Feed efficiency and Genetics

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“Organic and low-input dairying – an option to Northern European Dairy Sector?”
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Outline

• Overview
• Challenges in breeding for feed efficiency
• Different feed efficiency traits – where we are?

Acknowledgement

Luke
Seppo Ahvenjärvi, Terhi Mehtö, Enyew Negussie,
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Importance of feed efficiency in dairy cattle

- **Food security**
  - About 1 billion people of the world’s population have not enough food
  - World’s food demand increases 70% until 2050 (FAO, 2009)
  - ~2/3 of world’s agricultural land can be use through ruminants only
Importance of feed efficiency in dairy cattle

- **Environmental mitigation**
  - CH4 output / kg ECM (FAO, 2010)
    - Countries south of Sahara: 8 CO₂ eq.
    - Western European countries: 2 CO₂ eq.
  - Carbon sequestration
    - Grassland management (~25% of world’s milk is produced from grassland)
    - Arable land management
Importance of feed efficiency in dairy cattle

• Economically
  – Economic value of improved feed efficiency
    • Simulation study by T. Sipiläinen & P. Akkanen, University of Helsinki, (part of Finnish Feed Efficiency project)
    • Current Finnish market situation, silage 12.0kg DM, concentrate 11.5 kg DM, milk output 31.3 kg ECM; 250 000 cows
  – What if we improve feed efficiency by 5%
    • Same total output with less cows
      – Total surplus 23,2 million €
      – CH$_4$ emission reduced by 1.9 million kg
    • Same total output with less concentrate
      – Total surplus 27,7 million €
      – CH$_4$ emission reduced by 0.55 million kg
Improving of feed efficiency by animal breeding

Long history in other animal species

- Feed conversion rate (kg feed : kg meat)
- Broiler <2 : 1 (~250% progress during last 50 years)
- Pig <3 : 1 (~100% progress during last 50 years)
- Beef cattle <10 : 1 (~6% progress during last 20 years)

Dairy cattle

- So far only indirect genetic progress by breeding for correlated traits kg ECM : kg dry matter intake
- 1990 ~1.4 : 1
- 2010 ~1.5 : 1 (~7% progress during last 20 years)

but progress slows down

if milk production increases another 1000kg → progress only 1.3%
Challenges in breeding for feed efficiency

- Lifecycles of a cow
- Different products (milk, offspring, meat, ...)
- Lactation stages
- Use of tissue energy (energy status during lactation)
- How to define feed efficiency?
- What do we need to measure and for how long?
- Observations from a large number of cows are needed
- Observations have to be from a recent time period
- Measuring techniques
Challenges in breeding for feed efficiency

Apparently, the complexity of feed efficiency in dairy cattle cannot be described by one unique trait.

Several traits will be needed:
- Overall efficiency
  - Residual energy intake, …
- Efficiency to utilize feed stuff (soluble fiber)
  - Organic dry matter digestibility, dry matter digestibility, …
- Efficiency to produce milk
  - Energy conversion efficiency, …
- Ability to conceive and avoid metabolic disorders
  - Energy balance during early lactation, …
Dry Matter Intake (DMI)

Has central importance in genetic improvement of feed efficiency

- The most limiting factor in developing genetic evaluations for feed efficiency traits
- So far, comprehensive data from research and nucleus herds only
- Measuring DMI on farms
  - Direct measures (by weighing): still expensive
  - Indirect methods
    - DMI prediction based on different sources of information
    - Accuracy of prediction?
- DMI is not the same genetic trait along the course of lactation
  - This makes measuring even more challenging (a lot data needed)
Dry Matter Intake

Modelling of research farm data

• Genetic evaluation for feed intake (Berry et al., 2014)
  – Global Dry Matter Initiative
  – DMI data from 10 Holstein populations of 9 countries
  – ~7000 cows and 1700 heifers with DMI observations
  – Genomic prediction model for predicted DMI at lactation day 70
  – Lack of strong genetic links made analyses difficult

• Feed Utilization in Nordic Cattle (FUNC) project
  – DNK, FIN, NOR, SWE
  – DMI data from Holstein, Nordic Red and Jersey
  – ~2200 cows with ~120 000 weekly DMI observations
  – Analyses by multiple-trait models and random regression models
Dry Matter Intake

