Effect of group size on performance and egg quality of laying hens during 20 to 36 weeks of age

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Abstract

The aim of this study was to improve knowledge on the effect of group size on productive performance and egg quality of hens raised in furnished cages equally designed. A total of 520, 15-week-old Lohmann Brown laying hens were divided into 2 groups to have a similar initial body weight (average 1392±16.3 g). The cages of S25 group (240 L x 78 W x 50 H cm, 749 cm²/hen) hosted a total of 200 hens, while those of S40 group (462 L x 65 W x 50 H, 751 cm²/hen) included 320 birds. Experimental data were recorded after an adaptation period of 5 weeks (20 to 36 weeks of age). Hens were submitted to 15 h of light/12 h of dark. The average temperature inside the building was 24.6±2.5°C over the entire experimental period with higher values at 24, 26, 28 and 30 weeks of age. The relative humidity recorded inside the building was 55% at week 20 and 60% all through the experimental period. Hens raised from S40 group had lower percentage of egg production (84.91 vs 88.30%, P<0.01) and higher feed conversion ratio (2.70 vs 2.25, P<0.0001) than S25 group. The percentage of eggs laid out of the nest was higher in S25 than S40 group (0.26 vs 0.19%, P<0.01). As expected, the week of age affected almost all the parameters (feed intake, body weight, laying percentage, egg weight, yolk, shell and albumen indexes, shell thickness, Haugh unit). However, the effect of group size was particularly evident during the hot period.

Introduction

The European Council directive 1999/74/EC (European Commission, 1999) established that, starting from 2012, laying hens had to be raised in furnished cages providing 750 cm²/hen. In addition, it established that each cage had to be large at least 2000 cm². However, no indications were given on the maximum group size.

The question of group size has aroused great interest worldwide as it can have several practice implications on laying hens production (Wall, 2011). Larger group size implies economic benefits as the production cost per hen decreases and the birds have a larger total cage area (Wall, 2011). However, as the number of laying hens per cage increases, there are possible relapses on animal welfare and behaviours indicating a non-adequate status of the animals (feather pecking, aggressive interaction, cannibalism) are more frequent (Bilecik and Keeling, 2000; Fiks-van Nierek, 2001; Hetland et al., 2004). Regarding the effect of group size on egg quality, almost all the studies indicate that as group size increases, shell quality decreases and the number of eggs laid out of the nest increases. As a consequence there is an increase of dirty, cracked or soiled eggs (Abrahamsson and Ragnar, 1997; Huneau-Salaün et al., 2011), while no effects were observed on internal egg quality (Karanan et al., 2006). The effect of group size on performance of laying hens raises in cages with equal amount of space available per bird, as it has been studied in groups with less than 10 birds (Abrahamsson and Tauson, 1997; Shimmura et al., 2010) or with different cage models (Vits et al., 2005). Recently, there is an increasing number of studies on the effect of group size on performance of laying hens raised in cage with similar design and structures but with group sizes ranging from 8 to 60 birds (Wall, 2011; Huneau-Salaün et al., 2011). However, the studies available in literature do not allow to reach a definitive opinion on the maximum number of hens in enriched cages.

The aim of our paper was to improve knowledge on the effect of group size on productive performance and egg quality of hens raised in furnished cages with the same structures but with group sizes ranging from 8 to 60 birds (Wall, 2011; Huneau-Salaün et al., 2011). However, the studies available in literature do not allow to reach a definitive opinion on the maximum number of hens in enriched cages.

