Feed Efficiency

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Outline

- Importance of feed efficiency in dairy cows
- Challenges in breeding for feed efficiency
- Feed efficiency research internationally
- Developing feed efficiency traits
- How to measure feed intake?
- Towards genetic evaluations for feed efficiency
- Conclusion

Importance of feed efficiency in dairy cows

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Forage-based livestock production

- About 800 million people suffering from chronic undernourishment (FAO 2016)
- Global demand for food is expected to increases between 60-100% by 2050 (Valin et al., 2014)
- **2/3 of the world's agricultural land can only be utilized through ruminants**

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Forage-based livestock production

World's milk production

- About 700 million tons (FAO 2012)
- Annual growth 1.4% until 2030
- Largest increase in developing countries

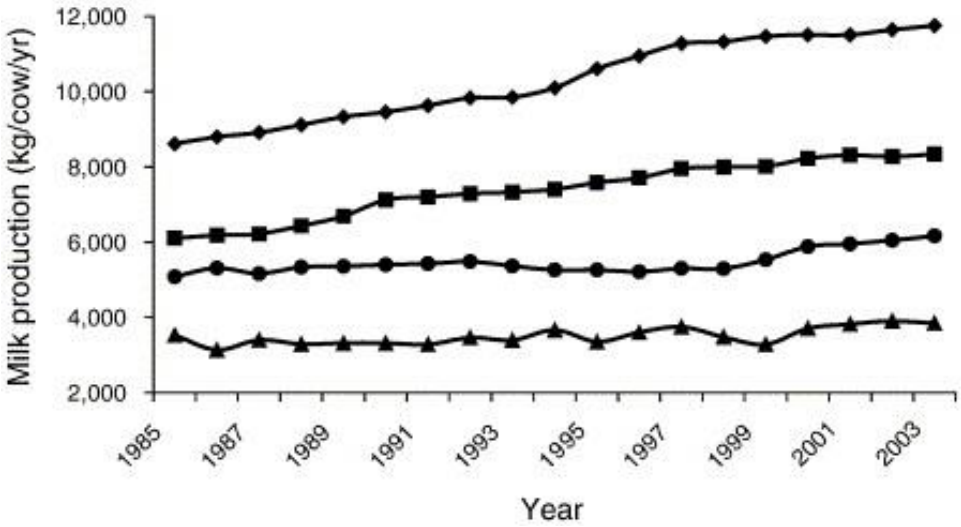


Fig. 1. Trends in milk production per cow for The Netherlands (■), United States (♦), New Zealand (▲) and Ireland (●) from 1985 to 2003 (NRS, 2003, USDA, 2003, LIC, 2003 and ICBF, 2003).

Forage-based livestock production in the North

- Forage-based livestock production is the backbone of agriculture in the North
- Finnish dairy sector brought 1.55 billion € income to farmers in 2013
- In Finland 34% of cultivated land is used for forage production
- About 7.5 million tons of silage are produced yearly in Finland

Feed costs

- Feed accounts for about 50% of costs of milk production
- However, there is large variation across farms

- Feed cost comparison (Peltola et al., 2010; University of Helsinki)
  - 7 farms in FIN, SWE, DNK, POL & DEU

Location of farm	Number of cows	Feed cost / 100 kg milk (ECM)
Päijät-Häme	44	31 €
Keski-Pohjanmaa	60	25 €
Skåne, SWE	50	17 €
Schleswig-Holstein, DEU	80	19 €

Economic importance of feed efficiency

Impact of improving feed efficiency by 5%?

- Simulation study by Prof. T. Sipiläinen & P. Akkanen, (University of Helsinki, part of Finnish Feed Efficiency project, 2013-2017)
- Study is based on Finnish market prices and production situation 2015
  - 250 000 cows
  - 9546 kg ECM
  - Milk price 0.35€ / kg ECM
  - Concentrate price 0.24 € / kg DM
  - Optimal concentrate intensity 11.5 kg DM when silage intake is 12 kg DM
- 3 scenarios:

Scenario	Total surplus
Same output with less cows	23.2 million €
Same output with less concentrate	27.7 million €
Increased output with same number of cows	38.3 million €

Environmental importance

Greenhouse gas emission

Greenhouse gas emission / kg milk in CO_2 equivalents (FAO, 2010)

- Sub-Saharan Africa: 8 CO_2 eq. / kg milk
- Industrialized world: 2 CO_2 eq. / kg milk

- 5% improvement of feed efficiency reduces CH_4 exhalation by ~11lt /cow /day
  (Simulation study by Prof. T. Sipilänen & P. Akkanen)

