Europ.Poult.Sci., 80. 2016, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2016.163

Europ.Poult.Sci., **80.** 2016, ISSN 1612-9199, © Verlag Eugen Ulmer, Stuttgart. DOI: 10.1399/eps.2016.163

# Effects of different feed forms and cage densities on laying hen performance and stress status

## Einfluss verschiedener Futterformen und Besatzdichten auf die Legeleistung und den Stressstatus

**S.N. Mousavi**[1], **E. Fahimi**[1] and **R. Taherkhani**[2*]

[1] Dept. of Animal Science, College of Agriculture, Varamin-Pishva Branch, Islamic Azad University, Varamin, Iran

[2] Dept. of Animal Science, Faculty of Agriculture, Payame Noor University, Tehran, Iran

*Correspondence: r_taherkhani@pnu.ac.ir

Manuscript received 26 April 2016, accepted 19 August 2016

## Introduction

It is a common practice to increase the number of laying hens per cage to reduce production costs. However, reduced cage space (which is accompanied with reduced feeder space) generally results in impaired laying performance due either to insufficient feed (nutrient) intake and/or to the negative effects of induced stress.

Replacing mash feed with pellet feed may alleviate the negative effects of reduced cage space on feed uptake. The better performance of broiler chicks fed on pelleted diets relative to those fed on mash diets is well known in poultry production and is associated with higher dietary density, better starch digestibility due to chemical changes resulting from processing, higher feed intake, changes in physical form of the feed, and reduced feed waste and energy use for feed consumption (Amerah et al., 2007; Dozier et al., 2010). Zang et al. (2009) demonstrated that the better performance of broiler chicks receiving pelleted feeds is associated with higher apparent metabolisable energy (AME) intake, better protein digestibility, as well as better intestinal function, as shown by increased villi height and ratio of villi height to crypt depth.

It has been demonstrated that stress can disrupt breeding in either wild or domestic chickens. Glucocorticoids (GC), as the final effectors of the hypothalamic-pituitary-adrenal axis, participate in the control of whole body homeostasis and the arousal of stress responses. GCs transmit information about environmental conditions to the hypothalamic-pituitary-gonadal axis, ultimately influencing the reproduction of poultry. Wang et al. (2013) reported that infusion of corticosterone resulted in reduced egg production in laying hens.

The current study was carried out to determine if impaired egg production in hens with reduced cage space is due to insufficient reception of feed (nutrient) and consequently could be restored by using pelleted feed instead of mash diets, or rather is attributable to the negative effects of induced stress.

## Materials and methods

A total of 384 Shaver laying hen were used to assess effects of different feed forms and cage densities on their performance, welfare and stress status. Hens were selected from a commercial flock so that the experimental unit had equal mean weight (1652 ± 15 g) and weight distribution. The experiment, which began at 50 weeks and lasted up to 60 weeks of age was carried out using a complete block design with a factorial arrangement of treatments (2×3).

Factors consisted of feed form (pellet and mash) and cage density (320, 400 and 533 cm$^2$ per bird corresponding to 5, 4 and three hens per cage, respectively). Birds had a 10-day adaptation period to the type of feed they were given before being allocated to cages of different density. Forty-eight experimental units included 6 treatments, each of which was replicated 8 times. Each cage (40×40×35 cm) was equipped with 2 nipple drinkers and trough feeders (8, 10 and 13 cm feeding space for 533, 400 and 320 cm$^2$ density, respectively). The house temperature was kept at 22 ± 2°C, and a lighting program with 16 h light with 10 lux intensity was used during the entire experiment.

The content of dry matter, CP, ash, ether extract and crude fibre was determined for maize, soybean meal and wheat (AOAC, 1999) samples. The metabolisable energy content of each ingredient was calculated using the NRC (1994) regression equation. The amino acid content of ingredients was determined using a near-infrared spectroscopy (NIRS) technique. These data were employed to formulate diets that met Shaver nutrient requirements according to the egg production of the hen and the daily feed intake (Table 1). Ingredients were mixed using a horizontal mixer and half of the mixed diet was used in pelleted feed preparation. Prior to entering the die (3.5 mm), the mixed feed was exposed to approximately 73°C in a steam conditioner for 40 s. Feed and water were available *ad libitum* throughout the experiment.