Materials and methods

The trial was carried out in a specialised laying hen farm in the province of Caserta (Southern Italy). A total of 520, 15-week-old Lohmann Brown laying hens were divided into 2 groups to have a similar initial body weight (BW) (average 1392±16.3 g). The hens were housed in furnished cages with the same structures but able to host a different number of birds. The cages of S25 group hosted 25 hens (240 L x 78 W x 50 H cm, 749 cm²/hen), while those of S40 group were designed to host 40 birds (462 L x 65 W x 50 H, 751 cm²/hen). Each group consisted of 8 replicates of 25 and 40 hens respectively; thus S25 group had a total of 200 laying hens and S40 group 320. Each hen in both groups had 67 cm² for the nest, 65 cm² for the scratching area, 12 cm trough space and 15 cm of perches. The nest area was enclosed by plastic red curtains and located in the corners of the cages away from the feed line; the scratching area was represented by a plastic carpet with a rough surface and was placed under the feed line; a little amount of feed falls on the carpet, stimulating the scratching activity of the hens. The cages were placed in the same building under the same environmental conditions. The hens were submitted to 15 h of light (25 lux) intensity per day over the entire experimental period. Average temperature and humidity inside the building were recorded biweekly. The trial was carried out from 20 to 36 weeks of age, in the period from the beginning of June and the middle October 2013.
The hens were fed ad libitum the same diets before and after the beginning of laid. The diets were formulated to meet poultry requirements according to National Research Council (1994) indications; the ingredients and chemical nutritional characteristics of the diets (Table 1) were determined according to AOAC (2004) or calculated according to National Research Council (1994).

After 5 weeks of adaptation period (starting from 20 weeks of age), the hens of each group were individually weighted once per month and the average value of each cage was considered as experimental data. Mortality rate was recorded daily. Biweekly, feed intake, egg production and egg weight were recorded per cage in order to calculate the laying rate and the feed conversion ratio (FCR), expressed as the grams of feed required to produce 1 g of egg. At the same intervals, the numbers of eggs laid out of the nest were detected and a sample of 6 eggs per cage was collected to evaluate external and internal quality. Before being opened, the eggs were weighed and the egg shape index was measured following Al-saffar et al. (2013). The shell, yolk and albumen were also weighed (egg shells were washed, the inner egg shell was separated and air dried until constant weight before weighing) to measure shell (Attia et al., 1994, 1995; Burke and Attia, 1994), yolk (Attia et al., 2013b) and albumen index (Al-saffar et al., 2013). The Haugh unit score was calculated following Al-saffar (et al. 2013). Eggshell thickness measurements were conducted in three equidistant locations around the equator of the egg, using a micrometer (Mitutoyo, Kawasaki, Japan), to the nearest 0.01 mm; the mean obtained from the three values was used for statistical analysis.

Statistical analysis
The data were analysed by a two way ANOVA using the GLM procedure of SAS (2000). The model included as main effects the group size (S25 and S40) and the weeks of age (20, 22, 24, 26, 28, 30, 32, 34, 36). The interaction between the two tested effects was also considered in the following model:

\[ Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + e_{ijk} \]

where \( \mu \) is general mean, \( \alpha_i \) is the effect of group size, \( \beta_j \) is the effect of week of age; \((\alpha\beta)_{ij}\) is the interaction between group size and week of age, and \( e_{ijk} \) is random error. Differences among mortality rates were analysed by chi-square test.

### Results and discussion

Mortality rate was unaffected by both group size and week of age and it was 2.3% on average over the entire experimental period. The average temperature inside the building all through the experimental period (20 to 36 weeks of age) was 24.6±2.5°C, with higher values at 24, 26, 28 and 30 weeks when the average temperature was 25, 29, 28 and 26°C, respectively. In the other weeks, the temperature ranged from 22 to 23°C. The relative humidity recorded inside the building was 55% at week 20 and 60% over the whole experimental period.

