Breeding for more sustainable dairy cows

"Dairy Girls"

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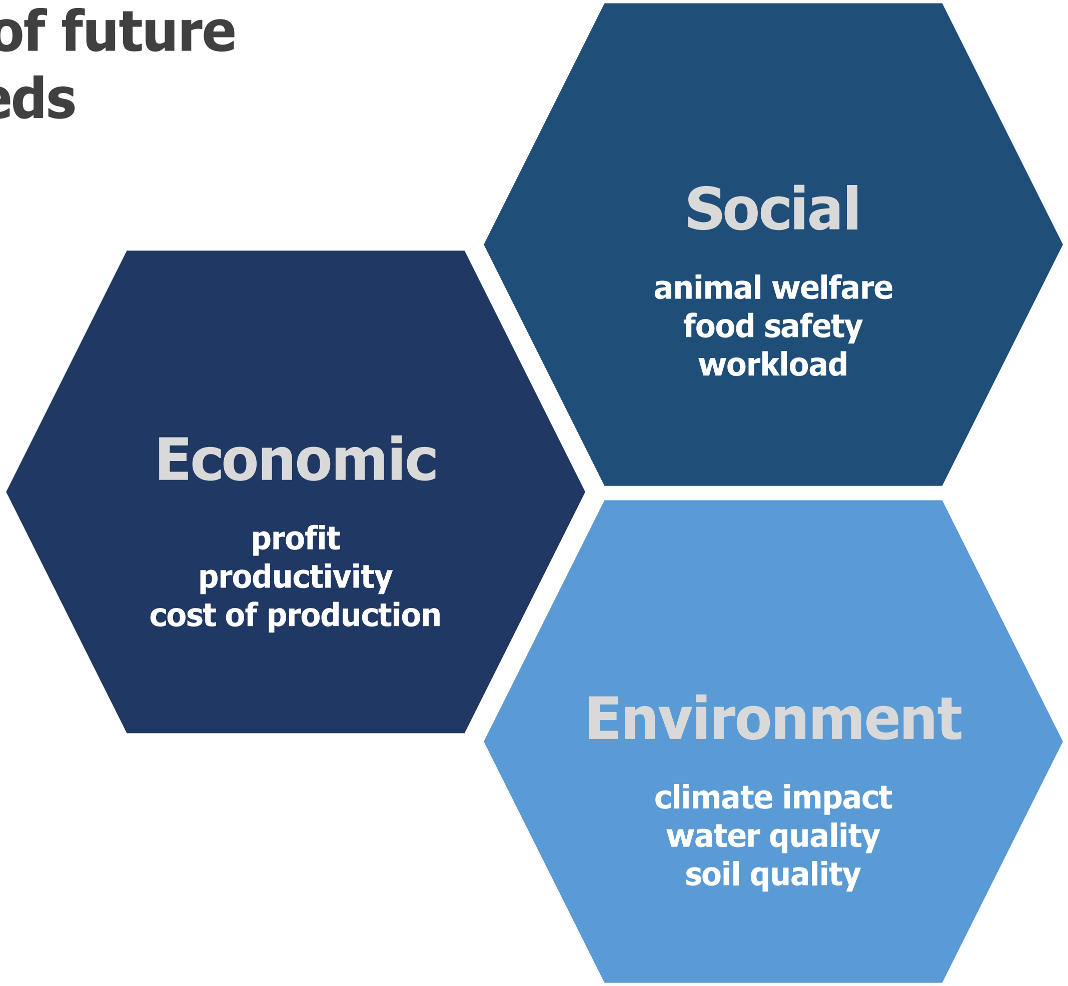
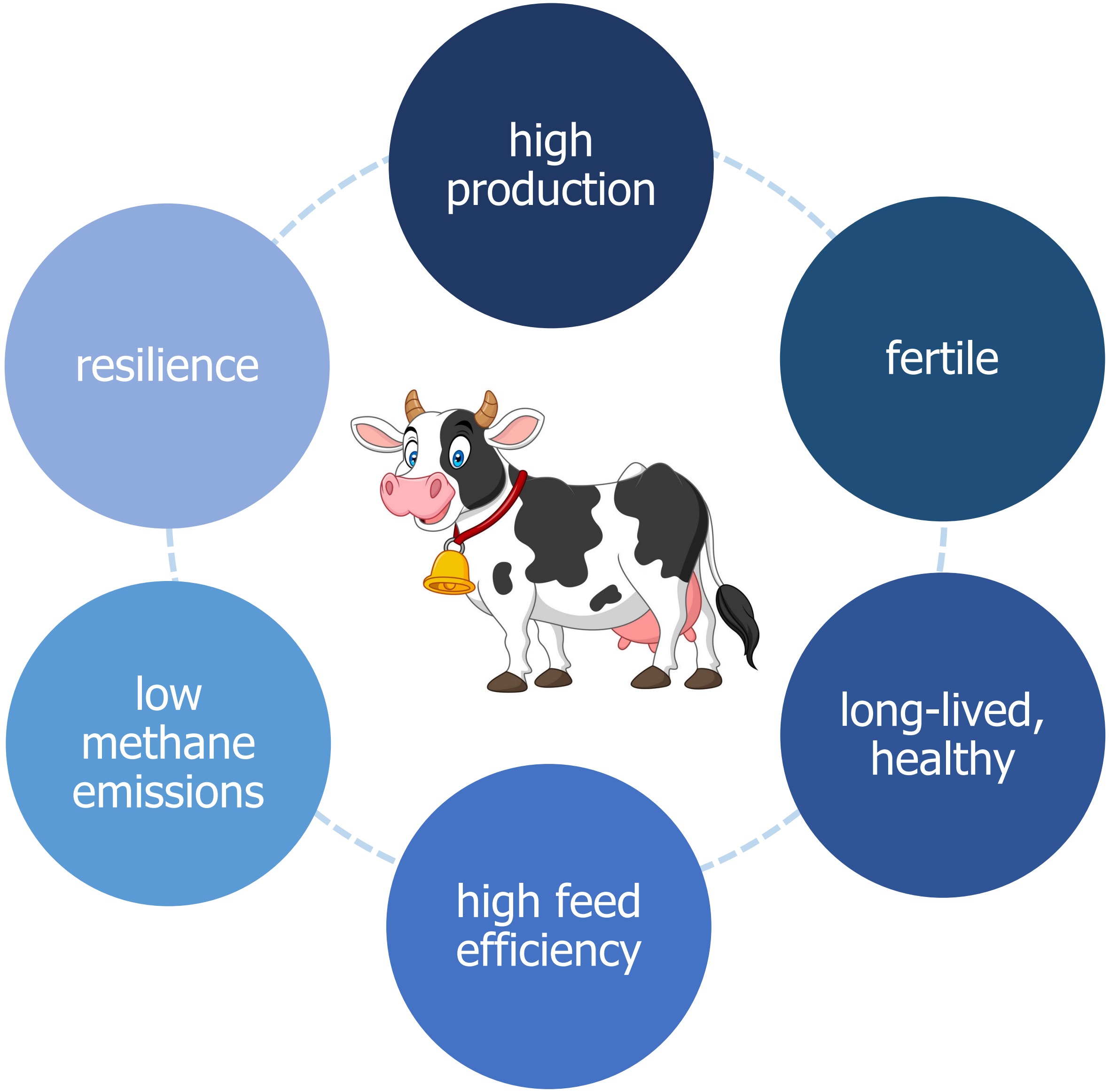
Sustainability

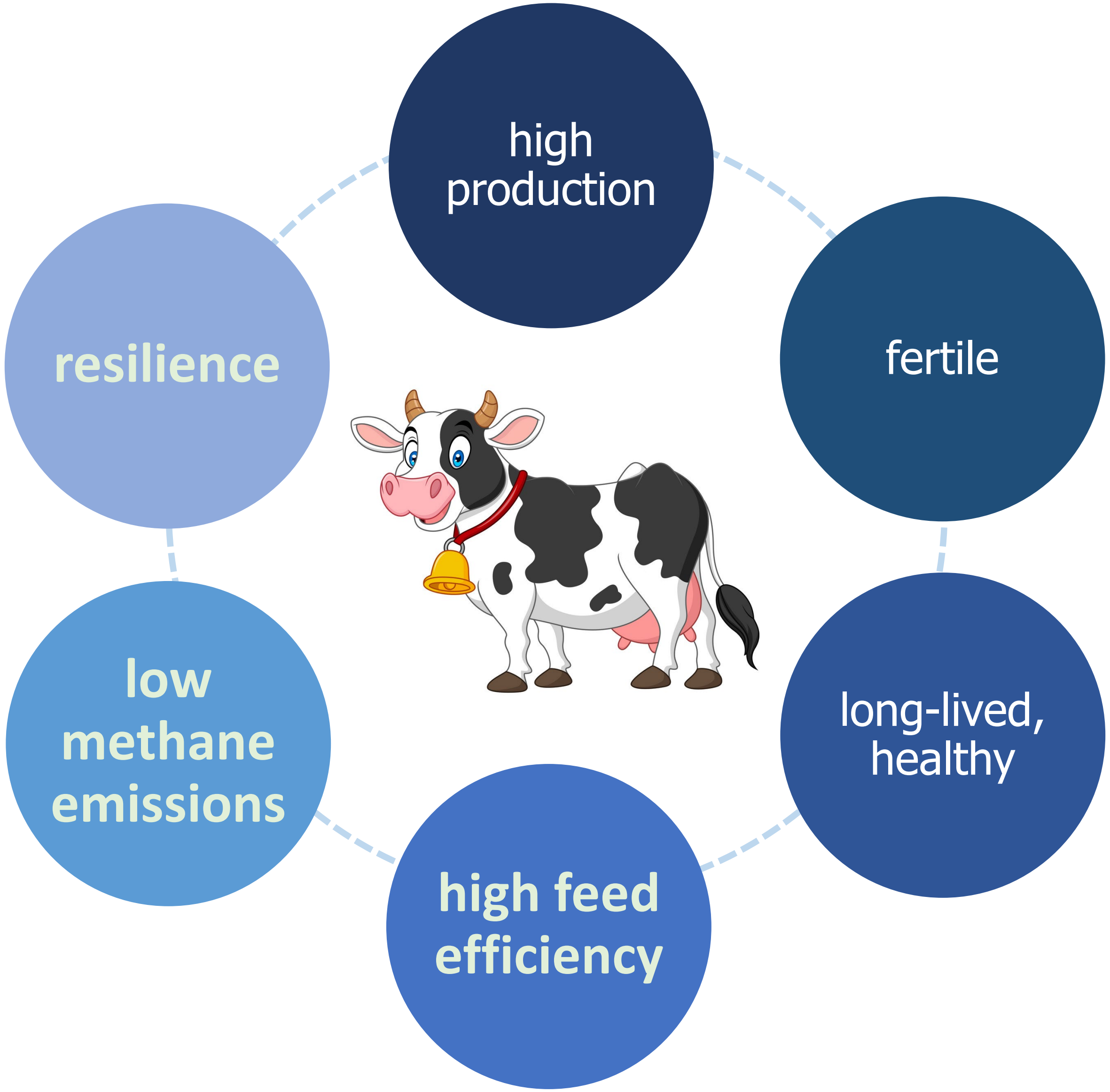
meeting the needs of the present without compromising the ability of future generations to meet their own needs