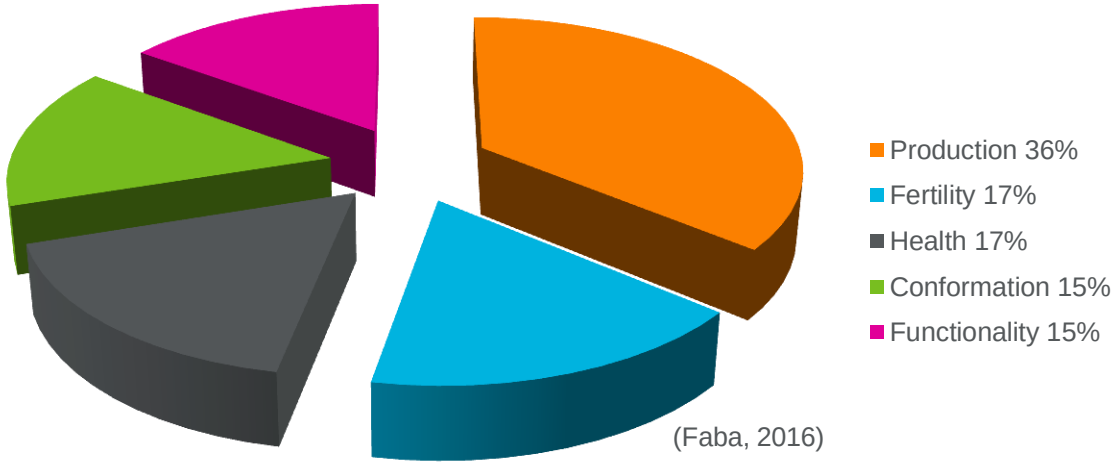
Carbon sequestration

- ~25% of world's milk is produced from grassland

Genetic improvement of Nordic dairy cattle

Nordic total merit index NTM

- Includes 15 traits (or trait groups)
- Weights of main trait groups for Nordic Red Cattle



(Faba, 2016)

Feed efficiency is improved only indirectly (positive correlation with production)

Breeding for feed efficiency

- Genetic improvement of feed conversion has significantly contributed to feed efficiency in various livestock species

Feed conversion efficiency in:	Feed (kg) : Meat (kg)	Achieved Progress
Broiler	<2:1	~250% during last 50 years
Pig	<3:1	~100% during last 50 years
Beef cattle	<10:1	~6% during last 20 years

- **In dairy cows:** genetic improvement indirectly only

Based on Luke data:	1 kg ECM : DMI (kg)	Achieved Progress
1990	~1.4 : 1	
2010	~1.5 : 1	~7% during last 20 years

- However, progress in correlated response is slowing down
- Additional 1000 kg increase in milk production improves feed efficiency only by ~1.3% (P. Huhtanen)

Challenges in breeding for feed efficiency

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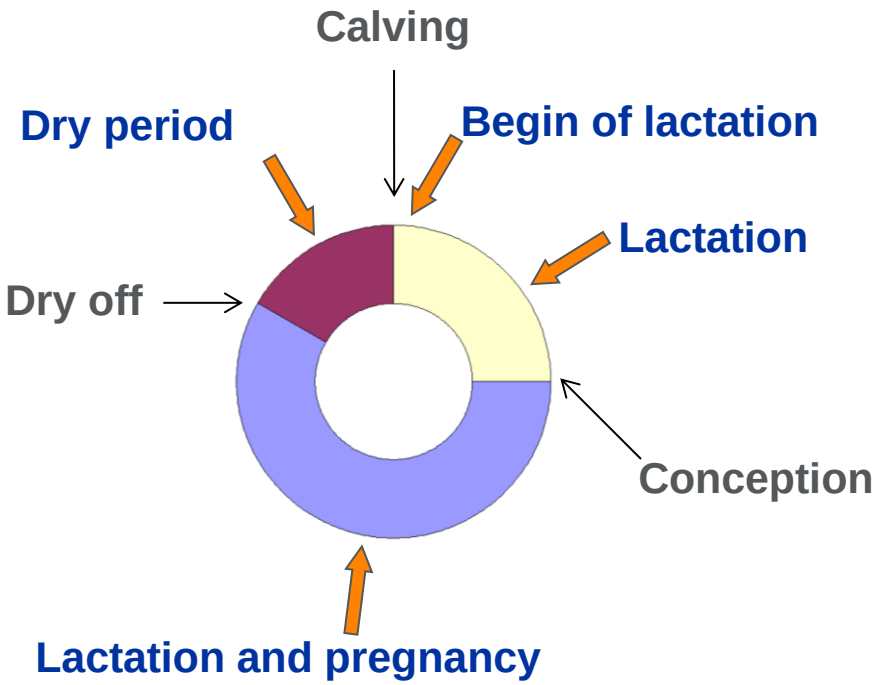
Cyclicality of milk production

