The effects of space allowance on egg yield, egg quality and plumage condition of laying hens in battery cages

M. Sarica, S. Boga, U.S. Yamak

Agricultural Faculty, Department of Animal Science, Ondokuz Mayis University, Kurupelit, Samsun, Turkey

ABSTRACT: This study was conducted to investigate the effects of cage stocking density on egg yield, some egg quality traits and plumage condition in laying hens. Eighteen weeks-old 264 ISA-Brown pullets were divided into four cage density groups. The densities were 2 000, 1 000, 667 and 500 cm^2 per hen (by allocating 1, 2, 3 and 4 hens per cage; floor area 40 × 50 cm) with 48, 30, 24 and 21 replicate cages, totally 123 three-tier battery cages. During the experimental period from 18 to 53 weeks of age, all birds were provided illumination for 16 hours a day. The hens were fed a diet containing 11.7 MJ ME/kg and 180 g CP during the period of 18 to 40 weeks of age and 11.3 MJ ME/kg and 170 g CP during the period of 41 to 54 weeks of age. Feed and water were available for *ad libitum*. Egg yield, mortality, live weights at 50% egg production age and at the end of experiment, pecking related mortalities, some egg quality traits and plumage condition were recorded weekly. Hen-housed egg production, egg mass, viability, and live weights were significantly decreased by higher densities. Most of the egg quality traits were not affected by cage densities. Pecking related mortalities increased in cage densities of 667 cm^2 and 500 cm^2 per hen compared to the other densities ($P < 0.05$) while plumage scores were higher in all body parts of hens kept in cages of 2 000 cm^2 and 1 000 cm^2 densities compared to the higher densities. The results showed that brown laying hens should be kept in cages having 1 000–2 000 cm^2 densities in order to improve their welfare and performance.

Keywords: cage space allowance; egg yield; feather score; plumage condition; mortality; egg quality

Poultry production has improved dramatically over the last four decades. Consequently, production capacity increased with the use of technologies aimed at genetic improvements, breeding, nutrition and developments in housing systems. High levels of mechanization are used in production systems including housing systems: egg collecting, ventilation, feeding, lighting and waste handling (Siegel, 1993; Blokhuis et al., 1998; Blokhuis, 2004).

Egg producers have increased their net income by utilizing available housing facilities at maximum capacity (Jalal et al., 2006). Currently, commercial layer farms tend to overcrowd the hens by increasing the number of birds per cage and by increasing the density per bird (Hester and Wilson, 1986; Nahashon at al., 2006). It has been shown that producers increase density knowing that there will be an increase in net income with a potential negative effect on hens due to crowding (Adams and Craig, 1985). Animal rights activists have portrayed the production practices in a negative manner, which has resulted in social and cultural pressures being placed on producers to change the housing practices (Blokhuis et al., 1998). Especially, the public opinion has changed in the last 10 years and animal welfare has become an important subject of recent studies such as the effects of increased stocking density on animal welfare (Anderson et al., 1995; Channing et al., 2001). In the EU countries, subsequent regulations in 1998 and in 2002 stipulated that a layer cage should have 550 cm^2 cage area per hen, 10 cm feeder trough per hen, 2 nipple drinkers, floor slope less than 8 degrees, 40 cm height over 65% of cage area (Blokhuis, 2004; Tauson, 2005). The traditional cage

Table 1. Subjected space allowances (cm^2 per hen) and cage properties for experimental hens

Number of hens per cage	Total hens (number)	Feeder length (cm per hen)	Replicates	Cage space (cm^2)	Number of nipple drinkers
1	48	50.0	48	2 000	2
2	60	25.0	30	1 000	2
3	72	16.6	24	666.7	2
4	84	12.5	21	500.0	2

construction will be prohibited from 2012 (Council Directive, 1997/74/EC). United Egg Producers (Atlanta, GA) published animal welfare guidelines that recommend a cage space of 432 cm^2 per hen for small White Leghorn hens compared with the current industry practice of 336 to 348 cm^2 per hen in 2001 (Jalal et al., 2006). In cage systems, hens are more vulnerable to stress and disease factors (Broom and Corke, 2002), skeletal or leg problems (Fleming et al., 1994) because of their restricted normal behaviours. Cage systems continue to be used for egg production in most countries since this system results in a lower exposure of hens to diseases and parasites and in a cleaner egg (De Reu et al., 2006; Mallet et al., 2006).