Sustainable dairy farming



Sustainable dairy farming



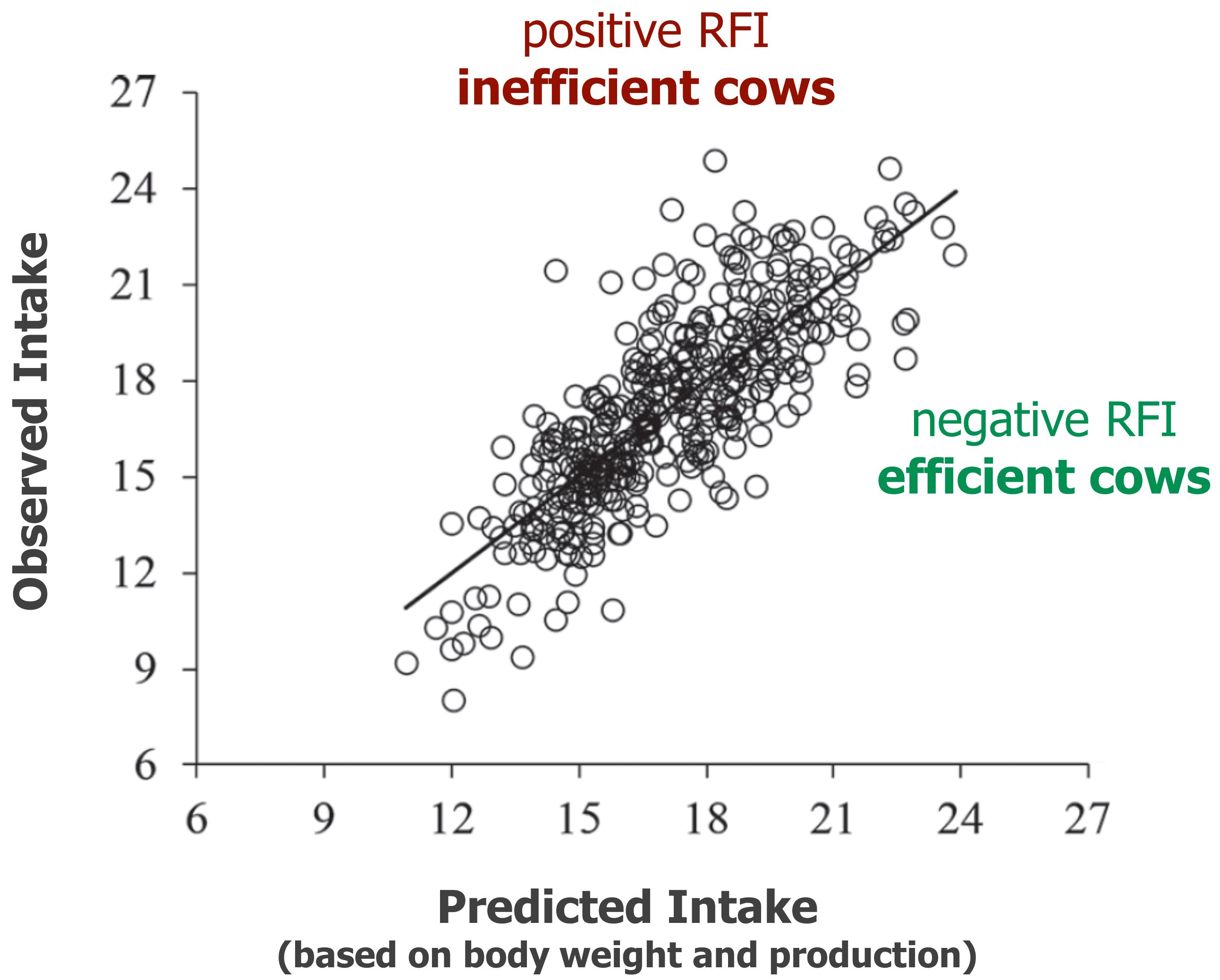
What's the importance of feed efficiency?

- ❑ feed represents more than 50% of the total production costs

- ❑ benefits of improving feed efficiency:
  - increase farm profitability
  - reduce the environmental impact of dairy farming

How do we measure feed efficiency?

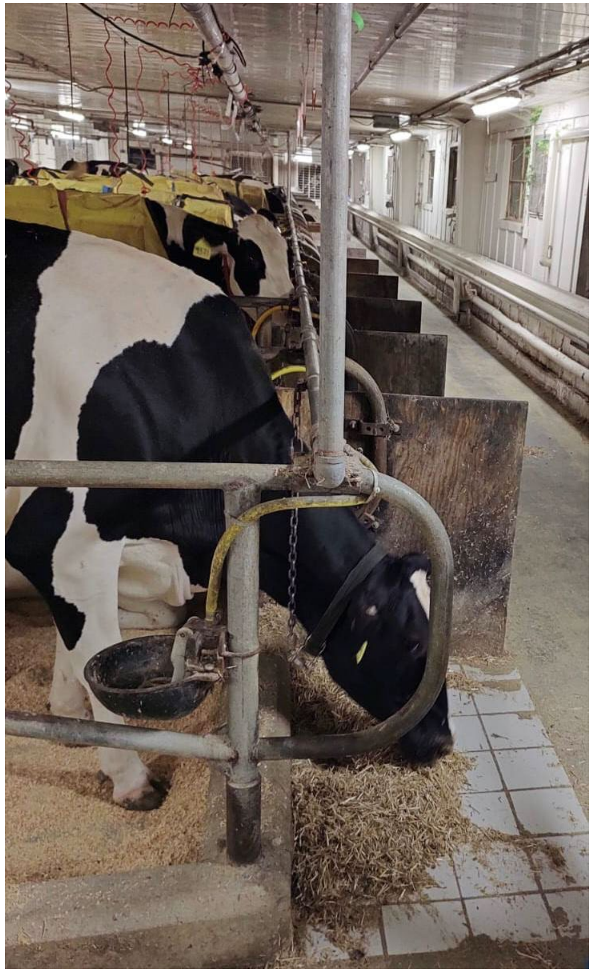
Residual feed intake (RFI) = Observed intake – Predicted intake



Individual feed intake recording

Insentec Gates

Calan Gates



Tie Stalls

Residual feed intake

Residual feed intake (RFI) = Observed intake – Predicted intake

DMI dry matter intake (based on feed intake)

MilkE milk energy (based on milk production and composition)

mBW metabolic body weight (based on body weight records)

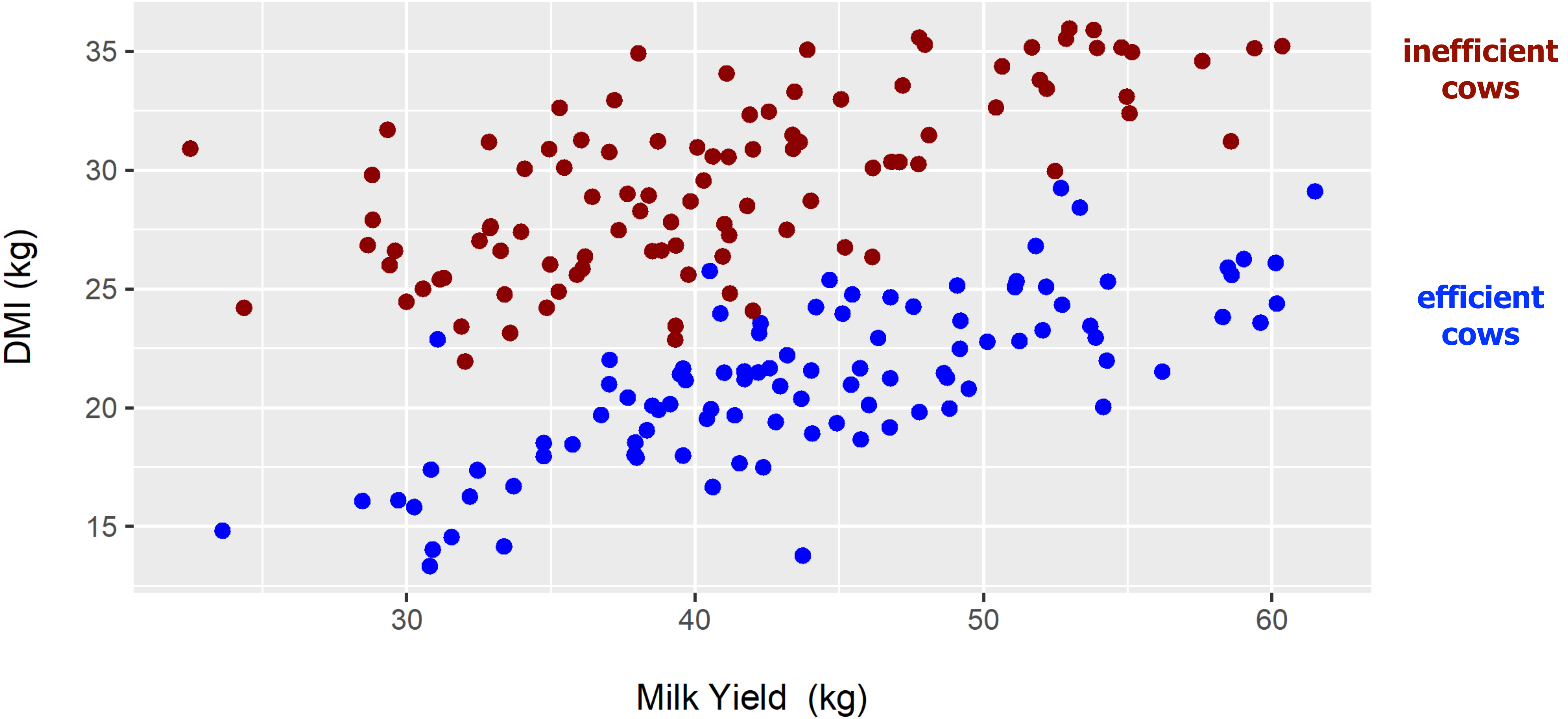
ΔBW change in body weight (based on body weight records)

$$\mathbf{DMI} = \mathbf{DIM} + \mathbf{Lact} + \boldsymbol{\beta}_1\mathbf{MilkE} + \boldsymbol{\beta}_2\mathbf{mBW} + \boldsymbol{\beta}_3\boldsymbol{\Delta}\mathbf{BW} + \mathbf{cohort} + \mathbf{week} + \mathbf{e}$$

$$\mathbf{e} = \mathbf{DMI} - \widehat{\mathbf{DMI}} = \mathbf{residual\ feed\ intake}$$

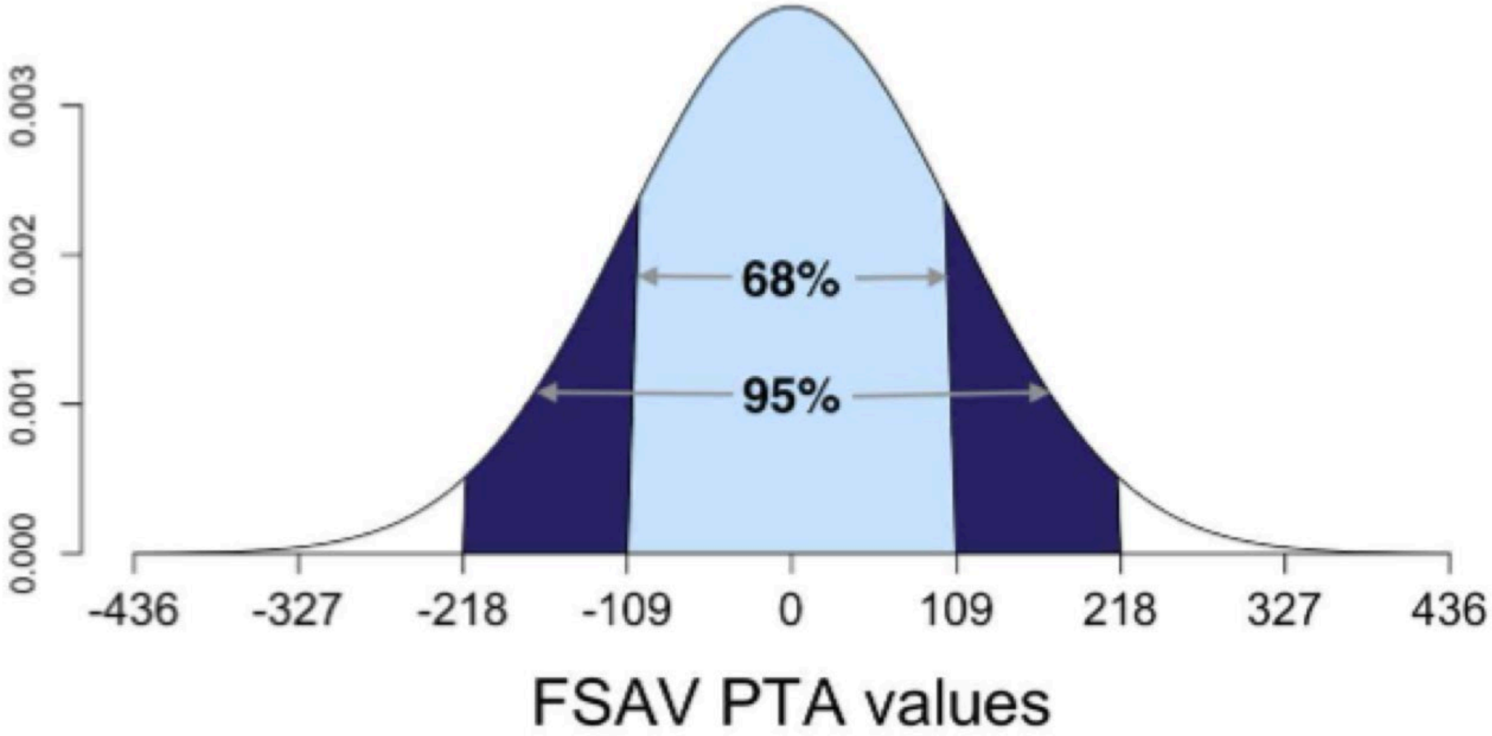
Cavani et al. (2023) JDS Communications 4: 201-204