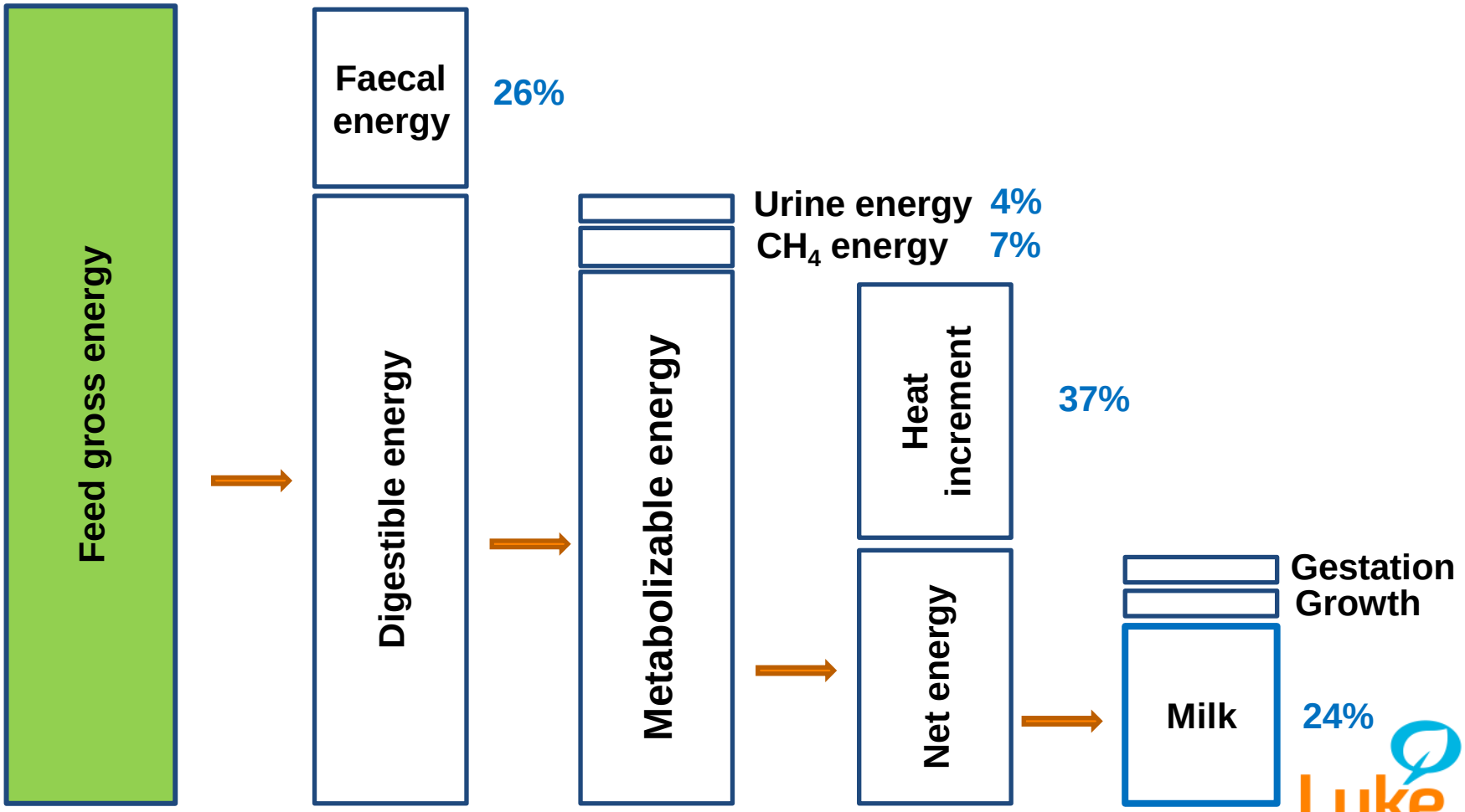


Biological realities

- Lifecycles of a cow (lactations)
- Differences in lactation stages
- Different products (milk, calf, growth)
- Retention & use of tissue energy

Cow's energy use

(Based on calorimetric research, Xue et al., 2011)



Requirements for building genetic evaluation

- Definition of feed efficiency
- A breeding goal
- Traits which describe the breeding goal
  → Several traits will be needed to describe feed efficiency in dairy cattle
- Measurements for the traits
  → when to measure and from which animals?
  → Is there an appropriate measuring method available?
- Continues measuring of the traits from a sufficient large number of cows

Feed efficiency research internationally

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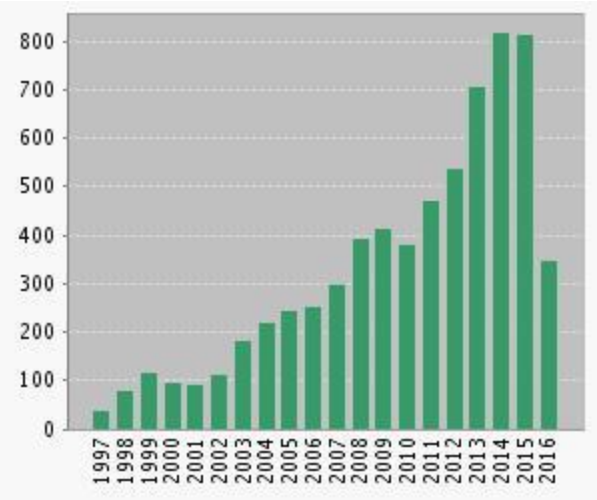
Progress in research

- First studies in the early 1990's (NLD, DNK, CAN, GBR, USA)
- During last years many research project on feed efficiency initiated worldwide



Citations of feed efficiency publications
During last 20 years (Web of Sciences)

- AI industry's demand for feed efficiency breeding values increases
  - 2015: US Holstein has added *Extra Feed & Maintenance Costs* to *Total Performance Index*. (based on production & body weight)
  - 2015: *Feed Saved* breedings value for Australian dairy cattle. (based on RFI & body weight)
  - 2016: Dry matter intake breeding values for Holstein in The Netherlands

Finnish Feed Efficiency Project

Knowledge and tools for future genetic evaluation of feed efficiency in dairy cattle

- 2013 - 2017
- € 2.5 million
- Research partners:

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UNIVERSITY OF HELSINKI FACULTY OF AGRICULTURE AND FORESTRY

Valio

- Funding partners:

mmm.fi ruokaa ja luonnonvaroja

Valio

faba

RAISIOagro

VIKINGGENETICS

SUOMEN NAUDANJALOSTUSSÄÄTIÖ

- Nordic cooperation (FUNC):

AARHUS UNIVERSITY

NMBU Norwegian University of Life Sciences

SLU

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Finnish Feed Efficiency Project

Aims

- New measuring techniques & indicator traits
- Collection of comprehensive feed efficiency data
- Developing feed efficiency traits

Research group

- **Luke:** M. Lidauer, M. Rinne, S. Ahvenjärvi, P. Mäntysaari, A. Sairanen, A. Palmio, T. Mehtiö, E. Negussie, A.E. Liinamo, K. Shingfield, E. Mäntysaari
- **University of Helsinki:** T. Kokkonen, J. Juga, T. Sipiläinen, P. Hietala, P. Akkanen
- **Valio:** L. Nyholm

