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RESEARCH ARTICLE

Comparison of Hen Performance and Mortality of Commercial Layer Flocks by Strain and Cage Type

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ABSTRACT

The study aimed to compare the effects of strain and cage type on egg production, mortality and the rates of dirty eggs and broken eggs in commercial flocks of laying hens. The study was conducted on four commercial flocks of layers in medium-sized poultry farms in the city of Afyonkarahisar. Two white (Hy-Line and Super Nick) and two brown (Nick Brown) layer flocks were housed in conventional cages and enrichable cages. The laying flocks were visited weekly, and the egg production and the number of dead birds, dirty eggs, and broken eggs were collected on a daily basis from flock records between 19 and 56 weeks of age. Both strain and cage type had a significant effect on hen-day and hen-housed egg production. The brown strains (2.74%) and hens housed in conventional cages (2.61%) had higher mean egg production. The effect of strain on weekly mortality became insignificant after 32 weeks of age, while the highest mortality rates were observed in the enrichable cages. The weekly rates of dirty eggs and broken eggs showed significant differences between the groups of strains and cage type. The effects of strain x cage type interactions on egg production and on the rates of dirty eggs and broken eggs were found to be significant. White and brown laying hens in conventional cages had higher egg production than the hens kept in enrichable cages. In conclusion, brown strains had higher egg production than white strains and enrichable cages had lower egg production and higher mortality, as well as dirty and broken eggs.
Key Words: Cage type, Dirty and broken eggs, Egg production, Mortality, Strain

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Genotip ve Kafes Tipine Göre Ticari Yumurtacı Sürülerde Tavuk Performansı ve Ölüm Oranlarının Karşılaştırılması

ÖZ

Bu araştırmada ticari yumurtacı tavuk sürülerinde genotip ve kafes tipinin yumurta verimi, ölüm oranı ile kirli ve kırık yumurta oranları üzerine etkilerinin karşılaştırılması amaçlanmıştır. Araştırma Afyonkarahisar'daki orta ölçekli kanatlı işletmelerinde bulunan dört ticari yumurtacı tavuk sürüsünde yürütülmüştür. İki beyaz (Hy-line ve Super Nick) ve iki kahverengi (Nick Brown) yumurtacı sürü geleneksel ve zenginleştirilebilir kafeslerde barındırılmıştır. Yumurtacı sürüler 19-56 haftalık yaş döneminde haftalık olarak ziyaret edilmiş ve günlük yumurta üretimi, ölen tavuk sayısı ile kirli ve kırık yumurta sayıları çiftlik kayıtlarından toplanmıştır. Genotip ve kafes tipi tavuk-gün ve tavuk-kümes (%) yumurta üretimini önemli ölçüde etkilemiştir. Kahverengi genotiplerin (%2.74) ve geleneksel kafeslerde barındırılan tavukların (%2.61) ortalama yumurta üretimi daha yüksek bulunmuştur. En yüksek ölüm oranları zenginleştirilebilir kafeslerde gözlenirken 32 haftalık yaştan sonra genotipin haftalık ölüm oranlarına etkisi önemsiz hale gelmiştir. Haftalık kirli ve kırık yumurta oranları genotip ve kafes tipi grupları arasında önemli derecede farklılık göstermiştir. Genotip x kafes tipi interaksiyonlarının yumurta üretimi, kirli ve kırık yumurta oranlarına etkisi önemli bulunmuştur. Zenginleştirilebilir kafeslerde barındırılanlara göre geleneksel kafeslerdeki beyaz ve kahverengi yumurtacı tavukların yumurta üretimi daha yüksek bulunmuştur. Sonuç olarak, kahverengi genotiplerin beyaz genotiplere göre önemli derecede daha yüksek yumurta üretimine sahip olduğu, zenginleştirilebilir kafeslerde barındırılan tavukların yumurta üretiminin daha düşük, ölüm oranı ile kirli ve kırık yumurta oranlarının daha yüksek olduğu belirlenmiştir.
Anahtar Kelimler: Genotip, Kafes tipi, Kirli ve kırık yumurta, Ölüm oranı, Yumurta üretimi