There are numerous studies regarding the effect of cage stocking density on the production of commercial layers. A decrease in floor densities causes a reduction in egg production (EP), egg weight (EW) and feed intake (FI), an increase in mortality and feather pecking with poorer plumage scores (Bell, 1981; Roush et al., 1984; Anderson et al., 1989; Sandoval et al., 1991; Hester et al., 1996; Huber-Eicher and Sebö, 2001; Anderson et al., 2004; Onbasilar and Aksoy, 2005; Tauson, 2005; Jalal et al., 2006; Nahashon et al., 2006; Nicol et al., 2006). However, there is still a need to carry out further studies regarding egg production, egg quality, lower mortality and plumage damage of layers, as responses to reduced cage densities. Therefore, the present study aimed to investigate the effects of different cage densities on egg production and quality traits, mortality and feather loss of layers kept in a traditional battery cage system.

MATERIAL AND METHODS

The study was carried out in a house which had 3-tier battery cages over a dropping pit. The floor area of each battery cage was 40 × 50 cm, front height 43.5 cm and back height 38 cm, feeder space 50 cm and there were 2 nipple drinkers. There are four cage blocks in the poultry house and each block has 246 cage units. The room was ventilated by windows and by a fan over the droppings pit.

Experimental hens were 300 brown laying pullets including spare ones, pullets (ISA Brown) purchased from a commercial breeding company before the laying period at 16 weeks of age. Spare pullets replaced the dead ones from the same density cages during experimental periods. This study was based on cage stocking regulations in traditional cage systems legitimate in the EU countries since 2002. The highest stocking density started with the lowest stocking density permitted by the rules and the other applications were realized with lower stocking densities. Experimental space allowances and cage properties are given in Table 1. The dead animals were replaced by spare birds having similar live weights in order to keep the allowed space per hen constant for experimental groups.

Hens were fed *ad libitum* with a layer diet containing 11.7 MJ ME/kg, 180 g crude protein, 31.1 g crude fibre and 36 g Ca per kg diet during the period of 18–40 weeks of age and a layer diet containing 11.3 MJ ME/kg, 170 g crude protein, 37.1 crude fibre and 38 g Ca per kg diet during the period of 41 to 54 weeks of age.

Artificial illumination was provided for an optimal lighting regimen (14.5 hours at the 18th week, 15 hours at the 19th week of age, 16 hours from 20 to 54 weeks of age) by additional lighting in the evenings with fluorescent electrical bulbs of 40 watt capacity.

During the experimental period, weekly recorded egg production traits were egg yield (hen/day), mortality rate (%), 50% egg production age (day), live weights at 50% egg production age and live weights at the end of the experiment. Egg quality parameters were egg weight, shape index, specific gravity, shell breaking strength, shell thickness,

Table 2. Effects of cage stocking density on egg yield, viability, 50% egg production age and live weights of hens

Traits	Cage stocking density (cm²/hen)				
	2 000	1 000	667	500	SEM
Eggs produced per hen/day	224.7[a]	212.7[b]	211.7[b]	204.9[c]	3.89
Viability (%)	100.0[a]	98.3[b]	97.3[bc]	96.4[c]	–
50% egg production age (days)	201.0[a]	204.0[b]	204.0[b]	211.0[c]	2.14
Live weight at 50% egg production age (g)	1 711.6	1 676.7	1 638.8	1 680.8	5.47
Live weight at the end of production period (g)	2 114.1[a]	2 087.9[ab]	1 998.9[b]	1 990.7[b]	7.21

[a,b,c]designate the statistical difference between treatments within each row ($P < 0.05$)

shell weight, yolk percentage, yolk index, yolk colour, albumen percentage, albumen index, Haugh unit score, meat and blood spot percentage on a biweekly basis from a random sample of 11 eggs from each treatment between 24 and 52 weeks of age. Six hundred twenty sample eggs were used for the quality analyses. Fourteen analyses were done in total. Yolk colour was measured by the Roche colour scale and egg specific gravity was determined by plunging eggs into salt solutions of different concentrations. The other quality traits were evaluated by methods described by Stadelman (1995). Plumage scores were graded in all animals according to a feather loss on the neck, chest, dorsal side, tail and wings at 52 weeks of age. Feather losses were graded as follows: a few feathers and nakedness 1, spilling more than half 2, a few spilling 3 and protected plumage 4, and the total of these grades as plumage score. There was a different opinion of some researches that this grading was made from the highest point to lowest point which is protected plumage (Ambrosen and Petersen, 1997; Onbasilar and Aksoy, 2005).

