Short communication: egg size and quality of hens housed in three different group sizes

Ramiro Soler Castillo, Carlos Mínguez Balaguer, Carla Ibáñez Sanchis and Joel Bueso Ródenas

Department of Animal Production and Public Health, Faculty of Veterinary Medicine and Experimental Sciences, Catholic University of Valencia “San Vicente Martir”, Valencia, Spain

ABSTRACT
The aim of this study was to analyse the performance and the quality of the eggs produced by hens housed in three group sizes (20, 26 and 60 individuals). Twenty-two lots of high-production Hy-Line hens in the Murcia region (Spain) were included in this study. The total area of the cages was, respectively, 1.5, 2.0 and 4.5 m², maintaining the same population density (750 cm² per animal). The influence of the productive phases of the laying cycle was also included in the study: Initial (18–26 weeks of life), Middle (27–52 weeks) and Final (53–74 weeks). The variables examined were: laying percentage, egg weight, percentage of removed eggs (broken, cracked or dirty), mortality and feed intake. The group size had an influence on the egg weight and shell quality. In this sense, a group size of 20 hens achieved higher egg weight and lower number of broken and cracked eggs, so it is proposed as the recommended group size to optimize the profitability of cage hen farms.

Introduction
The poultry industry is in continuous growth, having shown a worldwide increase of 56.70% in the number of hens between 2000 and 2020, rising from 14.39 billion birds in 2000 to 33.23 billion birds in 2020 (FAOSTAT 2020). The world egg production is 76.7 million tons, with China (26,956,478 tons), the United States (6,466,263 tons) and India (5,236,935 tons) as the main producing countries (FAOSTAT 2020). The EU-27 produces, on the whole, 7.08 million tons, with Spain as the third producing country at 833,000 t, behind France (924,000 t) and Germany (851,000 t) of these eggs were produced in in-cage production systems, as revealed by the data on global distribution of laying hens by housing system. Specifically, in China, 97% of eggs were produced in this type of system, followed by 76% in USA and 100% in India. In the EU-27 the situation is not much different, as 61% of the eggs produced in France, 77% in Spain and 54% in Italy are produced in cage systems. Among the top egg producers in the EU-27, only the egg production of Germany is mainly carried out in alternative systems, with 7% of the eggs produced in cages (Schuck-Paim et al. 2021).

Consumers are increasingly concerned about the welfare of laying hens (Van Asselt et al. 2015). In this sense, in Europe, as of January 2012, regulations prohibited the use of old non-enriched cages (Directive 1997/74EC). The aim of the new enriched cages is to improve the well-being of laying hens by providing opportunities for them to perform their natural behaviours (Elson et al. 2012). Enriched cages consider both the configuration and the general sizes of the cage. According to the European Directive, laying hens must have at least 750 cm². This involves not exceeding 13.3 laying hens per square metre. Moreover, enriched hens must include a nest, perch and a litter substrate. High housing densities in non-enriched cages (550 cm²/bird) have corresponded with alterations in well-being, mainly with increased pecking (Gilani et al. 2013). It may also cause greater stress, hierarchical struggles and lower live weight due to low use of the feed (Cepero and Hernández 2015; Ikenna et al. 2016). Although the European Directive is very clear in terms of density and the additional elements mentioned, it does not stipulate the size of the group or the cage.

