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Resilience to heat stress in a commercial line and four autochthonous Spanish breeds of laying hens

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Introduction

Global warming provokes extreme climate events such as storms, floods, heat and cold waves, with potentially negative impacts on feed production, animal production and animal welfare (Godde *et al*., 2021). Laying hens are highly sensitive to ambient temperature due to their limited capacity for heat dissipation. Elevated environmental temperatures result in reduced feed intake and metabolic efficiency, and altered endocrine function, compromising egg production, egg weight, and shell quality (Wasti *et al*., 2020). As climate change continues to intensify, understanding the mechanisms by which elevated temperatures impair egg production in laying hens is essential for developing adaptive management strategies and ensuring the sustainability of poultry production systems worldwide.

Animal resilience can be defined as the capacity of an animal to cope with episodic or sporadic perturbations in their environment (Colditz and Hine, 2016). The animal responds with behavioural and physiological responses to the stressful stimuli, triggering the metabolism for maintenance or reinstatement of homeostasis (Basile *et al*., 2020). Autochthonous breeds of laying hens are believed to be particularly valuable in a climate change context because of adaptation to the local environment.

This study aimed at investigating persistency in egg production during heat stress as a measure of resilience in a commercial line and four autochthonous Spanish breeds of laying hens. It was hypothesized that hens from local poultry breeds will show a better capacity to maintain production under heat stress than those from high producing commercial lines.

Materials & Methods

All animals of this study were maintained at the experimental poultry research facility "El Encín" (INIA-CSIC, Alcalá de Henares, Spain). Twelve autochthonous Spanish breeds are maintained at this facility in a Genetic Resources Conservation and Investigation Program since 1975 (Campo and Orozco, 1982; INIA-CSIC, 2026). Differences in daily egg production was evaluated between one commercial line (Hy-Line Brown - HL) and four local Spanish breeds of laying hens (Castellana Negra - CN, Andaluza Franciscana - AF, Prat Leonada - PL, Andaluza Azul - AA) in five periods (P1-P5) of 50 days each for seven months between February and September 2025. Sixty animals per breed were housed in four pens per breed (15 animals per pen). Daily egg production per pen was recorded 41, 19, 24, 39, and 33 days in period 1 to 5, respectively. Daily maximum, minimum, and average 24h temperature, measured at the Adolfo Suárez Madrid-Barajas Airport weather station, is given in Figure 1. Average 24h temperature in P1-P5 was 8, 11, 22, 28, and 22 °C, respectively. Animals were 11 months of age at the start of the experiment. Animals were housed indoors in four pens per breed (15 hens per pen) in one building that was not climate controlled, therefore, the animals were subjected to natural climate fluctuations. HL are bred in climate controlled housing but sibs of selection candidates are exposed to commercial conditions in field test across multiple

locations with varying challenges including heat stress and their information is used for selection.

