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Effects of Housing System and Age on Early Stage Egg Production and Quality in Commercial Laying Hens

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Summary

This study was made to investigate early stage egg production and cracked egg percentage, daily feed intake, feed consumption per produced egg and egg quality traits of a total of 320 hens (Super Nick) from 22 to 38 weeks of age housed in cage (40 experimental units, each containing 4 hens with a surface of 750 cm^2 per bird) and free-range systems (consisting of fixed house and paddock for grazing; 2400 cm^2 floor area with 10 m^2 grazing area per bird). The effect of age on measured traits was investigated with 4 weeks intervals. Four replicates containing each 40 birds were designed for both of free-range and cage systems. The egg production and cracked egg percentage, daily feed intake and feed consumption per produced egg were different between housing systems. Regardless the housing system; daily feed intake and feed intake per produced egg increased, while egg production, cracked egg percentage decreased by the age of layer. Interactions between layer age and housing systems were found significant for egg production, cracked egg percentage, albumen index, albumen pH and haugh unit parameters. Yolk color ($P<0.03$) was considerably darker and shell thickness was significantly greater ($P<0.01$) in free-range eggs while albumen pH was significantly higher ($P<0.01$) in cage group. We concluded that egg production and quality traits were significantly affected by the housing system furthermore, maintaining external and internal egg quality parameters in constant state especially in free-range system appeared to be difficult.

Keywords: *Laying hens, Housing system, Age, Egg production and quality*

Ticari Yumurtacı Tavuklarda Barındırma Sistemi ve Yaşın Erken Dönem Yumurta Verimi ve Kalitesi Üzerine Etkileri

Özet

Bu çalışma barındırma sistemi ve yaşın ticari yumurtacı tavuklarda erken dönem yumurta verimi, kırık-çatlak yumurta oranı, yem tüketimi ve yemden yararlanma özellikleri ile iç ve dış yumurta kalite özelliklerini incelemek amacıyla yapılmıştır. Çalışma kafes ve serbest dolaşımlı barındırma sistemlerinde gerçekleştirilmiştir. Denemede her iki gruba eşit olarak dağıtılmış Super Nick genotipinden toplam 320 adet yumurtacı tavuk kullanılmıştır. Kafes sisteminde her birinde 4 tavuk ve tavuk başına 750 cm^2 zemin alanı bırakılan 40 kafes bölmesi yer almış, serbest dolaşımlı sistemde tavuk başına 2400 cm^2 kapalı alan ve 10 m^2 gezinti alanı bırakılmıştır. Her iki barınak grubunda her biri 40 tavuktan oluşan 4 tekrarlı grup yer almıştır. Deneme 22 - 38 haftalık yaş döneminde toplam 16 hafta devam etmiş, barınak sisteminin yanında 4'er haftalık dönemler halinde belirtilen özellikler üzerine yaşın etkisi incelenmiştir. Yumurta verimi, kırık-çatlak yumurta oranı, yem tüketimi ve yemden yararlanma üzerine barındırma sisteminin etkisi önemli bulunmuş, yem tüketimi ve yemden yararlanma yaşla birlikte artartken, yumurta verimi ve kırık-çatlak yumurta oranı yaşla birlikte azalmıştır. Yumurta verimi, kırık-çatlak yumurta oranı, ak indeksi, ak pH ve Haugh birimi için barındırma sistemi x tavuk yaşı arası interaksiyonlar önemli bulunmuştur. Serbest dolaşımlı sistemde yumurta sarısı ($P<0.03$) belirgin bir şekilde daha koyu sarı, kabuk belirgin bir şekilde daha kalın ($P<0.01$), kafes sisteminde ak pH'ı önemli düzeyde daha yüksek ($P<0.01$) bulunmuştur. Sonuç olarak yumurta verimi ve kalite özelliklerinin barındırma sisteminden önemli düzeyde etkilendiği, özellikle serbest dolaşımlı sistemde iç ve dış kalite özelliklerinde sürekliliği sağlamanın oldukça zor olduğu gözlenmiştir.

