Genetic and genome-wide analysis of longitudinal egg-production data in laying hens

A. Wolc\textsuperscript{1,2}, J. Arango\textsuperscript{2}, P. Settar\textsuperscript{2}, J.E. Fulton\textsuperscript{2}, N.P. O’Sullivan\textsuperscript{2}, R. Fernando\textsuperscript{1}, D.J. Garrick\textsuperscript{1}, J.C.M. Dekkers\textsuperscript{1}

\textsuperscript{1} Department of Animal Science, Iowa State University, Ames, IA 50011-3150, USA
\textsuperscript{2} Hy-Line International, Dallas Center, IA 50063, USA
Outline

- Background
- Variance components for egg production
- Dynamics of genetic correlations
- Adding genomics to the picture
- Conclusions
Genetic Excellence®

Life of a layer chicken is longitudinal

Feed, temperature, ventilation, disease...

Hatch

Start laying

Keep laying

Keep laying

Retire

0 20 40 60 80 100
weeks

Genetic Excellence®
Selection for egg production

- Single measurement
- Changes over time
Trait trajectories can be modified

Hy-Line Brown Selection for Egg Weight Change

Egg Weight (g)

Age in Weeks

- 2010
- 2000
- 1990

Upward Selection
Downward Selection
Methods to analyze longitudinal data

- Single trait model for cumulative data
- Repeatability model
- Fixed regression model
- Multitrait model
- Random regression model
On a flock level chicken data looks like dairy cows

- Actual value
- Adams and Bell
- Ali and Schaffer
- Grossman et al.
- McMillan et al.
- McMillan
- Wood
- Yang et al.
- McNally
On the individual level

Egg

No egg
Express egg production as weekly, bi-weekly or monthly records

Assume normally distributed
Study 1

Variance components for egg production
- **Small white-egg (SWE) line**
  - 26,719 birds
  - 307,462 bi-weekly records

- **Large white-egg (LWE) line**
  - 31,531 birds
  - 379,786 bi-weekly records

- **Brown-egg (BE) layer**
  - 31,059 birds
  - 372,288 bi-weekly records

- Daily records from first egg to **47 wk of lay**
- **6 generations**
Pedigree based analysis in 3 layer lines

Egg production 2 week period

- SWE
- LWE
- BE

period of lay (2 wk)
Methods

Biweekly egg production

Hatch week-age

Additive genetic effects

Permanent Environment

Residual

\[ y_{ikl} = HY_i x \sum_{m=0}^{n_1} b_m z_{klm} + \sum_{m=0}^{n_2} a_{km} z_{klm} + \sum_{m=0}^{n_3} p_{km} z_{klm} + e_{ikl} \]
Variance components

**SWE**
- Animal
- Residual
- Pe

**LWE**
- Animal
- Residual
- Pe

**BE**
- Animal
- Residual
- Pe

Period of lay (2 wk)
Heritability and repeatability

- SWE heritability
- SWE repeatability
- LWE heritability
- LWE repeatability
- BE heritability
- BE repeatability

Period of lay (2wk)
Conclusions

- Linear polynomial for genetic component gave a good description of the data in all 3 lines
- Similar shape of variance components to higher order polynomials
- Interpretable parameters
- We can keep it simple!
Study 2

Dynamics of genetic correlations
- Egg number and egg defects
- 13,475 animals
- 6 generations
- 137,998 biweekly records
Genetic correlation between egg number and number of defects is 0.061
Data – trait means

period of lay (2 wk)
Biweekly egg production

Additive genetic effects

Residual

Hatch week - age

Permanent Environment

\[ y_{ijkn} = \text{hatchgen}_i \times \sum_{m=1}^{5} b_{m} z_{mn} + \sum_{m=0}^{m_1} a_{jkn} z_{mn} + \sum_{m=0}^{m_2} p_{jm} z_{mn} + e_{ijkn} \]
Results – RRM egg production

Sum of variance components was overall phenotypic variance

Based on these pictures we went for animal linear and quadratic pe

period of lay (2 wk)
Bivariate RRM - Genetic parameters

Rg = 0.061

eggs vs defects

Days in lay
Life is more complicated than linear
Genetic correlations change over time
Study 3

Adding genomics to the picture
Objectives

- Estimate variance components using genomic relationship information
- Evaluate predictive ability of random regression reduced animal model with genomic relationships
Brown egg-layer line, 5 generations
24,430 segregating SNPs

Data
- daily egg production up to 46 weeks in lay accumulated into 85,462 biweekly records
- 17,570 records on genotyped hens
- other records on their non-genotyped progeny

Validation on 288 genotyped and phenotyped individuals from generation 6 with 5,787 biweekly records
Biweekly egg production

Additive genetic effects

Permanent environment

Hatch week -age

Mendelian sampling

\[ y_{ijk} = HY_i \sum_{m=0}^{n1} b_m z_{kml} + (P + \frac{1}{2} QS + \frac{1}{2} QD) \sum_{m=0}^{n2} a_{km} z_{kml} + W \sum_{m=0}^{n3} a_1_{km} z_{kml} + \sum_{m=0}^{n4} p_{km} z_{kml} + e_{ikl} \]

n1=5, n2 to n4=1 or 2
Variance components with linear regression for additive and permanent environmental effects.
Heritability with linear regression for additive and permanent environmental effects

Heritability

period of lay (2 wk)

h2G

h2A
Variance components with quadratic regression for additive and permanent environmental effects
Heritability with quadratic regression for additive and permanent environmental effects
Accuracy with quadratic regression for additive and permanent environmental effects

Correlation in validation

period of lay (2 wk)
Prediction of total egg number was more accurate with genomic than with pedigree relationships (0.26 vs. 0.16)

Random Regression Models can be used for evaluation of egg production

No one model fits all traits

Variance components change over time

Genetic correlations are dynamic
Conclusions

- RRM can be utilized in breeding programs using genomic information
- Practical implementation will depend upon reducing computing and genotyping costs; both of which are reducing at a breathtaking rate
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