Breeding for feed efficiency in German Holsteins: the new RZFeedEfficiency
E. Abdalla, L. Polman, S. Rensing, H. Alkoder, R. Reents, J. Heise

Genetic Evaluation (zws@vit.de)
IT Solutions for Animal Production (vit)
Heinrich-Schröder-Weg 1, 27283 Verden, Germany
What is feed efficiency?

- The ratio of input and output
- More precisely: The ratio of feed intake (input) to income-relevant performance (output)
- Ratios not easy to handle in context of breeding values

- Feed efficiency should refer to the cow's entire life
- Since this is very complex: currently feed efficiency is assessed only for time of productive life

ECM: energy-corrected milk
DMI: dry matter intake
BW: body weight
BWC: body weight change
Feed efficiency: feed saved concept

- schematic example: two animals with same input but different output

Animal 1

ECM | BWC | -1 * (Feed Saved)

Animal 2

ECM | BWC | -1 * (Feed Saved)

- Computation of expected DMI needed for
  - ECM
  - BWC
- … and comparison to actually measured DMI
- the difference of expected and measured DMI is „feed saved“

- Animal 1 is more feed efficient than animal 2
Data

Common data pool of the countries in the RDGP project
- Data for individual feed intake records
  - At least on a weekly basis (partly daily records)
  - Additional data for ECM and body weight
  - Animals are genotyped

(RDGP)
Data from international data exchange project RDGP

- Number of cows with feed intake records per country

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Cows</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUS</td>
<td>576</td>
</tr>
<tr>
<td>CAN</td>
<td>1984</td>
</tr>
<tr>
<td>CHE</td>
<td>298</td>
</tr>
<tr>
<td>DEU</td>
<td>2338</td>
</tr>
<tr>
<td>DNK</td>
<td>1349</td>
</tr>
<tr>
<td>ESP</td>
<td>667</td>
</tr>
<tr>
<td>USA</td>
<td>7562</td>
</tr>
</tbody>
</table>

In total 14,774 cows (Oct. 2023)
## Phenotypic performance of cows with feed intake records

- Common data pool of 7 countries in the RDGP project
- About 14’000 cows with dry matter intake from 6 countries (excluding Australia)

<table>
<thead>
<tr>
<th></th>
<th>N cows</th>
<th>Ø DMI 305</th>
<th>Ø ECM 305</th>
<th>Ø BW 305</th>
<th>Ø DMI /day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. La</td>
<td>8,718</td>
<td>6,291</td>
<td>9,762</td>
<td>619</td>
<td>20.6</td>
</tr>
<tr>
<td>2. La</td>
<td>5,911</td>
<td>7,207</td>
<td>11,538</td>
<td>684</td>
<td>23.6</td>
</tr>
<tr>
<td>3. La</td>
<td>3,173</td>
<td>7,432</td>
<td>11,902</td>
<td>721</td>
<td>24.4</td>
</tr>
<tr>
<td>4. La</td>
<td>1,255</td>
<td>7,454</td>
<td>12,187</td>
<td>736</td>
<td>24.4</td>
</tr>
<tr>
<td>5. La</td>
<td>571</td>
<td>7,579</td>
<td>12,172</td>
<td>737</td>
<td>24.8</td>
</tr>
</tbody>
</table>
Model: Random-Regression-Animal-Model

- Phenotypes:
  - DMI, BW and ECM

- Model per trait:
  - Multi-Lactation-Random-Regression-Animal-Model per trait
  - Legendre polynomials of 2\textsuperscript{nd} order
  - Fixed Effects:
    - Herd-testweek
    - calving\_age x lactationweek (Legendre, 2\textsuperscript{nd} order)
    - Regression on inbreeding
  - Random effects:
    - Permanent environment
    - Genetic animal effect

- Single Step
  - 13’883 animals with phenotypes (for DMI & BW & ECM)
  - 1’433’391 animals with genotypes
Advantages of modeling the underlying component traits in GE

- Flexibility to define target trait(s) freely
  - Also adjust later easily, if necessary

- Advantages of the model
  - Genetic curves change over time (feed efficiency is a different trait in different periods and lactations)
  - Residuals modelled per measurement
    - Different to phenotypic RFI approaches
    - Switching to daily measurements would be straightforward
  - Precise modelling
  - Future improvements relatively easy
Estimation of variance components

- 4 periods per lactation of 11 weeks each
- Multi-trait model
- Back-regression on random regression

