Improving feed efficiency and net merit by including maintenance requirement in selection of dairy cattle

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Feed efficiency in dairy cows

• Various traits are needed to describe feed efficiency
• Almost all traits require feed intake observations
• Yet, there is no reasonable method to measure feed intake on large scale
Are there useful traits that do not require feed intake?

- **Production and maintenance** explain by far the largest share of variation in feed efficiency (Mehtio et al. 2018, JDS, accepted)

- We found:
  
  \[
  \text{Energy Conversion Efficiency (ECE)} = \frac{\text{ECM}}{\text{MEI}} \quad \& \quad \text{are genetically highly correlated} \quad (r_g > -0.8)
  \]

  \[
  \text{Maintenance Requirement Ratio (MRR)} = \frac{c_{MBW}}{\text{ECM}}
  \]

- Could MRR be used for selection?

ECM = **energy corrected milk**

MEI = **metabolizable energy intake**

MBW = **metabolic body weight**
Aim

Comparison of different selection indices to assess the value of MRR

→ estimation of variance components
→ linearization of ratio traits ECE and MRR
→ setting up selection indices
Estimation of variance components

• Data
  Lactation averages: based on 43,243 daily records of 539 Nordic Red cows

• Traits
  • M = milk yield
  • P = protein yield
  • F = fat yield
  • MBW = metabolic body weight
  • MEI = metabolizable energy intake
  • ECE = energy conversion efficiency
  • REI = residual energy intake
  • MRR = maintenance requirement ratio

• Multiple-trait model for REML analyses (using DMU, Madsen & Jensen 2013)
  \[ y_{tijl} = \sum_{q=1}^{2} b_{tijq} \alpha e_{i}^{q} + HCYS_{tij} + a_{tijl} + e_{tijl} \]
Linearization of MRR by Taylor series expansion

- The ratio of the genetic values of MRR

\[
MRR_g = \frac{c_{ME} g_{MBW}}{c_M g_M + c_P g_P + c_F g_F}
\]

where \( g_{MBW}, g_M, g_P, g_F \) are genetic values and \( c_{ME}, c_M, c_P, c_F \) are coefficients

- equals

\[
MRR_g = MRR_g(\mu_{MBW}, \mu_M, \mu_P, \mu_F) + \frac{\partial MRR_g}{\partial g_{MBW}} \bigg|_{\mu_{MBW}, \mu_M, \mu_P, \mu_F} (g_{MBW} - \mu_{MBW}) \\
+ \frac{\partial MRR_g}{\partial g_M} \bigg|_{\mu_{MBW}, \mu_M, \mu_P, \mu_F} (g_M - \mu_M) + \frac{\partial MRR_g}{\partial g_P} \bigg|_{\mu_{MBW}, \mu_M, \mu_P, \mu_F} (g_P - \mu_P) \\
+ \frac{\partial MRR_g}{\partial g_F} \bigg|_{\mu_{MBW}, \mu_M, \mu_P, \mu_F} (g_F - \mu_F) + \text{terms of higher order}
\]

- and is approximately

\[
MRR_g \approx \frac{1}{\mu_{ECM}} g_{MBW} - \frac{\mu_{MBW}}{\mu_{ECM}^2} (c_M g_M + c_P g_P + c_F g_F)
\]

where \( \mu_{ECM} = c_M g_M + c_P g_P + c_F g_F \)
Selection index to assess net merit

- **Maximizing net merit** \( H = \mathbf{g}' \mathbf{a} \)
  
  where genetic values \( \mathbf{g}' = [g_M \ g_P \ g_F \ g_{MBW} \ g_{MEI} \ g_{ECM} \ g_{REI} \ g_{MRR}] \)
  
  and economic values \( \mathbf{a}' = [a_M \ a_P \ a_F \ 0 \ a_{MEI} \ 0 \ 0 \ 0]. \)
  
  \( (a_M = 0.0013, a_P = 4.56, a_F = 1.23, a_{MEI} = -0.0164) \)

- **Index coefficients** \( \mathbf{b}_i = \mathbf{P}_{n_i n_i}^{-1} \mathbf{G}_{n_i \times m} \mathbf{V}_i \mathbf{a}_i \)
  
  where for ECE and MRR \( \mathbf{V}_{m \times m} \) is a transformation matrix (Lin & Aggrey, 2013)
  
  and otherwise identity matrix

- **Genetic response** \( \Delta_i = \frac{\mathbf{G} \mathbf{b}_i}{\sqrt{\mathbf{b}_i' \mathbf{P}_i \mathbf{b}_i}} \)