**Table 1. Composition and nutrient contents of experimental diet**

**Zusammensetzung und Nährstoffgehalte der Versuchsfutterration**

| Ingredient | g/kg |
|---|---|
| Maize | 464 |
| Soybean meal | 253 |
| Wheat | 150 |
| Soybean oil | 10.0 |
| Oyster shell | 98.6 |
| Dicalcium phosphate | 13.8 |
| Sodium chloride | 2.70 |
| NaHco3 | 1.00 |
| Vitamin premix[1] | 2.50 |
| Mineral premix[2] | 2.50 |
| DL-Methionine | 1.60 |
| Nutrient (analysed except for ME) | |
| Metabolisable energy (MJ/kg) | 11.2 |
| Crude protein (%) | 17.0 |
| Ca (%) | 4.00 |
| Available P (%) | 0.350 |
| Total P (%) | 0.490 |
| Na (%) | 0.160 |
| Met+Cys (%) | 0.720 |
| Lys (%) | 0.870 |
| Thr (%) | 0.640 |
| Ether extract (%) | 3.40 |

[1] To supply per kg diet: 8800 IU vitamin A; 3300 IU vitamin D3; 16.5 IU vitamin E; 2.2 mg vitamin K; 0.022 mg vitamin B12; 1.7 mg thiamine; 3.3 mg pyrodoxine; 5.5 mg riboflavin; 28 mg niacin; 6.6 mg pantothenic acid; 0.6 mg folacin; 0.055 mg biotin; 90 mg

[2] Manganese; 55 mg iron; 5.5 mg copper; 88 mg zinc; 1.7 mg iodine; 0.3 mg selenium.

### *Data collection*

Body weights were recorded individually when the hens were 50 and 60 weeks of age, at which point body weight change (BWC) was calculated.

For each cage, hen day egg production (HDP) was calculated after daily egg counts; feed consumption (FC) and egg weight (EW) were measured weekly, and then egg mass (EM) was calculated as follows: EM = HDP×EW. Furthermore, feed conversion ratio (FCR) was calculated using the following formula: FCR = FC÷EM. All the data were analysed after pooling daily or weekly data into 10-week periods.

Upon completion of the study, blood samples from 2 birds for each cage were taken from the ulnar vein using a 23-gauge needle and heparinised syringe. To minimise the effects of sampling on plasma corticosterone, a standardised capture and bleeding method (Silverin, 1998) was used and all samples were taken within 2 min of each bird being removed from its cage. Blood samples were immediately centrifuged at 2000 *g* for 15 min to collect blood plasma. Plasma samples were stored at −20°C pending for glucose and corticosterone (CS) assays. Plasma CS concentrations were determined by enzyme-linked immunoassay (EIA; Correlate-EIA for CS, Assay Designs, Inc., Ann Arbor, MI). Heterophil/lymphocyte ratios were determined according to the method described by Tactacan et al. (2009).

At 60 weeks of age, two birds from each cage were selected randomly to evaluate feather score as described by TAUSON et al. (1984).

### Statistical analyses

Statistical analyses were carried out using GLM procedure of SAS software (SAS, 1999). Results are generally presented as least squares means values based on the statistical model used. The following statistical model were used for data analyses: $Y_{ijk} = \mu + R_i + a_j + b_k + (ab)_{jk} + e_{ijk}$, where $Y_{ijk}$ = responsible variable, $\mu$= overall mean, $R_i$ = fixed effect of block, $a_j$ = fixed effect of density, $b_k$ = fixed effect of feed form, $ab_{jk}$ = interaction between cage density and feed form and $e_{ijk}$ = random error.

### Results and discussion

*Performance*

Results on body weight change (BWC), HDP, egg weight (EW), egg mass (EM), feed consumption (FC) and feed conversion ratio (FCR) are presented in Table 2.

**Table 2. Effects of feed form and cage density on egg production, egg weight, egg mass, feed consumption, feed conversion ratio and body weight change**

**Einfluss der Futterform und der Besatzdichte auf die Legeleistung, die Eigewichte, die Eimasseproduktion, die Futteraufnahme, die Futterverwertung und die Veränderung der Körpergewichte**

