Feed efficiency and Genetics

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“Organic and low-input dairying –
an option to Northern European Dairy Sector?”
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Luke
NATURAL RESOURCES INSTITUTE FINLAND

Outline

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

Acknowledgement

Luke

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Bingjie Li

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 CO_2 eq.
    - Western European countries: 2 CO_2 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

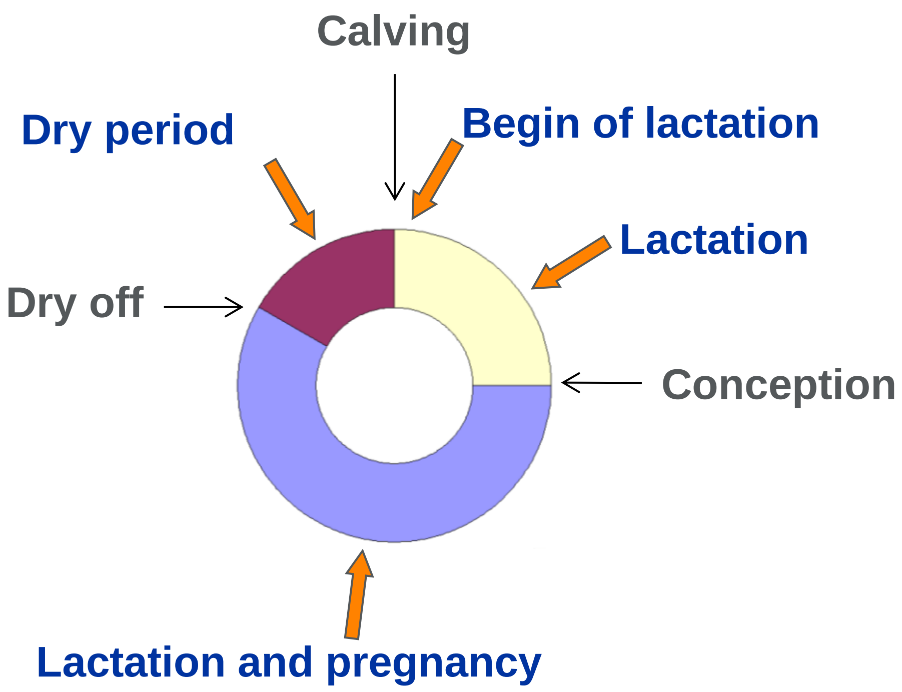
  kg ECM : kg dry matter intake
- 1990 ~1.4 : 1
- 2010 ~1.5 : 1 (~7% progress during last 20 years)