Data were subjected to analyses of variance for a fully randomised design using the General Linear Models (Windows version of SPSS, release 12). The main factor was stocking density. The percentage mortality data were subjected to Arcsin square root transformations and numerical data were subjected to logarithmic transformations prior to *Chi*-square analysis. A probability of $P < 0.05$ was used for statements of significance using Scheffe test within same SPSS software.

RESULTS

Increased space allowance or decreased cage stocking density significantly enhanced egg production (Table 2, $P < 0.05$). Hens kept either at 667 cm^2 or 1 000 cm^2 cage densities produced the same amount of eggs while those kept at 500 cm^2 space allowance decreased egg production with a delay in reaching the 50% egg production age ($P < 0.05$).

There were no differences between the treatment groups with respect to live weights at 50% production age, which was taken as a criterion of sexual maturity. However, live weights of hens at the end of the study were the highest in 2 000 cm^2 space allowance cages ($P < 0.05$, Table 2). Viability rates were decreased by lower space allowances with the lowest viability at 500 cm^2/hen. Hens housed at lower space allowances reached yield age 50% egg production (sexual maturity) significantly earlier than the others ($P < 0.05$).

The external egg quality traits such as egg weight, specific gravity, shell breaking resistance, shell weight, shell percentage and shell thickness were not affected by stocking densities. However, egg shape indexes were different between the treatments and the highest shape index was in 500 cm^2 treatment ($P < 0.05$, Table 3). During egg collections after 40 weeks of age, the respective cracked and broken eggs amounted to 2.86%, 3.04%, 3.40%, 3.44% at 2 000, 1 000, 667 and 500 cm^2 space allowances with the highest proportion of cracked and broken egg at minimum space allowance although differences between the stocking densities were not significant.

Limiting the space allowance tended to decrease yolk and albumen quality without statistical significance while the numbers of eggs with meat and blood spots were higher in cages of 667 cm^2 and 500 cm^2 space allowance per hen (Table 3).

In the present study, total mortalities and pecking related mortalities were significantly affected by the

Table 3. Effects of cage stocking density on external and internal egg quality

Traits	Cage stocking density (cm^2/hen)				
	2 000	1 000	667	500	SEM
External traits					
Egg weight (g)	63.9	64.1	62.9	62.8	0.12
Egg mass (egg weight × egg yield, kg)	13.4[a]	13.0[a]	12.7[b]	12.2[b]	1.45
Shape index (%)	78.1[a]	78.0[a]	77.9[a]	78.97[b]	0.13
Specific gravity (g/cm^2)	1.10	1.09	1.10	1.10	0.001
Breaking strengths (kg/cm^2)	3.14	3.12	3.13	3.21	0.02
Egg shell weight (g)	7.8	7.9	7.8	7.9	0.03
Shell percentage (%)	12.3	12.4	12.4	12.6	0.04
Shell thickness (mm)	0.378	0.382	0.380	0.383	0.001
Broken and cracked eggs (%)	2.9	3.0	3.4	3.4	0.11
Internal traits					
Yolk percentage (%)	9.37	9.49	9.44	9.64	0.08
Yolk index (%)	46.70	47.40	47.30	46.30	0.04
Yolk colour	10.80	10.90	10.80	10.90	0.02
Albumen percentage (%)	63.20	63.20	63.20	63.40	0.12
Albumen index (%)	23.40	23.60	23.60	23.60	0.16
Haugh unit	81.90	83.30	83.30	83.20	0.17
Meat and blood spots (%)	1.70	1.80	1.90	1.90	0.01

[a,b]designate the statistical difference between treatments within each row ($P < 0.05$)

space allowance ($P < 0.05$, Table 4). No mortality occurred in cages having 2 000 cm^2 space allowance per hen while the highest mortality rate occurred in cages having 500 cm^2 per hen. Pecking related mortalities were higher in cages having 667 cm^2 and 500 cm^2 per hen. No pecking related mortalities were observed in cages having 2 000 and 1 000 cm^2 space allowance per hen (Table 4).