Research cooperation with Nordic partners (FUNC)

DNK

Aarhus University
P. Løvendahl
P. Lund
M. Weisbjerg
D. Olijhoek
J. Lassen
M. Kargo

University of Copenhagen
H. Kadarmideen
S. Salleh

NOR

Norwegian University of Life Sciences
T. Meuwissen
E. Prestløkken
S. Wallén
G. Klemetsdal
O.M. Harstad

SWE

SLU Uppsala
B. Berglund
J. Bertilsson
B. Li
T. Eriksson
F. Fikse

SLU-Umeå
P. Huhtanen

FUNC coordinator
J. Jensen

Developing feed efficiency traits

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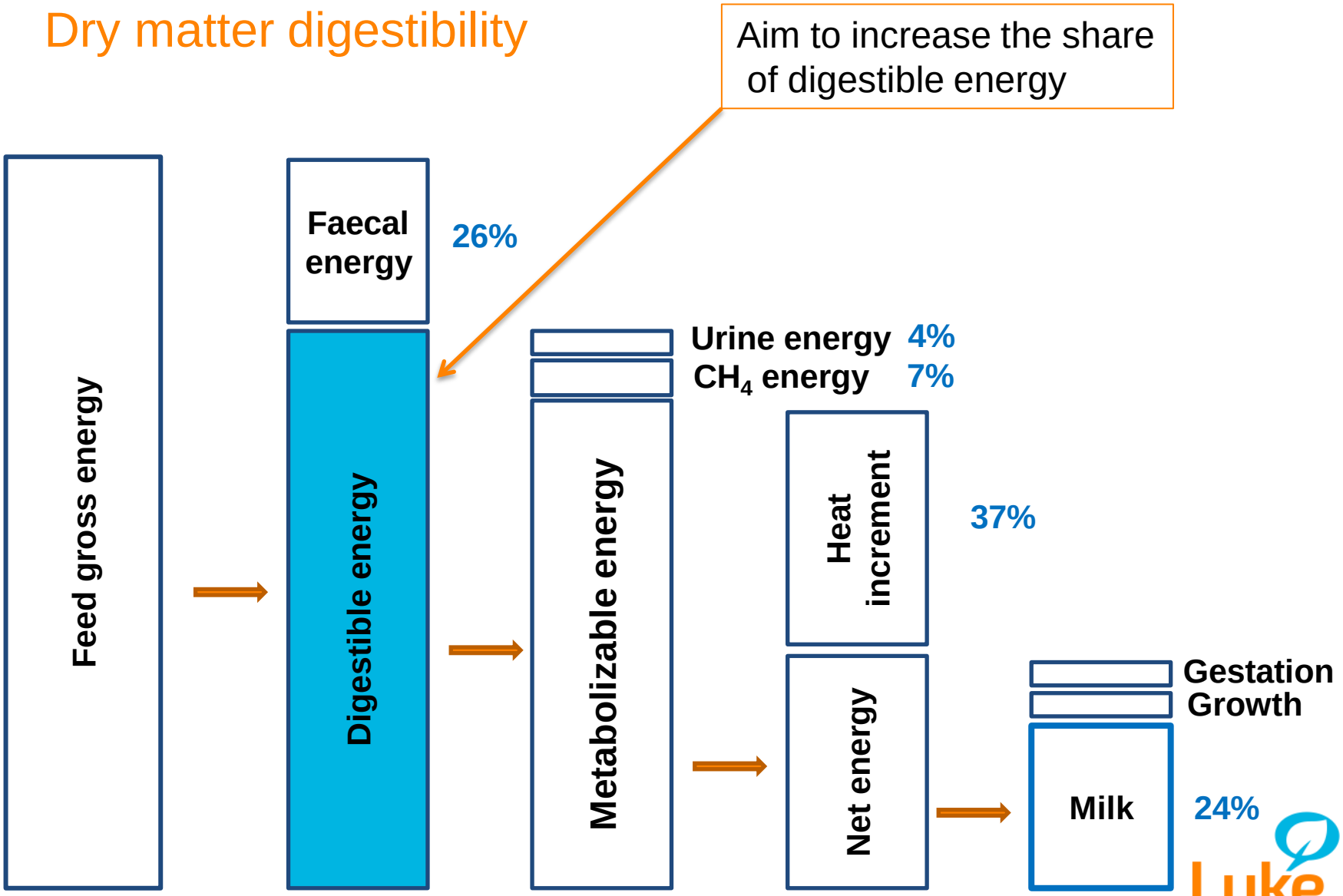
Dry matter digestibility

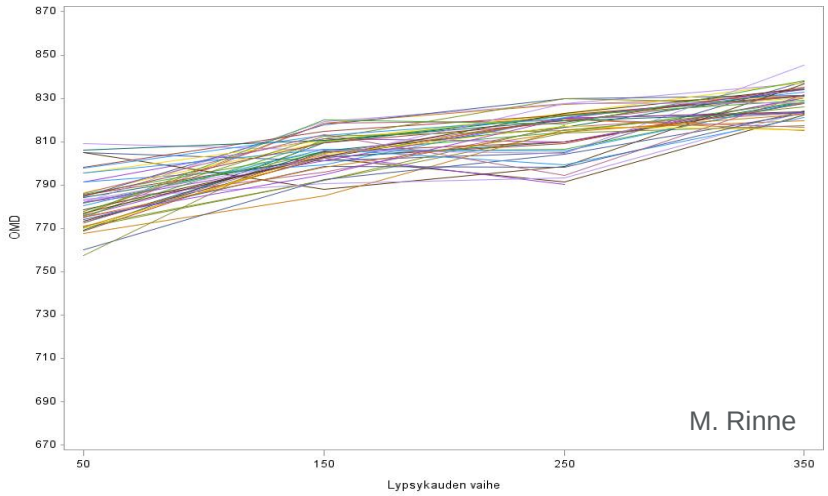


Dry matter digestibility

Improves utilization of fibre and overall efficiency

Questions to be answered:

- How can it be measured?
- How large variability we find across cows?
- Is it heritable?