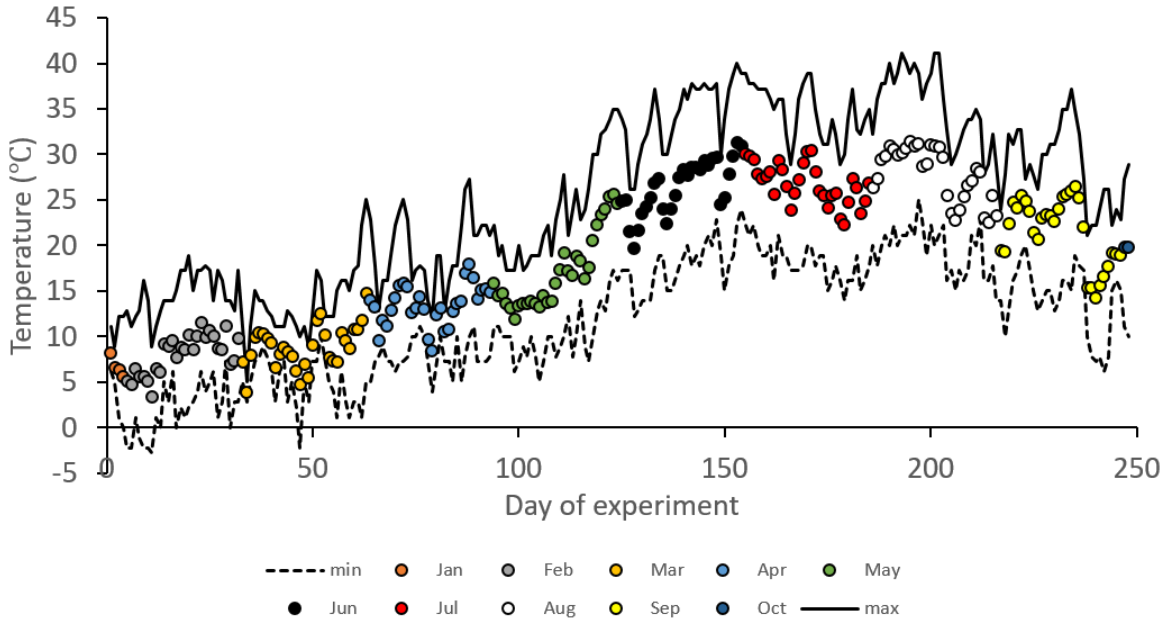

Figure 1. Minimum (min), maximum (max) and average temperatures (°C) between January and October 2025.

All procedures followed the Spanish policy for the protection of animals used in research and other scientific purposes RD53/2013. The project was approved by the INIA-CSIC Ethics Committee on Animal Experimentation, reference number PROEX 313.32/23. The SAS program (SAS Institute, Cary, USA) was used for the statistical analyses. A mixed model with Homogeneous Autoregressive variance-covariance structure for repeated measures was fitted to describe average daily egg production per period:

$$Y_{ijk} = \mu + Breed_i + Period_j + (Breed \times Period)_{ij} + e_{ijk}, \quad (1)$$

where Y_{ijk} = the phenotype measured on animal k, μ = the overall population mean, $Breed_i$ = effect of poultry breed i (HL, CN, AF, PL, AA), $Period_j$ = effect of Period j (P1 – P5), $(Breed \times Period)_{ij}$ = interaction effect between breed i and period j, $e_{ijk} \sim NID(0, \delta^2_e)$. Period was identified as the repeated effect in the model for each individual. The model also included the random effect of the pen. For temperatures between 15 and 32 ˚C, corresponding to period P3 and P4, for each pen, a linear regression was fitted for data on individual egg production against temperature.

Results

Average daily egg production was similar for all breeds in P1 (Figure 2). In the Spanish breeds, average daily egg production was similar between P1 and P2; thereafter production declined between P2 and P5 ($P<0.01$). On the contrary, in the commercial HL, egg production increased between P1 and P2, and thereafter was similar between P2 and P5. During P3 and P4, corresponding to daily temperatures between 15 and 32 ˚C, egg production significantly reduced with 0.004 ($P = 0.05$), 0.007 ($P < 0.01$), 0.010 (< 0.0001), and 0.011 ($P < 0.0001$) egg/˚C in PL, AF, CN, and AA, respectively. No significant relationship was found between temperature and egg production in HL.