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INTRODUCTION

Following the Brambell Committee Report in 1965, which reported that intensive cage systems severely restricted hen behaviour and compromised welfare, research into alternative systems began to gather pace (Singh et al. 2009). In this context, there has been a growing momentum towards animal-friendly and environmentally sustainable approaches, reaching far beyond Europe. Concerns regarding the well-being of laying hens have prompted a widespread industry pursuit of improved housing systems (Tactacan et al. 2009). However, the results of research into animal health and welfare (animal diseases, aggressive pecking, biosecurity etc.), egg production (costs, economic returns, high labour requirements etc.) and the environmental impact of the industry (ammonia emissions, pollution etc.) have increased the interest in the alternative systems (Tactacan et al. 2009; Xin et al. 2011; David et al. 2015). Furthermore, it remains a controversial issue with no consensus among researchers on the extent to which different housing systems affect hen performance, including economic parameters such as liveability, egg production and egg quality (Fulton 2017). Efforts are ongoing to develop better housing systems for hens (Tactacan et al. 2009). The health and welfare of the birds should be balanced with consumer preferences and the needs and environmental impacts of the industry when designing alternative housing systems for laying hens. In addition, strain x environment interactions should be considered when developing poultry housing systems (Singh et al. 2009).

Intensive selection and crossbreeding of pure lines has increased egg production while significantly reducing mortality and the incidence of egg defects through high standards of care and feeding. However, dirty and broken or cracked defective eggs remain a problem in commercial laying flocks used today, affecting both the economic performance of the flock and food quality, and posing a challenge to the egg processing industry (Ledvinka et al. 2012; Wolc et al. 2012; Hamilton and Bryden 2021).

Research is being conducted on alternative housing systems to conventional cages for laying hens, including enrichable (Alig et al. 2023) and enriched cages (Pavlik et al. 2008; Tactacan et al. 2009), and free-range systems (Ledvinka et al. 2012; Freire and Cowling 2013). The decision on which housing system is best for laying hens is based on evaluations of animal welfare status, economic factors, and food safety indices (Ledvinka et al. 2012). Enrichable colony cages are enriched cages that contain no equipment other than feeders and drinkers (Heflin et al. 2018; Ortiz et al. 2021; Alig et al. 2023). These cages can be converted to enriched cages at any time or used as a permanent housing system when there is no market or regulatory pressure. However, there is limited or no research on the effects of enrichable cages on hen performance and mortality. In addition, according to the results of controlled laboratory studies, the results of research on commercial laying hen flocks under on-farm conditions may be more useful for sector-specific assessments and the development of new strategies.

The aim of this study was to compare the effect of strain and cage type on egg production, the rates of dirty and broken eggs and mortality in commercial layer flocks.

MATERIALS and METHODS

Information on Laying Hen Flocks and Bird Management

The study was conducted on four commercial laying hen flocks from 18 to 56 weeks of age. These flocks belonged to medium-scale egg production farms located in Susuz and Çukurköy villages in the central districts of Afyonkarahisar. Collaboration was established with these farms after explaining the purpose, needs and implementation of the research. The research began with four 18-week-old flocks raised in rearing cages. Hy-Line W-80 (white) and Nick Brown (brown) pullets were housed in enrichable cages, while Super Nick (white) and Nick Brown (brown) pullets were housed in conventional cages. Table 1 provides information on housing condition of the laying hens, cage characteristics, and the commercial layer flocks used in the research. The conventional cages housed 8 or 9 hens per cage in an area of 3249 cm^2 while the enrichable cages housed 18 or 19 hens per cage in an area of 7200 cm^2. The bird cages were with multiple tiers and levels. A linear feeder was used in front of every cage and on each level of the cages. In each cage, there were a minimum of two nipple drinkers. In the four laying houses, feeding, manure removal, egg collection, and ventilation were fully automated for the commercial flocks. In addition, the automatic ventilation system included cooling pads.

The laying hens were fed with standard layer diets prepared on the farms (15.8% protein, 2600 Kcal metabolic energy in brown strain diets and 16-17% protein, 2600-2840 Kcal metabolic energy in white strain diets). Automatic feeders and drinkers provided ad libitum access to feed and water for the hens. For lighting, 9-watt LED lamps were used, providing a photoperiod of 16.5 hours of light and 7.5 hours of darkness. The structure of the cage systems and the stocking densities within the cages were determined by the farms according to their own commercial and administrative policies. Farmers followed breeders' recommendations and guidelines for bird care and management (Hy-Line W-80 2016; Brown Nick 2016; Super Nick 2017). Beak trimming in chicks was performed by the Minimum Standards Related to the Protection of Laying Hens Regulation (Anonymous 2014). White and brown layer birds were vaccinated against potential disease risks including Newcastle Disease (ND), Infectious Bursal Disease (IBD), Infectious Coryza (IC), Avian Encephalomyelitis (AE), Infectious Bronchitis (IB) Egg Drop Syndrome (EDS) and Pox. The study received ethical approval from the Local Animal Ethics Committee of Afyon Kocatepe University on June 20, 2017, with reference number AKUHADYEK-244-17.