Genetic correlations in 1st lactation

![Genetic correlations heatmap]
Genetic evaluation of feed efficiency traits

- Calculation of kg Feed Saved based on EBV for DMI, ECM and BWC
  - 305 days in lactations 1, 2 and 3
  - as sum of lactations 1, 2, and 3

\[
GEBV_{FeedEfficiency} = -GEBV_{DMI} + 4.5GEBV_{BWC} + 0.4GEBV_{ECM}
\]

- Genetic variance: 247 kg feed saved per lactation 1-3 (~ 3.5% of total feed intake)
- Reliability of the gEBV for feed efficiency: ~ 40%
- Publication as relative EBV (RZFeedEfficiency, RZFE)
EBV correlations RZFeedEfficiency to other traits

- GEBV correlations calculated for 352'692 genotyped females born 2021 and 2022

<table>
<thead>
<tr>
<th>Breeding value</th>
<th>Trait complex</th>
<th>Correlation to RZFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>RZG</td>
<td>total merit</td>
<td>0.02</td>
</tr>
<tr>
<td>RZE</td>
<td>total merit (€)</td>
<td>0.05</td>
</tr>
<tr>
<td>RZM</td>
<td>production</td>
<td>-0.07</td>
</tr>
<tr>
<td>RZN</td>
<td>longevity</td>
<td>0.05</td>
</tr>
<tr>
<td>RZE</td>
<td>conformation</td>
<td>-0.11</td>
</tr>
<tr>
<td>RZR</td>
<td>reproduction</td>
<td>0.02</td>
</tr>
<tr>
<td>RZHealth</td>
<td>health</td>
<td>-0.03</td>
</tr>
<tr>
<td>RZKm</td>
<td>calving, maternal</td>
<td>0.03</td>
</tr>
<tr>
<td>RZKd</td>
<td>calving, direct</td>
<td>0.10</td>
</tr>
<tr>
<td>RZCalffit</td>
<td>young stock survival</td>
<td>0.06</td>
</tr>
</tbody>
</table>

- Overall low GEBV correlations among RZFE and other main complexes
  - feed efficiency is independent from other main traits
What characterizes feed-efficient and less feed-efficient animals?

- GEBV profiles top/bottom 25% according to RZFE of genotyped SBT females born 2021/2022
- Total = 352'692 females (per quartile 88'173 females)

<table>
<thead>
<tr>
<th>Weibl. 2021/22</th>
<th>Top 25 %</th>
<th>Bottom 25 %</th>
<th>Diff. T-L</th>
</tr>
</thead>
<tbody>
<tr>
<td>RZFE</td>
<td>107,9</td>
<td>91,5</td>
<td>16,4</td>
</tr>
<tr>
<td>FE kg</td>
<td>607</td>
<td>-657</td>
<td>1264</td>
</tr>
<tr>
<td>ECM (L123_kg)</td>
<td>743</td>
<td>625</td>
<td>118</td>
</tr>
<tr>
<td>BWC (L123_kg)</td>
<td>0,6</td>
<td>2,2</td>
<td>-1,5</td>
</tr>
<tr>
<td>DMI (L123_kg)</td>
<td>-307</td>
<td>917</td>
<td>-1224</td>
</tr>
<tr>
<td>BW (L123_kg)</td>
<td>4,1</td>
<td>27,1</td>
<td>-23,0</td>
</tr>
</tbody>
</table>

- Significant differences between top and bottom animals in RZFE and FE kg
- Similar production level
  - Top RZFE +39 kg ECM/lactation
- Hardly any difference in BWC
  - But Top RZFE slightly lighter
- **Top females need less feed**
  - For similar production level

all kg figures refer to the sum of 3 lactations
Summary - RZFeedEfficiency (RZFE)

- The German trait definition and genetic evaluation considers milk production and weight gain as output and refers to the entire productive life (3 lactations)
- Reliability (40%) is still limited
- Feed efficiency is heritable and has significant genetic variation (1 gSD ~ approx. 3.5% total feed intake)
- Feed efficiency is genetically mostly independent from other breeding goal traits
  - Genetic trend slightly negative, almost no trend
  - Previous breeding for milk output maximization (performance per cow and lactation independent of feed intake) has led to a significant increase in milk production = output, but obviously not to an increase in efficiency

➢ The basis for genetic improvement of feed efficiency is the RZFeedEfficiency (RZFE), which was introduced in April 2024