Relationship between egg quality traits and hatchability in pure-line white layer strains

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Abbreviated title: Hatchability related to egg quality

Summary

Hatchability is a very important trait in a breeding program which has a great economical impact on franchise hatcheries. The variability between and within strains raises the question whether reproductive performance can be improved by selection within lines. The aim of this study is to analyse the genetic background of the hatchability and its correlations between egg quality and production traits. Data from two pure-bred female lines at an age of 45 weeks of an LSL commercial breeding program were used. The heritability for reproductive traits was between low and medium: 0.13 and 0.15 for fertility, as well as 0.27 and 0.29 for hatchability respectively. The correlation between hatchability and egg weight is negative with rg= -0.43 to -0.52. The same with the albumen height with rg= -0.25 to -0.42. There was a negative but not significant correlation with body weight. On the contrary, the correlation with yolk proportion was slightly positive (rg= +0.08 to +0.39), and the correlation with egg production (rg= -0.01 to +0.28). For egg quality traits like shell strength and shape index (length/width), positive correlations ranging from rg= +0.14 to +0.32 were estimated.

Selection for better hatchability will be in line with improved external egg quality in the analysed lines of White Leghorns.

Introduction

Increasing reproductive performance is of major importance in the poultry industry. This ensures the efficient production of commercial cross-bred progenies. The heritability of these traits is normally low; therefore their improvement would be achieved mainly through the optimisation of the environment, by hatchery and breeder farm management (Förster et al., 1992). One possible genetic mechanism to counteract the decline of fitness traits with age is heterosis (Ledur et al., 2000). However, a low heritability does not exclude the possibility of improvement through breeding. Estimations of heritability for hatchability of fertile eggs in the literature range from 0.15 to 0.20 (Förster, 1993; Szwaczkowski et al., 2000; Bennewitz et al., 2007).

Egg characteristics greatly influence the process of incubation and are responsible for its success (Narushin and Romanov, 2002). The egg shell has an important role during embryonic development. It should isolate the embryo from the external environment while allowing the proper gas exchange across the shell at the same time. Barnett et al. (2004) reported that hairline-cracked eggs show an increase in bacterial exposure, an increased incubation weight loss and a decrease in hatchability (56.4% compares to 80.9%) compared with normal shelled eggs.
The aim of this study is to estimate genetic parameters for the reproductive traits and to evaluate the genetic relationship between hatchability and egg quality traits so that breeding possibilities of these traits can be assessed.

Materials and methods

Data of 6,226 and 6,516 laying hens of two full pedigreed pure-bred female lines A and B of an LSL White Leghorn commercial breeding program was evaluated. The average number of daughters per sire and per dam was 48.3 and 6.4 and 50.5, and 6.6 for the lines A and B respectively. Each hen was tested twice at the age of 45 weeks. Hatching eggs were collected for a period of 7 days each time.

The data was not recorded under normal conditions. On the contrary, the incubation of the hatching eggs was submitted to some challenging trials, which explain the low values of the reproductive traits (Table 1). First, the eggs were not incubated immediately after laying, but were stored at the hatchery for 7 days after the last collection day. This means that the eggs had an age ranging between 7 to 14 days after being laid. Furthermore, the time of incubation was deliberately shortened to exactly 21 days. These challenging conditions were used to see bigger differences between families. Pooled semen was used from different males so as to prevent favouring or penalising the hens as a result of the effect of the male.

Table 1. Phenotypic descriptive statistics for the reproductive traits of the two lines (n = 6,226 hens for line A and n = 6,516 hens for line B)

Trait	Mean	SD	Minimum	Maximum
Line A				
Number of eggs set per hen	6.60	0.73	3	7
F	83.4	16.7	0	100
HE	48.7	24.5	0	100
HFE	57.6	25.5	0	100
Line B				
Number of eggs set per hen	6.54	0.75	3	7
F	83.3	16.5	0	100
HE	53.0	24.0	0	100
HFE	62.3	24.9	0	100

* fertility rate (F), percentage of first-quality chicks hatched of eggs set (HE) and percentage of first-quality chicks hatched of fertile eggs set (HFE)

The transfer of the eggs from the setters to the hatchers was done on the 18th day of incubation. Fertility was measured by candling the eggs during transfer. Clear eggs were not open and were therefore not separated into infertile eggs and dead embryos. Moreover, families with less than 3 fertile eggs were completely removed.
Data of two generations were used for this study. In each generation, three different houses were tested for two hatches. The traits recorded in this test are: fertility rate (F), percentage of first-quality chicks hatched of eggs set (HE) and percentage of first-quality chicks hatched of fertile eggs set (HFE). Information about egg quality and egg production of these pedigree birds was available as well.

