Genotype by environment interaction (G×E) for female fertility under conventional and organic production systems in Danish Holsteins

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Introduction
Introduction

- 13% milking cows are from organic herds (Lauridsen, U., 2018)
- Bulls used for organic are selected from data of all herds
Objectives

For female fertility traits in Danish Holsteins:

☑ Estimate variance components and heritabilities for conventional and organic production systems separately

☑ Investigate G×E under these two production systems
Material and methods
Workflow

- Environmental descriptor
- Grass ratio -> Energy balance -> fertility

Clean phenotype

Workflow:
1. Grass ratio of feed (2011/2016)
2. Typical Convention
3. Typical Organic
4. Full pedigree
5. 3 gen. DmuTrace

Environmental descriptor:
- Grass ratio
- Energy balance
- Fertility

Different from 1

GxE

h²

r_g
Data-Traits

- Same traits as Nordic routine evaluation
- Heifers (h) and cows (c) as different traits

<table>
<thead>
<tr>
<th>Heifer &amp; Cow</th>
<th>Cow</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conceive and keep pregnancy</strong></td>
<td><strong>Recycle after calving</strong></td>
</tr>
<tr>
<td>AIS  Number of inseminations</td>
<td>ICF  Interval from calving to</td>
</tr>
<tr>
<td>IFL Interval from first to last</td>
<td>1st insemination</td>
</tr>
<tr>
<td>NRR Non-return rate at 56 days</td>
<td></td>
</tr>
<tr>
<td>after first insemination</td>
<td></td>
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</tbody>
</table>
Data- Grass ratio of feed

- Differences of grass ratio between seasons varied across herds
  - Herds with both seasons
  - Average over Summer and Winter

No. of herds with grass ratio of feed:
- Summer: 195
- Winter: 203

Grass ratio of feed

- Organic > Conventional
Data - Typical conventional/organic

Distribution of grass ratio of feed

- Conventional
  - Herds: 204 herds grass ratio < 0.2
  - Records: ~85,000 (heifer)
  - ~120,000 (cow)

- Organic
  - Herds: 130 herds grass ratio > 0.38
  - Records: ~35,000 (heifer)
  - 50,000 (cow)
Two-trait animal model

\[
\begin{bmatrix}
    y_1 \\
    y_2
\end{bmatrix} =
\begin{bmatrix}
    X_1 & 0 \\
    0 & X_2
\end{bmatrix}
\begin{bmatrix}
    \beta_1 \\
    \beta_2
\end{bmatrix} +
\begin{bmatrix}
    Z_1 & 0 \\
    0 & Z_2
\end{bmatrix}
\begin{bmatrix}
    \alpha_1 \\
    \alpha_2
\end{bmatrix} +
\begin{bmatrix}
    e_1 \\
    e_2
\end{bmatrix}
\]

\[
\begin{bmatrix}
    \alpha_1 \\
    \alpha_2
\end{bmatrix} \sim N\left(0, A \otimes \begin{bmatrix}
    \sigma_{a_1}^2 & \sigma_{a_1 a_2} \\
    \sigma_{a_1 a_2} & \sigma_{a_2}^2
\end{bmatrix}\right)
\]

\[
\begin{bmatrix}
    e_1 \\
    e_2
\end{bmatrix} \sim N\left(0, I \otimes \begin{bmatrix}
    \sigma_{e_1}^2 & 0 \\
    0 & \sigma_{e_2}^2
\end{bmatrix}\right)
\]
Two-trait animal model

Repeatability model (lactation 1-3)

\[
[y_1] = [X_1 \ 0 \ 0 \ X_2][\beta_1 \ \beta_2] + [Z_{a1} \ 0 \ Z_{a2}][a_1 \ a_2] + [Z_{pe1} \ 0 \ Z_{pe2}][pe_1 \ pe_2] + [e_1 \ e_2]
\]

\[
[a_1 \ a_2] \sim N \left( 0, A \otimes \begin{bmatrix} \sigma_{a1}^2 & \sigma_{a1a2} \\ \sigma_{a1a2} & \sigma_{a2}^2 \end{bmatrix} \right)
\]

\[
[pe_1 \ pe_2] \sim N \left( 0, I \otimes \begin{bmatrix} \sigma_{pe1}^2 & 0 \\ 0 & \sigma_{pe2}^2 \end{bmatrix} \right)
\]

\[
[e_1 \ e_2] \sim N \left( 0, I \otimes \begin{bmatrix} \sigma_{e1}^2 & 0 \\ 0 & \sigma_{e2}^2 \end{bmatrix} \right)
\]
Results and discussion
Results—Mean of phenotypes

- NRR (%)
  - Heifer: 60
  - Cow: 2.5

- AIS (#)
  - Heifer: 70
  - Cow: 75

- IFL (day)
  - Heifer: 60
  - Cow: 60

- ICF (day)
  - Cow: Organic better than Conventional

- NRRh: organic is ~5 percentage point higher than conventional

- Organic better than Conventional
Heritabilities were low in both organic and conventional.

Heterogeneity in heritabilities between organic and conventional, indicating genetic evaluation based on data of all herds requires a model able to handle the heterogeneity.
Significant G×E were observed for NRRh, AISH and for ICF.

G×E for three traits and increasing organic population suggested it may have a potential to develop a breeding program optimal for both production systems.
Conclusion
Conclusion

- Fertility functions: **organic better than conventional**
- Heterogeneity in heritabilities
- Significant \( G \times E \) were observed for AISh, NRRh and for ICF
- The existence of \( G \times E \) for three traits and the increasing organic population suggested that it maybe have a **potential to develop a breeding program optimal for both production systems**
Acknowledgement

• Per Madsen, Aarhus University
• Lu Cao, Aarhus University
• Xiaowei Mao, Cornell University
• Han Mulder, Wageningen University & Research
Organic dairy breeding lines? – Possibilities and requirements
Morten Kargo, Aarhus University
Time: Feb 13 (TUE), 14:30-14:45

Breeding goals for organic dairy farming in Denmark based on the principles of organic agriculture
Presenter: Margot Slagboom, Aarhus University
Time: Feb 15 (THU), 10:00-10:15
Definition of $G \times E$

\[ P = G + E + G \times E \]

Different $G$ response differently to different $E$

Is there a $G \times E$?

Data Grass ratio in feed

- Organic: grass ratio (summer-winter)
- Conventional: grass ratio (summer-winter)