Partitioning genetic variance of metabolizable energy efficiency in dairy cows

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Motivation

• A cow has different pathways of energy use

• Could we estimate partial efficiencies for different energy pathways?
  → it would increase understanding of cows’ feed efficiency
  → supports defining of the breeding goal
  → breeding values for partial efficiencies
Finnish feeding is based on metabolizable energy.

- Feed gross energy intake
- Faecal energy
- Digestible energy
- Metabolizable energy
- Urine energy
- CH4 energy
  - 0.515 MJ per kg BW^{0.75}
  - 34 MJ per kg gain
  - 5.15 MJ per kg ECM

Feeding requirement norms are based on metabolizable energy.

- Maintenance
- Growth
- Milk
Energy pathways of a lactating cow

Feed gross energy intake
- 366 MJ

Digestible energy
- 271 MJ

Metabolizable energy
- 234 MJ

Faecal energy
- 95 MJ

26%

Urine energy

CH₄ energy

0.515 MJ per kg BW⁰.⁷⁵

34 MJ per kg gain

5.15 MJ per kg ECM

Body weight: 592 kg
Growth: 0.5 kg / day
Milk yield: 30 kg ECM / day

Maintenance
- 62 MJ

Growth
- 17 MJ

Milk
- 155 MJ

42%

36 MJ

22 MJ

15 MJ

26%
AIM

Assessing partial efficiencies for different energy pathways in dairy cows by random regression analyses
Metabolizable energy efficiency

Modelling metabolizable energy (ME) intake with regressions on energy pathways in the model. Including random regressions should allow estimation of partial efficiencies.

- Expectation for ME intake
  - Maintenance
  - Growth
  - Milk

Modifiers:
- $e_1 \cdot BW^{0.75} + a_{1i} \cdot BW^{0.75}$
- $e_2 \cdot BW_{gain} + a_{2i} \cdot BW_{gain}$
- $e_3 \cdot ECM + a_{3i} \cdot ECM$
Used feed efficiency data

- From Luke’s research farms Rehtijärvi & Minkiö
- 495 primiparous Nordic Red dairy cows
- 12 350 weekly observations (averages of daily observations)
- Recorded from lactation week 2 to 40

Means for different variables by lactation weeks

<table>
<thead>
<tr>
<th>Lactation weeks</th>
<th>Metabolizable energy intake (MJ)</th>
<th>Energy corrected milk (kg)</th>
<th>Metabolic body weight (kg)</th>
<th>Body weight gain (kg)</th>
<th>Body weight loss (kg)</th>
<th>Residual energy intake (MJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALL</td>
<td>208.7</td>
<td>28.5</td>
<td>119.1</td>
<td>0.3</td>
<td>-0.1</td>
<td>-3.6</td>
</tr>
<tr>
<td>2-5</td>
<td>183.3</td>
<td>27.9</td>
<td>116.5</td>
<td>0.1</td>
<td>-0.5</td>
<td>-16.5</td>
</tr>
<tr>
<td>16-20</td>
<td>214.8</td>
<td>29.0</td>
<td>118.2</td>
<td>0.2</td>
<td>0.0</td>
<td>1.7</td>
</tr>
<tr>
<td>36-40</td>
<td>210.9</td>
<td>26.5</td>
<td>125.7</td>
<td>0.5</td>
<td>0.0</td>
<td>-7.8</td>
</tr>
</tbody>
</table>
Applied Statistical Models

1) Metabolizable Energy Efficiency (MEE)
   • Repeatability animal model for metabolizable energy intake
   • Expectation for intake modelled by regressions on energy pathways

\[
\text{MEI}_{isl} = rym_i + lw_j + \\
e_{1s}BW_{isl}^{0.75} \times \text{lactcl}_s + e_{2s}ECM_{isl} \times \text{lactcl}_s + e_{3s}BWG_{isl} \times \text{lactcl}_s + e_{4s}BWL_{isl} \times \text{lactcl}_s + a_l + \\
pel + \\
\epsilon_{ijsl}
\]
Applied Statistical Models

2) Partial Metabolizable Energy Efficiency (pMEE)
• Random regression animal model for metabolizable energy intake
• Expectation for intake modelled by regressions on energy pathways
• Random regressions for animal effects

\[ MEI_{ijsl} = rym_i + lw_j + e_{1s}BW_{isl}^{0.75} \times lactcl_s + e_{2s}ECM_{isl} \times lactcl_s + e_{3s}BWG_{isl} \times lactcl_s + e_{4s}BW L_{isl} \times lactcl_s + a_{0l} + a_{1l}BW_{isl}^{0.75} + a_{2l}ECM_{isl} + a_{3l}BWG_{isl} + a_{4l}BW L_{isl} + pe_{0l} + pe_{1l}BW_{isl}^{0.75} + pe_{2l}ECM_{isl} + pe_{3l}BWG_{isl} + pe_{4l}BW L_{isl} + \epsilon_{ijsl} \]
Applied Statistical Models