Live weight of laying hens from 20 to 36 weeks of age was unaffected by group size (Table 2). Considering the different weeks of age, the live weight of 36-week-old hens was higher (P<0.0001) than the other weeks. There was an effect of the interaction

| Table 1. Ingredients and chemical-nutritional characteristics of the diets for laying hens. |
|---------------------------------|-----------------|-----------------|
|                                | Pre-laying diet | Early-laying diet |
|                                | (16 to 20 weeks of age) | (21 to 36 weeks of age) |
| Ingredients, %                 |                 |                 |
| Corn                           | 55.00           | 52.00           |
| Soybean meal (44%)             | 24.00           | 28.00           |
| Wheat middling                 | 12.00           | 5.00            |
| Calcium carbonate              | 5.00            | 9.00            |
| Soybean oil                    | 2.00            | 4.00            |
| Bicalcium phosphate            | 1.00            | 1.00            |
| Vitamin and mineral mix        | 0.44            | 0.45            |
| Salt                           | 0.30            | 0.30            |
| Sodium bicarbonate             | 0.10            | 0.10            |
| DL-methionine                  | 0.16            | 0.15            |
| Chemical-nutritional characteristics |         |                 |
| Crude protein °, %             | 17.5            | 18.0            |
| Ether extract °, %              | 3.8             | 5.2             |
| Ash ‰, %                       | 9.5             | 13.0            |
| Crude fibre °, %               | 4.2             | 3.2             |
| DL-methionine °, %             | 0.42            | 0.42            |
| L-lysine °, %                  | 0.8             | 0.85            |
| Ca ‰, %                        | 2.2             | 3.6             |
| P ‰, %                         | 0.6             | 0.6             |
| ME, MJ/kg                      | 11.50           | 11.60           |

Ca, calcium; P, total phosphorus; ME, metabolisable energy. °Analysed chemical composition; ‰estimated values according to National Research Council (1994).

| Table 2. Effect of group size and week of age on live weight, feed intake and feed conversion ratio of laying hens. |
|---------------------------------|-----------------|-----------------|
|                                | Live weight, g  | Feed intake, g/d | FCR |
| Group size                     |                 |                 |     |
| S25                            | 1764.0          | 113.26          | 2.25°|
| S40                            | 1751.1          | 112.58          | 2.70°|
| Week of production             |                 |                 |     |
| 20                              | 1715.2°         | 113.6°          | 3.73°|
| 22                              | -               | 113.8°          | 3.03°|
| 24                              | 1743.5°         | 119.0°          | 2.66°|
| 26                              | -               | 114.2°          | 2.25°|
| 28                              | 1737.9°         | 106.7           | 2.20°|
| 30                              | -               | 106.6           | 2.09°|
| 32                              | 1752.5°         | 110.9°          | 2.04°|
| 34                              | -               | 116.0°          | 2.06°|
| 36                              | 1884.9°         | 116.0°          | 2.07°|
| P                               | 0.1339          | 0.3408          | <0.0001|
| Group effect                    |                 |                 |     |
| Week effect                     | <0.0001         | <0.0001         |     |
| Group x week effect             | 0.0249          | 0.9979          | 0.0389|
| RMSE                            | 121.6           | 2.30            | 0.31  |

FCR, feed conversion ratio; RMSE, root mean square error. °Means within the same column having different letters are significantly different at P<0.01.
(P<0.05) between the tested effects for live weight (Figure 1): the hens from S25 group showed a progressive increase of BW along the weeks; on the contrary, hens from S40 group showed a decrease of BW at 28 weeks of age. Then, the BW increased until reach a final BW higher than S25 group. Feed intake (Table 2) as well was unaffected by group size. At 28 and 30 weeks of age, feed intake was lower (P<0.0001) than the other weeks of trial with the exception of week 32; at 26 weeks of age, feed intake was higher (P<0.0001) than weeks 28, 30 and 32. The FCR (Table 2) of S25 hens was lower (P<0.0001) than that of hens from S40 group. At the beginning of the trial (20 weeks of age) the FCR was higher (P<0.0001) than the other weeks, with the exception of week 22 when FCR was higher (P<0.0001) than 28, 30, 32, 34 and 36 weeks of age. There was an effect (P<0.05) of the interaction between the tested effects for FCR (Figure 1): in general, S40 hens had a FCR higher than S25; however, the FCR of S40 group tended to be constant (an average 2.42) from 26 to 30 weeks then decreased up to 2.05 and increased at week 34 (2.24); on the contrary, in the S25 group the FCR decreased from 2.15 to 1.89 from 26 to 30 weeks, then it increased up to 2.03 (30 weeks) and had a further decrease (1.93) at 34 weeks.