| Treatment | | Egg production (%) | Egg weight (g) | Egg mass (g) | Feed consumption (g) | Feed conversion ratio | Body weight change (g) |
|---|---|---|---|---|---|---|---|
| Feed Form | Mash | 92.4 | $63.5^{b}$ | 59.1 | $115^{a}$ | $1.98^{a}$ | $24.7^{a}$ |
| | Pellet | 90.1 | $64.6^{a}$ | 58.3 | $107^{b}$ | $1.85^{b}$ | $-16.0^{b}$ |
| SEM | | 0.880 | 0.280 | 0.520 | 1.10 | 0.030 | 7.26 |
| Density | 533 | $92.8^{a}$ | 63.8 | 59.6 | $113^{a}$ | 1.93 | $5.25^{ab}$ |
| | 400 | $91.6^{ab}$ | 64.4 | 59.0 | $112^{ab}$ | 1.90 | $27.6^{a}$ |
| | 320 | $89.1^{b}$ | 64.2 | 57.4 | $109^{b}$ | 1.92 | $-19.8^{b}$ |
| SEM | | 1.08 | 0.350 | 0.640 | 1.40 | 0.020 | 9.01 |
| Feed form | Density | | | | | | |
| Mash | 533 | 94.4 | 63.1 | 60.4 | $120^{a}$ | 2.03 | $38.8^{ab}$ |
| Mash | 400 | 94.0 | 64.0 | 60.2 | $117^{ab}$ | 1.95 | $45.3^{a}$ |
| Mash | 320 | 88.3 | 63.4 | 56.6 | $110^{bc}$ | 1.97 | $-9.87^{bc}$ |
| Pellet | 533 | 91.2 | 64.4 | 58.7 | $108^{c}$ | 1.84 | $-28.3^{c}$ |
| Pellet | 400 | 89.3 | 64.7 | 57.8 | $107^{c}$ | 1.86 | $9.88^{abc}$ |
| Pellet | 320 | 90.0 | 64.8 | 58.3 | $109^{c}$ | 1.86 | $-39.7^{c}$ |
| SEM | | 1.30 | 0.490 | 0.900 | 1.90 | 0.040 | 12.8 |
| SOV | | | | | | | |
| Feed form | | 0.100 | 0.009 | 0.280 | < 0.001 | < 0.001 | < 0.001 |
| Density | | 0.050 | 0.450 | 0.060 | 0.050 | 0.800 | 0.010 |
| Feed form×density | | 0.100 | 0.750 | 0.060 | 0.031 | 0.470 | 0.031 |

*a-c* Means in a column with no common superscript letter are significantly different
SOV: Source of variation

Hens fed on pelleted feed had significantly lower ($P<0.001$) feed intake compared to those that received mash feed. Furthermore, pelleted feed resulted in mean body-weight reduction of 16.1 g during the experiment ($P<0.001$). The feed conversion ratio was significantly ($P<0.001$) lower in pellet fed hens in comparison to those who were fed by mash diet. Although HDPs were not significantly different between the two forms of feed, hens fed with mash diet had numerically higher HDP (2.22% more egg production). Pellet fed hens laid significantly ($P<0.009$) heavier eggs than did their mash-fed counterparts.

Increased feed intake in broiler chicks receiving pelleted diets in comparison to mash diets is well documented (MORITZ et al., 2003; CUTLIP et al., 2008). Contrary to broiler chicks, laying hens fed on pelleted feed in the present experiment consumed less feed. This result is consistent with those reported by SCOTT et al. (1999) and HAMILTON and PROUDFOOD (1995). SCOTT et al. (1999) suggested that laying hens prefer to consume mash diets compared to pelleted diets. HAMILTON and PROUDFOOD (1995) assumed that difficulty in taking up pelleted feed by beak- trimmed hens is the main reason for decreased feed intake. In the present experiment, hens were not beak-trimmed, and beak trimming was most likely not involved in the decreased feed intake. Another possible explanation for decreased feed intake in pellet fed hens may be related to improved digestibility of nutrients in pelleted feed (WAHLSTROM et al., 1999) and the fact that contrary to today's broiler chicks, laying hens are able to precisely control their feed intake (SUMMERS and ROBINSON, 1995).

Improved FCR and heavier eggs in pelleted fed hens are probably attributable to increased nutrient digestibility, along with reduced feed wastage and energy use for feed consumption (AMERAH et al., 2007; DOZIER et al., 2010). SAVORY (1974) concluded that laying hen pullets spend less time and energy in the ingestion of pelleted feed compared to mash, and the pellets appeared more digestible than the mash.