Research farm trial with 44 cows

- Cow-specific digestibility measurements based on predictions of faeces' iNDF% by near-infrared reflectance spectroscopy are possible
- Digestibility(%) of lowest and highest quartile of cows was 69.7% and 75.1%
- We found small phenotypic SD:1.2%

Within lactation variation in digestibility measured for 44 cows

Dry matter digestibility

- However, reasonable repeatability estimates for iNDF% in faeces: 0.32 to 0.42

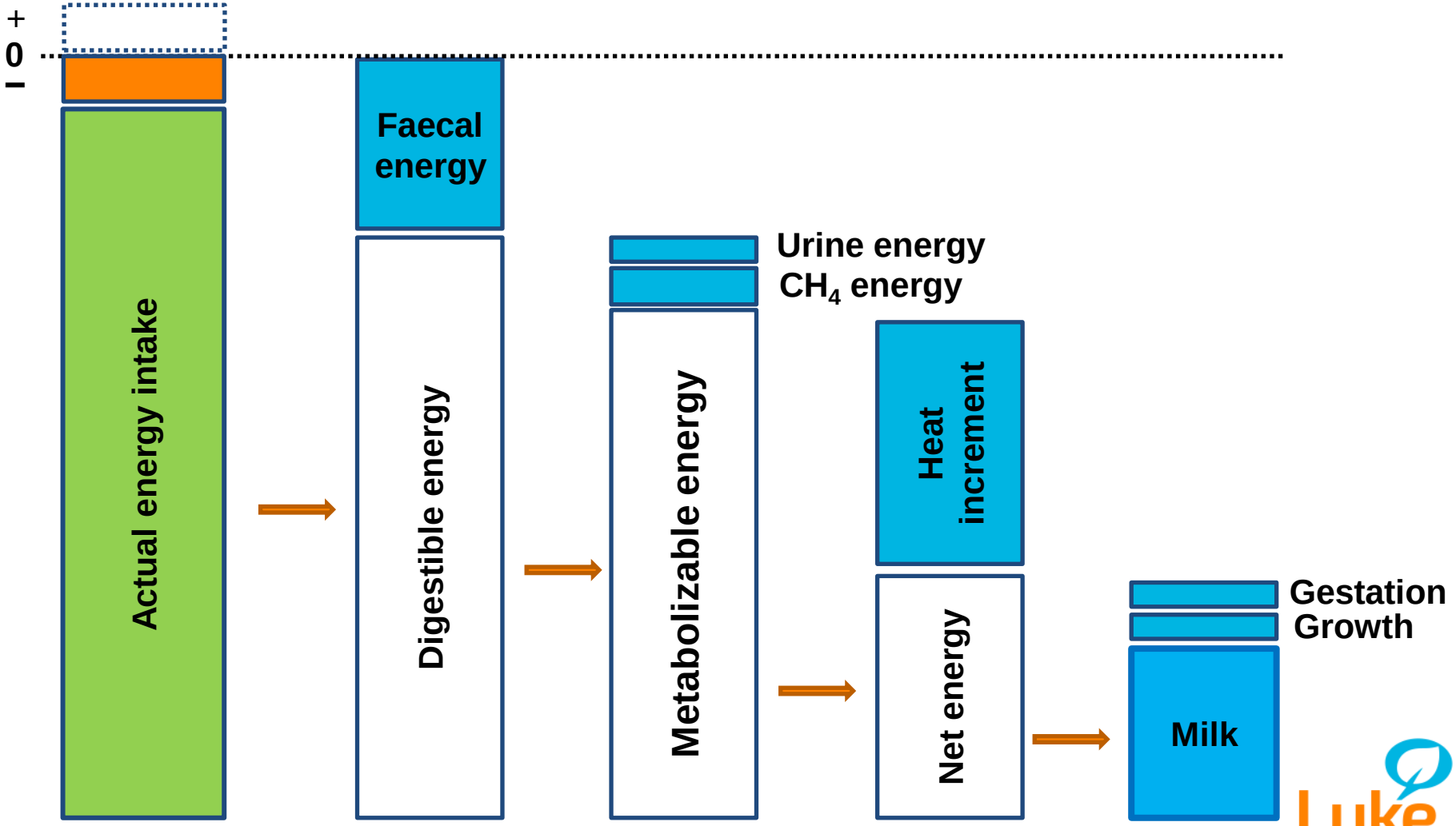
Collection of digestibility measurements

- Ongoing collection of faecal samples from Minkiö, Maaninka and Viikki research farms
- Same collection protocol also applied in Norway
- So far, digestibility estimates from ~200 cows

Aim

- Estimation of heritability for:
  - dry matter digestibility
  - iNDF% in faeces