  but progress slows down

  if milk production increases another 1000kg → progress only 1.3%

Challenges in breeding for feed efficiency

Cyclicality of milk production



- 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

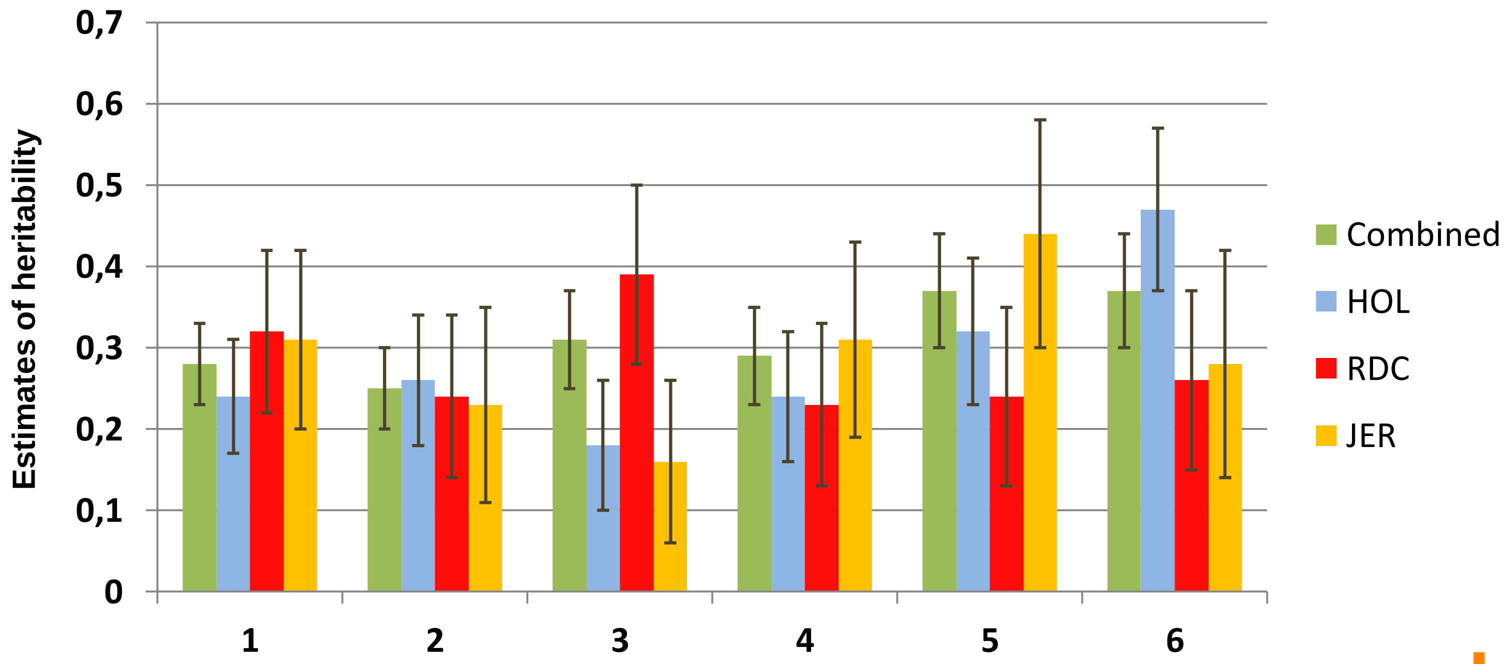
Modelling of research farm data

- 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.)

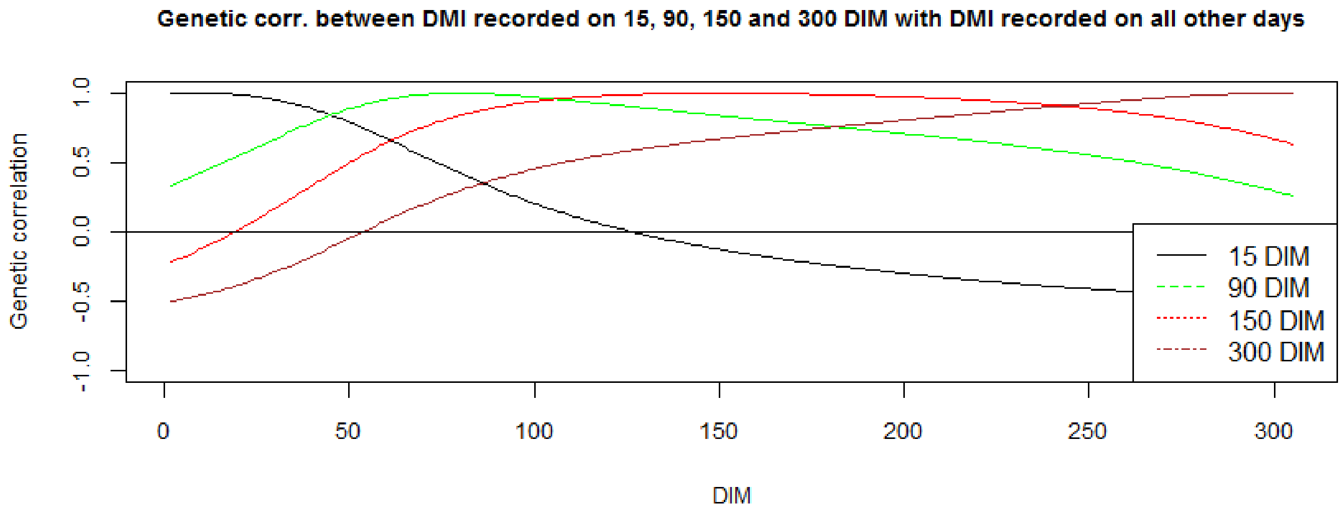
- Weekly DMI observations from DNK, FIN, SWE
- Holstein (HOL), Nordic Red Cattle (RDC) Jersey (JER)



Dry Matter Intake

Genetic correlation of DMI within 1st parity (Negussie et al.; in prep.)