Most/least efficient cows



Trait definition: Feed Saved

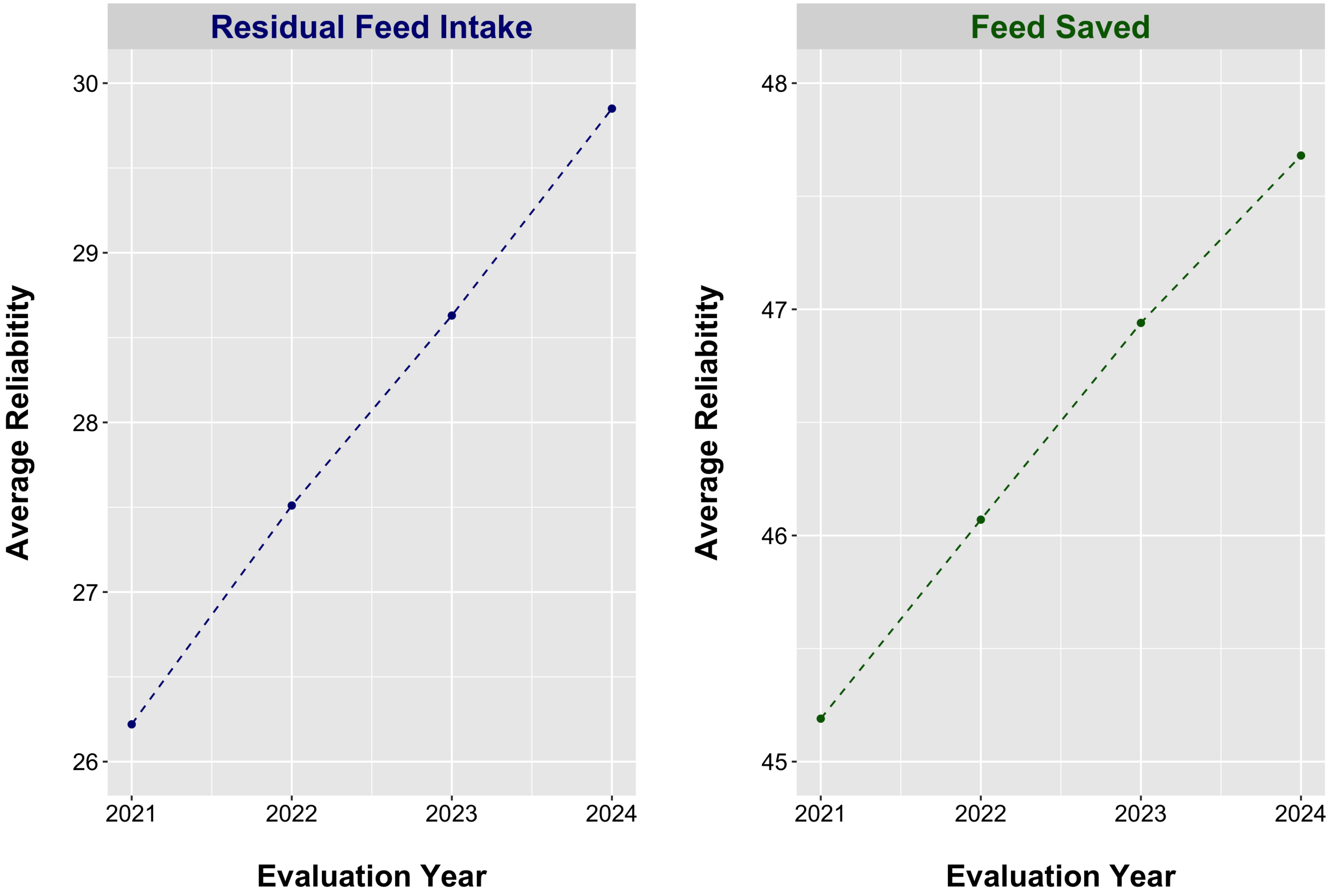
Feed Saved combines Residual Feed Intake + Body Weight Composite



pounds of feed saved per lactation
(larger, positive values are more favorable)

Change in reliabilities

Reliabilities are slowly but steadily improving



The million-dollar question

Why some cows are more efficient than others?

(some cows need less feed than others of similar body weight and milk production)

some processes that contribute to feed efficiency:

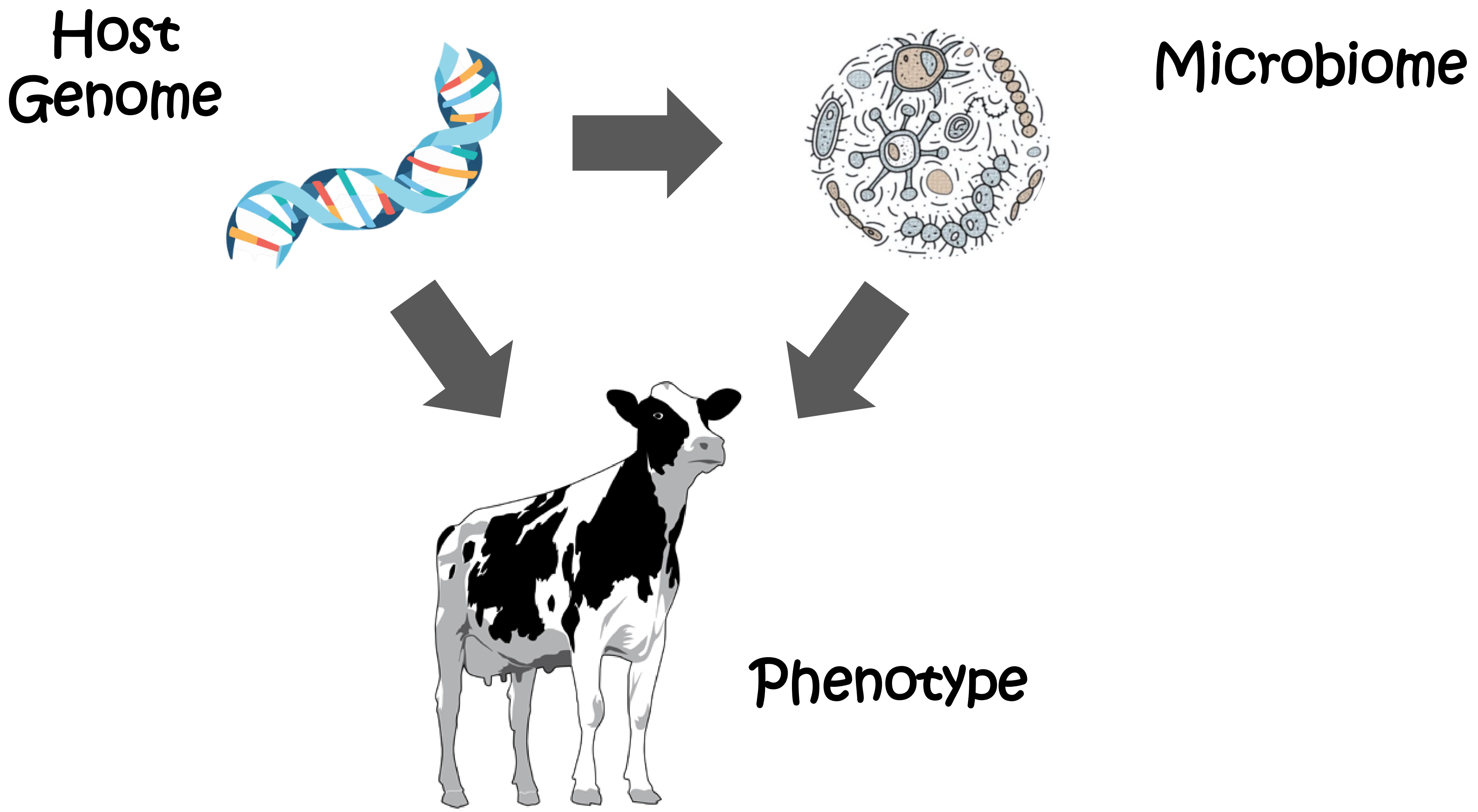
- **feeding behavior, feeding patterns**
- **rumination, physical activity, and lying behavior**
- **rumen microbiome composition**
- **thermoregulation**
- **metabolism, mitochondrial function**
- **diet digestibility**

Behavioral traits

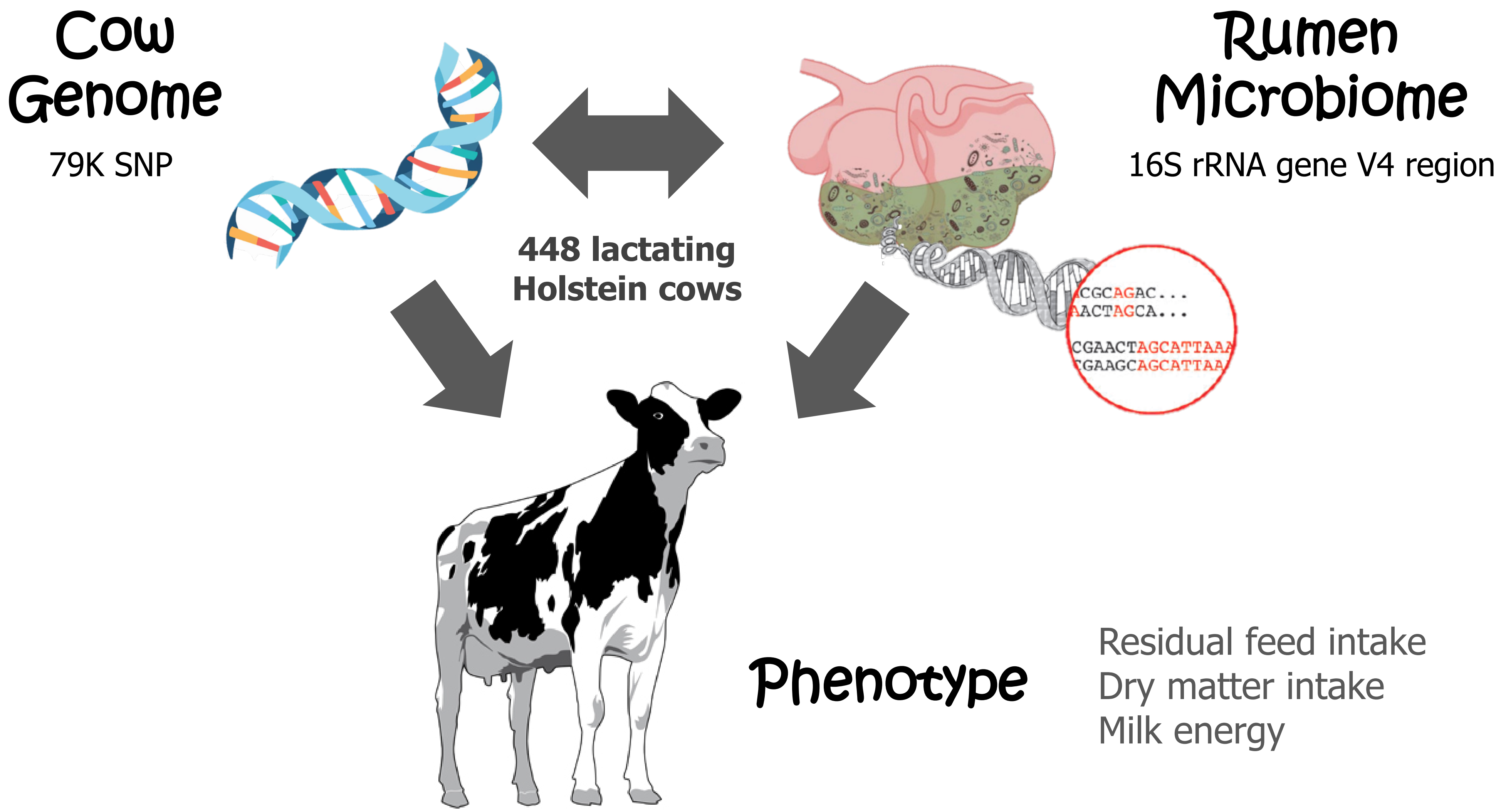
Genetic Correlations	**Rumination time** (min/d)	**Lying time** (min/d)	**Activity** (steps/d)
Dry matter intake (kg/day)	0.47 ± 0.17	-0.07 ± 0.10	0.18 ± 0.20
Milk energy (Mcal/day)	0.42 ± 0.21	0.06 ± 0.16	0.03 ± 0.19
BW change (kg/week)	-0.27 ± 0.73	-0.03 ± 0.43	0.04 ± 0.17
Metabolic BW ($kg^{0.75}$)	0.12 ± 0.13	0.14 ± 0.08	-0.02 ± 0.12
Residual feed intake (kg/day)	**0.40 ± 0.19**	**-0.27 ± 0.11**	**0.31 ± 0.22**

