SHORT COMMUNICATION

Genetic parameter estimation for feather damage in laying hens

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ABSTRACT
Feather damage (FD) in laying hens is an economic and welfare issue globally. FD can be influenced by environmental, genetic, and nutrient factors. It is worth understanding the inheritance patterns and influencers of FD in layers for further improvement of feather quality. In the present study, tail and neck feather coverage of White Leghorn (WL) and Rhode Island Red (RIR) hens were recorded to evaluate the genetic parameters of FD and their impact on the production performance were estimated. The heritability of the tail and neck FD for White Leghorn is 0.22 and 0.09, respectively, and the genetic correlation between them is 0.40. The heritability of neck FD of Rhode Island Red is 0.27. FD had a limited influence on egg production. Collectively, FD is influenced by many factors, including genetic factors, appropriate breeding strategies, and improved feeding environments, which are necessary to reduce FD in laying hens.

1. Introduction

Eggs are an important protein source for humans, and laying hens are the main source of these eggs. This demand has led to a huge laying hen industry. The welfare of agricultural animals has become increasingly important. Feather damage (FD) is a phenomenon in which feathers are broken or shed from the skin in laying hens. FD is a serious threat to hens, but it is not often discussed. FD reduces the capacity for thermal insulation from feathers (Richards 1977), and this unexpected heat loss may cause unnecessary feed wastage, and cold stress. Furthermore, FD may increase the incidence of skin infections.

The reasons for FD are multifactorial. FD is associated with the environmental and nutrition factors. Nicol et al. (2006) found that group size and population density had a negative impact on FD. Su et al. (2006) found that FD occurs more often during the late laying period. van Krimpen et al. (2009) reported that hens fed standard non-starch polysaccharide diets had more FD than hens fed high non-starch polysaccharide diets. FD is found to be genetic. FD occurs more frequently in White Leghorns than in other breeds (Jensen et al. 2005; Uitdehaag et al. 2008; Campe et al. 2018).

In order to analyse FD quantitatively, FD is treated as a qualitative trait instead of a quantitative trait in many studies. Most research on quantitative FD uses a score system, wherein separate body parts (e.g. neck, tail, and back) are scored. FD is assessed by the sum score or the worst score of any of the body parts (Bilcik and Keeling 1999; Bestman and Wagenaar 2003; Yamak 2012). However, some studies have suggested that the whole-body score is inappropriate, as FD in different body parts is due to different reasons (Campe et al. 2018). For example, FD on the back and tail is mainly caused by feather pecking (Bilcik and Keeling 1999), and FD on the neck is mainly caused by the abrasion of equipment (Blokhuis et al. 2007).

The current research focuses on FD caused by pecking feathers. However, FD may be different in cage, few researches have noticed at present. In the present study, to investigate the genetic rules and influence of FD, we estimated the genetic parameters of FD in two-layer lines and their potential association with other production parameters.

2. Material and methods

2.1. Housing conditions and feeding

In order to study the effect of genetic factors on feather damage, two chicken populations with pedigree, White Leghorns (WL) and Rhode Island Reds (RIR), were used in our study. The WL population included 2609 chickens and 95 families, and the RIR population included 3049 chickens and 81 families. The experimental chickens were provided by a breeding company in China, and all birds were kept in three-tier, individual cages. According to the protocol, the bird was checked for SP antibody and ALV p27 antigen titres. We confirmed that all chickens were free of the two pathogens.

2.2. Data collection

We observed that FD occurred mostly in the neck and tail in our experimental hens (Figure 1). FD was measured using a 3-point
scale at 45 weeks of age (Table 1), in two body regions (neck, tail) for WL and one region (neck) was selected in RIR to assess the FD. We did not evaluate the RIR tail for FD because there were a limited number of RIR hens showing FD in the tail. The FD was evaluated by one observer to minimize systemic error (Tahamtani et al. 2016). The cage height (1, 2, 3) was recorded as a fixed effect.

Data of eggshell strength, shell thickness, egg shape index, egg weight at 45 weeks of age, and egg number at 54 weeks were collected to test the effect of FD on egg performance. For eggshell strength, shell thickness, and egg shape index, we randomly selected two eggs for each birds at 45 weeks to measure egg parameters, and the results were averaged together. In egg number, all eggs, except malformed eggs, were counted.