Increasing the cage density from three to 5 hens per cage significantly ($P<0.05$) reduced mean egg production from 92.9 to 89.2, a difference of 3.69%. But, HDP was not significantly different between 4 and three or 5 hens per cage. Neither egg weight, nor egg mass were influenced by different cage densities. Feed consumption was affected by a significant interaction between feed form and cage densities. Feed intake significantly reduced in mash fed hens as numbers of hens per cage increased; similar reductions did not occur in their counterparts fed with pellet feed. Concurrent with reduction in the feed intake, an HDP reduction (a difference of 5.7–6.1%) was observed in hens fed mash diet with 5 birds per cage compared to 4 and three birds per cage ($P<0.10$). Similar to the results of present study, JALAL et al. (1996), SOHAIL et al. (2001, 2004), ADAMS and CRAIG (1985), and DAVAMI et al. (1987) also found that increasing cage density and reduction of feeder space/birds caused a decline in egg production. However, in the present study using pelleted feed instead of mash, compensated the reduced feeder space in high density cages. NIR et al. (1994) reported in broiler chicks that replacing mash diet with pellet reduced feeding time by one third.

Egg weight results obtained in the current study were similar to those obtained by RIOS et al. (2009), GOODLING et al. (1984), LEE (1989), and CAREY et al. (1995), who also did not find any effect of cage density on egg weight, whereas ROUSH et al. (1984) observed a trend of increasing egg weight as cage area per bird was reduced. DAVAMI et al. (1987) found that egg weight decreased in the treatment of highest density.

Although RIOS et al. (2009), ADAMS and CRAIG (1985), DAVAMI et al. (1987) and GARCIA et al. (1993) observed an improvement in feed conversion ratio per kg of produced eggs as the available space per bird in the cage increased, the feed conversion ratio was not significantly different in the current study among the different cage densities.

Body weight changes were significantly ($P<0.01$) affected by cage density. Hens from cage densities of 320 and 400 $cm^2$ gained 5.25 and 27.6 g, respectively, hens in cages with a density of 533 $cm^2$ lost 19.8 g during the course of the experiment.

A significant interaction between feed form and cage density were observed for body weight changes. In accordance with feed consumption (for which birds receiving pelleted feed were not influenced by being kept in cages of different densities) the BWC of birds kept at different cage densities was significantly different only in mash-fed hens. Using pelleted feed instead of mash apparently eliminated competition for feed in over-crowded cages, resulting in similar intake and BWC.

### *Welfare and stress status*

The mean ratios of heterophil to lymphocyte and plasma glucose and corticosterone concentrations are presented in Table 3. The findings are in contrast to MASHALY et al. (1984) showing that corticosterone concentrations were consistently higher in the serum of birds housed 5 per cage than in birds housed three or 4 per cage. Contradictory evidence has been published concerning the effect of stressors on plasma concentrations of corticosterone. Circadian pattern (WILSON et al., 1984; DE JONG et al., 2001) or the ovulatory cycle (WILSON and CUNNINGHAM, 1981) and handling during bleeding are known stressors (RADKE et al., 1985), which have given contradictory results.

**Table 3. Effects of feed form and cage density on heterophil/lymphocyte ratio and plasma corticosterone and glucose concentration**

**Einfluss der Futterform und der Besatzdichte auf das Heterophilen/Lymphozyten-Verhältnis und die Konzentration von Glukose sowie Kortikosteron im Blutplasma**

| Treatment | | Corticosterone (ng/ml) | Heterophil/lymphocyte ratio | Plasma glucose (mg/dl) |
|---|---|---|---|---|
| Feed Form | Mash | 1.82 | 0.620 | 231 |
| | Pellet | 1.74 | 0.600 | 229 |
| SEM | | 0.070 | 0.010 | 3.51 |
| Density | 533 | 1.72 | 0.610 | 231 |
| | 400 | 1.74 | 0.620 | 229 |
| | 320 | 1.89 | 0.600 | 231 |
| SEM | | 0.080 | 0.010 | 4.29 |
| Feed form | Density | | | |
| Mash | 533 | 1.72 | 0.640 | 230 |
| Mash | 400 | 1.73 | 0.630 | 222 |
| Mash | 320 | 2.02 | 0.600 | 220 |
| Pellet | 533 | 1.72 | 0.590 | 232 |
| Pellet | 400 | 1.76 | 0.620 | 225 |
| Pellet | 320 | 1.75 | 0.610 | 232 |
| SEM | | 0.110 | 0.030 | 6.13 |
| SOV | | | | |
| Feed form | | 0.380 | 0.470 | 0.830 |
| Density | | 0.270 | 0.710 | 0.910 |
| Feed form×density | | 0.330 | 0.540 | 0.610 |

SOV: Source of variation

The present results indicated no significant effect of either feed form or cage density on H/L ratio. In the same way, plasma glucose and corticosterone concentration were not significantly different among hens were mash or pellet diets in different cage densities. These observations are in accordance with those reported by DAVIS et al. (2000) and MENCH et al. (1986). In agreement with the present results, PATTERSON and SIEGEL (1998) reported that despite a significant reduction in feed intake and body weight loss, cage density treatments had no significant effect on the H/L ratio of commercial White Leghorn pullets. They concluded that the impact of stress on the H:L ratio can be transient, and the duration of the H:L ratio response may be lasted after a short period of time.