The group size and housing system have important consequences on the investment cost per hen and on the welfare of the animals. Both factors significantly affect the quality characteristics of the egg, including undesirable changes in the external characteristics of the egg (Hidalgo et al. 2008). These changes can affect marketing, as the consumer acceptance of eggs is strongly influenced by visual characters (Wardy et al. 2015). The external quality of the egg is determined by the size of the egg, the shell quality (egg strength and thickness), its integrity (cracks), and stains or traces of dirt (Holt et al. 2011). It has been observed that the percentage of broken eggs depends mainly on the genetics of the hen, the housing, the environmental conditions and the handling of the eggs (Wall and Tauson 2002; Wall 2011; Ketta and Tůmová 2016). Moreover, the size of the egg is valued by the consumer, as the classification by egg weight directly influences its price. In Spain, the XL category egg (≥73 g) is 55.0% more expensive than the L category egg (≥63 and <73 g), i.e. € 1.24 per dozen compared to € 0.80 per dozen.
Studies have been carried out comparing egg quality under different commercial housing systems: cage-free aviary systems vs enriched cages (Holt et al. 2011; Karcher et al. 2015). However, there is little literature on which is the most suitable group size using the same population density related to egg size and quality in commercial farm conditions. The aim of this study was to evaluate the performance, weight and external quality of the shell of the eggs produced by hens housed in three group sizes (20, 26 and 60 hens) with the same population density (750 cm² per animal), as well as the mortality rate and feed intake.

Materials and methods

Animals and accommodation

To conduct this study, 22 lots of Hy-Line Brown laying hens ($n = 2,849,869$) housed in 22 different farms with batteries of enriched cages that met the requirements of Directive 99/74 / EC were used. The farms were located in the municipalities of Cobatillas (15 farms; Longitude: O1° 4’34.958°’ / Latitude: N38° 3’18.098°’) and Bullas (7 farms; Longitude: O1° 40’20.17°’ / Latitude: N38° 2’48.01’’) in the Autonomous Community of the Region of Murcia (Spain). The data collection period ranged from June 2018 to November 2020. Table 1 shows the characteristics of the cages, the distribution of the farms according to hen group size, the number of farms (replicates) and the average number of hens housed per farm.

All the farms belonged to the same poultry company, following the same handling and environmental conditions. Rearing of the hens was carried out until 16 weeks of age in cage housing system in specific rearing sheds. Then, the young hens were transferred to the laying sheds, staying in the definitive cages where they remained until 74 weeks of age. Laying began at 18 weeks of age due to a light-stimulus period, increasing the photoperiod from 10 h to 16 h progressively during weeks 16–30 of the hens’ life. The laying period was divided into three production phases: Initial (18–26 weeks), Middle (27–52 weeks) and Final (53–74 weeks). Feeding was carried out with a diet based on the following ingredients listed in order of concentration: corn, soybeans, wheat, calcium carbonate, sunflower flour, soybean oil, salt and dicalcium phosphate and methionine (2795 kcal / kg of ME, 16.90% of CP, 4.09% of Ca and 0.23% of available P). The feed was manufactured by the company itself and was administered automatically twice a day. The animals had free availability of water through nipple drinkers, with two nipple drinkers per cage for 20 and 26 hens and three nipple drinkers in the cages for 60 hens. Photoperiod regulation was carried out following the indications of the hen supplier company (Hy Line Management Guide 2021), with a light period of 16 h (06:00–21:00) and a dark period of eight hours (22:00–05:00). The environmental conditions and temperature were regulated by forced ventilation and the use of cooling panels to adjust to the needs of the birds (Hy-Line Management Guide 2021). Eggs were automatically collected every day and manure was automatically removed three times a week.

Hens were housed in batteries in three types of enriched cages, with a capacity of 20 (C20), 26 (C26) and 60 hens (C60). All cages were adaptations of the MEC model (Zucami Poultry Equipment, Beriain, Spain):

- C20: 2440 mm wide, 630 mm deep, 455 mm high at the bottom of the cage (1.54 m²), including 1 nest.
- C26: 3174 mm wide, 630 mm deep, 455 mm high at the bottom of the cage (2 m²), including 2 nests.
- C60: 3600 mm wide, 1260 mm deep and 455 mm high at the bottom (4.54 m²), including 4 nests.