Table 3 shows data of laying rate and eggs laid out of the nest for the two groups of hens. Both percentages were the highest (P<0.01) in S25 group. As expected, along the weeks of the trial, egg production tended to increase. Egg production at 20 weeks was not different than that at 22 weeks, but it was lower (P<0.0001) than all the other weeks. The percentage of eggs laid out of the nest recorded at 20 weeks was lower (P<0.0001) than that from 22 weeks. No differences were recorded among other weeks. The Haugh unit was unaffected by week of age. No effects of the interaction were observed on the three parameters reported in Table 5.

**Effect of group size**

Even if the feed intake was not different between S25 and S40 groups and live weight of hens was unaffected by group size, the FCR was more favourable in S25 group and this result was tied to the higher laying rate obtained in S25 group. Our results are partly in accordance with findings by Guo et al. (2012). The authors, comparing two flocks of laying hens consisting of 21 and 48 birds along 4 weeks, observed no differences in feed intake. However, the same authors also found no differences for percentage of laid eggs (even if

*Table 3. Effect of group size and week on laying rate and percentage of eggs laid out of the nest.*

|           | Laying rate, % | Eggs laid out of the nest, % |
|-----------|----------------|------------------------------|
| **Group size** |                |                              |
| S25       | 88.90<sup>a</sup> | 2.61<sup>b</sup>              |
| S40       | 81.91<sup>b</sup> | 1.89<sup>b</sup>              |
| **Week of production** |                |                              |
| 20        | 64.23<sup>c</sup> | 2.33<sup>abc</sup>            |
| 22        | 77.12<sup>c</sup> | 2.50<sup>b</sup>              |
| 24        | 85.03<sup>c</sup> | 3.67<sup>ab</sup>             |
| 26        | 94.88<sup>c</sup> | 3.21<sup>b</sup>              |
| 28        | 88.28<sup>c</sup> | 2.62<sup>ab</sup>             |
| 30        | 89.71<sup>c</sup> | 2.11<sup>ab</sup>             |
| 32        | 93.25<sup>c</sup> | 2.13<sup>ab</sup>             |
| 34        | 93.54<sup>c</sup> | 1.32<sup>ab</sup>             |
| 36        | 88.35<sup>c</sup> | 0.74<sup>c</sup>              |

**P**

| Group effect | 0.0016 | 0.0034 |
|--------------|-------|--------|
| Week effect  | <0.0001 | <0.0001 |
| Group x week effect | 0.0455 | 0.0529 |
| RMSE        | 6.51 | 0.67 |

RMSE, root mean square error. *Means within the same column having different letters are significantly different at P<0.01.
the small group size showed a percentage of laid eggs two points more than the large group size) and FCR. Comparing the productive performance of laying hens raised at different group size (32 vs 48 hens per cage) from 22 to 42 weeks of age, Karaman et al. (2006) obtained a higher percentage of laid eggs in the small group size (89.4 vs 85.7%). In another study comparing the laying performance of hens raised in groups of 8, 10, 20 and 40 from 20 to 72 weeks of age, Wall (2011) found no differences in terms of egg production among groups. The discrepancies among the different results available in the literature can be ascribed to the length of the experimental period, the genetic makeup of hens involved in the trials, the design of the cages as well as the stocking density per bird.