2.3. Statistical analysis

For FD variance component estimation in WL hens, a two-trait linear animal model was used (Equation (1)).

\[
\begin{bmatrix}
  y_{1i} \\
  y_{2i}
\end{bmatrix} =
\begin{bmatrix}
  X_1 & 0 & \mathbf{b}_1 \\
  0 & X_1 & \mathbf{b}_2
\end{bmatrix}
\begin{bmatrix}
  \mathbf{a}_1 \\
  \mathbf{a}_2
\end{bmatrix} +
\begin{bmatrix}
  Z_1 & 0 & \mathbf{a}_1 \\
  0 & Z_2 & \mathbf{a}_2
\end{bmatrix}
\begin{bmatrix}
  \mathbf{e}_1 \\
  \mathbf{e}_2
\end{bmatrix} +
\begin{bmatrix}
  \mathbf{e}_i
\end{bmatrix}_{1i} +
\begin{bmatrix}
  \mathbf{e}_i
\end{bmatrix}_{2i}
\]

(1)

For RIR hens, we used a general model to estimate the FD variance component (Equation (2)).

\[
y_{3ij} = X_2b_3 + Z_3a_3 + e_{3ijk}
\]

(2)

where $y_{1i}$ is the vector of neck FD in WL, $y_{2i}$ is the vector of tail FD in WL, $y_{3ij}$ is the vector of neck FD in RIR, $\mathbf{b}$ is the vector of fixed effects, $\mathbf{a}$ is the vector of breeding values, $\mathbf{e}$ is the vector of random residuals, $X$ and $Z$ are incidence matrices for fixed and random effects.

We assumed that:

\[
\begin{bmatrix}
  \mathbf{p}_{1i} \\
  \mathbf{p}_{2i}
\end{bmatrix} \sim N\left(0, \begin{bmatrix}
  \sigma^2_{p1} & \sigma_{p1p2} \\
  \sigma_{p1p2} & \sigma^2_{p2}
\end{bmatrix}\right), \quad \begin{bmatrix}
  \mathbf{a}_1 \\
  \mathbf{a}_2
\end{bmatrix} \sim N\left(0, A\begin{bmatrix}
  \sigma^2_{a1} & \sigma_{a1a2} \\
  \sigma_{a1a2} & \sigma^2_{a2}
\end{bmatrix}\right),
\]

\[
\begin{bmatrix}
  \mathbf{e}_1 \\
  \mathbf{e}_2
\end{bmatrix} \sim N\left(0, I\begin{bmatrix}
  \sigma^2_{e1} & \sigma_{e1e2} \\
  \sigma_{e1e2} & \sigma^2_{e2}
\end{bmatrix}\right), \quad \mathbf{a}_3 \sim N(0, A\sigma^2_{a3}), \quad \mathbf{p}_{3i} \sim N(0, I\sigma^2_{p3}), \quad \mathbf{e}_3 \sim N(0, I\sigma^2_{e3}),
\]

where $A$ is the numerator relationship matrix among animals, and $I$ is the identity matrix. $\sigma^2_{a}$ is the additive effect variance, $\sigma_{a1a2}$ is the additive effect covariance, $\sigma^2_{pe}$ is the permanent environmental effect variance, $\sigma_{pe1pe2}$ is the environmental effect covariance, $\sigma^2_{pe}$ is the residual effect variance, and $\sigma_{Te1T2}$ is the residual effect covariance. The Gibbs sampling method in DMU (v6) software was used to estimate the genetic parameters of FD (Madsen et al. 2014).

The effect of cage height on FD was examined using the Chi-squared test. Two-way analysis of variance (ANOVA) was used to analyse and evaluate the effect of FD and cage height on egg performance (Equation (3)).

\[
y_{ijk} = \mu + \alpha_i + \beta_j + e_{ijk},
\]

(3)

where $y_{ijk}$ is the performance of bird $k$ in level $i$ and feature damage $j$, $\mu$ is the fixed mean effect, $\alpha_i$ is the effect of cage height, $\beta_j$ is the feather damage effect, and $e_{ijk}$ is the random residual effect. First, the frequency histogram method and Bartlett’s statistic were used to check for normality and homogeneity of variance. If any one of the above conditions was not satisfied, the Kruskal–Wallis (KW) test was used to analyse the relevance (Kruskal and Wallis 1952). All analyses were conducted using R v3.5.1.

3. Results and discussion

3.1. The heritabilities of FD in White Leghorns and Rhode Island reds

We first excluded individuals with incomplete pedigrees and missing records; 2284 WL chickens and 2928 RIR chickens passed the data quality control. The variance components are presented in Table 2. The FD heritability in the neck ranged from 0.22 to 0.28. FD in the tail had the lowest heritability, and there was a strong genetic correlation to neck FD. FD in caged chickens is a representation of behaviour, as FD is directly related to activities, and many studies have demonstrated that genetic factors contribute to animal behaviour. Similar genetic phenomena are observed in feather pecking. Kjaer et al. (2001) conducted a selection experiment between a high feather pecking line and a low feather pecking line. The low feather pecking line exhibited better overall plumage condition than the high feather pecking line. Biscarini et al. (2010) found that SNP rs13640917 on chromosome 4, and SNP rs14999300 on chromosome 13 were associated with FD and feather pecking. Flisikowski et al. (2009) found that two sub-haplotypes of the dopamine D4 receptor (DRD4) gene were strongly associated with feather pecking behaviour.