- Daily DMI observations from Luke’s research farm (Jokioinen)
- 459 Nordic Red Cattle cows with 39277 DMI observations



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Dry Matter Intake

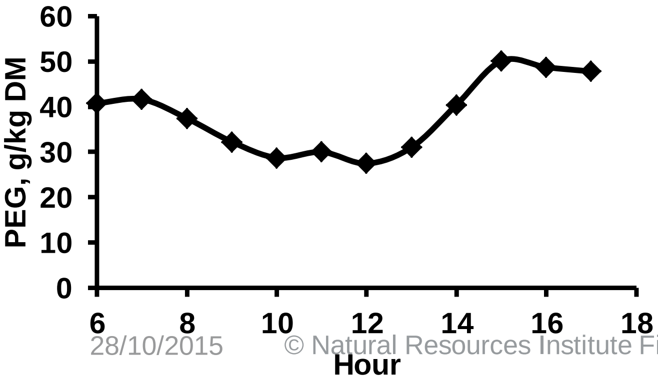
Indirect methods to predict DMI

- 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

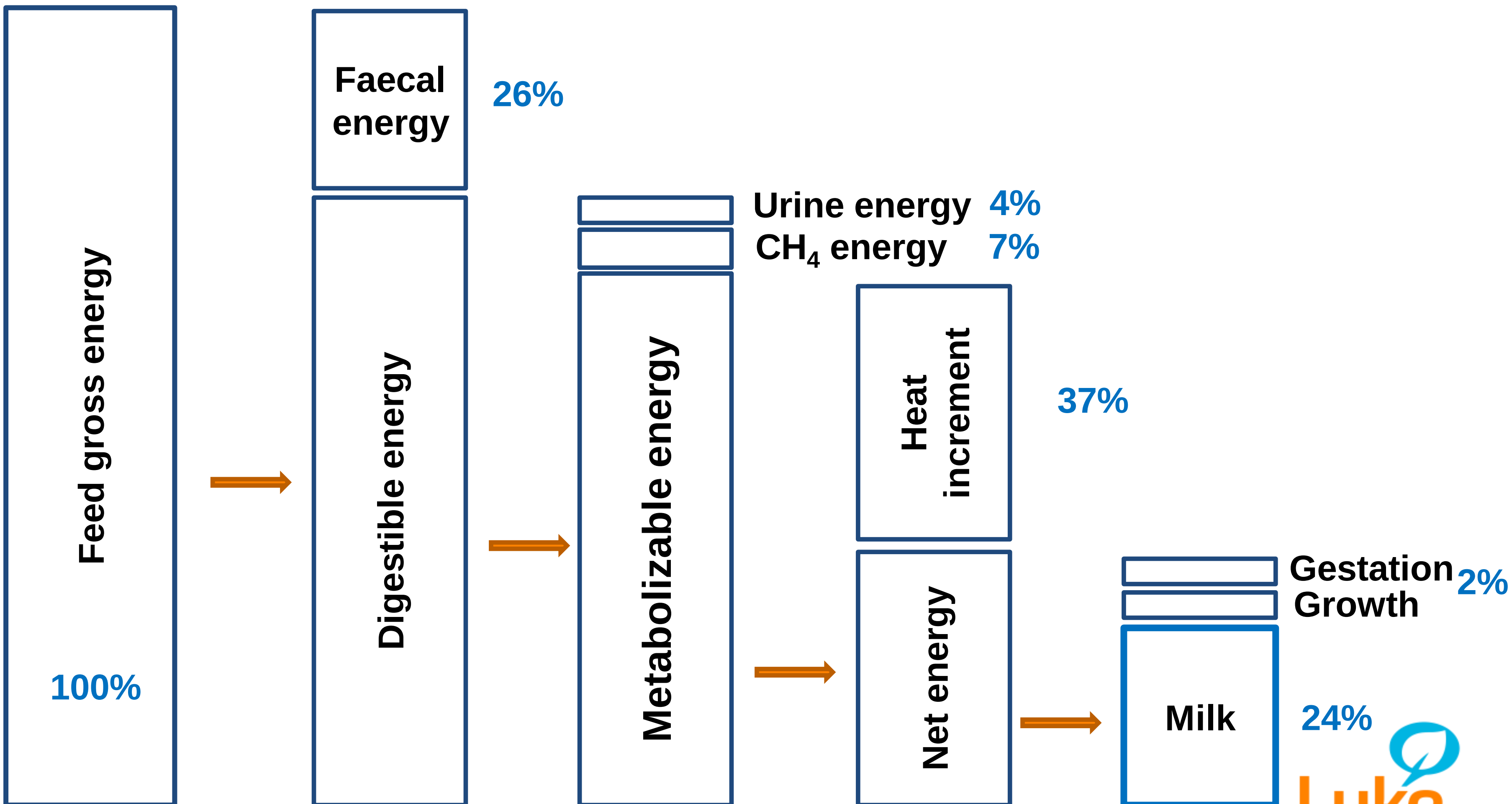
Dry Matter Intake

Indirect methods to predict DMI

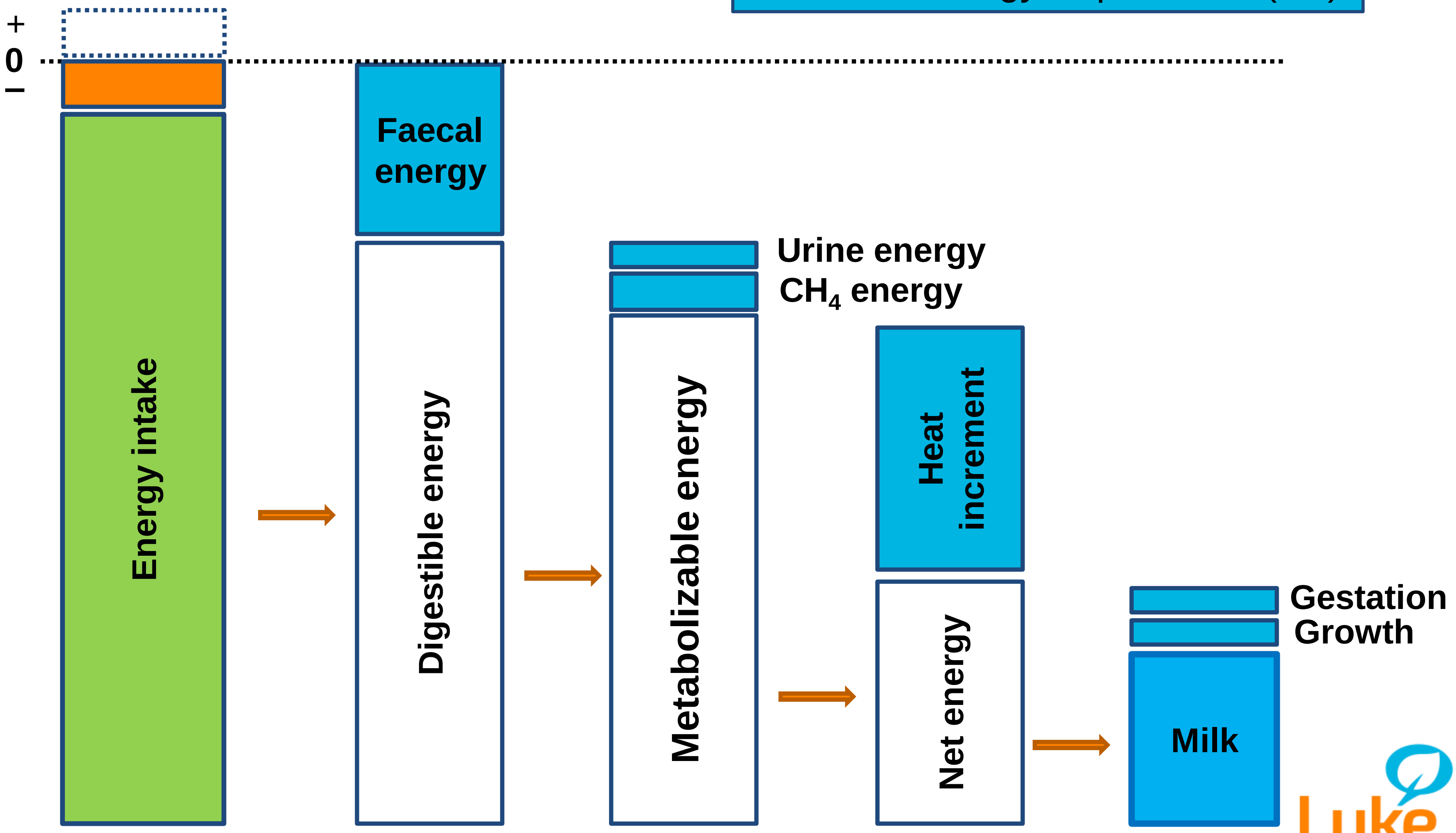
- Predicting DMI by a marker method (Ahvenjärvi et al., in prep.) Luke and Valio Ltd (part of Finnish Feed Efficiency project)
  - Faecal DM output determined using an external marker
  - Feed digestibility determined using an internal marker (iNDF)
  - DMI kg/d = Faecal DM output / (1 – DM digestibility)
  - Analyses of external marker and iNDF by NIRS scans of faeces
  - Physiological studies with fistulated cows
    - Recovery of polyethylene glycol (PEG) ~100%
    - Diurnal variation of PEG in faeces was large



Which traits are best suitable for genetic improvement of feed efficiency?