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



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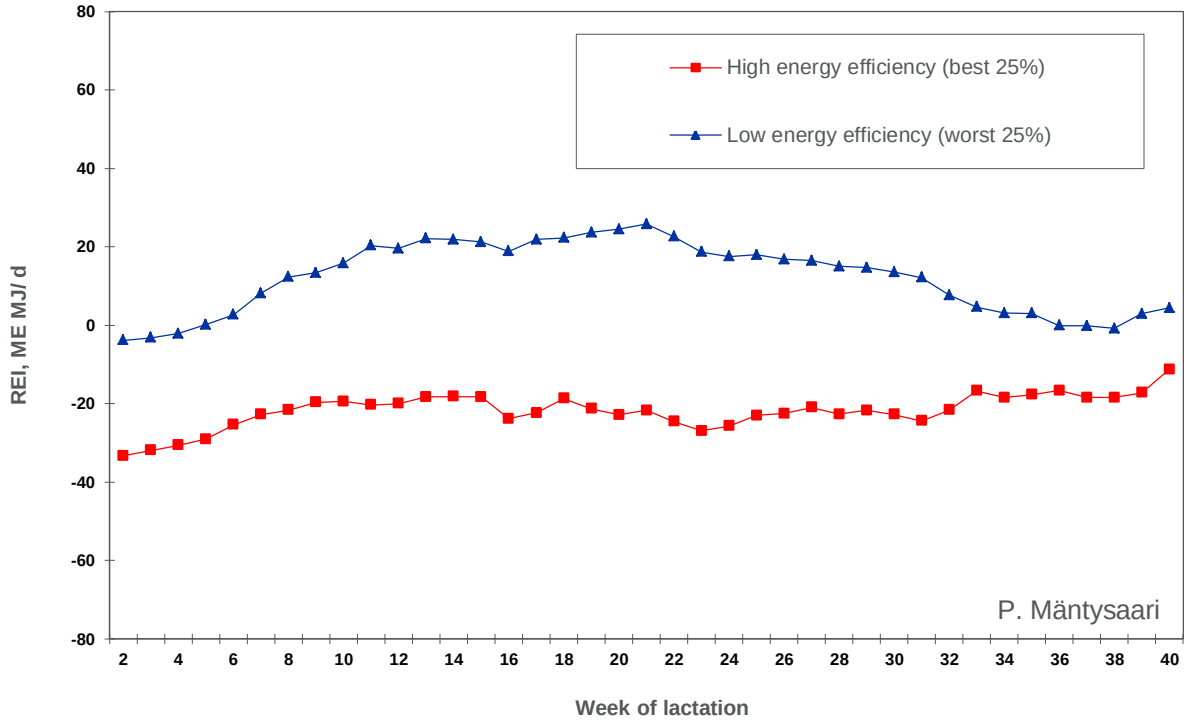
Residual energy intake

Describes the general ability of a cow to use the energy of the feed efficiently

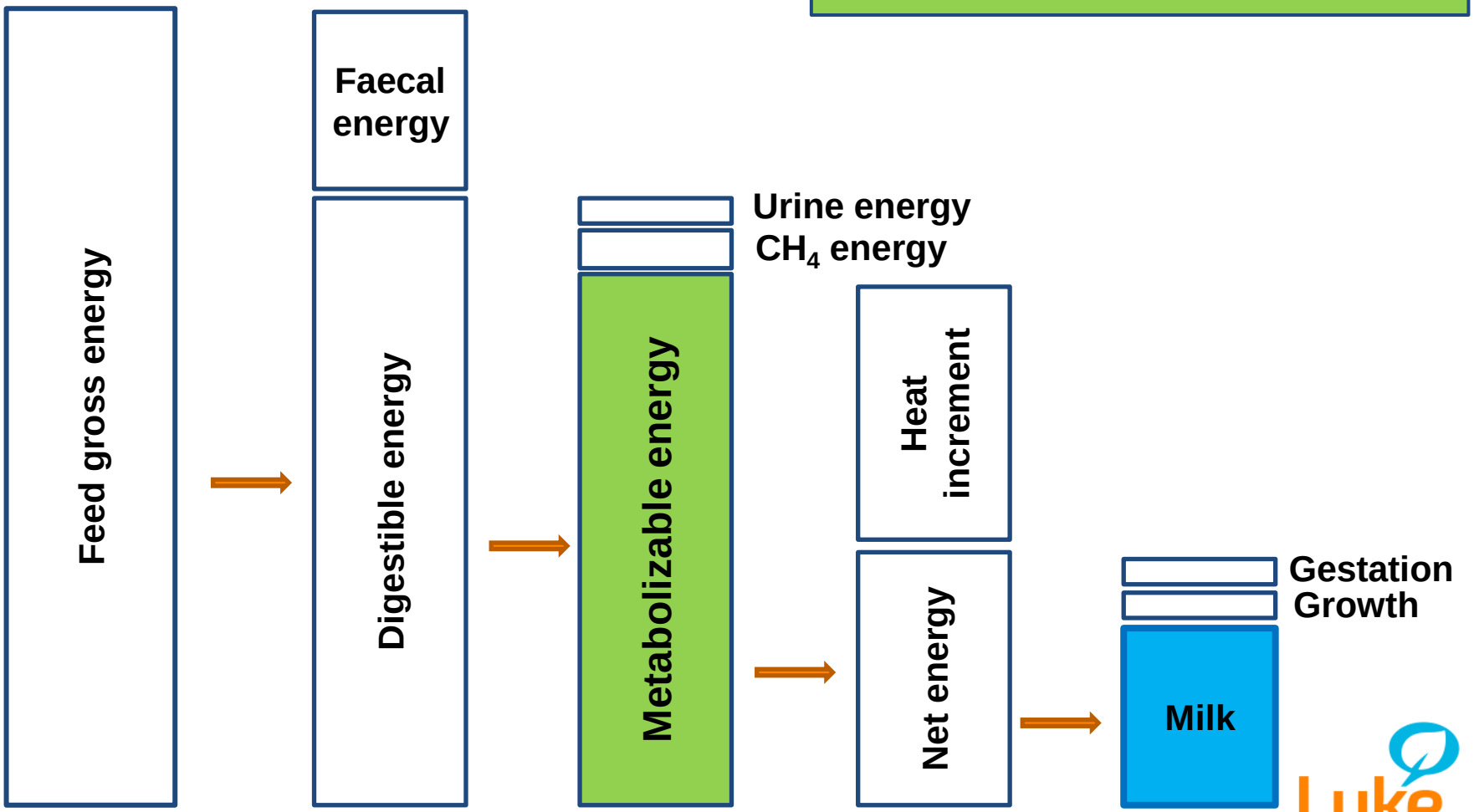
Phenotypic difference in residual feed intake in Nordic Red cows at Minkö research farm