The highest feather losses occurred on the neck in all experimental hens. Plumage scores of neck, chest, tail, back and wings were higher for layers kept at 2 000 cm^2 and 1 000 cm^2 space allowance per

Table 4. Effects of cage stocking density on pecking related mortalities and feather scores

Traits	Cage stocking density (cm/hen)				
	2 000	1 000	667	500	SEM
Mortality rate (from pecking; %)	0.00[a]	0.00[a]	2.70[b]	3.58[b]	
Total mortality (%)	0.00[a]	1.67[b]	2.70[bc]	3.58[c]	
Plumage condition scores					
Neck	3.58[a]	3.82[a]	2.98[b]	2.86[b]	0.03
Chest	3.67[a]	3.63[a]	2.78[b]	2.70[b]	0.04
Tail	3.74[a]	3.72[a]	2.93[b]	2.71[b]	0.05
Back	3.74[a]	3.72[a]	2.93[b]	2.71[b]	0.03
Wings	3.82[a]	3.80[a]	3.60[a]	2.93[b]	0.02
Total	18.99[a]	18.81[a]	15.40[b]	14.19[b]	0.01

[a,b]designate the statistical difference between treatments within each row ($P < 0.05$)

hen. In other words, greater plumage damage was determined at high stocking densities (Table 4).

DISCUSSION

In the present study, egg production increased by a decrease in the cage stocking density for hens. This increase in egg production averaged 15.9 number decreasing the space allowance from 2 000 cm^2 to 500 cm^2 per hen. Decreasing egg production was shown to be attributable to the reduced feeding area per hen, cannibalism (Hester and Wilson, 1986; Craig and Milliken, 1989; Lee and Moss, 1995; Süto et al., 1997; Sohail et al., 2001; Onbasilar and Aksoy, 2005; Jalal et al., 2006; Nicol et al., 2006) and stocking density (Adams and Craig, 1985). Anderson et al. (2004) found out that the reduced cage stocking in Hy-Line W36 and Dekalb XL commercial layer genotypes decreased hen-day egg production. They reported a decrease in egg production from 82.3% to 77.4% because of reducing the cage stocking from 482 cm^2 to 361 cm^2 per hen. Onbasilar and Aksoy (2005) determined hen-day egg production as 94.1%, 89.3% and 78.5% at the respective stocking densities 1 968, 656 and 393.8 cm^2 per hen with statistical significance ($P < 0.05$).

In the present study, viabilities decreased with the reduced space allowance and the pecking rate also increased. Similar findings were reported by many researches (Roush et al., 1984; Adams and Craig, 1985; Sandoval et.al, 1991; Rodenburg et al., 2003). Nicol et al. (2006) showed that mortality rate and poor plumage score increased with stocking density whereas no relationships were observed between mortality and pecking and plumage pulling. Ambrosen and Petersen (1997) observed that most mortalities were related to cannibalism in 4 white and 3 brown layer genotypes. Pavan et al. (2005) showed that mortality rates were not affected in ISA Brown hens kept in cages having 563, 450 and 375 cm^2 space allowance per hen, agreeing with the results of other studies in brown layers (Süto et al., 1997; Nicol et al., 1999; Huber-Eicher and Sebö, 2001; Guesdon et al., 2006; Wezyk et al., 2006).

Hens housed at lower stocking densities reached sexual maturity significantly earlier than the others. 50% egg production occurred at 201 days in single bird cages at 2 000 cm^2/hen and it was delayed by 3, 3 and 10 days as a response to more limited space allowances of 1 000, 667 and 500 cm^2, respectively, which was the same order as in egg production. However, live weights both at 50% egg production age and at the end of experimental period were moderately higher in hens allowed more space (2 000 and 1 000 cm^2 per hen) compared to those kept at lower space allowance ($P < 0.05$). The higher live weights at 2 000 and 1 000 cm^2 space allowances could be explained by higher feed consumption and water intake because of the greater feeder space and nipple per hen during the experimental period. This may also explain why these birds produced more eggs and these eggs were heavier than those of hens kept in more restricted spaces. A significant increase in live weights of Single Comb White Leghorns at lower stocking densities was previously related to the feeder lengths in cages (Cunningham and Ostrander, 1982; Ouart and Adams, 1982a,b). Onbasilar and Aksoy (2005) also found out that increased stocking density by increasing the number of hens per cage from 1 to 5 decreased live weights of Hy-Line Brown genotype. However, Jalal et al. (2006) did not find any significant effect of space allowance on live weights of hens in cages having 690 cm^2, 516 cm^2, 413 cm^2 and 372 cm^2 per hen in spite of insignificantly higher live weights at lower stocking densities.