Higher percentage of eggs laid out of the nest in the S25 group was in line with the findings by Huneau-Salaün et al. (2011), who found a significant decrease of this criterion when group size increased from 20 to 40 birds, but no further improvement was observed for groups of 60 birds. However, the percentages (average 526%) found by Huneau-Salaün et al. (2011) were higher than that found in our study. The very high percentage of nesting rate recorded in our study was partly due to the design of the cages, developed to enhance nesting behaviour. Moreover, the farmer usually moves the hens in the laying cages at 15 to 16 weeks of age to allow an easy adaptation to the nests. The effect of group size on nesting percentage can be explained according to a different space allowance at two group size. In fact, as each hen in the two tested groups had 67 cm² of nest, the overall area of the nest increased with the number of hens per cage. In general, the hens were highly motivated to lay in the nest (Cooper and Appleby, 1996), but the most of eggs were laid in the first hours after lights were turned on (Barnett et al., 2009) and this behaviour can be responsible of competitions for the nest (Shimamura et al., 2008) more detectable in the S25 group in which the allowance of nesting space was reduced. On the other hand, in a study on the effect of group size on welfare of laying hens, Guo et al. (2012) observed that birds in small group size (21 animals) significantly spent more time in nesting activity with respect to the hens from large group size (48 birds). Appleby et al. (2004) suggested that the ratio of nest space per bird needed to avoid crowding declines with group size. In general, eggs laid out of the

### Table 4. Effect of group size and week of production on some qualitative characteristics of eggs.

| Group size | Egg weight, g | Shell weight, g | Shell index, % | Yolk weight, g | Yolk index, % | Albumen weight, g | Albumen index, % |
|------------|---------------|----------------|---------------|---------------|--------------|------------------|-----------------|
| S25        | 57.29         | 6.55           | 11.46         | 12.49         | 21.60        | 38.34            | 66.94           |
| S40        | 56.20         | 6.50           | 11.35         | 12.48         | 22.23        | 37.97            | 66.49           |

| Week of production | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 |
|--------------------|----|----|----|----|----|----|----|----|----|
| Group x week effect| 10.64d | 15.27d | 8.51c | 11.84c | 15.12c | 12.78c | 14.89a | 17.00c | 13.70c |
| P                  | 0.28c | 0.65c | 0.76c | 0.78c | 0.67c | 0.79c | 0.67c | 0.79c | 0.67c |

| RMSE              | 4.72 | 0.56 | 0.67 | 1.43 | 2.39 | 3.41 | 1.86 |

RMSE, root mean square error. *p*Means within the same column having different letters are significantly different at P<0.01.

### Table 5. Effect of group size and week of production on shell thickness, shape index and Haugh unit.

| Group size | Shell thickness, mm | Shape index | Haugh unit |
|------------|---------------------|-------------|------------|
| S25        | 0.39                | 1.28        | 77.09      |
| S40        | 0.39                | 1.28        | 75.57      |

| Week of production | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 |
|--------------------|----|----|----|----|----|----|----|----|----|
| Group x week effect| 0.41a | 0.40ab | 0.40ab | 0.41a | 0.38c | 0.41a | 0.38c | 0.42c | 0.38c |

| RMSE              | 0.050 | 0.064 | 0.051 |

RMSE, root mean square error. *p*Means within the same column having different uppercase letters are significantly different at P<0.01; *p*Means within the same column having different lowercase letters are significantly different at P<0.05.
nest are more often broken or soiled and can show a higher eggshell contamination (Appleby et al., 2002; Mallet et al., 2006). Once again, this is related to the cage design and its hygienic conditions. In particular, the furnished cages adopted in the farm in which the trial was made had a safe egg system to protect the laid eggs from situations that could cause crack of the shell (Iannacone et al., 2013). However, the group size did not affect external or internal egg quality according to Karaman et al. (2006).

Effect of week

Obviously, the week of production (or age of hens) strongly affected almost all the parameters measured in the trial. The BW of hens increased at 36 weeks (immediately after the lowering of the environmental temperatures) when feed intake was increased at the same levels recorded before the end of July until August. As the FCR decreased, hens had the possibility to improve the laying rate and also to increase BW. However, the average BW falls in the range for the Lomann Brown laying hen at the correspondent week. Excluding the first two controls, the percentage of deposition tends to remain constant from the 24 weeks of age. The percentage of eggs laid out of the nest tends to decrease as the week of laid increases. This result is in accordance with other findings available in the literature (Appleby et al., 2002; Wall and Tauson, 2002; Guedson and Faure, 2004; Huneau-Salain et al., 2011) and can be explained over time, since hens are capable to better adapt to the group and to the cage design and, as a consequence, the nesting activity is generally increased along the weeks of deposition.