Each hen had more than 750 cm² of surface in the three types of cage. The cages met the requirements of the European regulations on enriched cages: a minimum area of 750 cm² / bird with a total area of the cage of at least 2000 cm², a nest with a comfortable floor where the birds can lay their eggs, an area where chickens can peck and scratch, and perches with a minimum length of 15 cm / bird. In addition, the cage provided a feeder of at least 12 cm of available width per hen, a minimum of two nipple drinkers per cage, and a device so that the hens could scratch their nails (Directive 1997/74/EC, Table 1).

Variables studied

Absolute values of the following variables were recorded during the daily egg collection: total number of eggs (TE), number of dirty eggs (DE), number of broken eggs (BE), number of cracked eggs (CRA), feed intake (FI, expressed individually in g / day / hen) and mortality (MT).

Egg weight was determined by a MOBA OMNIA XI 170 sorting machine (Barneveld, Netherlands), following Commission Regulation (EC) number 589/2008; XL: very large, weight ≥73 g; L: large, weight ≥63 and <73 g; M: medium, weight ≥53 and <63 g; S: small, weight <53 g. According to this procedure, the following variables were calculated: percentage of eggs classified S (%S), percentage of eggs classified M (% M), percentage of eggs classified L (%L) and percentage of eggs classified XL (%XL). External defects affecting the shell were categorized according to Coutts and Wilson (2010). These parameters were visually detected by specialized operators using the MOBA Crack Detection equipment (Barneveld, The Netherlands).

The following formulas were used to perform the calculations of the studied variables:

Laying percentage = (TE / No. hens per replicate) * 100
Mortality = (MT / No. hens per replicate) * 100

Table 1. Housing conditions for hens in the different group size.

|          | C20  | C26  | C60  |
|----------|------|------|------|
| Area/bird| 768.60 cm² | 769.08 cm² | 756.00 cm² |
| Total area| 1.54 m² | 2.00 m² | 4.54 m² |
| Perches (cm) per bird | 15 cm | 15 cm | 15 cm |
| Feeder (cm) per bird | 12 cm | 12 cm | 12 cm |
| Drinkers per cage | 2 | 2 | 4 |
| Nests per cage | 1 | 2 | 4 |
| Number of replicates (farms) | 7 | 6 | 9 |
| Average hens housed per farm | 150,000 | 104,000 | 110,000 |

Note: Models of cages according to the group size of hens: C20 = 20 hens; C26 = 26 hens; C60 = 60 hens.
Broken eggs: percentage of eggs that present fairly large breaks in the shell that generally affect the internal membranes of the egg: (BE / TE per replicate) * 100

Dirty eggs: percentage of eggs in which all or part of their shell appears stained by faeces, blood or other substances: (DE / TE per replicate) * 100. Both broken eggs and dirty eggs were visually detected by specialized operators and removed from the chain.

Cracked eggs: percentage of eggs that present small shell fractures without affecting the internal membranes: (CRA / TE per replicate) * 100. They are detected with the MOBA CRACK DETECTION equipment coupled to the MOBA sorting machine model OMNIA XF 170 (Barneveld, The Netherlands).

Statistical analysis

The estimates of the differences between the cages were obtained by generalized least squares, using the R Project programme (R Core Team 2013). The model used in this analysis was: Ykl = Jk + Jk*El + εkl, where Ykl is the character register; Jk is the effect of the group size (three levels: C20, C25, C60); Jk*El is the interaction between group size and the productive phase of the laying cycle and εkl is the residual effect. A significance level was set at α = 0.05.

Results

The interaction of the productive phase of the laying period and the group size had no effect on any variable studied. The results of the variables studied according to the cited interaction are presented in Table 2.

The statistical analysis performed according to group size revealed that there were no significant differences in the laying percentage, mortality, L% and S%. XL% varied according to group size, showing higher values in C20 (11.09%) than in C60 (8.65%) and S26 (7.5%). In the case of M%, higher values were obtained in C26 (31.7%) than in C60 and C20. For the variables corresponding to shell quality, the % of broken eggs was lower in C20 (0.38%) compared to the other two groups, where no significant differences were appreciated (0.54 and 0.52, for C26 and C60 respectively). In the percentage of cracked eggs, the groups with the lowest incidence were C20 and C26 (4.26 and 4.14%, respectively), and both had significant differences compared to the C60 group (5.22%). Finally, feed intake was significantly higher in the C20 group (119.14 g). Between groups C26 and C60, no significant differences were observed in this variable (110.23 and 111.24 g, respectively).