Residual energy intake = Energy intake (MJ) − Predicted energy requirement (MJ)



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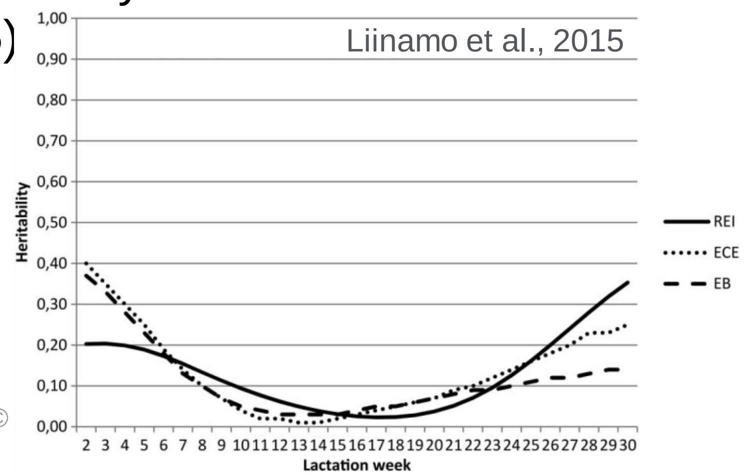
Residual energy intake (REI)

- 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)

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Energy utilization of metabolizable energy (ME) in Holstein Friesian

Material and method

- 469 records from 161 cows
- 1297 animals in pedigree
- Model

  y_{ijklm} = $Experiment_i$ + Forage $proportion_j$ + Permanent cow $effect_k$ + Additive animal $effect_m$ + e_{ijklm},

  where, y_{ijklm} = observation (MEm, kl, LWT)
- Variance components estimated by AI-REML (DMU, Madsen et al.)

Results

Variable	c^2	c^2SE	h^2	h^2SE	V_P
MEm	0.00	0.00	0.00	0.09	0.01
kl	0.00	0.00	0.00	0.10	0.00
LWT	0.26	0.23	**0.50**	0.23	3695.24

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 MEm 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 MEm 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

DMD_{iNDF}

– Diet dry matter digestibility based on iNDF concentration in feed and faecal spot samples

OMD_{faeces}

– Organic matter digestibility analysed by NIRS from faeces

$iNDF_{faeces}$

– 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 (Mehtiö et al., 2015)

Cow-specific variability

- was small (estimated SD for OMD_{AIA} 12.3 g/kg and average 724 g/kg),

NIRS

- ($R^2_{iNDFfaeces}$=0.85; R^2_{OMD}=0.69) larger reference data should improve accuracy

Repeatability estimates

- 0.22 (OMD_{faeces}) – 0.65 (OMD_{AIA})
- indicated that we may find also genetic variation

$iNDF_{faeces}$ 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

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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

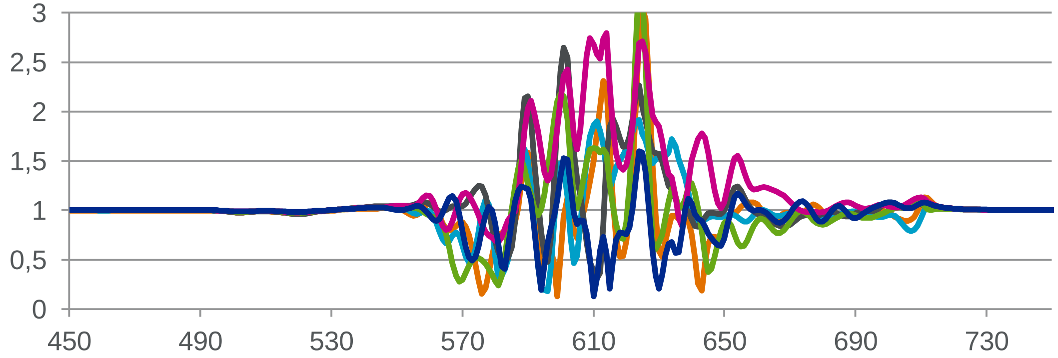
Energy status during early stage of lactation

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

Fat/prot	C16_1c	C18_0	C18_1cis9	MONO	LCFA	totC18_1
0.24	0.49	0.42	0.58	0.55	0.53	0.57

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