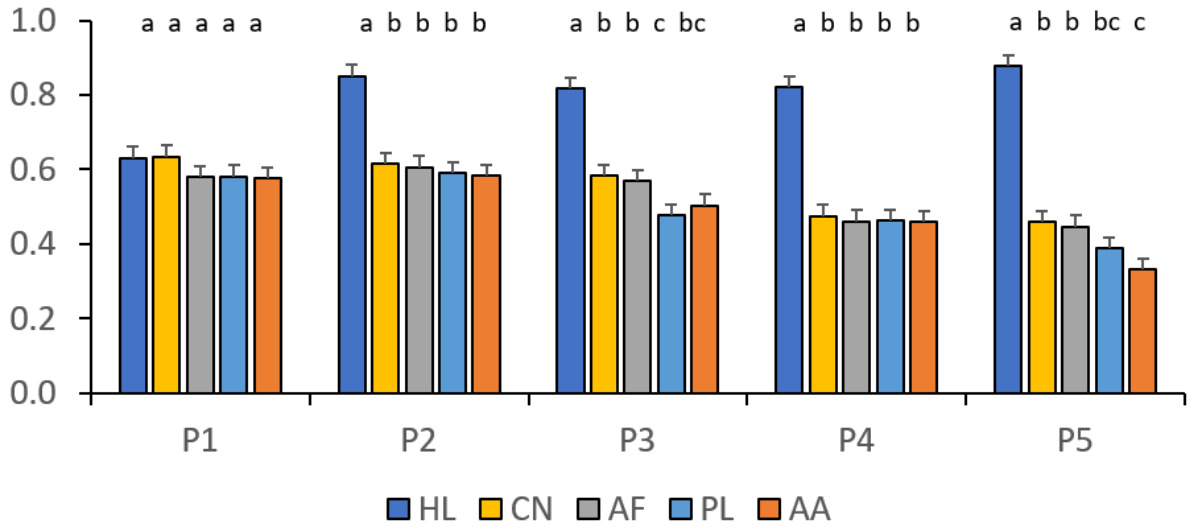

Figure 2. Average egg production per breed (Hy-Line Brown - HL, Castellana Negra - CN, Andaluza Franciscana - AF, Prat Leonada - PL, Andaluza Azul - AA) in period 1-5 (P1-P5). Differences within period: means that do not have a common superscript differ ($P < 0.05$).

Discussion

It is often observed that high production in livestock animals results in increased environmental sensitivity (Rauw and Gomez-Raya, 2015), therefore, commercial high-producing animals are thought to be more sensitive to suboptimal environmental conditions than autochthonous breeds adapted to their local environments. However, our results show that hens from a commercial line produced more eggs with a higher persistency in egg production under heat stress than hens of four local Spanish breeds.

Nonetheless, crossbreeding of commercial with local poultry breeds may combine the benefits of high production with further adaptation to the local environment. Hoffman (2013) showed a wide range of resilience and plasticity across livestock breeds that are valuable to climate change adaptation. Hence, there is a need to further explore the potential of local breeds with less optimal production efficiency, however, most local breeds are not well characterized for adaptation traits (Hoffman, 2013). Our results show that, of the four autochthonous breeds, AF and CN have highest egg production, while PL and AF show high resilience to heat stress. High resilience in these breeds is supported by a previous study that showed that PL and AF have a lower stress response as quantified by the heterophil to lymphocyte ratio (H/L) during natural heat stress (Gil *et al*., 2023). Conservation of genetic resources has mainly focused on phenotypic characteristics, especially morphological traits. Whole Genome Sequencing (WGS) is a powerful tool aided to conservation programs of autochthonous chicken breeds. Preliminary result show that, in spite of breeding in a closed population, PL, AF, AA, and CN show chromosomal regions that are highly differentiated between the breeds, that may offer possibilities of improvement in both adaptation and production traits. Estimation of Runs of Homozygosity can aid in making breeding decisions for conservation. Sustainability of production systems in the context of climate change requires novel breed choice and genetic selection objectives for improved heat tolerance. Of the Spanish breeds, Andaluza Franciscana is a breed of particular interest because it combines high production with high resilience to heat stress.

Conclusions

It was hypothesized that commercial high-producing animals are less resilient to heat stress than autochthonous breeds adapted to their local environments. However, our results show that hens from a commercial line produced more eggs and showed a higher persistency in egg production under heat stress than hens of four local Spanish breeds. There is a need to further explore adaptation traits in autochthonous breeds with less optimal production efficiency. The Spanish Andaluza Franciscana breed is of interest because it combines high production with high resilience to heat stress.

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