Residual energy intake

- Most studied trait
- Different alternatives for modelling this trait have been suggested
- We suggest an alternative where efficiency of metabolizable energy use is modelled directly: “Metabolizable Energy Efficiency”
  - We found a heritability of ~0.25
- However:
  - all these alternatives require to measure feed intake of the cows (currently the most limiting factor)
  - it does not account for lower maintenance requirements due to smaller body size

Energy conversion efficiency = $\frac{\text{Energy corrected milk (kg)}}{\text{Metabolizable energy intake MJ}}$



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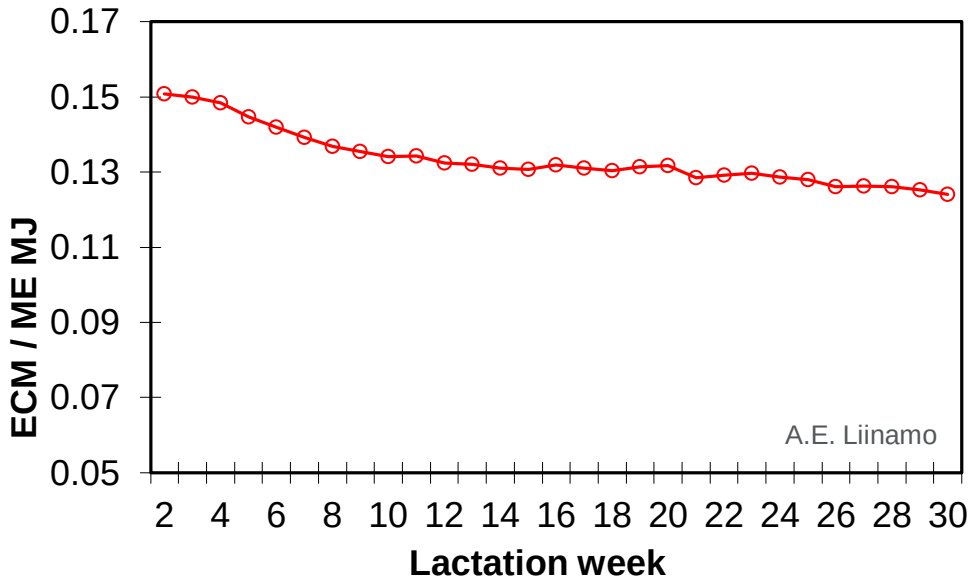
Energy conversion efficiency

Describes the cows efficiency to produce milk

Energy conversion efficiency in Nordic Red cows at Minkö research farm



- We found a heritability of ~0.16
- However, the trait is highly negative correlated with energy balance
  → therefore, a trait for energy status would need to be included

Indicator traits for energy status

Analyses of relationship between plasma NEFA concentrations and milk fatty acid contents

- We collected milk and blood samples from ~150 cows
    - lactation wk 2, 3 (2 samples/wk), negative energy balance -> high NEFA
    - lactation wk 20 (1 sample), positive energy balance -> low NEFA
- Laboratory analyses are currently finalized

Some first preliminary results:

- Predicting negative energy status by multiple linear regressions
  – correlation between predicted and observed NEFA: 0.77
    (higher than correlation between NEFA and calculated energy status)
- Moderate to strong positive correlations between plasma NEFA and milk long chain fatty acid concentrations

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

How to measure feed intake?

Feed intake measured by weighing

- Most accurate
- Expensive (usually at research farms)

Collected data at research farms:

	Daily observations	Weekly observations	Cows	Breeds
Finland	>75000	>14 000	> 600	RDC
All Nordic countries		> 120 000	> 2400	RDC, HOL, JER

Feed intake predicted by a marker method

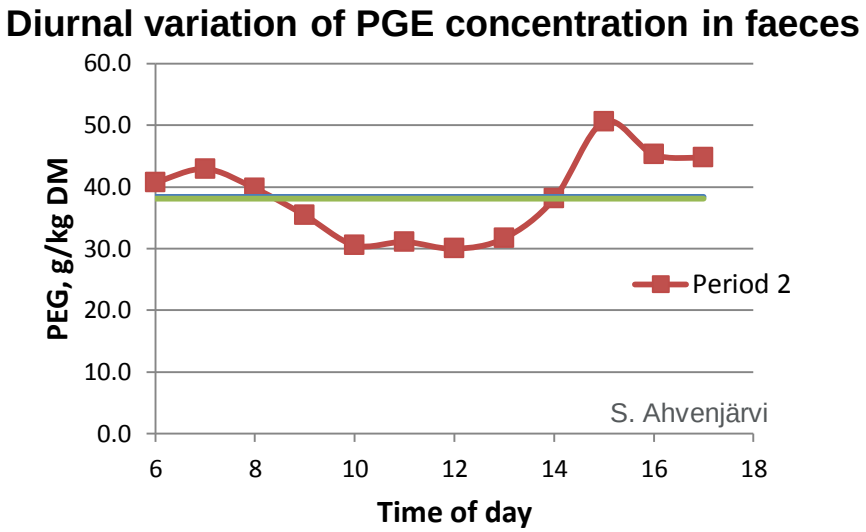
Idea

- If there exists an inert marker compound in the feed,
- and we can feed a known amount of another inert marker compound,
- and we can measure both marker concentrations in the faeces