Discussion

The influence of the production phase was observed in all the different variables studied. The results obtained are in line with the values set out in the Hy-Line Management Guide (2021), and with the data reported by several authors, such as Nicodemus et al. (2012), Vlčková et al. (2018) and Castelló et al. (2010).

In our experiment, it was hypothesized that larger groups could have higher mortality and lower laying percentage due to the higher probability of aggressions between animals. However, the size of the group had no effect on the laying percentage values or on mortality. It is difficult to conclude that the absence of differences in the frequency of aggressions between experimental groups is related to similar animal welfare. If hens of this study had not been debeaked, this result could have been different, as has been noted in other studies (Schuck-Paim et al. 2021). Our results were similar to those obtained by other authors (Wall and Tauson 2002; Hunneau-Salain et al. 2011; Nicodemus et al. 2012; Widowski et al. 2017). On the contrary, Vits et al. (2005) found differences in laying performance when different sizes were compared. In this latter study, three different cages were used and the hens were in groups of 10, 20, 40 and 60 animals, with no relationship established between group size and the hens’ performance, since in the comparisons made, sometimes the small group had higher production and sometimes it was the large group. Moreover, the maximum differences in this variable were only up to 1.1%.

In the present study, the C20 group reported the highest feed intake values, differences that could be considered of little practical relevance (8 g). Vits et al. (2005) also obtained higher feed intake in group sizes of 10 hens compared to sizes of 40–60 hens. This result can be explained by two reasons: first, as the larger the group of animals, the greater the competitiveness for the feed, so in small groups hens have more availability of the feeders; second, as there is less surface area available, hens are committed to focus their behaviour on the feeders instead the feathers of other birds. Our results did not agree with those of Hunneau-Salain et al. (2011) who found no differences when comparing groups of 20, 40 and 60 hens. Other studies (Hetland et al. 2003) considered that the activity of birds in larger groups causes greater feed intake, together with poorer utilization of feed, mainly due to increased pecking.

The larger exercise, marked by the higher percentage of XL weight eggs, in the C20 hens agrees with the higher intake of feed found in this group. As the availability of nutrients and energy is higher, hens are more capable of laying eggs with more weight. Moreover, hens housed in a smaller cage space do not consume as much energy in movements or behaviour patterns, allocating that energy to a better performance (Meng et al. 2015). Mench et al. (1986) also described that egg weight is higher in smaller groups of birds. However, other studies (Vits et al. 2005; Nicodemus et al. 2012), reported that, in cages with larger group sizes, hens produced heavier eggs than in those with group sizes with fewer hens. In any case, in the experiments conducted by Vits et al. (2005), the differences between experimental conditions of the different groups also included a different cage model, with no differences between the groups when the cage model used was the same.

The better results of the smaller groups of hens in terms of egg quality (best results regarding broken and cracked eggs) are consistent with studies (Abrahamsson and Tauson 1997; Wall 2011) in which the smallest cages offered better egg quality values (fewer dirty, broken and cracked eggs). Egg quality results obtained in larger cages might be due to a lower use of the nests by the hens, due to hierarchies and competition between them, which would increase the number of...
eggs laid outside the nests. This leads to a greater risk of being damaged (Meng et al. 2015). Several authors consider that the increased stress in hens housed in large groups is significant, which would also influence shell alterations (Roberts 2004; Rodenburg and Koene 2007). Another important aspect to consider is to have an adequate egg collection system to prevent them from accumulating in the nests, in order to reduce the risk of affecting the external quality and integrity of the eggs. The work of Vits et al. (2005) found that the frequency of broken eggs was obtained in groups of 60 birds, due to the accumulation of eggs before collection. Later studies reported a greater number of dirty eggs in smaller groups, due to the nest design and the presence of the sand bath in the cages (Li et al. 2017), although these differences were not observed in our study.