Nascimento et al. (2024) Journal of Dairy Science 107: 8141-8149

Microbiome and feed efficiency

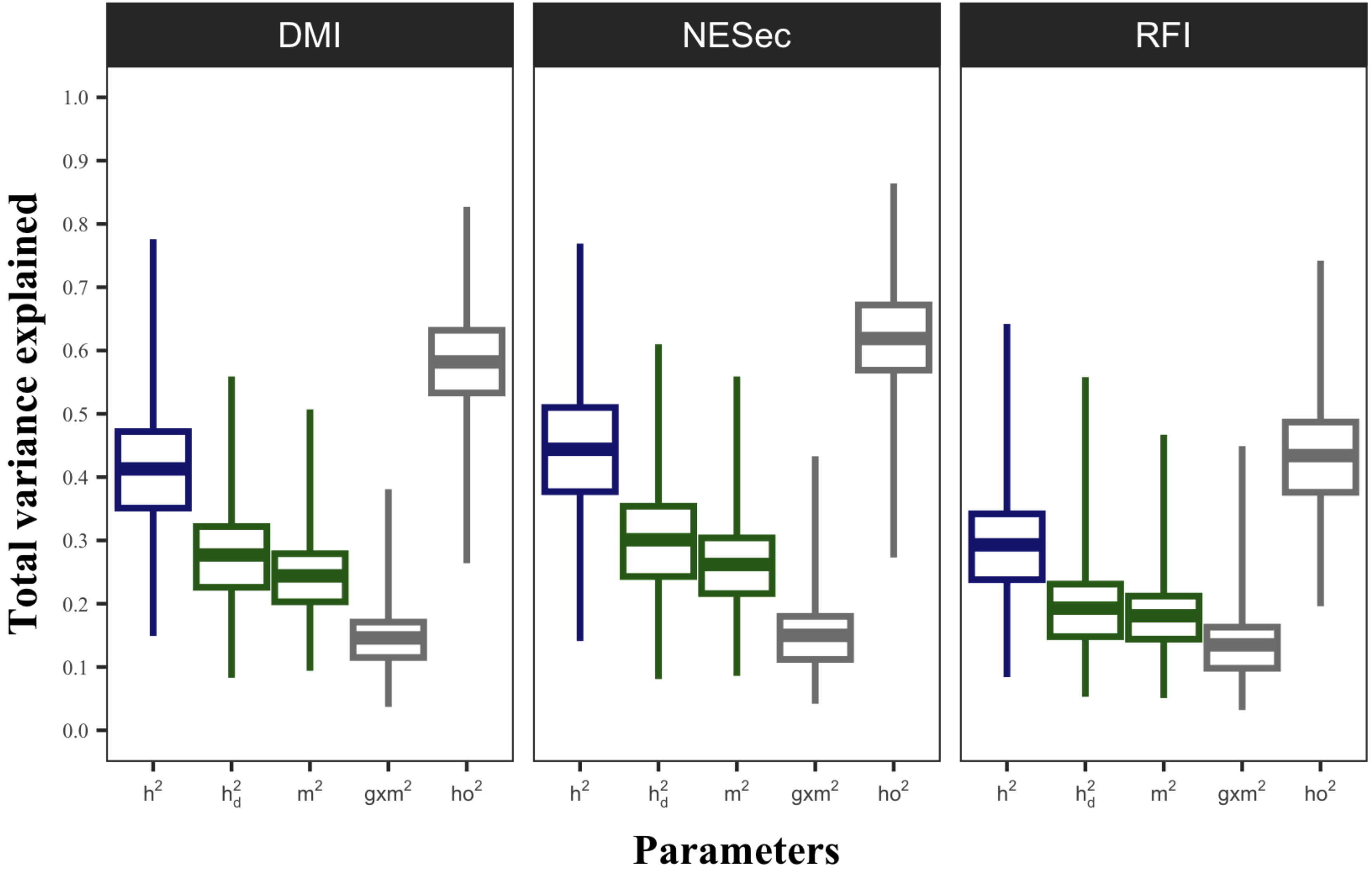


Microbiome and feed efficiency



Microbiome and feed efficiency

Rumen microbiome mediates part of the host genetic effects

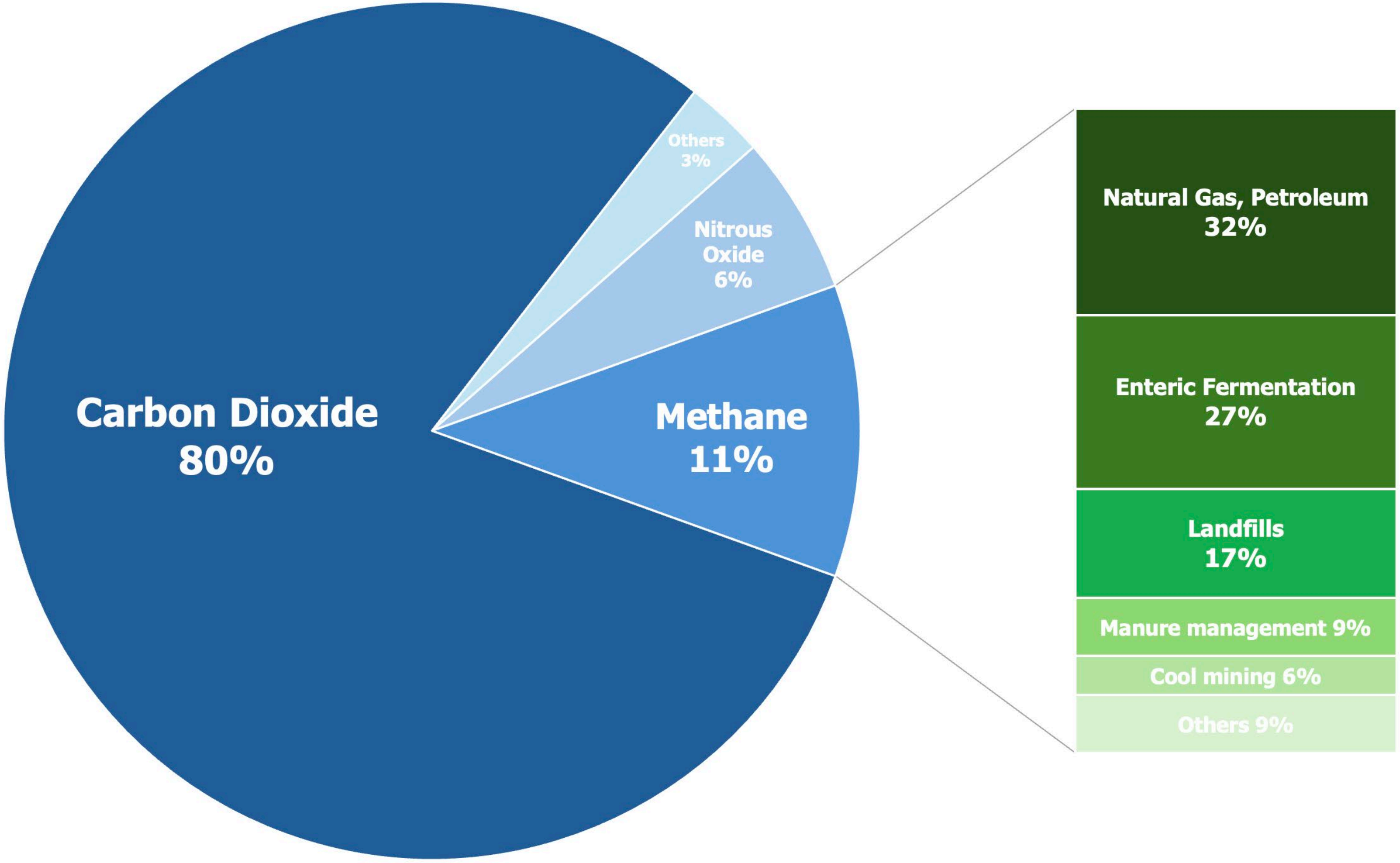


Martinez Boggio et al. (2024) Journal of Dairy Science 107: 3090-3103

Feed efficiency: current efforts

- phenotyping, phenotyping, phenotyping!
- same question: why some cows are more efficient than others?
- whole-genome scans using sequence data
- prediction using (sensors + metabolites + spectra + genome)
- quantify genotype-by-diet interaction
- novel efficiency trait: residual heat production

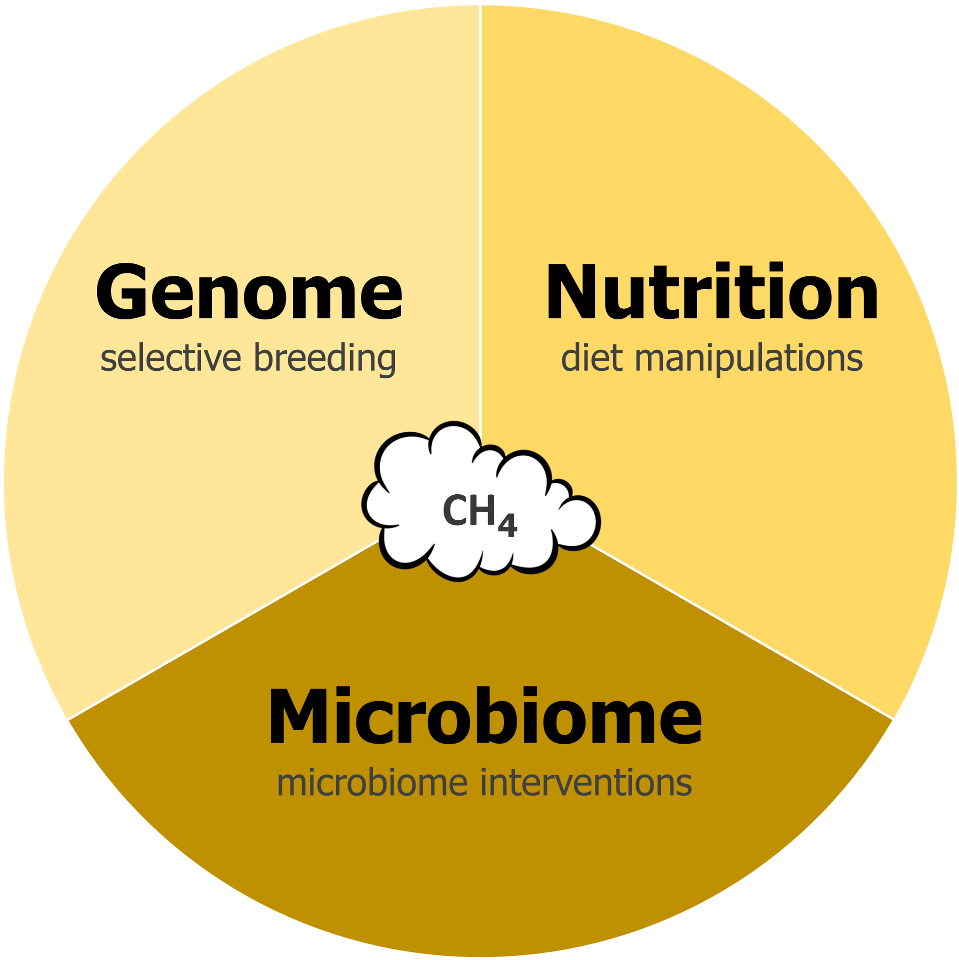
Methane emissions



CH4 is a loss of energy
(6-12% of gross energy intake)