Table 4 presents the feather cover area of the body at the end of the experiment. The present results showed poor feather cover in all areas except for the tail in cages with higher density. These findings are similar to those of VALKONEN et al. (2008) and ONBASILAR and AKSOY (2005). The present findings also agree with OUART and ADAMS (1983) who reported better feather cover in laying hens with lower cage density. The authors showed that the birds housed at higher density tended to be more nervous. As shown in Table 4, hens fed on pellet diets had significantly lower wing feather cover than those fed on mash diet. Interaction between cage density and feed form was significant for back feather cover of hens ($P < 0.01$). Effect of higher cage density on feather cover was only observed in hens receiving pellet feed. It is reported that laying hens fed on mash diets spend more time in the ingestion of feed than birds fed on pelleted diets and satisfy their eating behaviour, which may reduce feather pecking and feather loss (SAVORY and HETHERINGTON, 1997; BLOKHUIS and ARKES; 1984). On the other hand, WAHLSTROM et al. (2001) concluded that diet form generally had little effect on plumage condition, while there were significant differences between hybrids for plumage condition. The results were obtained from laying hens reared in an aviary system with enough floor space, which was different from the confined cage system used in the present experiment.

**Table 4. Effects of feed form and cage density on feather cover of different body area (scores)**

Einfluss der Futterform und der Besatzdichte auf die Befiederung der verschiedenen Körperregionen (Scores)

| Treatment | | Neck | Back | Wing | Breast | Cloaca | Tail |
|---|---|---|---|---|---|---|---|
| Feed Form | Mash | 2.40 | 3.21 | $2.27^{a}$ | 2.98 | 2.65 | 1.48 |
| | Pellet | 2.10 | 3.13 | $1.90^{b}$ | 2.79 | 2.98 | 1.33 |
| SEM | | 0.140 | 0.120 | 0.100 | 0.100 | 0.140 | 0.080 |
| Density | 533 | $2.75^{a}$ | $3.66^{a}$ | $2.44^{a}$ | $3.19^{a}$ | $3.19^{a}$ | 1.47 |
| | 400 | $2.09^{b}$ | $3.22^{b}$ | $2.06^{b}$ | $2.75^{b}$ | $2.81^{ab}$ | 1.40 |
| | 320 | $1.90^{b}$ | $2.63^{c}$ | $1.75^{b}$ | $2.72^{b}$ | $2.44^{b}$ | 1.34 |
| SEM | | 0.170 | 0.150 | 0.130 | 0.130 | 0.170 | 0.100 |
| Feed form | Density | | | | | | |
| Mash | 533 | 2.75 | $3.44^{a}$ | 2.56 | 3.25 | 3.06 | 1.44 |
| Mash | 400 | 2.75 | $3.88^{a}$ | 2.31 | 3.13 | 3.31 | 1.50 |
| Mash | 320 | 2.38 | $3.19^{a}$ | 2.19 | 2.81 | 2.62 | 1.50 |
| Pellet | 533 | 1.81 | $3.25^{a}$ | 1.94 | 2.69 | 3.00 | 1.30 |
| Pellet | 400 | 2.06 | $3.00^{ab}$ | 2.06 | 2.88 | 2.25 | 1.50 |
| Pellet | 320 | 1.75 | $2.25^{b}$ | 1.44 | 2.56 | 2.66 | 1.19 |
| SEM | | 0.340 | 0.200 | 0.180 | 0.170 | 0.340 | 0.140 |
| SOV | | | | | | | |
| Feed form | | 0.150 | 0.630 | 0.010 | 0.200 | 0.090 | 0.220 |
| Density | | 0.002 | < 0.001 | 0.002 | 0.010 | 0.010 | 0.690 |
| Feed form×density | | 0.520 | 0.010 | 0.510 | 0.960 | 0.960 | 0.420 |

*a-b* Means in a column with no common superscript letter are significantly different
SOV: Source of variation

## Conclusion

In summary, we did not observe any stress sign in birds reared in over-crowded cages, although increasing cage density resulted in higher feather cover loss. Using pelleted feed instead of mash resulted in similar feed consumption in low or high density cages, but feed form had no significant effects on egg production.