Heritability of DMI using FUNC data (Bingjie Li et al.; in prep.)
- Weekly DMI observations from DNK, FIN, SWE
- Holstein (HOL), Nordic Red Cattle (RDC), Jersey (JER)
Dry Matter Intake

Genetic correlation of DMI within 1\textsuperscript{st} parity (Negussie et al.; in prep.)
- Daily DMI observations from Luke’s research farm (Jokioinen)
- 459 Nordic Red Cattle cows with 39277 DMI observations
Dry Matter Intake

Indirect methods to predict DMI

- Prediction model for feed intake (Gruber et al., 2004)
  - 10 research partners from Austria, Germany, Switzerland
  - Large and comprehensive data (over 31 000 records) on feed intake, diet composition, production information, body weight, etc.
  - $R^2$ of cross validation for best model: 0.87

- Prediction of DMI from cow activity tags (Difford et al., 2015)
  - Danish research farm data, 460 Holstein and 230 Jersey cows (DMI, activity tags)
  - Genetic correlation between DMI and cow activity: 0.28-0.67

- Prediction of DMI from MIR spectral data (McParland et al., 2014)
  - 378 Irish Holstein cows with DMI and MIR data
  - Correlation between predicted and true energy intake: 0.64
Dry Matter Intake

Indirect methods to predict DMI

- Predicting DMI by a marker method (Ahvenjärvi et al., in prep.) Luke and Valio Ltd (part of Finnish Feed Efficiency project)
  - Faecal DM output determined using an external marker
  - Feed digestibility determined using an internal marker (iNDF)
  - \( \text{DMI kg/d} = \frac{\text{Faecal DM output}}{1 - \text{DM digestibility}} \)
  - Analyses of external marker and iNDF by NIRS scans of faeces
  - Physiological studies with fistulated cows
    - Recovery of polyethylene glycol (PEG) \( \sim 100\% \)
    - Diurnal variation of PEG in faeces was large
Which traits are best suitable for genetic improvement of feed efficiency?

- Feed gross energy: 100%
- Digestible energy
- Faecal energy: 26%
- Metabolizable energy
- Urine energy: 4%
- CH₄ energy: 7%
- Heat increment: 37%
- Net energy
- Gestation growth: 2%
- Milk: 24%
Residual energy intake = Energy intake (MJ) - Predicted energy requirement (MJ)

Energy intake
- Digestible energy
- Faecal energy
- Urine energy
- CH₄ energy
- Metabolizable energy
- Heat increment
- Net energy
- Milk

Gestation
Growth
Residual energy intake (REI)

- Has been studied most by dairy cattle breeders
  - better statistical properties than ratio traits
- But has also shortcomings
  - corrects for energy requirement for maintenance
  - does not give information for which pathway the cow is efficient
- Heritability estimates
  - 0.01 … 0.38 (Veerkamp et al., 1995, …, Vallimont et al., 2011)
- REI is difficult to model based on daily or weekly measurements
  (Spurlock et al. 2012; Liinamo et al., 2015)
Energy utilization of metabolizable energy (ME) in Holstein Friesian

- Estimation of genetic parameters (Sevón-Aimonen et al., in prep.)
  Luke, Finland & Agri-Food and Biosciences Institute (AFBI), UK

- **SOLID project Task 2.4 Calculating the efficiency of energy utilization for maintenance and lactation in conventional and adapted breeds**

- Data:
  - derived from respiration calorimeter measurements at AFBI in UK

- Aim:
  estimate heritability for
  - utilization of metabolizable energy (ME) for lactation ($k_l$)
  - ME requirement for maintenance ($ME_m$)
  - live weight (LWT, used as comparison trait)
Energy utilization of metabolizable energy (ME) in Holstein Friesian

Material and method

• 469 records from 161 cows
• 1297 animals in pedigree
• Model
  \[ y_{ijklm} = \text{Experiment}_i + \text{Forage proportion}_j + \text{Permanent cow effect}_k + \text{Additive animal effect}_m + e_{ijklm}, \]
  where, \( y_{ijklm} = \) observation (MEm, kl, LWT)
• Variance components estimated by AI-REML (DMU, Madsen et al.)