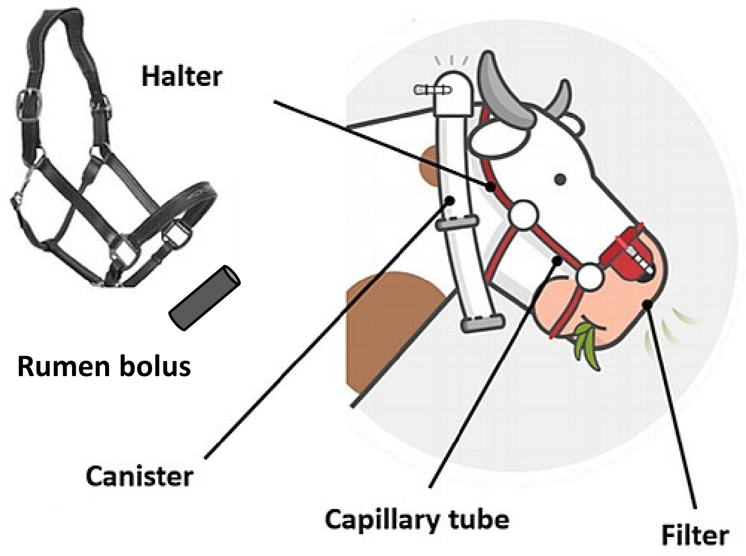
reducing enteric CH_4 would benefit the environment and improve efficiency

Mitigation strategies



Phenotyping CH4

respiration chamber
(gold standard)



Sulphur Hexafluoride (SF6) tracer technique

GreenFeed system

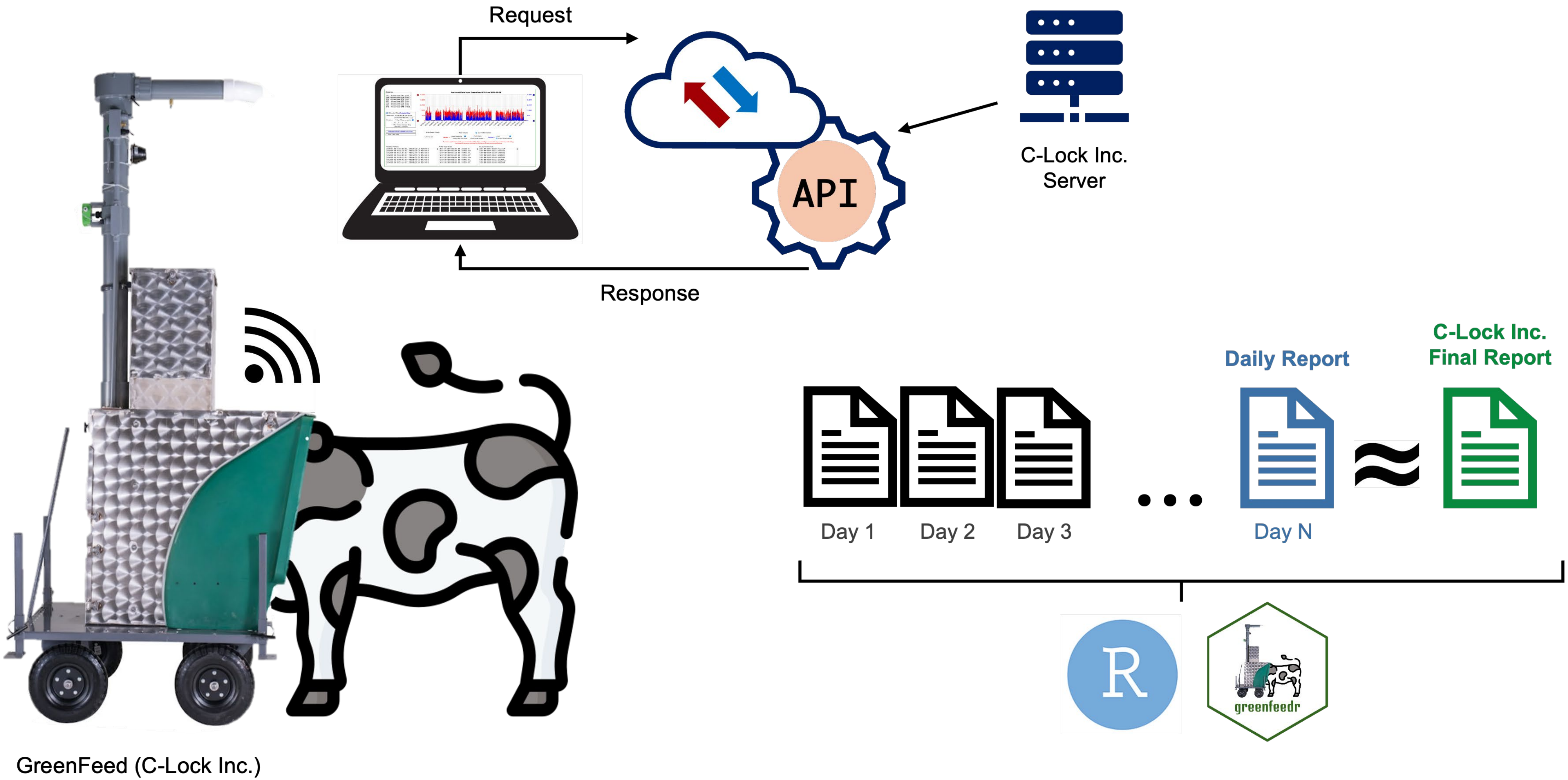
sniffers
(automatic milking systems)

Laser detector

Phenotyping CH4

GreenFeed system: many records at different times of the day for multiple days

greenfeedr R-package



Martínez Boggio et al. (2025) JDS Communications 6: 227-230

Trait definition

Alternative methane emisión traits

- **methane production** (grams CH_4 per day)
- **methane yield** (grams CH_4 per kg of dry matter intake)
- **methane intensity** (grams CH_4 per kg of energy-corrected milk)
- **residual methane**

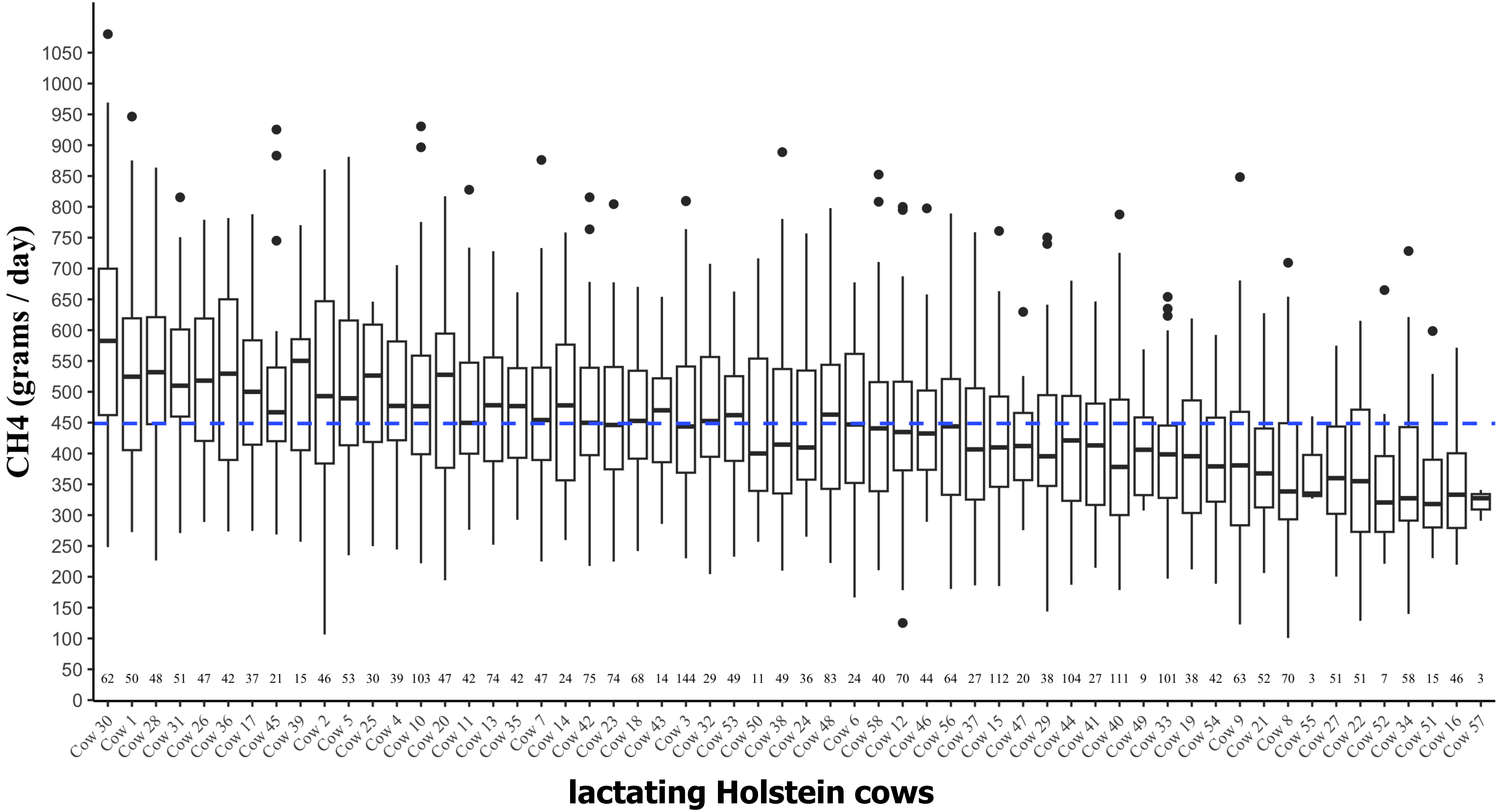
residual methane intensity (CH_4 regressed on milkE and mBW)

$$CH_4 = Xb + \beta_1 milkE + \beta_2 mBW + \boldsymbol{e_{RMI}}$$

residual methane yield (CH_4 regressed on DMI)

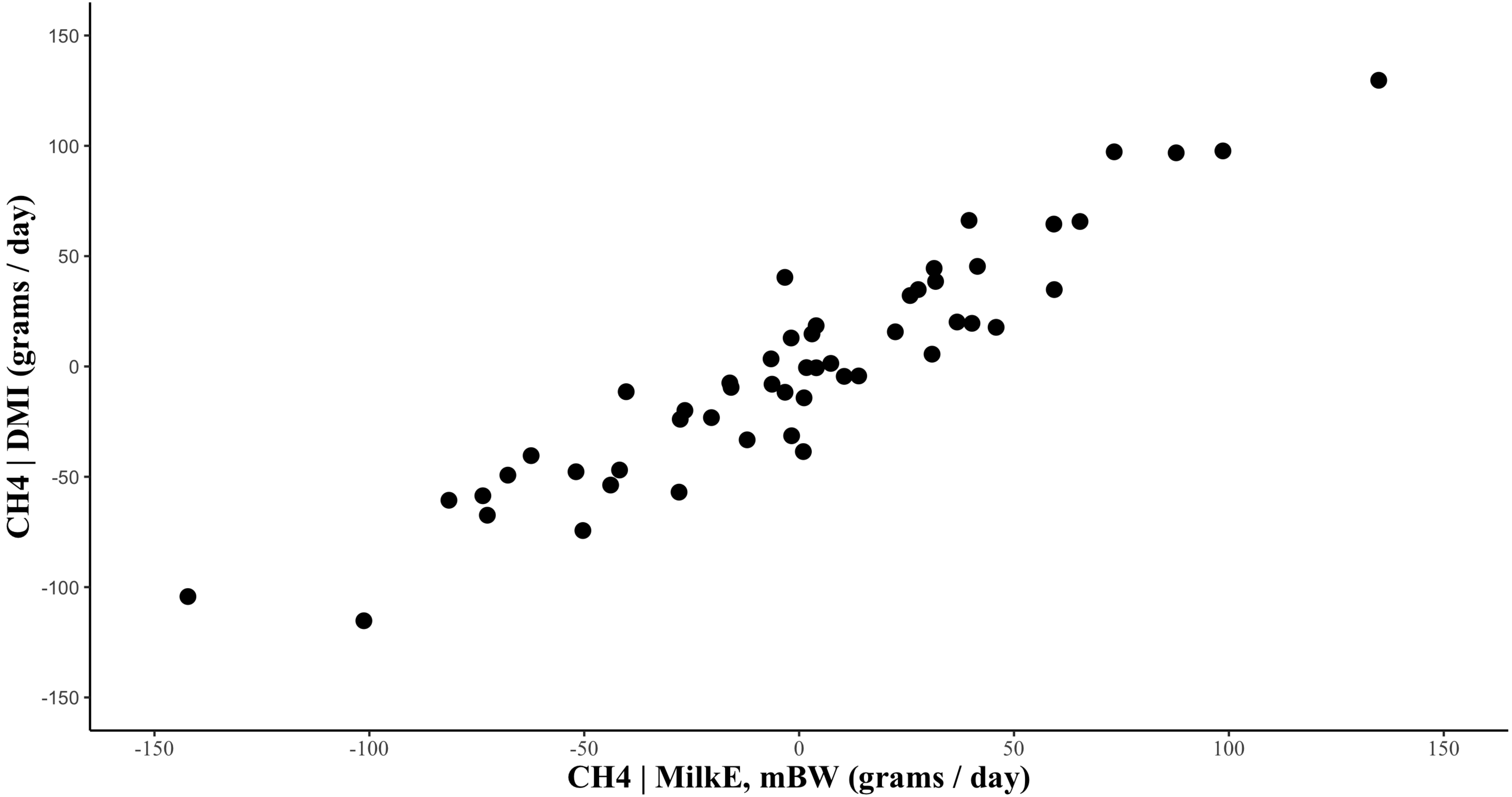
$$CH_4 = Xb + \beta_1 DMI + \boldsymbol{e_{RMY}}$$