## Summary

A total of 384 Shaver laying hens were used to assess the effects of different feed forms and cage densities on their performance, welfare, and stress status. The experiment began at 50 weeks and lasted until 60 weeks of age, and was carried out using a complete block design with a factorial arrangement of treatments (2×3). Factors consisted of feed form (pellet and mash) and cage density (320, 400 and 533 $cm^2$ per bird corresponding to 5, 4 and three hens per cage). Hen day egg production, feed consumption and egg weighs were measured, followed by calculation of the egg mass and feed conversion ratio. Furthermore, blood samples were taken to determine plasma glucose and corticosterone as well as heterophil/lymphocyte ratio.

Hens fed on pelleted feed had significantly lower ($P<0.0001$) feed intake and numerically produced fewer eggs in comparison to their mash-fed counterparts. Increasing density from three to 5 hens per cage significantly ($P<0.05$) reduced mean egg production from 92.9 to 89.2%. Feed consumption also decreased linearly as number of hens per cage increased from three to 5. Significant interactions (feed form × cage density) were found in feed consumption, while in mash form the feed consumption significantly decreased as the number of hens per cage increased; similar reduction was not observed with pelleted feed. The present results indicated no significant effect for either feed form or cage density on heterophil/lymphocyte ratio, plasma glucose and corticosterone concentrations. In summary, no signs of stress were observed in birds reared in over-crowded cages. Using pelleted feed instead of mash resulted in similar feed consumption in low- and high-density cages, but the form of feed used did not significantly affect egg production.

**Key words**

Laying hen, nutrition, stocking density, feed form, corticosterone, feather cover

**Zusammenfassung**

**Einfluss verschiedener Futterformen und Besatzdichten auf die Legeleistung und den Stressstatus**

Das Ziel der vorliegenden Studie war die Untersuchung des Einflusses von verschiedenen Futterformen und Besatzdichten in der Käfighaltung auf die Leistung, das Tierwohl und den Stresslevel von Legehennen. Hierzu wurden 384 Shaver Legehennen verwendet. Der Versuch begann in der 50. Lebenswoche und endete in der 60. Lebenswoche. Dem Versuch lag ein vollständiges Blockdesign mit den Faktoren Futterform (pelletiert, mehlförmig) und Besatzdichte (320, 400, 533 cm² je Tier) zu Grunde. Die Besatzdichten wurden erreicht, in dem die Versuchskäfige mit 5, 4 bzw. 3 Hennen besetzt waren. Die täglich produzierte Eimasse, die Futteraufnahme und die Eigewichte wurden erfasst und die Eimasseproduktion und die Futterverwertung berechnet. Ferner wurden Blutproben zur Bestimmung des Glukose- und das Kortikosteron-Spiegels im Blutplasma sowie des Heterophilen/Lymphozyten-Verhältnisses gezogen.

Die mit pelletiertem Futter gefütterten Hennen wiesen eine signifikant geringere Futteraufnahme ($P<0,0001$) und tendenziell eine geringere Legeleistung als die mit dem mehl-förmigen Futter gefütterten Tiere auf. Die Erhöhung der Besatzdichte von 3 auf 5 Hennen je Käfig verminderte die Legeleistung signifikant von 92,9 auf 89,2% ($P<0,05$). Parallel hierzu ging auch die Futteraufnahme linear zurück. Es traten signifikante Futterform × Besatzdichte-Interaktionen auf. Während bei der Fütterung mit mehl-förmigem Futter die Futteraufnahme bei steigender Besatzdichte zurückging, wurden bei Fütterung mit Pellets keine vergleichbaren Veränderungen beobachtet. Die Behandlungsfaktoren Futterform und Besatzdichte haben sich nicht signifikant auf das Heterophilen/Lymphozyten-Verhältnis und die Plasmaspiegel von Glukose und Kortikosteron ausgewirkt. Das bedeutet, dass die Erhöhung der Besatzdichte nicht zu Stress geführt hat. Die Fütterung von pelletiertem Futter führte zu einer ähnlichen Futteraufnahme bei geringer und hoher Besatzdichte wie das pelletierte Futter und hat sich nicht auf die Legeleistung ausgewirkt.

**Stichworte**

Legehenne, Fütterung, Besatzdichte, Futterform, Corticosteron, Befiederung

**References**

ADAMS, A.W., J.V. CRAIG, 1985: Effect of crowding and cage shape on productivity and profitability of caged layers: A Survey. Poult. Sci. **64**, 238-242.