The external and internal quality of eggs was strongly affected by the age of hens. The increase of egg weight during a normal production cycle is associated with an age-related change in the proportion of the different components of the egg (Travel, 2011; Attia et al., 1995). In general, the percentage contribution made by the yolk increases throughout laying resulting in a decrease in the proportion of yolk to albumen over time, while the percentage of eggshell remains relatively consistent (Ternes et al., 1994; Attia et al., 2013a, 2013b). In our trial, the percentage of shell was similar over the weeks and, even if there is a clear trend in increasing yolk weight, also albumen weight tended to increase along the trial so that the percentages of both had not great differences along the period of the trial. This can be due to the period of the trial (early laying) and the time of data recording (16 weeks). However, the obtained percentages of shell, yolk and white are in line with the findings of Ternes et al. (1994) for the examined period of lay. As the egg shell percentage remains consistent along the productive cycle, it is possible to record a larger number of eggs downgraded at the end of lay due to cracked and broken shells (Travel, 2011). This can justify the trend in decreasing shell thickness recorded during the trial.

The Haugh unit was not much different along the trial up to 34 weeks of age, and then an increase was observed. Petek et al. (2009) and Zita et al. (2009) also showed an increase of Haugh unit with increasing age of hens; on the contrary, van den Brand et al. (2004) observed a decreasing of white egg weight with age of hens. The Haugh unit value, particularly at 20 and 22 weeks, was not much high if one considers the early deposition. The time of oviposition could contribute to the obtained results: in our trial, the eggs were collected early in the morning (6:00 a.m.). Túnová and Ebeid (2005) showed that eggs laid in the afternoon were by more than 2 units higher than those laid in the morning.

Interaction between group size and laying age (or week of production)

The interaction between group size and age of hens (or week of production) did not affect most of the criteria evaluated in the trial. Just live weight, FCR and laid percentage were affected. The effects were particularly evident during the hot season (beginning of July till the end of August, 24 to 30 weeks of age), when the average temperature inside the building was 27°C and the S40 group seemed to suffer more than S25 group as the FCR was strongly increased and the live weight decreased. In this regard, we have to note that even if at 32 weeks of age the average environment temperature was 23°C, the animals still suffer the high temperature of the previous weeks. These results can be explained on two bases. In general, temperatures above 25°C have an adverse effect on Lohmann Brown hens production and heat production decreases, while dissipation increases. Gou et al. (2012) observed that under hot temperatures, hens raised in small group size had a lower rectal temperature than those raised in big group size, indicating a facilitating effect of thermoregulation. The birds tend to distance themselves from one another and let their wings droop and lift from their body to maximise sensible heat loss (Etches et al., 1995). The activity in large groups under hot climate can induce a greater expenditure of energy than small group size. So, feed intake but also laying rate were not different among groups during hot weeks, the higher energy expenditure induced a decrease of BW and an increase of FCR. Guo et al. (2012) concluded that furnished cage systems with small group sizes (around 20 hens) were more favourable than large group size for the thermal balance during summer. However, after the hot climate, there is a compensatory growth in hens as BW rapidly increases and FCR is not different from S25 group. The only difference on egg production recorded between the groups was at the beginning of laid (20 weeks), when the percentage of egg production from S25 group was almost double than that of S40.

Conclusions

Our results showed that the increasing of group size from 25 to 40 laying hens in furnished cage with similar design and available space per hen penalises laying rate and FCR, but reduces the percentage of eggs laid out of the nest. However, the external and internal quality of egg remains unaffected by group size. The negative impact of group size is more evident during the hot climate period.

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