Variability in CH4 production



Residual CH4 production

CH4 production regressed on (MilkE + mBW) or (DMI)



Genetic parameters

Preliminary results: 2400 Holstein cows, 10 farms

Heritabilities	MEP	RMI	RMY	RFI
MEP	0.28 ± 0.05			
RMI		0.18 ± 0.05		
RMY			0.17 ± 0.06	
RFI				0.17 ± 0.05

Genetic parameters

Preliminary results: 2400 Holstein cows, 10 farms

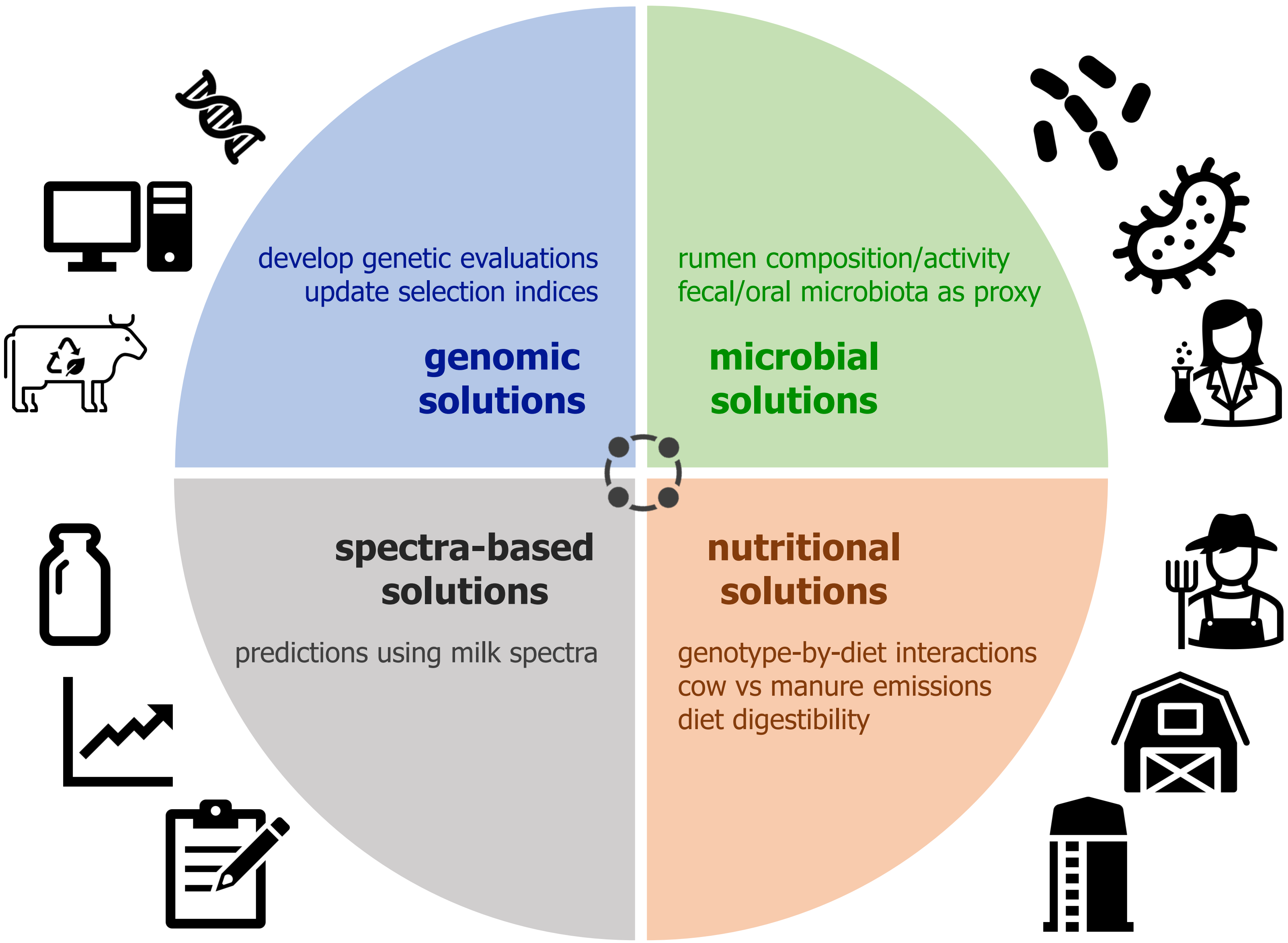
Genetic correlations	MEP	RMI	RMY	RFI
MEP	0.28 ± 0.05			
RMI		0.18 ± 0.05	**0.97 ± 0.05**	
RMY			0.17 ± 0.06	
RFI				0.17 ± 0.05

Genetic parameters

Preliminary results: 2400 Holstein cows, 10 farms

Genetic correlations	MEP	RMI	RMY	RFI
MEP	0.28 ± 0.05	**0.85 ± 0.05**	**0.78 ± 0.07**	**0.54 ± 0.17**
RMI		0.18 ± 0.05	**0.97 ± 0.05**	
RMY			0.17 ± 0.06	
RFI				0.17 ± 0.05

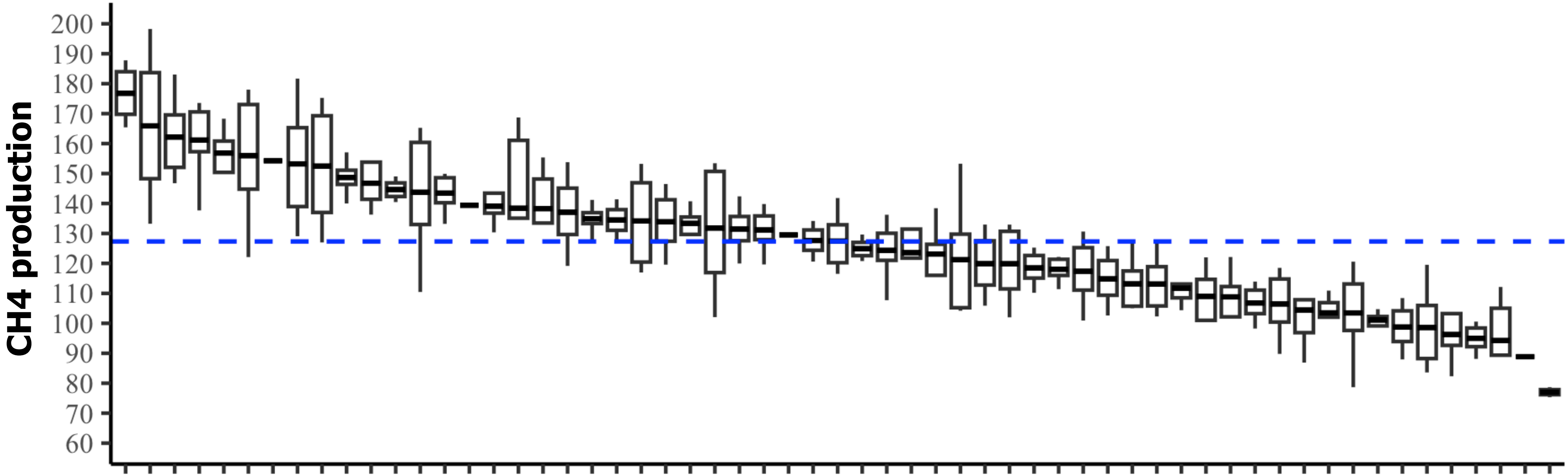
Methane emissions: current efforts



Phenotyping CH4: new horizons

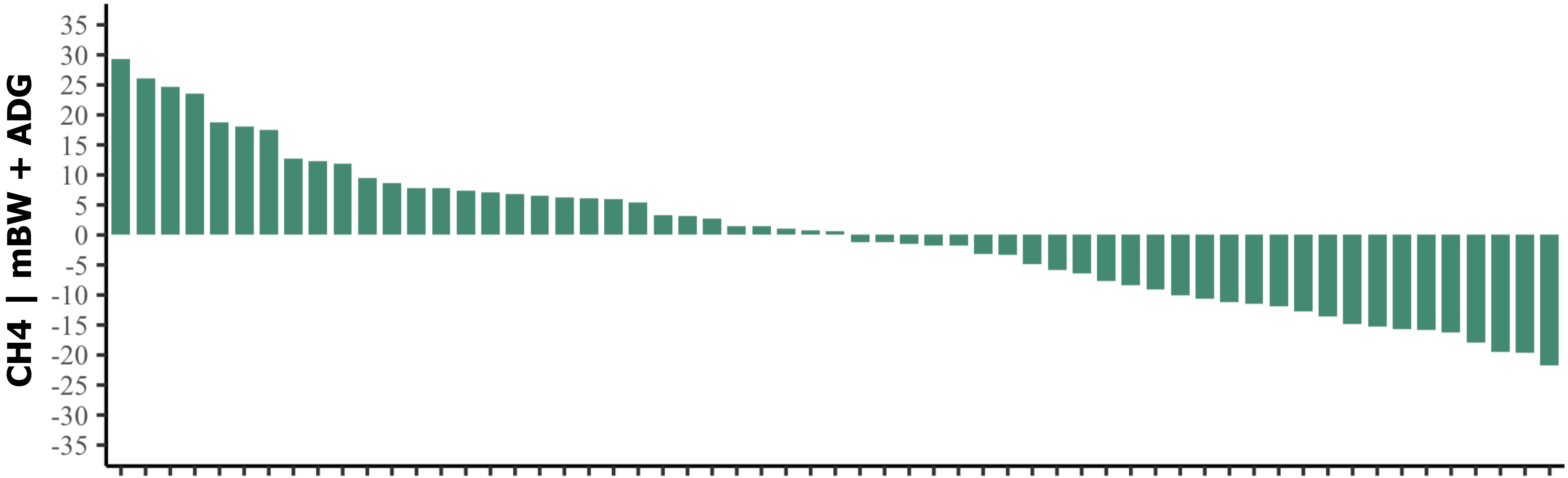
CH4 production

Preliminary results: 59 Holstein bulls, 5-6 months old, 3 weeks of records



Residual CH4 production

Preliminary results: 59 Holstein bulls, 5-6 months old, 3 weeks of records



what's the genetic correlation between
CH4 emissions in young bulls vs. CH4 emissions in lactating cows?