AMERAH, A.M., V., RAVINDRAN, R.G. LENTLE, D.G. THOMAS, 2007: Feed particle size: Implications on the digestion and performance of poultry. World. Poult. Sci. J. **63**, 439-455.

AOAC International, 2006: Official Methods of Analysis of AOAC International. 18th ed. AOAC Int., Gaithersburg, MD.

BLOKHUIS, H.J., J.G. ARKES, 1984: The development and causation of feather pecking in the domestic fowl. Appl. Anim. Behav. Sci. **12**, 145-157.

CAREY, J.B., F.L. KUO, K.E. ANDERSON, 1995: Effects of cage population on the productive performance of layers. Poult. Sci. **74**, 633-637.

CUTLIP, S.E., J.M. HOTT, N.P. BUCHANAN, A.L. RACK, J.D. LATSHAW, J.S. MORITZ, 2008: The effect of steam conditioning practices on pellet quality and growing broiler nutritional value. J. Appl. Poult. Res. **17**, 249-261.

DAVAMI, A., M.J. WINELAND, W.T. JONES, 1987: Effects of population-size, floor space, and feeder space upon productive performance, external appearance, and plasma-corticosterone concentration of laying hens. Poult. Sci. **66**, 251-257.

DAVIS, G.S., K.E. ANDERSON, A.S. CARROLL, 2000: The effects of long-term caging and molt of Single Comb White Leghorn hens on heterophil to lymphocyte ratios, corticosterone and thyroid hormones. Poult. Sci. **79**, 514-518.

De Jong, I.C., A.S. van Voorst, J.H. Erkens, D.A. Ehlhardt, H.J. Blokhuis., 2001: Determination of the circadian rhythm in plasma corticosterone and catecholamine concentrations in growing broiler breeders using intravenous cannulation. Physiol. Behav. **74**, 299-304.

Dozier, W.A., K.C. Behnke, C.K. Gehring, S.L. Branton, 2010: Effects of feed form on growth performance and processing yields of broilers chickens during a 42-day production period. J. Appl. Poult. Res. **19**, 219-226.

Goodling, A.C., D.G. Satterlee, G. Cerniglia, 1984: Influence of toeclipping and cage density on laying hen performance. Poult. Sci. **63**, 1722-1731.

Hamilton, R.M.G., F.G. Proudfood, 1995: Effects of ingredient particle size and feed form on the performance of leghorn hens. Can. J. Anim. Sci. **75**, 109-114.

Jalal, M.A., S.E. Scheideler, D. Marx, 2006: Effect of bird cage space and dietary metabolizable energy level on production parameters in laying hens. Poult. Sci. **85**, 306-311.

Lee, K., 1989: Laying performance and fear response of white leghorns as influenced by floor space allowance and group size. Poult. Sci. **68**, 1333-36.

Mashaly, M.M., L. Webb, S.L. Youtz, W.B. Roush, H.B. Graves, 1984: Changes in serum corticosterone concentration of laying hens as a response to increased population density. Poult. Sci. **63**, 2271-2274.

Mench, J.A., A.V. Teinhoven, J.A. Marsh, 1986: Effects of cage and floor pen management on behavior, production, and physiological stress responses of laying hens. Poult. Sci. **65**, 1058- 1069.

Moritz, J.S., K.R. Cramer, K.J. Wilson, R.S. Beyer, 2003: Feed manufacture and feeding of rations with graded levels of added moisture formulated to different energy densities. J. Appl. Poult. Res. **12**, 371-381.

National Research Council (NRC), 1994: Nutrient Requirement of poultry (9th Ed.) National Academy Press, Washington, DC.

Nir, I., Y. Twina, E. Grossman, Z. Nistan, 1994: Quantitative effects of pelleting on performance, gastrointestinal tract and behaviour of meat-type chickens. Br. Poult. Sci. **35**,589-602.

Onbasilar, E.E., F.T. Aksoy, 2005: Stress parameters and immune response of layers under different cage floor and density conditions. Livest. Prod. Sci. **95**, 255-263.

Ouart, M.D., A.W. Adams., 1982: Effects of cage design and bird space on layers. 1. Productivity, feathering and nervousness. Poult. Sci. **61**, 1606-1613.

Patterson, P.H., H.S. Siegel, 1998: Impact of cage density on pullet performance and blood parameters of stress. Poult. Sci. **77**, 32-40.