Collection of the Research Data

Eggs laid in each strain and cage type group were collected daily and the number of eggs, dead birds, and broken and dirty eggs were recorded daily by the farmers according to their routine flock management programme. Each flock was visited once at the beginning of the placement and at least once a week from 19 to 56 weeks of age period and data for this study were collected from daily flock records (Sherwin et al. 2010).

Hen-day egg production was calculated by dividing the number of eggs laid each day by the number of hens in the laying house on that day. Hen-housed egg production was determined by dividing the number of eggs laid each day by the total number of hens at the beginning of the laying period. The weekly rates of dirty and broken eggs were calculated by dividing the weekly cumulative number of dirty and broken eggs by the total number of eggs laid in that week. To determine the weekly mortality rate, the cumulative number of dead birds for each week was divided by the total number of birds present in the laying house at the beginning of that week (Yılmaz Dikmen et al. 2016).

Statical Analysis

Two-way analysis of variance (ANOVA) was used to analyse the differences between the groups of strain and cage type groups for daily egg production (hen-day and hen-housed %), weekly rates of broken eggs, dirty eggs and mortality (%). The data obtained from the research were analyzed using the SPSS 21st version for Windows. A significance level of P<0.05 was used.

Table 1. Information on housing conditions of the laying hens, cage characteristics and commercial layer flocks

Traits	Laying house 1	Laying house 2	Laying house 3	Laying house 4
Strain	Hy-Line	Nick Brown	Super Nick	Nick Brown
Egg shell colour	White	Brown	White	Brown
Type of colony cages	Enrichable	Enrichable	Conventional	Conventional
Cage dimensions (W× D × H cm)	120 x 60 x 60	120 x 60 x 60	57 x 57 x 45	57 x 57 x 45
Stocking density (birds/cage)	19	18	9	8
Poultry house floor area (m^2)	700	800	540	600
Number of funs	14	14	8	6
Number of chimney	6	10	6	8
Number of windows	108	132	60	38
Numbers of lighting lamps	84	98	36	42

RESULTS

The results regarding the impact of strain and cage type on hen-day and hen-housed egg production in commercial layer flocks are presented in Table 2. The effect of strain on egg production was significant (P<0.05, P<0.01 and P<0.001) across all laying periods starting from 25 weeks of age, with brown strain hens showing higher egg production compared to white strain hens. Hen-day egg production was not influenced by cage type in periods 1 and 3, but in periods 2 and 4, hens housed in enrichable cages produced more eggs (P<0.01). Hen-housed egg production was significantly affected by strain and cage type up to 56 weeks of age (P<0.05, P<0.001) except for period 1. Brown strain hens had higher hen-housed egg production than white strain laying hens. The hen-housed egg production was higher in the brown strains and conventional cage groups over the entire laying period (19-56 weeks) (P<0.05). Significant interactions between strain and cage type were found for the hen-day and hen-housed egg production (P<0.001) between 25-56 weeks of age.

The impact of strain and cage type on the weekly mortality rates of commercial flocks of laying hens are presented in Table 3. The mortality rate was significantly influenced by strain and the strain x cage type interaction only in laying periods 1 and 2 (P<0.001). However, the cage type affected mortality in all periods up to 56 weeks of age (P<0.01, P< 0.001). Higher mortality rates were observed in commercial brown layer flocks up to week 32. In general, the effect of strain on mortality was insignificant over the period 19-56 weeks. Throughout the egg production period in which the study was conducted, higher mortality was observed in flocks housed in enrichable cages.

The results regarding the impact of strain and cage type on weekly dirty and broken egg rates are given in Table 4. The rate of dirty eggs was significantly influenced by the strain in all periods up to 56 weeks of age (P<0.05, P<0.001), and it was significantly influenced by the cage type between 25 to 56 weeks (P< 0.01 and P< 0.001). Broken egg rate was significantly influenced by strain in periods 25-32, 45-56 and 19-56 weeks of age (P< 0.001) and by cage type in all laying periods after 25 weeks of age (P<0.01, P<0.001). The strain x cage type interaction was significant for dirty eggs at 25-32, 33-44, 45-56 and 19-56 weeks (P<0.001) and for broken eggs at 33-44, 45-56 and 19-56 weeks (P<0.05 and P<0.001).

