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 (Mehtiö et al. 2018, JDS, accepted)
- We found:

Energy Conversion Efficiency (ECE; $= \frac{ECM}{MEI}$) &

Maintenance Requirement Ratio (MRR; $= \frac{c_{ME} MBW}{ECM}$)

are genetically highly correlated ($r_g > -0.8$)

ECM = energy corrected milk
MEI = metabolizable energy intake
MBW = metabolic body weight

- Could MRR be used for selection?

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)

$$y_{t:ijk} = \sum_{q=1}^{2} b_{t:q}\, age_i^q + HCYS_{t:i} + a_{t:k} + e_{t:ijk}$$

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

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

- and is approximately

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

where $\mu_{ECM} = c_M g_M + c_P g_P + c_F g_F$

Selection index to assess net merit

- Maximizing net merit $H = \boldsymbol{g}'\boldsymbol{a}$

  where genetic values $\boldsymbol{g}' = [g_M\ g_P\ g_F\ g_{MBW}\ g_{MEI}\ g_{ECM}\ g_{REI}\ g_{MRR}]$

  and economic values $\boldsymbol{a}' = [a_M\ a_P\ a_F\ 0\ a_{MEI}\ 0\ 0\ 0]$.

  (a_M= 0.0013€, a_P = 4.56€, a_F = 1.23€, a_{MEI} = −0.0164€)

- Index coefficients $\boldsymbol{b}_i = \boldsymbol{P}^{-1}_{n_i n_i}\boldsymbol{G}_{n_i \times m}\boldsymbol{V}_i\boldsymbol{a}_i$

  where for ECE and MRR $\boldsymbol{V}_{m\times m}$ is a transformation matrix (Lin & Aggrey, 2013) and otherwise identity matrix

- Genetic response $\Delta_i = \boldsymbol{G}\boldsymbol{b}_{8i} \Big/ \sqrt{\boldsymbol{b}_i'\boldsymbol{P}_i\boldsymbol{b}_i}$

- Net merit for index $\Delta H_i = \boldsymbol{a}'\Delta_i$

Selection indices compared

Index		Index traits
C	current index	milk, protein, fat
C+MBW+REI	+ metabolic body weight + residual energy intake	milk, protein, fat, MBW, REI
C+MBW	+ metabolic body weight	milk, protein, fat, MBW
tr_MRR	transformed MRR= $\frac{c_{ME}\text{MBW}}{\text{ECM}}$	milk, protein, fat, MBW
tr_ECE	transformed ECE= $\frac{\text{ECM}}{\text{MEI}}$	milk, protein, fat, MEI

Estimated correlations

genetic

	Milk	Prot.	Fat	MBW	MEI	ECE	REI	MRR
Milk		0.88	0.74	-0.24	0.35	0.58	0.06	-0.81
Prot.	0.91		0.82	-0.29	0.41	0.57	0.15	-0.83
Fat	0.79	0.83		-0.28	0.38	0.62	0.10	-0.86
MBW	0.03	0.10	0.04		0.43	-0.58	0.24	0.67
MEI	0.43	0.44	0.41	0.37		-0.44	0.88	-0.05
ECE	0.58	0.60	0.65	-0.24	-0.38		-0.66	-0.81
REI	-0.01	-0.04	-0.06	-0.02	0.78	-0.70		0.11
MRR	-0.81	-0.79	-0.84	0.43	-0.22	-0.71	0.03	

phenotypic

Net merit and genetic response

	Net merit (in % of control)	Genetic response (in % of genetic SD)							
		Milk	Prot.	Fat	MBW	MEI	ECE	REI	MRR
C	100	0.68	0.61	0.63	-0.18	0.26	0.45	0.04	-0.61
C+MBW+REI	128	0.61	0.58	0.57	-0.58	-0.07	0.65	-0.17	-0.75
C+MBW	124	0.63	0.62	0.61	-0.57	0.03	0.59	-0.06	-0.76
tr_MRR	118	0.67	0.64	0.67	-0.39	0.16	0.55	-0.01	-0.73
tr_ECE	102	0.67	0.60	0.64	-0.20	0.24	0.48	0.01	-0.63

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!