- **Net merit for index** \( \Delta H_i = \mathbf{a}' \Delta_i \)
## Selection indices compared

<table>
<thead>
<tr>
<th>Index</th>
<th>Index traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>current index</td>
</tr>
<tr>
<td>C+MBW+REI</td>
<td>+ metabolic body weight + residual energy intake</td>
</tr>
<tr>
<td>C+MBW</td>
<td>+ metabolic body weight</td>
</tr>
</tbody>
</table>
| tr_MRR     | transformed MRR= \[
\frac{C_{ME}MBW}{ECM}\]
|            | milk, protein, fat, MBW |
| tr_ECE     | transformed ECE= \[
\frac{ECM}{MEI}\]
|            | milk, protein, fat, MEI |
## Estimated correlations

<table>
<thead>
<tr>
<th></th>
<th>Milk</th>
<th>Prot.</th>
<th>Fat</th>
<th>MBW</th>
<th>MEI</th>
<th>ECE</th>
<th>REI</th>
<th>MRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td></td>
<td></td>
<td></td>
<td>-0.24</td>
<td>0.35</td>
<td>0.58</td>
<td>0.06</td>
<td>-0.81</td>
</tr>
<tr>
<td>Prot.</td>
<td>0.91</td>
<td></td>
<td></td>
<td>-0.29</td>
<td>0.41</td>
<td>0.57</td>
<td>0.15</td>
<td>-0.83</td>
</tr>
<tr>
<td>Fat</td>
<td>0.79</td>
<td>0.83</td>
<td></td>
<td>-0.28</td>
<td>0.38</td>
<td>0.62</td>
<td>0.10</td>
<td>-0.86</td>
</tr>
<tr>
<td>MBW</td>
<td>0.03</td>
<td>0.10</td>
<td>0.04</td>
<td></td>
<td>0.43</td>
<td>-0.58</td>
<td>0.24</td>
<td>0.67</td>
</tr>
<tr>
<td>MEI</td>
<td>0.43</td>
<td>0.44</td>
<td>0.41</td>
<td></td>
<td>0.37</td>
<td>-0.44</td>
<td>0.88</td>
<td>-0.05</td>
</tr>
<tr>
<td>ECE</td>
<td>0.58</td>
<td>0.60</td>
<td>0.65</td>
<td>-0.24</td>
<td></td>
<td>0.24</td>
<td>-0.66</td>
<td>-0.81</td>
</tr>
<tr>
<td>REI</td>
<td>-0.01</td>
<td>-0.04</td>
<td>-0.06</td>
<td>-0.02</td>
<td>0.78</td>
<td></td>
<td>-0.70</td>
<td>0.11</td>
</tr>
<tr>
<td>MRR</td>
<td>-0.81</td>
<td>-0.79</td>
<td>-0.84</td>
<td>0.43</td>
<td>-0.22</td>
<td>-0.71</td>
<td></td>
<td>0.03</td>
</tr>
</tbody>
</table>

**genetic**

**phenotypic**
## Net merit and genetic response

<table>
<thead>
<tr>
<th></th>
<th>Net merit (in % of control)</th>
<th>Genetic response (in % of genetic SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Milk</td>
<td>Prot.</td>
</tr>
<tr>
<td>C</td>
<td>100</td>
<td>0.68</td>
</tr>
<tr>
<td>C+MBW+REI</td>
<td>128</td>
<td>0.61</td>
</tr>
<tr>
<td>C+MBW</td>
<td>124</td>
<td>0.63</td>
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<tr>
<td>tr_MRR</td>
<td>118</td>
<td>0.67</td>
</tr>
<tr>
<td>tr_ECE</td>
<td>102</td>
<td>0.67</td>
</tr>
</tbody>
</table>
Conclusions

• Highest net merit when adding **metabolic body weight** and **residual energy intake**

• **Maintenance requirement ratio** and **residual energy intake** describe different parts of feed efficiency

• Including **maintenance requirement ratio** increased net merit and feed efficiency

Thank you!