Statistical Analysis

For the estimation of the heritability of hatchability and fertility, the mean value of the two hatches was calculated for each hen. A multicode was created combining generations (2 generations), houses (3 houses), and tier-batteries y where the hens were allocated (4 batteries with 3 tiers per house). The additive genetic parameters of F, HE and HFE were estimated based on the following linear multi-trait animal model:

$$y_{ijk} = \mu + M_i + a_j + e_{ijk}$$

where y_{ijk} = observed F, HE or HFE of hen j; M_i = fixed effect of the multicode; a_j = random additive effect of hen j; and e_{ijk} = random environmental residual. The analysis, were done using the REML-method of the software VCE4 (Groeneveld, 1998). No arcsine transformation was done on the percentage data of hatchability and fertility. Based on the study from Förster et al. (1993), the effect of the transformation is relatively small.

Results and discussion

Table 2. Estimation of genetic parameters for fertility rate (F), percentage of first-quality chicks hatched of eggs set (HE) and percentage of first-quality chicks hatched of fertile eggs set (HFE)

Trait	F	CE	CF
Line A			
F	0.15	+ 0.63	+ 0.47
HE		0.30	+ 0.98
HFE			0.30
Line B			
F	0.13	+ 0.71	+ 0.53
HE		0.28	+ 0.98
HFE			0.27

* Heritabilities are on the diagonal and genetic correlations above the diagonal. The standard errors of the estimated heritabilities were 0.02.

Heritabilities and genetic correlations are shown in Table 2. As expected, the estimated heritabilities in this study were higher for hatchability compared to fertility, which is in accordance with other studies (Förster 1993; Szwaczkowski et al., 2000; Bennewitz et al. 2007). The values of the estimated heritabilities were similar for both lines and were at the top level of the literature values.

Table 3. Estimation of the genetic correlations between reproductive traits, production and egg quality traits.

Trait	P1[1]	P2[1]	P3[1]	EW[2]	SS[2]	AH[2]	ES[2]	YP[2]	BW[3]
Line A									
F	- 0.01	+ 0.04	+ 0.13	- 0.08	+ 0.06	- 0.08	- 0.11	- 0.08	- 0.09
HE	- 0.01	+ 0.01	+ 0.19	- 0.43	+ 0.19	- 0.25	+ 0.14	+ 0.08	- 0.08
HFE	+ 0.01	- 0.01	+ 0.17	- 0.46	+ 0.22	- 0.26	+ 0.19	+ 0.10	- 0.08
Line B									
F	- 0.07	+ 0.35	+ 0.33	- 0.18	+ 0.10	- 0.20	+ 0.15	- 0.05	- 0.17
HE	+ 0.04	+ 0.28	+ 0.24	- 0.48	+ 0.27	- 0.40	+ 0.29	+ 0.32	- 0.05
HFE	+ 0.05	+ 0.23	+ 0.20	- 0.52	+ 0.29	- 0.42	+ 0.32	+ 0.39	- 0.00

[1] Laying production: P1 - at the start of laying production; P2 - at the peak of laying; P3 - at the end of the laying cycle.
[2] Egg quality traits: egg weight (EW), shell strength (SS), albumen height (AH), egg shape (ES), yolk proportion (YP).
[3] Body weight with 30 weeks.

As expected, a negative correlation was found between egg weight and hatchability in both lines ranging -0.43 to -0.52. Förster et al. (1992) found correlations ranging from –0.50 to –0.54 in two pure lines of brown egg layers, whereas the value in a White Leghorn line was reported to be slightly lower (-0.22) by Hartmann et al. (2002).
A positive correlation was found between egg production at the end of the laying period and hatchability and fertility, especially in line B, which was also shown in the middle of the laying cycle. The values are according to the values indicated by Förster et al. (1993), who gave a possible explanation based on the negative correlation existing between egg production and egg weight, as well as by the fact that the first egg in a clutch shows a worse hatchability, and the increasing number of first eggs in a hen with lower productivity. Robinson et al. (1991) found that the eggs in the first position of the laying series had worse fertility compared to the following eggs.

There is a positive effect of the egg shell quality to hatchability. This has been confirmed in several studies (i.e., Bennet, 1992; Barnett et al., 2004). The correlations estimated in our study are positive and range between +0.19 to +0.29.

In Table 3, the genetic correlation between the albumen height and hatchability is clearly negative. However, this negative correlation might be overestimated as albumen height was not transformed to Haugh units and the effect of the egg weight was thereby not corrected. Flock et al. (2007) indicated that albumen consistency is an issue which the trade companies rather than the breeding companies should be dealing with. They have already exposed the breeding problem for improving albumen consistency due to the antagonism between high Haugh units and good hatchability. It is well known that more rounded eggs show a lower hatchability. The positive correlation values indicated in Table 3, demonstrate that larger egg shape (length/with) will improve hatchability.