  → then we can predict a cow's feed intake
- Method based on alkanes
  - used at Irish research farms since many years
  - not suitable for Nordic countries
- Luke and Valio are currently testing a method based on NIRS analyses of faeces samples
  - iNDF is used as internal marker
  - we identified three external markers suitable for closer testing
  - for two markers we have carried out test trials on 40 research farm cows, and faecal samples are currently processed

Feed intake predicted by a marker method

Challenge: to reach steady-state for marker concentration in faeces



Towards genetic evaluations for feed efficiency

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Answers we can give so far

- Feed efficiency is of economic and environmental importance
- Feed efficiency in dairy cows is complex and cannot be described by one trait
- Feed efficiency traits are reasonable heritable and genetic improvement is possible
- Energy status at onset of lactation should be included when breeding for feed efficiency
- Most feed efficiency traits require to measure feed intake

  → a low cost feed intake measurement method would be very beneficial

Answers we still want to address in the current Finnish Feed Efficiency project

- Heritability of dry matter digestibility
- Accuracy of a dry matter intake measurement method based on predictions from near-infrared reflectance spectroscopy scans of faeces samples
- Develop an (indicator) trait for energy status
- Currently most suitable traits for building a genetic evaluation

Building genetic evaluations

Optimal utilization of all useful information

- Single-step genomic prediction which includes:
  - feed efficiency measurements from research farms
  - feed efficiency measurements from commercial farms

Optimal design of data collection

- For instance: How many times feed intake should be measured on a farm?

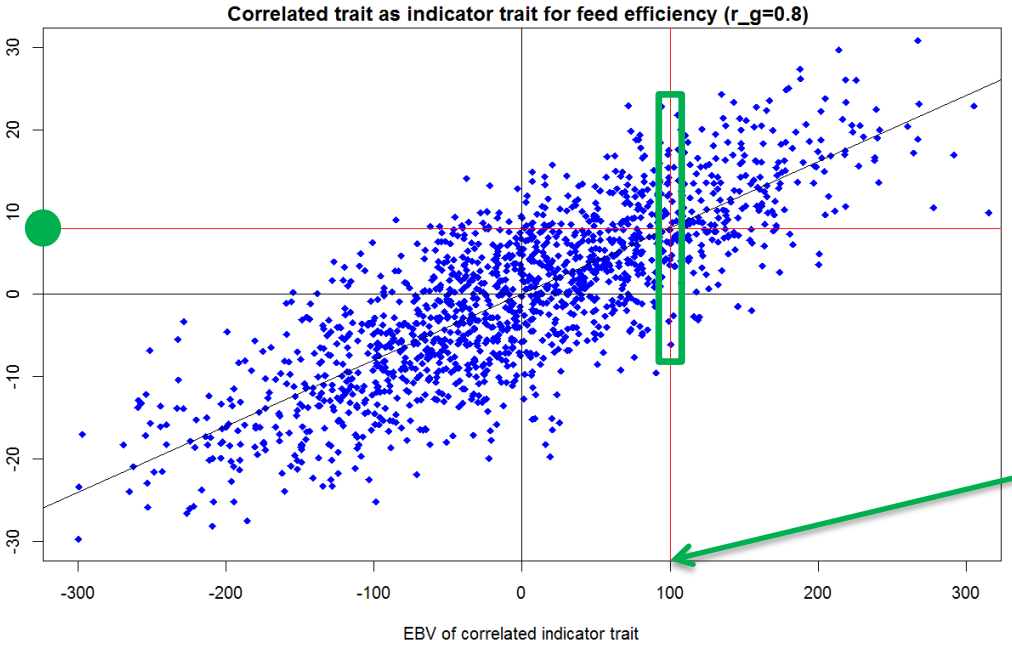
Results from an ongoing simulation study at Luke (E. Negussie et al.)

Recording of feed intake on commercial farms	Cow EBV reliability $(r_{TBV,EBV})^2$	Required number of daughters for a sire EBV reliability of 0.8	Obs. /cow	DMI obs. /sire
monthly	0.24	63	9.5	599
every 2nd month	0.20	76	4.4	334
every 3rd month	0.15	103	3.1	319
every 4th month	0.13	119	2.3	274

Building genetic evaluations

Correlated traits as indicators for feed efficiency

- Many research activities on finding suitable and cheap indicator traits
  - Cow activity tags, predictions based on MIR milk spectra, …
- Conventional traits
  - Body weight, yield traits, conformation traits
- **Problem:** give little information about the most interesting variation unless correlation to the feed efficiency trait is very high (>0.95)



all animals with EBV +100 equal to a FE EBV of +8 even their true BVs for FE vary between -8 and +20

Conclusion

The knowhow we generated and obtained in the current Nordic feed efficiency projects shall allow us to establish genetic evaluations for feed efficiency in the very near future

Thank you!