Table 2. The impact of strain and cage type on hen-day and hen-housed egg production (%) in commercial layer flocks

		Laying periods														
		1 (≤24 wks)			2 (25-32 wks)			3 (33-44 wks)			4 (45-56 wks)			19-56 wks		
			HD	HH		HD	HH		HD	HH		HD	HH		HD	HH
Strain	Cage type	n	Mean	Mean	n	Mean	Mean	n	Mean	Mean	n	Mean	Mean	n	Mean	Mean
White		80	44.008	43.912	112	84.151	83.178	168	86.674	82.483	162	86.404	79.960	522	79.510	75.938
Brown		84	45.105	44.827	112	91.730	89.789	169	88.165	84.098	177	89.158	82.547	542	82.553	78.681
	Conventional	80	45.506	45.383	112	86.318	85.349	169	87.379	85.280	161	87.081	83.631	522	80.642	78.672
	Enrichable	84	43.678	43.426	112	89.563	87.619	168	87.465	81.294	178	88.530	79.212	542	81.462	76.048
ANOVA																
SEM			2.358	2.343		0.487	0.466		0.279	0.268		0.236	0.226		0.622	0.588
R^2			0.004	0.005		0.382	0.382		0.100	0.222		0.174	0.333		0.008	0.012
P value																
Strain			0.809-	0.839-		0.000***	0.000***		0.008**	0.003**		0.000***	0.000***		0.014*	0.018*
Cage type			0.717-	0.694-		0.001**	0.016*		0.884-	0.000***		0.001**	0.000***		0.494-	0.028*
Strain x Cage type			0.472-	0.459-		0.000***	0.000***		0.000***	0.000***		0.000***	0.000***		0.193-	0.095-

*:P<0.05, **:P<0.01, ***:P<0.001, -: Non significant, **HD:** Hen-day egg production, **HH:** Hen-housed egg

Table 3. The impact of strain and cage type on weekly mortality rate (%) in commercial layer flocks

		Laying periods									
		1 (≤24 wks)		2 (25-32 wks)		3 (33-44 wks)		4 (45-56 wks)		19-56 wks	
Strain	Cage type	n	Mean	n	Mean	n	Mean	n	Mean	n	Mean
White		12	0.063	16	0.174	24	0.384	24	0.235	76	0.242
Brown		12	0.182	16	0.271	24	0.236	24	0.240	76	0.236
	Conventional	12	0.075	16	0.157	24	0.127	24	0.132	76	0.127
	Enrichable	12	0.171	16	0.287	24	0.493	24	0.343	76	0.351
ANOVA											
SEM			0.011		0.010		0.058		0.018		0.021
R^2			0.763		0.810		0.221		0.464		0.166
P value											
Strain			0.000***		0.000***		0.210-		0.870-		0.891-
Cage type			0.000***		0.000***		0.003**		0.000***		0.000***
Strain x Cage type			0.000***		0.000***		0.343-		0.169-		0.596-

**:P<0.01, ***:P<0.001, -: Non significant

Table 4. The effects of strain and cage type on weekly dirty and broken egg rates (%) in commercial layer flocks

		Laying periods														
		1 (≤24 wks)			2 (25-32 wks)			3 (33-44 wks)			4 (45-56 wks)			19-56 wks		
			Dirty	Broken		Dirty	Broken		Dirty	Broken		Dirty	Broken		Dirty	Broken
Strain	Cage type	n	Mean	Mean	n	Mean	Mean	n	Mean	Mean	n	Mean	Mean	n	Mean	Mean
White		12	0.267	0.150	16	0.112	0.060	24	0.135	0.072	24	0.135	0.075	76	0.151	0.083
Brown		12	0.087	0.074	16	0.071	0.046	24	0.075	0.059	24	0.065	0.047	76	0.073	0.055
	Conventional	12	0.187	0.123	16	0.061	0.033	24	0.083	0.052	24	0.076	0.046	76	0.093	0.057
	Enrichable	12	0.168	0.101	16	0.122	0.072	24	0.126	0.079	24	0.123	0.077	76	0.131	0.080
ANOVA																
SEM			0.036	0.024		0.002	0.001		0.005	0.004		0.004	0.001		0.007	0.004
R^2			0.236	0.118		0.962	0.939		0.633	0.433		0.773	0.914		0.273	0.130
P value																
Strain			0.023^{*}	0.133^{-}		0.000^{***}	0.000^{***}		0.000^{***}	0.109^{-}		0.000^{***}	0.000^{***}		0.000^{***}	0.001^{***}
Cage type			0.799^{-}	0.656^{-}		0.000^{***}	0.000^{***}		0.000^{***}	0.001^{***}		0.000^{***}	0.000^{***}		0.004^{**}	0.008^{**}
Strain x Cage type			0.883^{-}	0.919^{-}		0.000^{***}	0.657^{-}		0.000^{***}	0.000^{***}		0.000^{***}	0.000^{***}		0.000^{***}	0.036^{*}