In the present study, the space allowance did not affect any external and internal egg quality traits, except the egg shape index. Partly, there was an increase in meat and blood spotted eggs without statistical significance. Similar findings were reported in the studies of Carey et al. (1995). The results regarding the egg quality are expectable because the present study was conducted in a traditional cage system providing optimum conditions for animal welfare. Likewise, similar findings were obtained in higher stocking density experiments (Saylam et al., 1992; Carey et al., 1995; Onbasilar and Aksoy, 2005; Jalal et al., 2006). Guesdon et al. (2006) observed no significant difference in egg weight and shell quality between the layers caged 5 and 6 hens per cage having 660 cm^2 space allowance per hen, but significant increases in broken or cracked eggs were found. They determined the broken or cracked egg percentage including inner shell cracks in 5 and 6 hens stocked cages as follows: at 28th week 6.1% (5 hens/cage) and 3.3% (6 hens/cage); at 37th week 7.4% and 5.8%; at 47th week 8.9% and 8.2%; at 58th week 9.9% and 7.3%, while the differences were found significant. Carey et al. (1995) observed that broken-cracked eggs decreased significantly at lower stocking densities. Altan et al. (2002) reported that the Haugh unit value was affected by stocking density in white layers (640, 480 and 384 cm^2/hen; 3, 4, 5 hens/cage) but it was not affected in brown layers (640, 480 cm^2/hen; 3 and 4 hens/cage). Süto et al. (1997) reported no statistical difference in Roche colour score values and shell thickness between Leghorn and brown layers at 3 and 4 hens per cage stocking densities while the Haugh unit value was higher in Leghorn layers solely in the group of 3 hens per cage. An increase in albumen heights with the effect of space allowance in white Leghorn hens was observed by Lee and Moss (1995).

The effects of space allowances on the plumage score on different body parts at the end of the experiment were found significant. Plumage damage and feather loss occurred on all body parts when hens were kept in a more restricted area ($P < 0.05$). Egg production was higher at lower densities ($P < 0.05$). Space allowances affected feather losses in layers. The protected plumage level in more space allowed hens' thermoregulation and these healthy hens felt no pain and did not show any abnormal behaviour such as pecking on other animals' body surfaces because of wider space allowance and any competition for drinkers and feeders (McAdie and Keeling, 2000; Bright et al., 2006). The heat loss increases according to a decrease in plumage amount and energy needed to balance the body heat increases, resulting in an increase in feed consumption in order to compensate energy losses from their bodies (Leeson and Morrison, 1978; Ambrosen and Petersen, 1997). A cannibalism tendency also shows parallelism with the damage of plumage (Ambrosen and Petersen, 1997). The results obtained in this experiment support these findings, as pecking related mortalities and plumage damage on the same dead animals. The results of Onbasilar and Aksoy (2005) also showed that higher feather losses were observed in birds allowed restricted space. Apart from space allowance, breeding systems (Hansen and Braastad, 1994; Bright et al., 2006) and cage shape may affect feather loss in layers. Nicol et al. (2006) obtained different plumage scores in small and big flocks at 7, 9, 12 hens/m^2 stocking densities, in a pen with 2/3 of slatted platform and 1/3 of littered floor; they stated the importance of the flock size as well as stocking density. They also observed that lower stocking densities decreased plumage damage and plumage scores were better especially in the cage system (Nicol et al., 1999; LaBrash and Scheideler, 2005). Additionally, the genetic differences (white and brown layer flocks) are effective in plumage scores depending on experimental conditions (Ambrosen and Petersen, 1997; LaBrash and Scheideler, 2005; Allison, 2006).

In conclusion, ISA brown layers should be kept in cages having either 2 000 or 1 000 cm^2 space depending upon the economic situation of farms because these cage densities did not cause any welfare problems (pecking related mortalities and plumage damage) and did not decrease egg production.

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Corresponding Author

Prof. Dr. Musa Sarica, Agricultural Faculty, Department of Animal Science, Ondokuz Mayis University, Kurupelit, 55139 Samsun, Turkey
e-mail: msarica@omu.edu.tr