3) Residual Energy Intake (REI)

• Repeatability animal model for residual energy intake
• Served as reference analysis

\[ REI_{ijl} = rym_i + lw_j + a_l + pe_l + \epsilon_{ijl} \]
Analyses

- Restricted Maximum Likelihood analyses (AI-REML, EM-REML) [DMU package, Madsen & Jensen, 2013]
- Different random regression models were fitted
- Akaike’s information criterion (AIC) for model comparison
- Heritabilities based on random regression models were calculated for a “standard lactating cow”
  - Metabolic body weight = 119.1 kg
  - Energy corrected milk yield = 28.5 kg / day
  - Body weight gain = 0.27 kg / day
## Results

### Variances and heritabilities

<table>
<thead>
<tr>
<th>Model</th>
<th>Additive Genetic Animal Effects</th>
<th>$\sigma^2_a$</th>
<th>$\sigma^2_{pe}$</th>
<th>$\sigma^2_e$</th>
<th>$h^2$</th>
<th>$\eta^2_{\text{int.}}$</th>
<th>$\eta^2_{\text{MBW}}$</th>
<th>$\eta^2_{\text{ECM}}$</th>
<th>$\eta^2_{\text{BWG}}$</th>
<th>$\eta^2_{\text{BWL}}$</th>
<th>AIC</th>
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</thead>
<tbody>
<tr>
<td>REI</td>
<td>Intercept</td>
<td>188</td>
<td>116</td>
<td>266</td>
<td>0.33</td>
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<tr>
<td>MEE</td>
<td>Intercept</td>
<td>137</td>
<td>149</td>
<td>247</td>
<td>0.26</td>
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<td></td>
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<td>80370</td>
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<td>pMEE1</td>
<td>Intercept, MBW</td>
<td>159</td>
<td>137</td>
<td>246</td>
<td>0.29</td>
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<td>0.29</td>
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<td>pMEE2</td>
<td>Intercept, ECM</td>
<td>343</td>
<td>28</td>
<td>246</td>
<td>0.56</td>
<td>0.00</td>
<td></td>
<td>0.56</td>
<td></td>
<td></td>
<td>80383</td>
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<td>pMEE3</td>
<td>Intercept, MBW, ECM</td>
<td>132</td>
<td>169</td>
<td>221</td>
<td>0.25</td>
<td>0.00</td>
<td>0.04</td>
<td>0.04</td>
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<td>79695</td>
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<tr>
<td>pMEE4</td>
<td>Intercept, MBW, ECM, BWG, BWL</td>
<td>98</td>
<td>205</td>
<td>182</td>
<td>0.20</td>
<td>0.00</td>
<td>0.10</td>
<td>0.09</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>pMEE5</td>
<td>MBW, ECM</td>
<td>132</td>
<td>169</td>
<td>220</td>
<td>0.25</td>
<td>0.05</td>
<td>0.04</td>
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<td>79686</td>
</tr>
</tbody>
</table>
Results

Correlations
Genetic (upper tr.) and permanent environmental (lower tr.) correlations between partial efficiencies and overall efficiency

<table>
<thead>
<tr>
<th></th>
<th>pMEE(MBW)</th>
<th>pMEE(ECM)</th>
<th>MEE(overall)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pMEE(MBW)</td>
<td></td>
<td>-0.49</td>
<td>0.55</td>
</tr>
<tr>
<td>pMEE(ECM)</td>
<td>-0.97</td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>MEE(overall)</td>
<td>0.21</td>
<td>0.05</td>
<td></td>
</tr>
</tbody>
</table>

Genetic standard deviations of partial regression coefficients

<table>
<thead>
<tr>
<th></th>
<th>(\sigma a_{\text{pMEE(MBW)}})</th>
<th>(\sigma a_{\text{pMEE(ECM)}})</th>
<th>(\sigma a_{\text{(overall)}})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.10 MJ / kg MBW / day</td>
<td>0.39 MJ / kg ECM / day</td>
<td>11.5 MJ /day</td>
</tr>
</tbody>
</table>
Conclusions

• Models for metabolizable energy efficiency resulted better fit
• Partial energy efficiencies can be modelled by random regressions
• Additive genetic variance was almost entirely explained by regressions on maintenance and milk yield
• Additional analyses are needed for verifying the genetic correlations between partial efficiencies
Thank you for your attention

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