Table 1. The description of the three-point scale method for descriptions of damage to the neck and tail feathers of caged laying hens.

| FD score | Neck | Tail |
|----------|------|------|
| 1        | No damaged feathers | No damaged feathers |
| 2        | Visible bare patch but bare patch ≤ 5 cm diameter | Feathers broken but no bare patch |
| 3        | Bare patch > 5 cm diameter | A large number of feathers broken or no feather cover |
Table 2. The estimates of genetic parameter ± standard error (SE) for feather damage (FD) in caged laying hens.

| Trait          | $\sigma^2_g$ | $\sigma^2_p$ | COV($\alpha$, $\alpha$) | COV($\beta_1$, $\beta_2$) | $h^2$ | $R$  |
|----------------|--------------|--------------|--------------------------|---------------------------|-------|------|
| WLNFD          | 0.16 ± 0.025 | 0.56 ± 0.026 | 0.06 ± 0.016             | 0.083 ± 0.022             | 0.22  | 0.14 (P) |
| WLTFD          | 0.13 ± 0.031 | 1.21 ± 0.047 | –                        | –                         | 0.09  | 0.40 (A) |
| RIRNFD         | 0.16 ± 0.026 | 0.41 ± 0.024 | –                        | –                         | 0.28  | –    |

Note: WLNFD, White Leghorn neck feather damage; WLTFD, White Leghorn tail feather damage; RIRNFD, Rhode Island Red neck feather damage; $P$, phenotypic correlation coefficient; $A$, genetic correlation coefficient.

(Flisikowski et al. 2009). This indicates that genetic factors contribute to the development of FD in hens, and family selection can be used to eliminate FD. However, we should use this method carefully, as FD is directly affected by animal activities, so FD is a representation of animal behaviour. We can improve FD quickly during selection, but in the process of selection, we may also indirectly change animal behaviour, which may affect the genetic progress of other traits. Furthermore, in the present study, RIR had a higher proportion of moderate FD; in contrast, severe FD occurred more frequently in WL hens. We believe that this inconsistent tolerance originates from breed characteristics, as WL hens are more vulnerable to stress than RIR (Uitte-dehaag et al. 2008, 2009).

3.2. Cage height is strongly associated with FD

Chi-squared test results showed that cage height had a strong effect on WL neck FD ($\chi^2 = 107.45, p < 0.0001$), WL tail FD ($\chi^2 = 184.53, p < 0.0001$), and RIR neck FD ($\chi^2 = 21.82, p < 0.0002$) (Figure 2). We found that the highest cage had the highest frequency of severe FD in both WL and RIR, similar to a previous study (Brinker et al. 2014). The most likely explanation is that the chickens at the top tier are closer to the light source and more susceptible to being affected by light. Reducing the light intensity is conducive to reducing FD in hens. Light intensity has a huge impact on animal behaviour, especially in chickens. Boshouwers and Nicaise (1987) found that the number of movements was significantly positively correlated with the logarithm of light intensity and energy expenditure. According to previous research, light can indirectly affect animal behaviour by affecting hormone profiles. This principle has been widely used in poultry production, and ideal light can increase egg performance. It is also important to improve the uniformity of the light intensity of chicken house.

3.3. The effect of FD on production traits

In the present study, 2135 RIR and 1810 WL chickens were used to test the effect of FD on egg performance. Except for egg weight, all traits were tested by ANOVA. The average egg performance and $p$-value are shown in Tables 3 and 4. The KW test showed that FD in the neck of WL had a significant effect on egg number, but there was no significant difference in the average egg count between the three groups, with approximately 219.37, 219.48, and 220.71, respectively. At present, there is no systematic study regarding the effect of FD on the performance of laying hens. The impact of FD on chicken performance may changes with experimental design, as similar result was observed in feather pecking. Su et al. (2006) found that feather pecked hens had a greater egg weight, albumen height, shell thickness, and yolk percentage than less feather pecked hens. de Haas et al. (2013) found that feather pecking had a significant negative effect on egg weight and body weight. More research is needed to understand the effect of FD on chicken performance.

4. Conclusions

In summary, FD is a complex trait, and both environmental and genetic factors contribute to FD. However, there is no clear evidence in our experiment to show that FD has a negative effect on the production performance of laying hens.
**Ethical statement**

All experiments were approved by the Committee for Animal Care and Use of China Agricultural University (Approval ID: XXCB-200900209). The experimental procedures with chickens were operated according to the Guidelines for Experimental Animals established by the Ministry of Science and Technology (Beijing, China).

**Disclosure statement**

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

**Funding**

This research was conducted with the financial support of Beijing Innovation Team of the Modern Agro-industry Technology Research System [Project No. BAIC04-2020].

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