Anahtar sözcükler: *Yumurtacı tavuk, Barındırma sistemi, Yaş, Yumurta verimi ve kalitesi*

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INTRODUCTION

A variety of systems in egg production are currently available, including conventional and enriched laying cages, alternatives such as aviaries, percheries and deep litter, and free-range production in fixed or mobile houses [1-5]. For a long time, standard cages have been, used. Changes in consumer demand and the debate on animal welfare in many countries have forced the use of alternative cages. Due to the rising criticism of conventional cages, the EU passed a directive in 1999 [6] and improved in 2002 [7] in order to ban conventional cages by the beginning of 2012. Alternative housing systems like floor pens, aviaries or free range systems will gain importance in the next future. Laying hens in alternative housing systems, especially free-range, have the opportunity to live out their natural behaviors to a higher extent, more space and greater freedom than the cage system [8].

Though several papers related to the productivity of laying hens in free-range system have been published [3,9-12], to our knowledge data regarding to the internal and external egg characteristics in commercial egg production is limited or not properly investigated. The rapid changes from conventional cages to alternative systems might have been an effect on internal and external egg quality. Eggshell quality in alternative systems is less predictable due to stress levels and mortality rate. Quality parameters of egg may be changed by the advancing age of hens and housing conditions employed [13]. Silversides and Scotts [14] defined these two factors among the most important environmental factors influencing egg quality. Our previous results showed that housing conditions would significantly affect egg production [3,12]. In the present study, it was aimed at investigate the effects of age and housing systems on early egg production and internal and external egg quality traits in laying hens.

MATERIAL and METHODS

Management

Experimental design of housing systems was constituted according to criteria defined by EC standards regulations for labeling eggs [15,16]. For this purpose, a total of 320 pullets (Super Nick) that were growth under standard similar conditions in deep litter housing system were used. When the birds were reached at 22th weeks of age they were randomly transferred into free range and cage system where they will stay during laying period. Their laying output at that time was approximately 50%. Cage system was a triple deck with manure belt system (40 experimental units, each containing 4 hens with a surface of 750 cm^2 per bird). In free-range system, a slat-and-litter housing system with a 2400 cm^2 floor area and 10 m^2 grazing area having with shelters per bird were provided. Four replicates containing each 40 birds were designed for both of free-range and cage systems. In cage system, each replicate was composed from 10 experimental units. The experiment was performed in summer. Covered areas in both systems were equipped with a tunnel ventilation and pad-and fan cooling system. Nipple drinkers and trough feeders that were filled manually were used in cage system. The round drinkers constructed of plastic that hung from the ceiling and tube feeders were used in free-range housing systems. Photo-period employed was 16 h constant lighting in each housing systems. Feed and water were ad libitum and the chemical analyses of the commercial layer feed were given in the *Table 1*.

Table 1. *Chemical analyses of the diet used in the experiment*
Tablo 1. *Denemede kullanılan rasyonun besin madde analizi*

Chemical Analyses	(g/kg)
Dry matter	910.7
Crude protein	160.0
Metabolisable energy (k-cal)	2600
Crude fat	61.2
Ash	114.5
Calcium	30.5
Phosphorus	6.5
Starch	380.4
Carbohydrate	47.1

Data

Collection of data was started at 24 weeks of age, during which all hens were in active production period with an egg output reaching at 90.25% for cage and 90.66% for free-range housing systems. Freshly laid-eggs (totally 640 eggs) were collected at 24th, 28th, 32nd and 36th week of experiments. 80 eggs per housing system (20 eggs per replicate) were gathered in each collection period and analyzed in the laboratory within 24 h to determine egg quality. Normal and cracked eggs were counted daily, feed consumption and mortality rates were recorded per group basis. The egg production of hens in the groups was calculated by dividing the number of daily eggs by the number of hens at the beginning of the laying period (hen-housed). Total feed consumption in each biweekly period was divided into the number of hens at the beginning of the laying period (hen housed) for determining average feed consumption per hen [17]. The percentage of cracked egg in each group was calculated by dividing the number of cracked eggs to total eggs. The feed conversion ratio was calculated on the basis of feed consumption per produced egg.

