kept in enriched cages than in conventional cages. Further studies should be done with the design of a nest box for decreased cracked eggs in enriched cages. LB hens used the nest box more than LW hens. This study suggests that cage type, strain, cage type × strain, and period × strain interactions should be considered when alternative housing systems are used.

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