*:P<0.05, **:P<0.01, ***:P<0.001, $^{-}$:Non significant

DISCUSSION

Except for the period up to 24 weeks of age, egg production was influenced by strain. Brown strain hens showed higher egg production compared to white strain hens in the research. These results support other findings that indicate the significant impact of strain on egg production (Cunningham and Ostrander 1982). Vits et al. (2005) reported higher average hen-day egg production in brown hen strains compared to white hen strains. However, Singh et al. (2009), Riczu et al. (2004), Ershad (2005) and Stojčić et al. (2012) reported results contradicting this study, stating that egg production was higher in white egg-laying hens. This result may have been related to the strain x cage type interaction detected in this study. Because the brown strains had higher hen-day and hen-housed egg production for both cage types.

In this study, hen-day egg production was high in enrichable cages, but hen-housed egg production was low in the enrichable cages. This may be related to the mortality rate, as the mortality rate observed in the enrichable cages was higher than the mortality rate in the conventional cages. From 19 to 56 weeks, the average hen-housed egg production of the hens in conventional cages was 2.62% higher than that of hens in the enrichable cages. Similarly, Gerzilov et al. (2012) reported that hens in conventional cages produced more eggs throughout the entire production period. On the other hand, Stojčić et al. (2012) and Gerzilov et al. (2012) found that hens in enriched cages produced fewer eggs.

The interaction between strain and cage type affected the hen-housed egg production, with both white and brown strains showing lower egg production in enrichable cages. This interaction shows that egg production was affected in a correlated manner by both strain and cage type. These results indicate that egg production of both strains was negatively affected by enrichable cage conditions. Similar results for egg production between 20 and 30 weeks of age were reported by Singh et al. (2009). Enriched cage systems have been recommended as a balanced solution combining egg-laying efficiency and improved animal welfare (Gerzilov et al. 2012; Philippe et al. 2020). However, the lack of equipment such as perches and nests in the enrichable cages used in this study, as well as the fact that the cage area per bird was not superior to conventional cages, may have been reasons for the lower egg production. This suggests that the conditions in the enrichable cages may have been more stressful for the birds and the interaction between strain and environment may have had negative effects (Pavlik et al. 2008). This argument is consistent with Stojčić et al. (2012), who reported that birds kept in enriched cages, especially brown strains, had a shorter time to first egg. In addition, the lack of nests in enrichable cages and the possibility of laying eggs on the floor of these larger colony cages in crowded conditions may also have been a factor in the consumption of eggs by hens (Ledvinka and Klesalová 2012).

In enrichable cages, white strain hens produced fewer eggs (1.45 and 0.81 % hen-day and hen-housed egg production, respectively) compared to brown strains. This means that enrichable cage conditions had a negative effect on white hens. These results are consistent with the report by Stojčić et al. (2012), who found that white hens in conventional cages had the best hen-housed egg production. However, the brown strain hens in enrichable cages had lower hen-housed egg production than the brown hens in conventional cages (4.55%), showing that the brown strain hens were more negatively affected by being housing in enrichable cages. In fact, the mortality rate of brown hens in enrichable cages was higher than that of brown hens in conventional cages (0.17 and 0.27 % more for periods 1 and 2). It may be that the enrichable cage systems were more stressful for the hens as Pavlik et al. (2008) found that hens housed in enriched cages had similar or higher corticosterone levels than hens housed in standard conditions. They concluded that keeping hens in conventional cage systems was not stressful.