Resilience

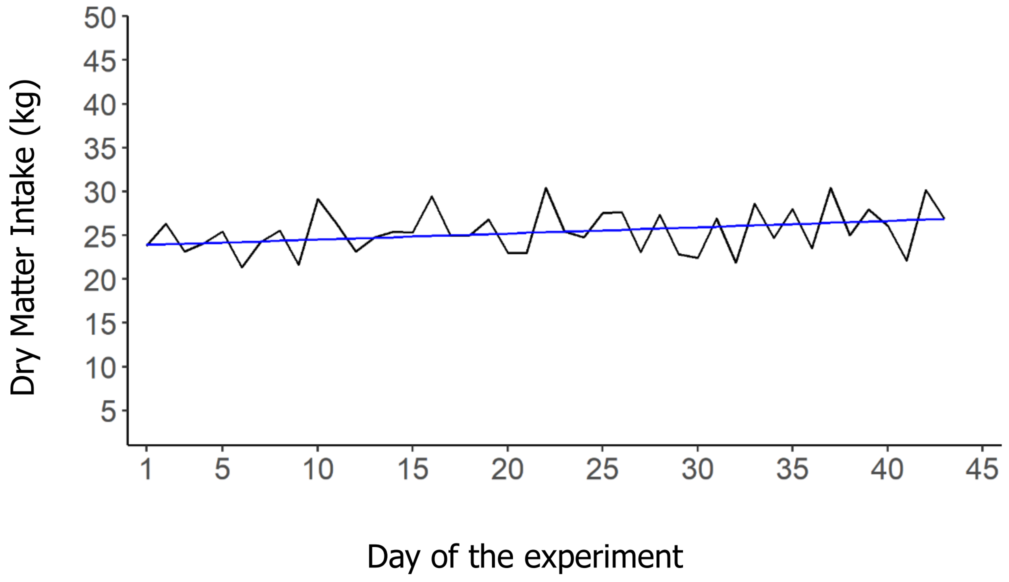
Advancing despite adversity

resilience as the capacity to maintain performance or bounce back to normal functioning after a disturbance

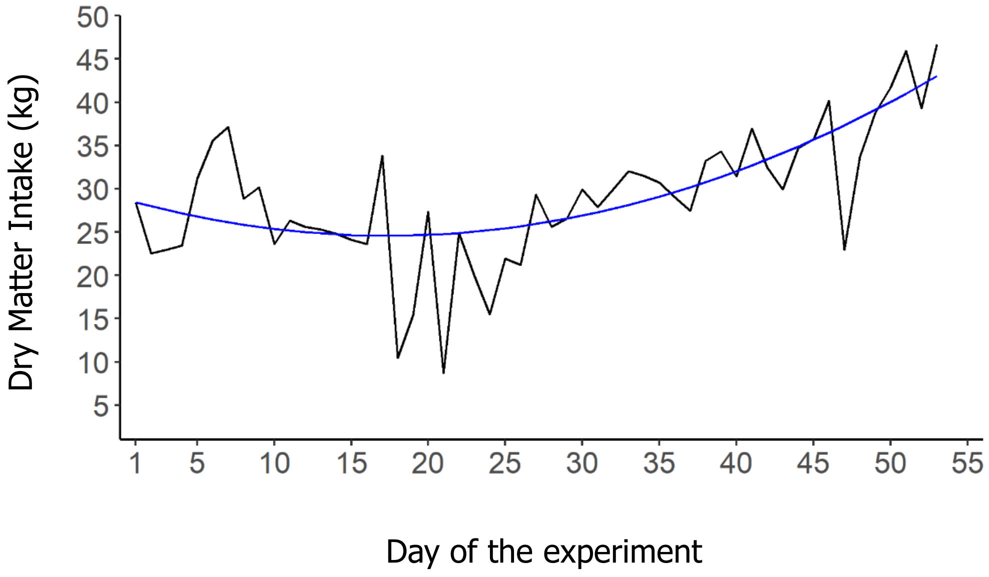
DMI consistency

Consistency of dry matter intake as an indicator of resilience

cow A: **consistent intake**



cow B: **inconsistent intake**



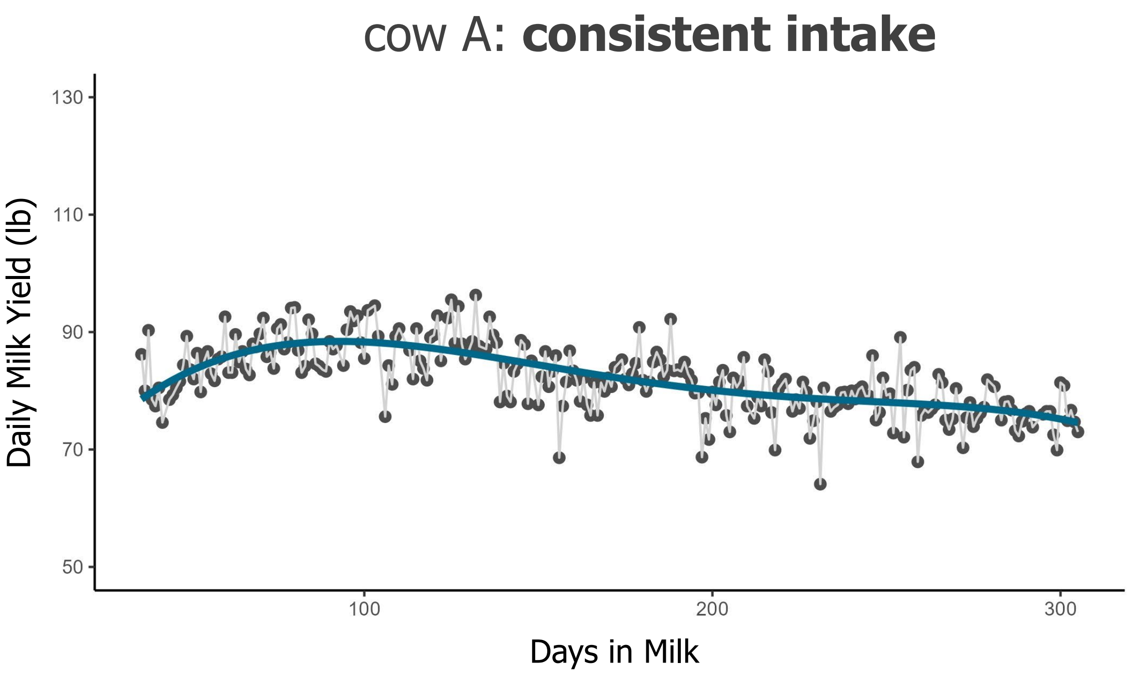
RESULTS

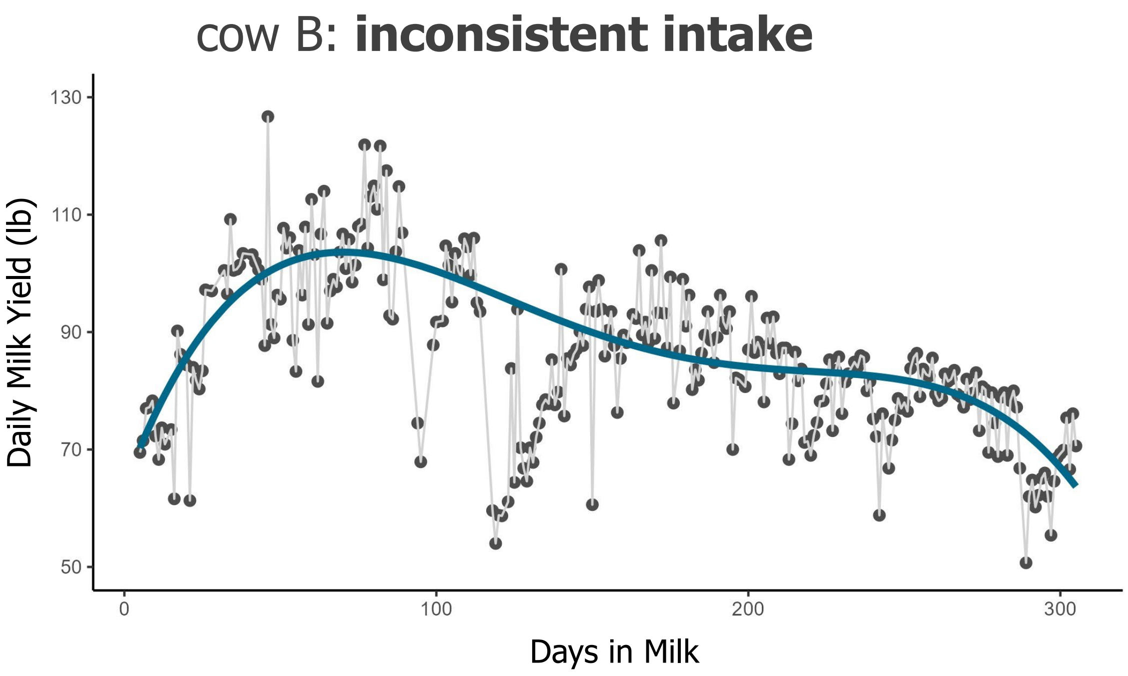
- DMI consistency is a heritable trait (0.11-0.14)
- DMI consistency and milk consistency are correlated (0.51-0.62)
- DMI consistency and RFI are correlated (0.26-0.31)
- DMI consistency is favorable correlated with fertility

Cavani et al. (2024) Journal of Dairy Science 107: 1054-1067

Milk consistency

Consistency of milk production as an indicator of resilience





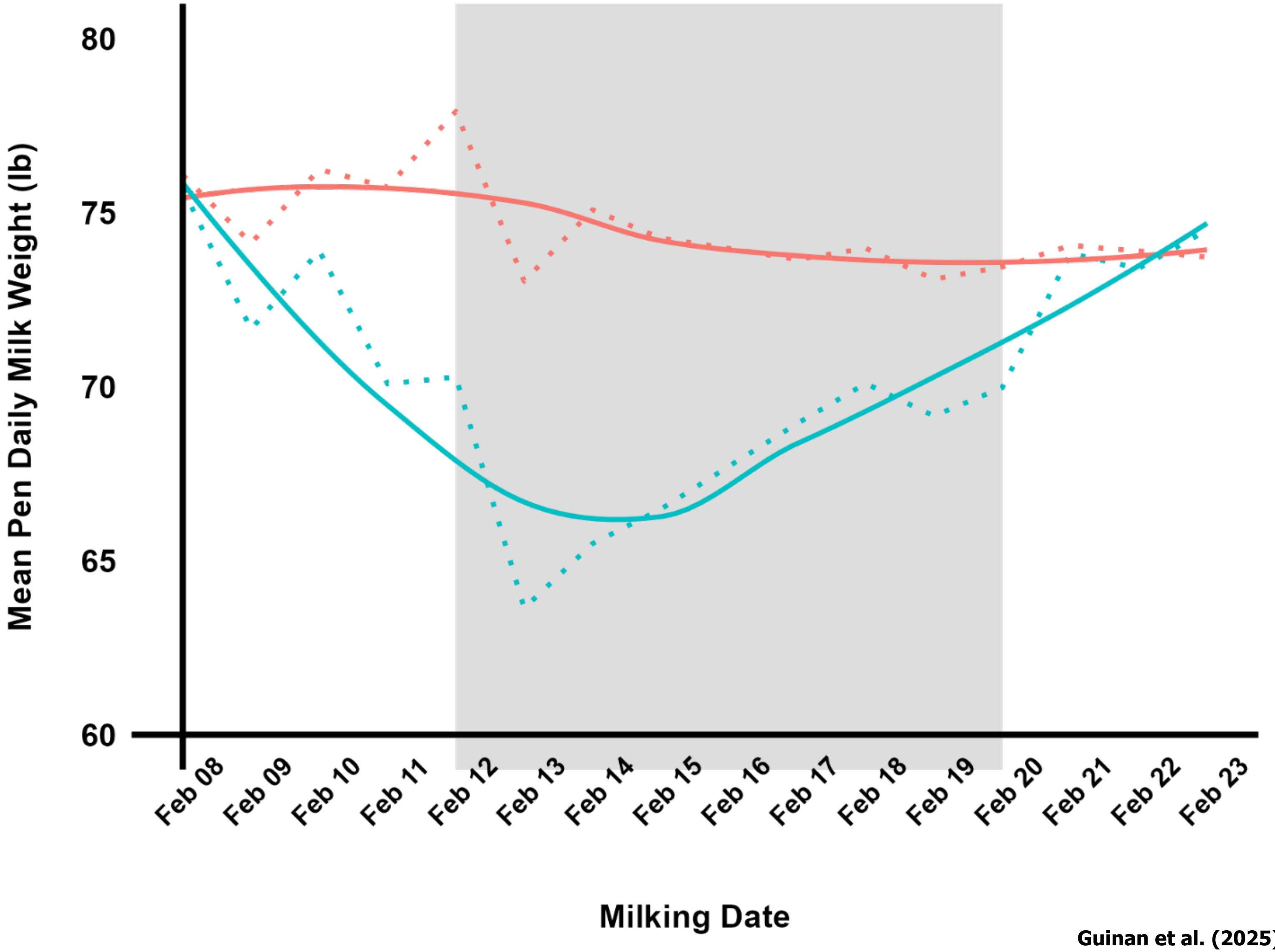
RESULTS

- Milk consistency is a heritable trait (0.21-0.23)
- Milk consistency is highly correlated across lactations (0.95)
- Milk consistency and milk production are correlated (0.57)
- Milk consistency is favorable correlated with health and longevity