Eggs were weighed and the length and breadth were measured. From these measurements the shape index was calculated (breadth/lengthx100). Specific gravity was estimated by Archimedes' method [17]. Shell strength was measured using a cantilever system by applying increased pressure to the broad pole of the shell [18] and recorded in Newton (N) force required to crack the shell surface. Thereafter all eggs were broken on to a flat surface; the height and width of both albumen and yolk were measured with a tripod micrometer. To measure shell weight, the albumen was first removed and shells were weighed. The color of the yolk was determined using the DSM color fan [19]. Shell thickness (without inner and outer shell membranes; membranes were removed manually) was measured at three areas (broad end, middle portion and narrow end of the shell), by using a micrometer (mitutoyo®, 0.01-20 mm, Japan). The albumen and yolk index were determined as the ratio of the yolk and albumen height to the yolk and albumen width, respectively. Haugh unit was calculated from the records of albumen height and egg weight using following formula [20]:

$HU = 100.Log (H - 1.7W^{0.37} + 7.6)$
Where,
HU= Haugh unit
H=Albumen height (mm)
W =Egg weight (g)

Statistical Analysis

Data for the egg production and cracked egg percentage, daily feed intake and feed conversion ratio were analyzed using ANOVA test procedure of SPSS version 13.00 [21]. Data was collected daily for strong and cracked egg numbers and weekly for feed consumption and feed conversion ratio. Layer age and housing system were the main effects. Mean separation was performed using the Duncan test [22]. Before statistical analyses traits given in proportions (Daily egg production and cracked egg ratios) were subjected to arc sine transformation. Due to the small number death occurred (only 2 bird in both group) mortality was not evaluated. Results in the tables are expressed as mean values ± SEM.

RESULTS

Effects of housing system and layer age on egg production, cracked eggs, daily feed intake and feed conversion ratio are presented in *Table 2*.

Table 2. *Effects of housing system and layer age on egg production, cracked eggs, daily feed intake and feed conversion ratio*

Tablo 2. *Barındırma sistemi ve yaşın yumurta verimi, kırık-çatlak yumurta, günlük yem tüketimi ve yemden yararlanma üzerine etkileri*

Factors	Egg production (%)	Cracked eggs (%)	Daily feed intake (g)	FCR (g feed:egg)
Main Effects				
Housing system				
Cage	95.50±0.4	1.50±0.1	120.91±2.9	126.53±2.6
Free-range	88.60±0.4	2.40±0.1	94.81±2.1	109.66±2.7
Layer Age (week)				
24-28	92.60±0.4	$2.70±0.1^{a}$	$102.62±2.4^{b}$	$110.65±2.0^{b}$
28-32	92.40±0.4	$2.30±0.2^{b}$	$107.53±2.4^{ab}$	$115.96±1.9^{b}$
32-36	91.30±0.5	$0.80±0.1^{c}$	$113.43±3.0^{a}$	$127.73±2.1^{a}$
Housing x Layer age (week)				
Cage x 24-28	94.4±0.6	2.30±0.2	114.56±1.8	121.35±1.7
Cage x 28-32	96.1±0.5	1.40±0.1	121.31±1.2	126.23±1.4
Cage x 32-36	96.1±0.5	0.70±0.1	126.87±1.3	132.02±1.6
Free-range x 24-28	90.8±0.6	3.10±0.2	90.68±1.5	99.86±2.0
Free-range x 28-32	88.7±0.5	3.10±0.1	93.75±1.6	105.69±1.8
Free-range x 32-36	86.4±0.6	0.90±0.2	100.00±1.7	123.45±1.5
ANOVA				
Housing	0.001	0.001	0.010	0.050
Layer Age	0.090	0.001	0.050	0.050
Housing x Layer age	0.001	0.002	0.198	0.185
SEM	0.382	0.021	0.401	0.397

a-c within columns, values with different superscript differ significantly (P<0.05)

The egg production (P<0.001) and cracked egg percentage, (P<0.001) daily feed intake (P<0.01) and feed consumption values (P<0.05) per produced egg were showed significantly differences when two different housing systems compared. Except for egg production percentage, the age factor had also significant effect on the other tested traits (P<0.001, P<0.05, P<0.05). Although egg production and cracked egg percentage were better in cage system, daily feed intake and feed consumption per produced egg were considerably lower in free-range layers. Daily feed intake and feed consumption per produced egg increased with layer age, whereas cracked egg percentage decreased with advancing age. The housing system-age interactions were significant for egg production and cracked egg percentage (P<0.001, P<0.002).

Data for external egg quality traits are presented in *Table 3*. The main effect, layer age was significantly important (P<0.001, P<0.001, P<0.002, P<0.001, P<0.039) for all external egg quality traits, except for shape index. The egg weight (P<0.08) and eggshell thickness (P<0.038) exhibited differences in housing systems.

There were no significant interactions between housing systems x layer age for external egg quality traits. The values of internal egg quality traits for these two housing systems are presented in *Table 4.*

Yolk color (P<0.03) and albumen pH (P<0.016) of the eggs exhibited difference for both systems and the color was considerably darker in free range eggs.