A high yolk proportion is appreciated by the manufacturing industry, thus an increase of yolk proportion to 30% in white layers is aimed (Flock et al., 2007). These authors further explained this goal by the positive correlation of yolk proportion with hatchability and chick quality. This is in accordance with the estimations of our study. We found a positive correlation to hatchability, especially in line B (+0.32 and +0.39 for HE and HFE, respectively). Similar results in a white Leghorn line were also reported by Hartmann et al. (2002). They found a positive correlation between the hatchability of fertile eggs and yolk weight, yolk proportion and albumen dry matter of 0.28, 0.52 and 0.26, respectively. In our study, this relation could be partly explain by the negative correlation existing between yolk proportion and egg weight (rg= -0.60 and – 0.65 for the lines A and B, respectively).

In this study, only a slightly negative correlation was found between body weight and hatchability traits. However, Förster et al. (1993) reported higher negative correlations in two brown layer lines ranging –0.12 to –0.25.

Conclusions

A good hatchability and a reduced spread of hatch is one of the major objectives for a hatchery in improving the homogeneity and the quality of the chicks.

Only major traits should be included in the selection index. A strategy with a minimum requirement for reproductive traits might be used in the selection progress.

In view of the negative correlation with egg weight, another solution would be to include these traits in the selection of female lines and to give more selection pressure to egg weight in the male lines. By doing so, egg weight in the female lines would be reduced to a biological optimum and the required commercial egg weight would be increased through the male lines, where reproductive traits are not so critical.

Last but not least, it was shown that selection for egg production will have a positive effect on improvement of reproductive traits. Selection for better hatchability will be in line with not only improved external egg quality, but also internal egg quality like the proportion of yolk in the analysed lines of White Leghorn.

References

BARNETT, D. M., KUMPULA, B. L., PETRYK, R. L., ROBINSON, N. A., RENEMA, R. A. and ROBINSON, F. E. (2004) Hatchability and early chick growth potential of broiler breeder eggs with hairline cracks. Journal of Applied Poultry Research 13: 65-70.

BENNET C. D. (1992). The influence of shell thickness on hatchability in commercial broiler breeder flocks. Journal of Applied Poultry Research 1: 61-65.

BENNEWITZ, J., MORGADES, O., PREISINGER, R., THALLER, G. and KALM, E. (2007) Variance component and breeding value estimation for reproductive traits in laying hens using a Bayesian threshold model. Poultry Science 86, 823-828.

FLOCK, D.K., SCHMUTZ, M. and PREISINGER, R. (2007) Optimierung der Eiqualität aus züchterischer Sicht. Züchtungskunde 79 (4): 309-319.

FÖRSTER, A., KALM, E. and FLOCK, D. K. (1992) Schlupfähigkeit aus züchterischer Sicht. Lohmann Information (September/Oktober): 13-16.

FÖRSTER, A. (1993) Züchterische Möglichkeiten einer Verbesserung der Schlupfrate in Reinzuchtlinien eines Zuchtprogrammes für braune Legehybriden. PhD Thesis. Schriftenr. Inst. Tierzucht und Tierhaltung, Christian-Albrechts-Univ., Kiel, Germany.

GROENEVELD, E. (1998) VCE4. User´s Guide and reference manual, version 1.3.

LEDUR, M. C., FAIRFULL, R. W., MCMILLAN, I. and ASSELSTINE, L. (2000) Genetic effects of aging on egg production traits in the first laying cycle of White Leghorn strains and strain crosses. Poultry Science 79:296-304.

HARTMANN, C., STRANDBERG, E., RYDHMER, L. and JOHANSSON K. (2002) Genetic relations between reproduction, chick weight and maternal egg composition in a white leghorn line. Acta Agriculturae Scandinavica, Sect. A, Animal Science 52: 91-101.

NARUSHIN U. G. and ROMANOV, M. N. (2002) Egg physical characteristics and hatchability. World's Poultry Science J. 58 (3): 297-303.

ROBINSON, F. E., HARDIN, R. T., ROBINSON, N. A. and WILLIAMS, B. J. (1991) The influence of egg sequence position on fertility, embryo viability, and embryo weight in broiler breeders. Poultry Science 70:760-765.

SZWACZKOWSKI, T., WEZYK, S., PIOTROWSKI, P. and CYWA-BENKO K. (2000) Direct and maternal genetic and environmental effects for fertility and hatchability in laying hens. Archiv für Geflügelkunde 64: 115-120.