**Conclusions**

The size of the group of hens had no effect on their laying percentage values or on their mortality. However, an influence on the egg weight and shell quality was observed. Considering the global results of this study, it can be proposed that the best performance was achieved with the 20 hens group size, which obtained 28% more XL weight eggs (with a 30% extra value in the market) and 29% fewer broken eggs, only involving an increase 7% in feed costs, so it is proposed as the recommended group size to optimize the profitability of cage hen farms.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

**References**

Abrahamsson P, Tauson R. 1997. Effects of group size on performance, health and birds’ use of facilities in furnished cages for laying hens. Acta Agric Scand A Anim Sci. 14(4):254–260. doi:10.1080/09064709709362394.

Castelló JA, Barragán JI, Borroeta AC, Calvet S. 2010. Producción de huevos. Real Escuela de Avicultura. Barcelona. 575 pp.

Cepero R, Hernández A. 2015. Effects of housing systems for laying hens on egg quality and safety. 16th European Symposium on the Quality of Eggs and Egg Products; Nantes, France.

Couts J, Wilson G. 2010. Optimum egg quality, 2nd ed. Sheffield: SM Publishing.

Elson HD, de Jong IC, Kjaer JB, Sossidou EN, Tauson R. 2012. Poultry welfare and management: WPSCA working group nine. Worlds Poult Sci. 68(4):768–775. doi:10.1016/j.wps.2012.01.004.

FAOSTAT. 2020. Food and Agriculture Organization of the United Nations, Statistical Division. Selected Indicator. [accessed 2021 Jun 22]. https://www.fao.org/faostat/es/#data/QCL.

Gilani AM, Knowles TC, Nicol CJ. 2013. The effect of rearing environment on feather pecking in young and adult laying hens. Appl Anim Behav Sci. 148:54–63. doi:10.1016/j.applanim.2013.07.014.

Hetland H, Sivhus B, Lervik S, Moe R. 2003. Effect of feed structure on performance and welfare in laying hens housed in conventional and furnished cages. Acta Agric Scand A Anim Sci. 53(2):92–100. doi:10.1080/090647031002387.

Hidalgo A, Rossi M, Clerici F, Ratti S. 2008. A market study on the quality characteristics of eggs from different housing systems. Food Chem. 106(3):1031–1038. doi:10.1016/j.foodchem.2007.07.019.

Holt PS, Davies RH, Dewulf J, Waltan D, William KR. 2011. The impact of different housing systems on egg safety and quality. Poult Sci. 90(1):251–262. doi:10.3382/ps.2010-00794.

Huneau-Salaün A, Guinebretière M, Taktak A, Huonnic D, Michel V. 2011. Litter provision and laying location, zootechnical performance and egg quality. Animal. 5(6):917. doi:10.1017/S1751731110002582.

Hy-Line Management Guide. 2021. [Internet], [accessed 2021 July 23]. https://www.hyline.com/fileimages/Hy-Line-Products/Hy-Line-Product-PDFs/Brown/BRN%20COM%20ENG.pdf.

Ikenna L, Pike P, Cooper J. 2016. Ranging behaviour of commercial free-range laying hens. Animals. 6(5):28. doi:10.3390/ani6050028.

Karcher DM, Jones DR, Abdo Z, Zhao Y, Shepherd TA, Xin H. 2015. Impact of commercial housing systems and nutrient and energy intake on laying hen performance and egg quality parameters. Poult Sci. 94(3):485–501. doi:10.3382/ps.2015-00794.

Ketta M, Tömövá E. 2016. Eggshell structure, measurements, and quality-affecting factors in laying hens: a review. Czech J Anim Sci. 61(7):299–309. doi:10.17221/46/2015-CJAS.