Guinan et al. (2024) Journal of Dairy Science 107: 2194-2206

Resilience

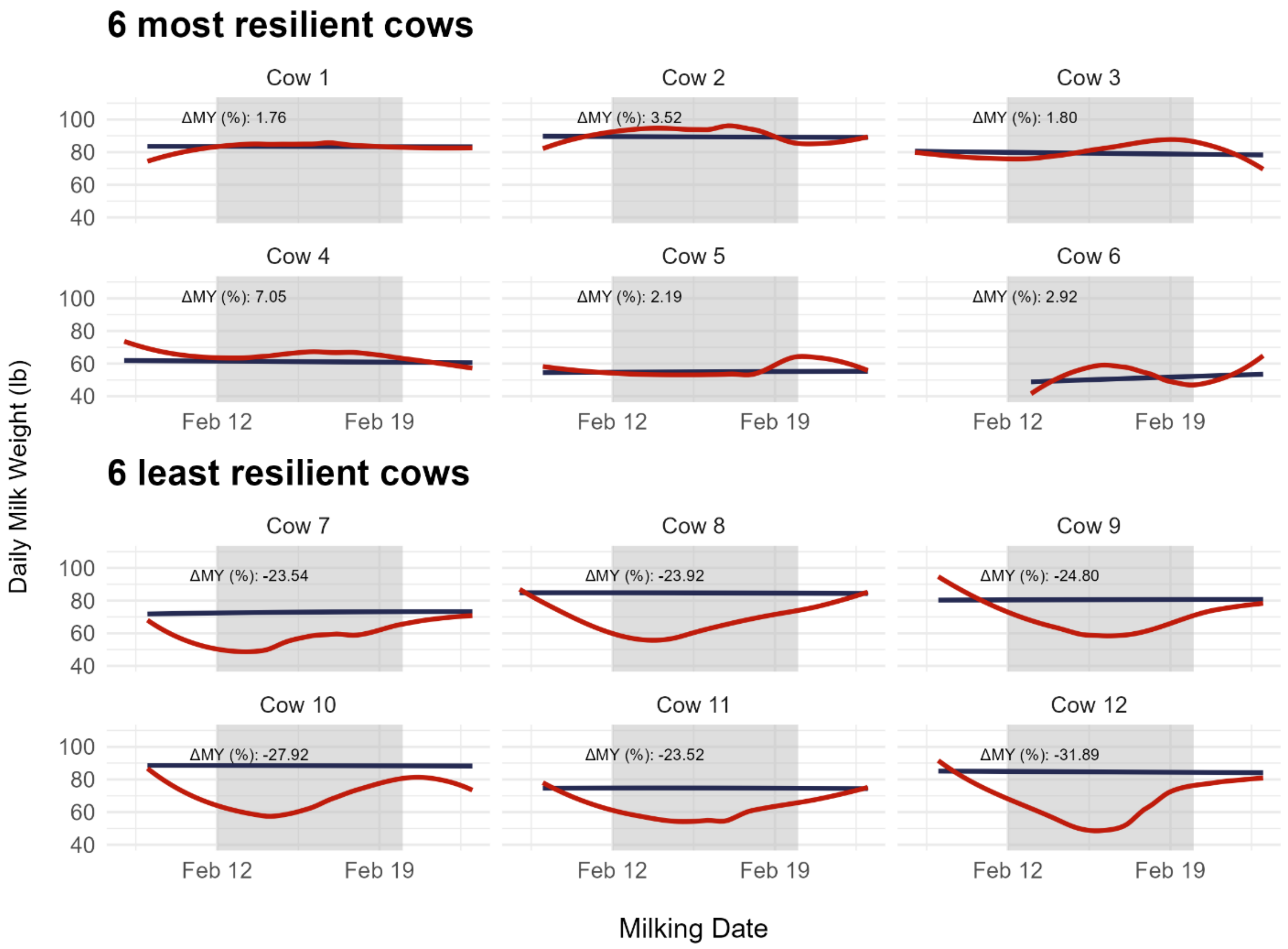
Data-driven detection of perturbations using daily milk records



Guinan et al. (2025) Journal of Dairy Science (under review)

Resilience

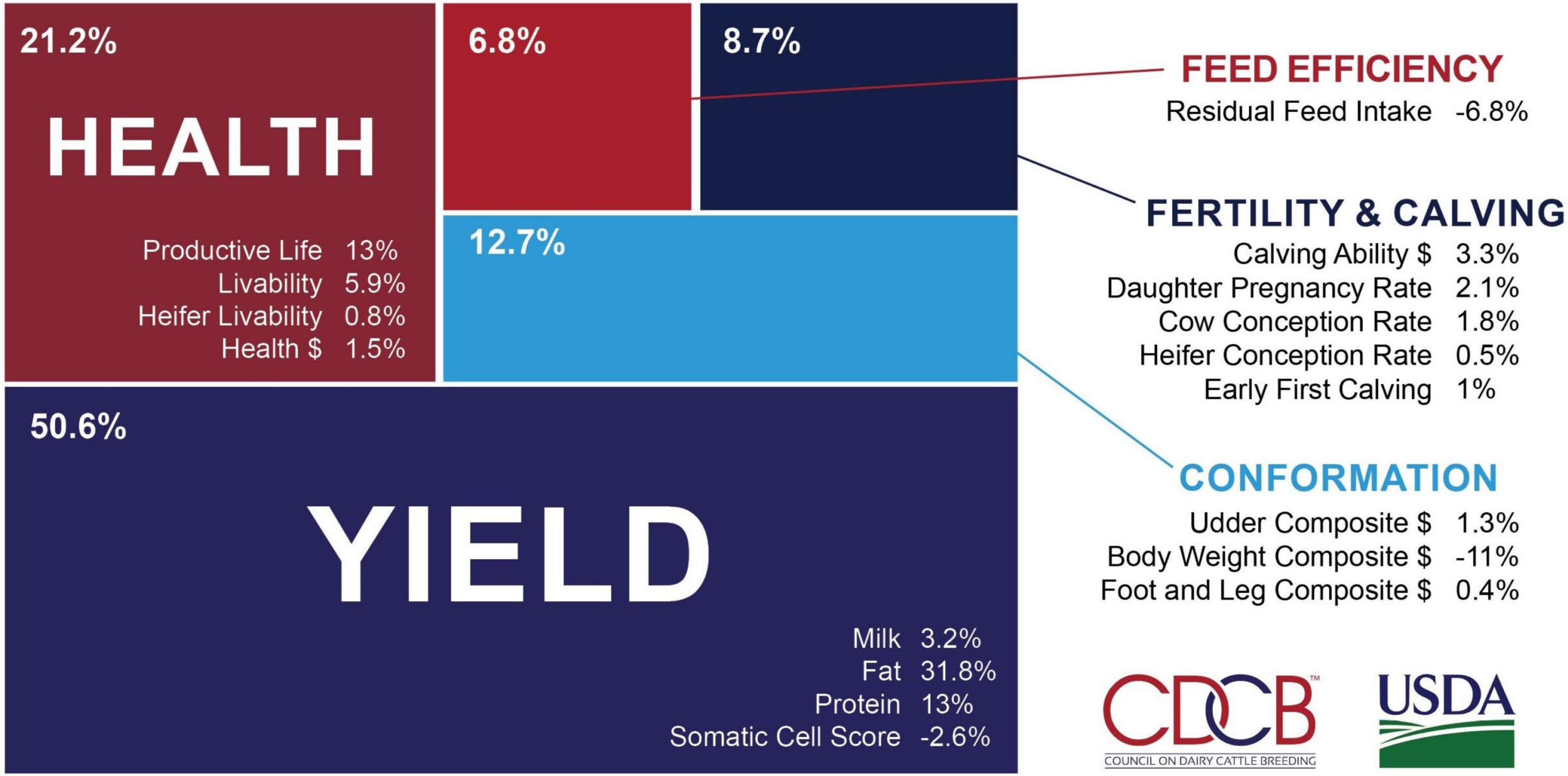
Differences in cows' response to the same perturbation



Guinan et al. (2025) Journal of Dairy Science (under review)

Index: best selection tool!

Net Merit Index ($NM)



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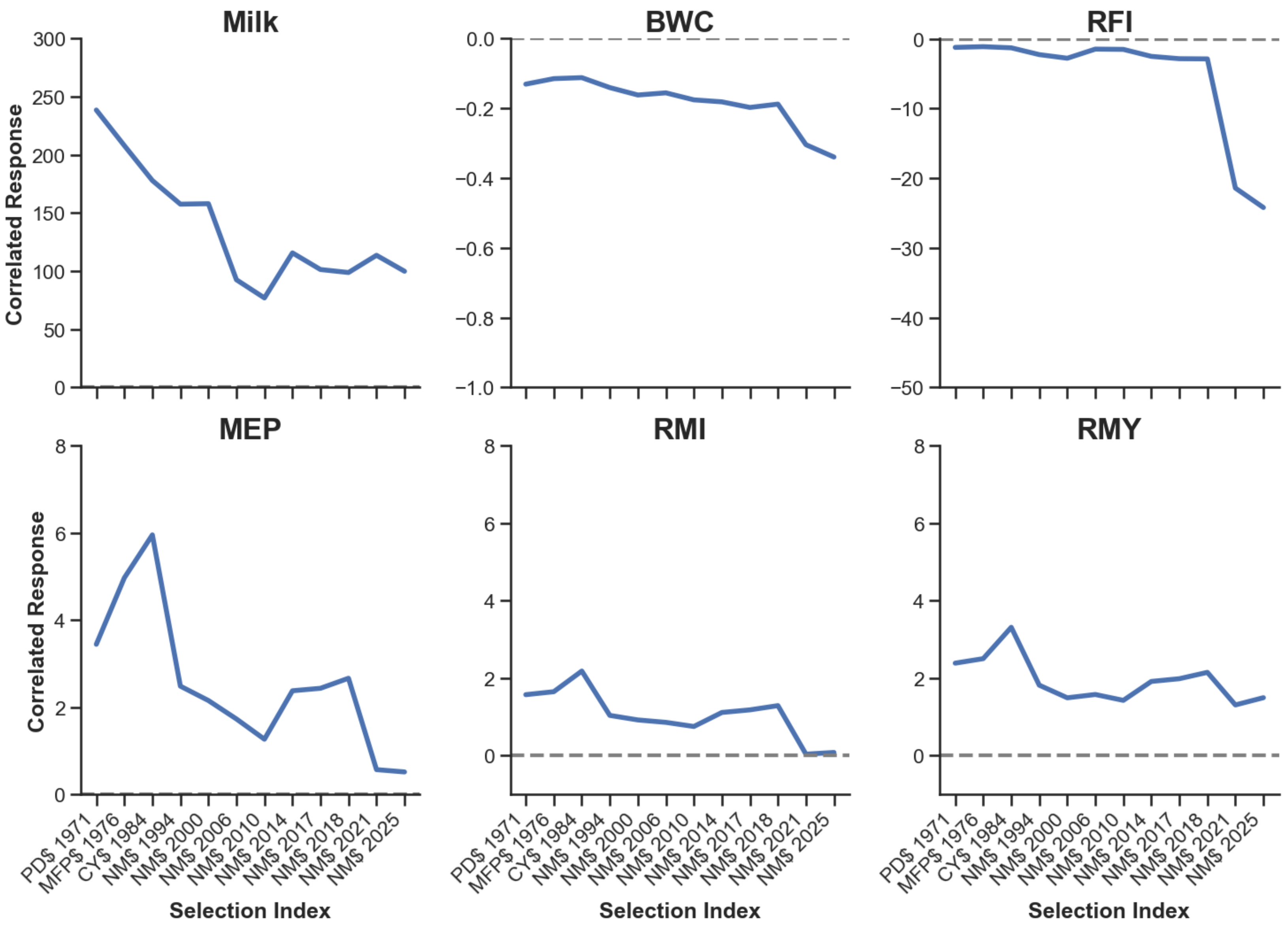
USDA

source: https://www.uscdcb.com

$NM: correlated responses



Martínez Boggio et al. (2025) in progress

Take home messages

- **growing public & consumer scrutiny over dairy farming**

  animal welfare, environmental impact, pharmacological interventions

- **genetic selection is a critical tool to improve dairy sustainability**

- **genetic selection is a very powerful tool**
- **best selection tool: economic selection index**
- **focus of selection has evolved:** from only production to fitness traits and efficiency

- **genomics facilitates the selection for novel, sustainable traits**

  feed efficiency, CH_4 emissions, resilience, estrus expression, thermoregulation, …

Team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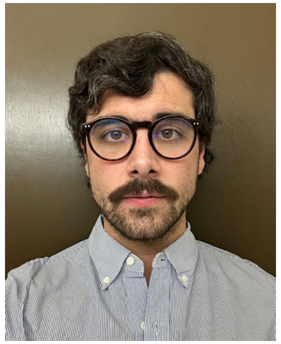
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GREENER CATTLE INITIATIVE

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PEAK

Thanks for your attention!

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