The impact of strain on mortality was only significant up to 32 weeks, after which it became insignificant. This result suggests that mortality rates were not different between the two strains of hens in the later stages of the laying cycle. These findings are consistent with studies by Tactacan et al. (2009) and Freire and Cowling (2013), who reported that mortality rates in commercial laying genotypes were similar regardless of cage design. However, weekly mortality rates were significantly affected by cage type across all laying periods in the study. Enrichable cages had the highest mortality rates, which is consistent with the egg production results and confirms the negative conditions in enrichable cages. Similarly, Gerzilov et al. (2012) reported higher mortality in enriched cages compared to conventional cages. Singh et al. (2009) also reported a significant effect housing system on mortality. In the present study, there was no significant strain x cage type effect on mortality, as the strain x cage type interaction became insignificant after 32 weeks of age. This result suggests that the high mortality in enrichable cages may have been influenced by factors other than genetic makeup or cage design, such as diseases, mineral deficiencies, fatty liver syndrome, prolapses and aggressive pecking (Fulton 2017).

Dirty and broken egg rates were influenced by strain, and Zita et al. (2009) repoted a similar strain effect. In this study, white strain hens had higher dirty and broken egg rates. The observed effects of the strain may be a result of the selection that has been carried out for higher egg production and better egg quality. (Wolc et al. 2012). These results are in line with the report of Campo et al. (2007) of higher broken egg rates in white hens but in contrast to Vits et al. (2005), who reported higher broken egg rates in brown hens. In this study, dirty and broken egg rates were influenced by cage type, in agreement with similar reports made by Wall et al. (2002). Wall et al. (2002) found that cracked eggs were generally more common in enriched cages than conventional cages, which may be related to the confined space in which eggs were laid, leading to easier collisions between eggs and potential damage to eggshells. However, Tactacan et al. (2009) stated that cage type did not affect the overall percentage of broken eggs. Dirty and broken egg rates were higher in enrichable cages. Similarly, compared to conventional cages, Tactacan et al. (2009) reported lower dirty egg rates. This might be due to the larger space in enrichable cages, resulting in more crowded conditions within the cages (Hamilton and Bryden 2021), or the presence of stationary claw abrasives at the front of the cages leading to the accumulating of droppings (Appleby et al. 2002; Tactacan et al. 2009).

The rate of dirty egg was influenced by the strain x cage type interaction from week 25 onwards, while the rate of broken eggs was influenced by this interaction from week 33 onwards. In white hens housed in enrichable cages, both the dirty and broken egg rates were higher (0.104% and 0.056%, respectively). However, broken eggs were more frequent (0.054 %) when brown hens were kept in the enrichable cage and in conventional cages dirty eggs were more frequent in the conventional cage (0.059 %).Vitz et al. (2005) reported that broken eggs were higher in brown hens, while dirty eggs were higher in white hens. The enrichable cages used in this study did not include equipment such as perches and nests, which are recommended for enhancing animal welfare for enriched cage systems and they had a different design from conventional cages in terms of colony size, being larger with 18 to 19 hens per colony compared to conventional cages. Indeed, Wall and Tauson (2007) found that small groups of hens housed in enriched colony cages exhibited similar production and mortality outcomes as those housed in conventional cages Fulton (2017) noted that increasing group size in poultry could have significant effects on animals, social organizations, and welfare of birds. As a result, the more crowded enrichable cages without enrichment equipment were observed to have lower egg production, higher mortality and higher rates of dirty and broken eggs.

CONCLUSION

Hen-day and hen-housed egg production were significantly affected by both strain and cage type. Egg production was higher in conventional cages and in brown egg strains. While the strain effect on mortality became insignificant after 32 weeks, the highest mortality rates were observed in enrichable cages. There were significant differences in dirty and broken egg rates among strain and cage types. The rates of dirty and broken eggs were higher in enrichable cages and for white strains. Egg production, broken and dirty egg rates and mortality were influenced by the strain x cage type interactions. In conclusion, enrichable cages had lower egg production, higher mortality, and higher dirty and broken egg rates compared to conventional cages.

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Ethical Approval: Ethical approval for this study has been obtained with reference number AKUHADYEK-244-17. In addition, the authors declare that research and publication ethics have been adhered to.

Similarity ratio: The authors declare that the similarity ratio of the article is the same as that reported in the system, which is 17%.

Explanation: This research has been summarised from the Master's thesis of the first author.

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