Li X, Chen D, Meng F, Su Y, Wang L, Zhang R, Li J, Bao J. 2017. Exterior egg quality as affected by enrichment resources layout in furnished laying-hen cages. Asian-Australas J Anim Sci. 30(10):1495–1499. doi:10.5713/ajas.16.0794.

Mench JA, van Tienhoven AV, Marsh JA, McCormick CC, Cunningham DL, Baker RC. 1986. Effects of cage and floor pen management on behavior, production, and physiological stress responses of laying hens. Poult Sci. 65(6):1058–1069. doi:10.3382/ps.0651058.

Meng F, Chen D, Li X, Li J, Bao J. 2015. Effects of large or small furnished cages on performance, welfare and egg quality of laying hens. Anim Prod Sci. 55:793–798. doi:10.1071/AN13552.

Nicodemus N, Callejo A, Blanco D, Buxadé C. 2012. Efecto de la densidad de gallinas por jaula y de la estirpe sobre la producción y la calidad del
huevo. Memoria en: 5ª reunión AECACEM, Querétaro, Mexico. [accessed 2021 Jun 25]. http://oa.upm.es/21207/1/INVE_MEN_2012_128008.pdf.

R Core Team. 2013. R: a language and environment for statistical computing. Vienna: R Foundation for Statistical Computing. http://www.R-project.org/.

Roberts J. 2004. Factors affecting egg internal quality and eggshell quality in laying hens. J Poult Sci. 41(3):161–177. doi:10.2141/jpsa.41.161.

Rodenburg T, Koene P. 2007. The impact of group size on damaging, behaviours, aggression, fear end stress in farm animals. Appl Anim Behav Sci. 103:205–214. doi:10.1016/j.applanim.2006.05.024.

Schuck-Paim C, Negro-Calduch E, Alonso WJ. 2021. Laying hen mortality in different indoor housing systems: a meta-analysis of data from commercial farms in 16 countries. Sci Rep. 11:3052. doi:10.1038/s41598-021-81868-3.

Van Asselt ED, van Bussel LGJ, van Horne P, van der Voet H, van der Heijden GW, van der Fels-Klerx HJ. 2015. Assessing the sustainability of egg production systems in the Netherlands. Poult Sci. 94(8):1742–1750. doi:10.3382/ps/pev165.

Vits A, Weitzenbürger D, Hamann H, Distl O. 2005. Production, Egg quality, bone strength, claw length, and keel bone deformities of laying hens housed in furnished cages with different group sizes. Poult Sci. 84(10):1511–1519. doi:10.1093/ps/84.10.1511.

Vlčková J, Tůmová E, Ketta M, Englimaierová M, Chodová D. 2018. Effect of housing system and age of laying hens on eggshell quality, microbial contamination, and penetration of microorganisms into eggs. Czech J Anim Sci. 63(2):51–60. doi:10.17221/77/2017-CJAS.

Wall H. 2011. Production performance and proportion of nest eggs in layer hybrids housed in different designs of furnished cages. Poult Sci. 90(10):2153–2161. doi:10.3382/ps.2011-01495.

Wall H, Tauson R. 2002. Egg quality in furnished cages for laying hens—effects of crack reduction measures and hybrid. Poult Sci. 81(3):340–348. doi:10.1093/ps/81.3.340.

Wardy W, Sae-Eaw A, Sriwattana S, No HK, Prinyawiwatkul W. 2015. Assessing consumer emotional responses in the presence and absence of critical quality attributes: a case study with chicken eggs. J Food Sci. 80(7):S1574–S1582. doi:10.1111/1750-3841.12930.

Widowski T, Caston LJ, Hunnford ME, Cooley L, Torrey S. 2017. Effect of space allowance and cage size on laying hens housed in furnished cages, Part I: performance and well-being. Poult Sci. 96(11):3805–3815. doi:10.3382/ps/pev197.