Table 3. *Main and interactive effects on external egg quality traits*
Tablo 3. *Yumurta dış kalite özelliklerine ana ve interaktif faktörlerin etkileri*

Factors	Egg weight (g)	Specific gravity (g/cm³)	Shape index (%)	Shell thickness (mm x 10⁻²)	Eggshell destruction strength (N)	Eggshell weight (g)
Main Effects						
Housing						
Cage	61.90±0.41	1.089±0.001	74.89±0.264	33.62±0.223	37.21±0.627	6.50±0.054
Free-range	60.30±0.41	1.090±0.001	74.72±0.265	34.28±0.221	37.39±0.626	6.38±0.055
Layer Age (week)						
24	58.04±0.57 a	1.092±0.001 a	75.19±0.372	34.88±0.315 a	37.93±0.887 ab	6.34±0.074 b
28	60.83±0.58 b	1.089±0.001 b	75.12±0.374	33.15±0.316 b	34.66±0.886 c	6.38±0.075 b
32	61.87±0.57 b	1.091±0.001 ab	74.37±0.373	33.93±0.313 b	40.25±0.885 a	6.63±0.076 a
36	63.71±0.56 c	1.087±0.001 c	74.54±0.374	33.85±0.312 b	36.36±0.887 bc	6.41±0.077 b
Housing x Layer age						
Cage-24 w	58.15±0.80	1.091±0.001	75.45±0.529	34.40±0.446	37.67±1.254	6.31±0.109
Cage-28 w	61.04±0.81	1.089±0.001	75.17±0.530	32.80±0.445	35.11±1.253	6.42±0.108
Cage-32 w	63.28±0.80	1.090±0.001	74.64±0.529	33.60±0.439	41.13±1.252	6.73±0.107
Cage-36 w	65.16±0.82	1.087±0.001	74.32±0.526	33.69±0.440	34.94±1.255	6.53±0.109
Free-range-24 w	57.93±0.79	1.092±0.001	74.93±0.527	35.37±0.443	38.20±1.251	6.36±0.108
Free-range-28 w	60.63±0.81	1.089±0.001	75.07±0.529	33.49±0.445	34.22±1.250	6.35±0.109
Free-range-32 w	60.47±0.83	1.091±0.001	74.09±0.528	34.25±0.446	39.38±1.250	6.53±0.108
Free-range-36 w	62.28±0.83	1.087±0.001	74.77±0.529	34.02±0.445	37.78±1.255	6.28±0.109
Housing x Layer age						
Housing	0.008	0.365	0.637	0.038	0.839	0.122
Layer Age	0.000	0.000	0.309	0.002	0.000	0.039
Housing x Layer age	0.198	0.888	0.755	0.914	0.285	0.508
SEM	0.291	0.001	0.187	0.157	0.443	0.039

a-c within columns, values with different superscript differ significantly (P<0.05)

Table 4. *Internal egg quality in the groups*
Tablo 4. *Gruplarda yumurta iç kalite özellikleri*

Factors	Haugh Unit	Yolk color	Yolk index (%)	Albumen index (%)	Albumen pH
Main Effects					
Housing					
Cage	85.95±1.095	9.89±0.076	42.72±0.276	9.73±0.242	8.96±0.021
Free-range	85.89±1.096	10.13±0.077	43.29±0.275	9.50±0.242	8.88±0.022
Layer Age (week)					
24	84.84±1.546 ac	11.13±0.109 a	43.00±0.389	9.81±0.343	9.25±0.028 a
28	82.16±1.545 a	10.74±0.108 b	43.19±0.388	8.92±0.342	8.81±0.029 bc
32	89.57±1.546 b	9.03±0.108 c	43.10±0.399	9.89±0.340	8.86±0.030 b
36	87.09±1.549 bc	9.14±0.109 c	42.72±0.400	9.84±0.345	8.75±0.029 c
Housing x Layer age					
Cage-24 w	87.76±2.190	10.83±0.154	42.05±0.550	10.35±0.482	9.36±0.042
Cage-28 w	80.11±2.191	10.73±0.155	43.28±0.552	8.71±0.481	8.77±0.041
Cage-32 w	92.04±2.190	9.03±0.153	43.20±0.549	10.71±0.479	8.87±0.040
Cage-36 w	83.85±2.189	8.98±0.154	42.35±0.550	9.15±0.480	8.82±0.042
Free-range-24 w	81.92±2.190	11.43±0.154	43.95±0.551	9.28±0.482	9.15±0.040
Free-range-28 w	84.21±2.191	10.75±0.153	43.11±0.552	9.12±0.481	8.85±0.041
Free-range-32 w	87.10±2.192	9.03±0.152	43.00±0.553	9.07±0.483	8.85±0.041
Free-range-36 w	90.32±2.190	9.30±0.152	43.08±0.550	10.53±0.484	8.69±0.040
Housing x Layer age					
Housing	0.975	0.030	0.146	0.507	0.016
Layer Age	0.007	0.000	0.842	0.140	0.000
Housing x Layer age	0.008	0.169	0.188	0.008	0.003
SEM	0.774	0.054	0.194	0.171	0.015