Results

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<th>Variable</th>
<th>( c^2 )</th>
<th>( c^2SE )</th>
<th>( h^2 )</th>
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Energy utilization of metabolizable energy (ME) in Holstein Friesian

Conclusions

• Number of animals was a restricting factor in variance component estimation
• No genetic variation was found for ME\textsubscript{m} and kl based on this data

One other attempt:

• Currently, at Luke, we try do partition genetic variance of metabolizable energy intake (part of Finnish Feed Efficiency project)
• Analyses of weekly energy intake data of Nordic Red Cattle cows from Luke’s research farms
  – Different repeatability and random regression models
  – Results indicate that there is genetic variation in ME\textsubscript{m} and kl
Breeding for Organic Matter Digestibility?

Background
• Near infrared reflectance spectroscopy (NIRS) has the potential to serve as a tool for cow-specific digestibility predictions

Aims
• study the variability in diet digestibility between cows
• assess accuracy of NIRS predictions
• develop a practically protocol for sampling faeces

Data
• Data from a trial with 44 cows (trail was connected to SOLID project)
• Faecal samples collected at 50, 150 and 250 DIM
  – Individual samples: 10 samples/lactation stage
• Faecal samples analysed by NIRS and AIA
Breeding for Organic Matter Digestibility?

**Traits**

\[ \text{DMD}_{\text{iNDF}} \]
- Diet dry matter digestibility based on iNDF concentration in feed and faecal spot samples

\[ \text{OMD}_{\text{faeces}} \]
- Organic matter digestibility analysed by NIRS from faeces

\[ \text{iNDF}_{\text{faeces}} \]
- iNDF concentration in faeces based on NIRS scans of faeces
  - Possible indicator trait for DMD?

Given cows of same contemporary groups consume same diet
Breeding for Organic Matter Digestibility?

**Results** (Mehtö et al., 2015)

**Cow-specific variability**
- was small (estimated SD for OMD$_{AIA}$ 12.3 g/kg and average 724 g/kg),

**NIRS**
- $(R^2_{\text{iNDF}_{\text{faeces}}}=0.85; R^2_{\text{OMD}}=0.69)$ larger reference data should improve accuracy

**Repeatability estimates**
- 0.22 (OMD$_{\text{faeces}}$) – 0.65 (OMD$_{AIA}$)
- indicated that we may find also genetic variation

$i\text{NDF}_{\text{faeces}}$ has potential to be used as indicator trait
- relatively high repeatability estimates

**Developed sampling protocol**
- composite samples from 2 - 3 daily samples from cows at least 1 month milking
- collection from all cows in the herd every 3 or 4 months

**Continuation**
- collection of samples continues for estimation of genetic variances
Energy status during early stage of lactation

Breeding for feed efficiency will require to have a reliable and inexpensive indicator of energy status

- Biomarkers like NEFA are too expensive
- Alternatives
  - BHB
  - Fatty acid profile of milk

Analyses of relationship between plasma NEFA concentrations and milk fatty acid contents (Finnish Feed Efficiency project)

- NEFA reference data (so far n>600)
  - Blood plasma samples and milk samples collected for two years
  - NEFA concentration and fatty acid profiles
Energy status during early stage of lactation

First preliminary results

• Predicting negative energy status by multiple linear regressions (Mäntysaari et al., 2015)
  – correlation between predicted and observed NEFA: 0.77
• correlation between plasma NEFA and milk fatty acids & fat/protein ratio

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Planned: Predicting negative energy status from MIR spectra
Some final considerations

• Large evidence that there is genetic variation in the ability of a cow to utilize feed efficiently
• We need reliable measurements or predictors for dry matter intake
• We need a good predictor for energy status
• A group of traits is needed to describe feed efficiency in dairy cows
• Genomic predictions will play an important role in genetic evaluations for feed efficiency
• Still a lot work needed to establish reliable genetic evaluations for feed efficiency
• However, my guess: we will see first pilot feed efficiency genetic evaluations soon
THANK YOU