Radke, W.J., C.M. Albasi, A. Rees, S. Harvey, 1985: Stress and ACTH stimulate aldosterone secretion in the fowl (Gallus domesticus). Comp. Biochem. Physiol. A Physiol. **82**, 285-288.

Rios, R.L., A.G. Bertechini, J.C.C. Carvalho, S.F. Castro, V.A. Costa, 2009: Effect of cage density on the performance of 25-to 84 week-old laying hens. Brazilian. J. Poult. Sci. **11**, 257-262.

Roush, W.B., M.M. Mashaly, H.B. Graves, 1984: Effect of increased bird population in a fixed cage area on production and economic responses of single comb white leghorn laying hens. Poult. Sci. **63**, 45-48.

SAS Institute, 2001: SAS/STAT User Guid. Release 8.02 ed. SAS Institute Inc.,Cary, NC.

SAVORY, C.J., 1974: Growth and behaviour of chicks fed on pellets or mash. Br. Poult. Sci. **15**, 281-286.

Savory, C.J., J.D. Hetherington, 1997: Effects of plastic anti-pecking devices on food intake and behaviour of laying hens fed on pellets or mash. Br. Poult. Sci. **38**, 125-131.

Scott, T.A., F.G. Silversides, D. Tietge, M.L. Swift, 1999: Effect of feed form, formulation, and restriction on the performance of laying hens. Can. J. Anim. Sci. **79**, 171-178.

Shaver, 2009: Nutrition management guide. Boxmeer, Netherlands.

SILVERIN, B., 1998: Stress response in birds. Poult. Avian Biol. Rev. **9**, 153-168.

SOHAIL, S.S., M.M. BRYANT, S.K. RAO, D.A. ROLAND, 2001: Influence of cage space and prior dietary phosphorus level on phosphorus requirement of commercial Leghorns. Poult. Sci., **80**, 769-775.

SOHAIL, S.S., M.M. BRYANT, S.K. RAO, D.A. ROLAND, 2004: Effect of reducing cage density on performance and economics of second-cycle (force rested) commercial Leghorns. J. Appl. Poult. Res. **13**, 401-405.

SUMMERS, J.D., F.E. ROBINSON, 1995: Comparative feeding programs for poultry production. Chapter 15 in P. HUNTON, ed. Poultry production. Elsevier, New York, NY.

TACTACAN, G.B., W. GUENTER, N.J. LEWIS, J.C. RODRIGUEZ-LECOMPTE, J.D. HOUSE, 2009: Performance and welfare of laying hens in conventional and enriched cages. Poult. Sci. **88**, 698-707.

TAUSON, R., T. AMBROSEN, K. ELWINGER, 1984: Evaluation of procedures for scoring the integument of laying hens – Independent scoring of plumage condition. Acta Agric. Scand. **34**, 400-408.

VALKONEN, E., E.V ENALAINEN, L. ROSSOW, J. VALAJA, 2008: Effects of dietary energy content on the performance of laying hens in furnished and conventional cages. Poult. Sci. **87**, 844-852.

WAHLSTROM, A., K. ELWINGER, S. THOMKE, 1999: Total tract and ileal nutrient digestibility of a diet fed as mash or crumbled pellets to two laying hybrids. Anim. Feed Sci. Technol. **77**, 229-239.

WANG, X-J., Y. LI, Q.Q. SONG, Y.Y. GUO, H.C. JIAO, Z.G. SONG, H. LIN, 2013: Corticosterone regulation of ovarian follicular development is dependent on the energy status of laying hens. J. Lipid Res. **54**, 1860-1876.

WILSON, S.C., F.C. CUNNINGHAM, 1981: Effect of photoperiod on the concentrations of corticosterone and luteinizing hormone in the plasma of the domestic hen. J. Endocrinol. **91**, 135-143.

WILSON, S.C., R.C. JENNINGS, F.J. CUNNINGHAM, 1984: Developmental changes in the diurnal rhythm of secretion of corticosterone and LH in the domestic hen. J. Endocrinol. **101**, 299-304.

ZANG, J.J., X.S. PIAO, D.S. HUANG, J.J. WANG, X. MA, Y.X. MA, 2009: Effects of Feed Particle Size and Feed Form on Growth Performance, Nutrient Metabolizability and Intestinal Morphology in Broiler Chickens. Asian – Austral. J. Animal Sci. **22**, 107-112.

Correspondence: Reza Taherkhani, Department of Animal Science, Faculty of Agricultural Science, Payame Noor University, P.O. Box, 19395–3697, Tehran, Iran; E-mail: r_taherkhani@pnu.ac.ir