a-c *within columns, values with different superscript differ significantly (P<0.05)*

The age had significant effect on haugh unit ($P<0.07$), yolk color ($P<0.001$) and albumen pH ($P<0.001$). The presence of interaction of housing x layer age for the haugh unit ($P<0.008$), albumen index ($P<0.008$) and albumen pH ($P<0.003$) was also evidenced.

DISCUSSION

The results of this study clearly indicate that the housing systems significantly affected early stage performance of laying hens. As expected, egg production of hens in free-range was lower compared to cage system [10,12,23]. Contrary to the finding of Petek et al.[12] cracked egg percentage in free-range was found to be greater than the cage system. These ambiguous results between the studies might be explained by the amount of dietary Ca and P content and walking activity in free-range system that may affect mineral metabolism. Hens that were kept in cage system consumed more feed than free-range and feed consumption per produced eggs in this system was greater. This could be explained by the variable environmental conditions of layers in outdoor systems. Lesser feed consumption in free-range animals may be linked to their ability to compensate their nutrient requirements by consuming vegetation, worms and insects when they are outside.

In this study, interactions for several parameters were found between layer age and housing system. Egg production percentage decreased with layer age in free-range group, whereas increased in cage group. Daily feed intake and feed consumption per produced egg exhibited an increase by the age in both housing systems. In advanced ages the percentage of cracked eggs decreased in both systems. This may be linked to the imbalance of Ca and P metabolism in early laying period.

Regardless of housing system layer age significantly affected all external egg quality traits measured, excepting shape index. With advanced age, in agreement with numerous other studies the egg weight increased in both housing systems, [9,14,24]. On the contrary to previous researches [9,11], it was found that housing system significantly affected egg weight ($P<0.01$). The weights of eggs obtained from free-range layers were lower compared to those of cage layers in each age period. Limited movement and energy saving in cage system may be responsible for this difference. Although housing system and age had no influence on shape index of eggs, it was found that eggs obtained from caged system were relatively longer than free-range housed layers. However, the shape index for both groups was in normal values (shape index; 72-76), only a numerical decrease was noted by the age in both system. Egg shell quality (shell thickness and specific gravity) remained constant over the laying period or even decreased. Shell thickness was significantly different in housing groups and decreased after 24th week of age. Specific gravity, egg shell weight and egg shell destruction were significantly affected by layer age, nonetheless some fluctuations were observed between the housing systems. These differences may be due to the feed consumption and laying rate.

The yolk color was influenced by the housing system. In free range system, the animals can take xanthophylls, a pigment found in plants, from their environment resulting in proper yolk color development [25]. A darker yolk in the free-range system was expected, because of the possibility of consumption of other feedstuffs, such as grass or herbs. The degree of yolk color in both housing systems was decreased by the age. This may be explained by the increased yolk weight by the age which results in lighter egg yolks [26]. The age relatedness with egg yolk and freshness parameters such as haugh unit and albumen pH is in good agreement with other studies [1,24,27]. Significant level of interactions were evidenced between housing system and age on internal egg quality traits such as haugh unit ($P<0.008$), albumen index ($P<0.008$) and albumen pH ($P<0.003$). These significant housing systems x age interactions were revealed that the positive effect of age was the highest when combined with free-range housing system. As expected [27,28], the albumen pH in both housing systems decreased with layer age.

On the basis of these findings it can be concluded that housing systems and layer age clearly affected early stage laying hen performance and egg quality. Also maintaining external and internal egg quality in constant conditions is appeared quite difficult. Environmental or managerial factors that determine the fluctuations in egg quality need to be investigated in more detail.

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