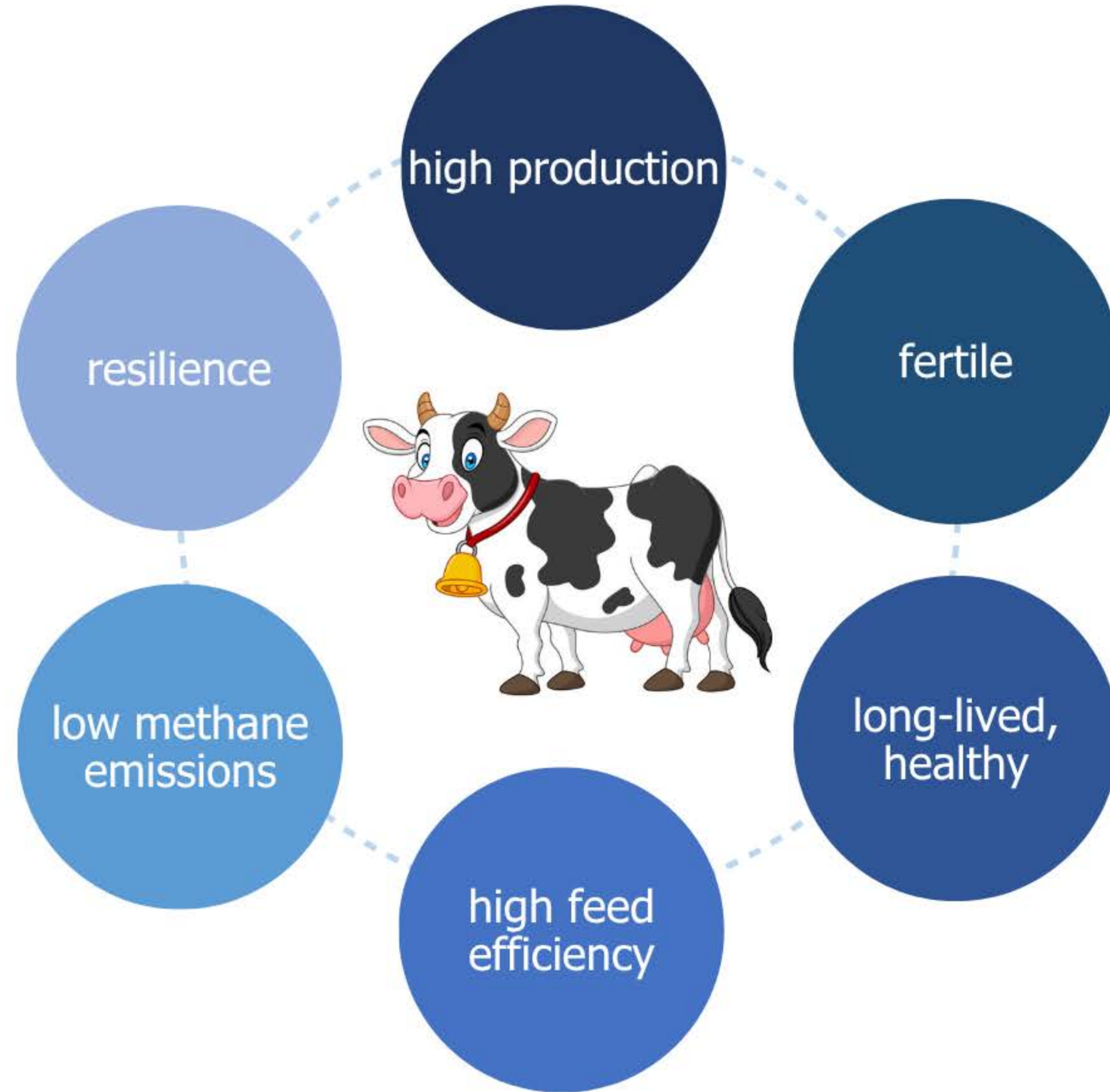


Sustainable dairy farming

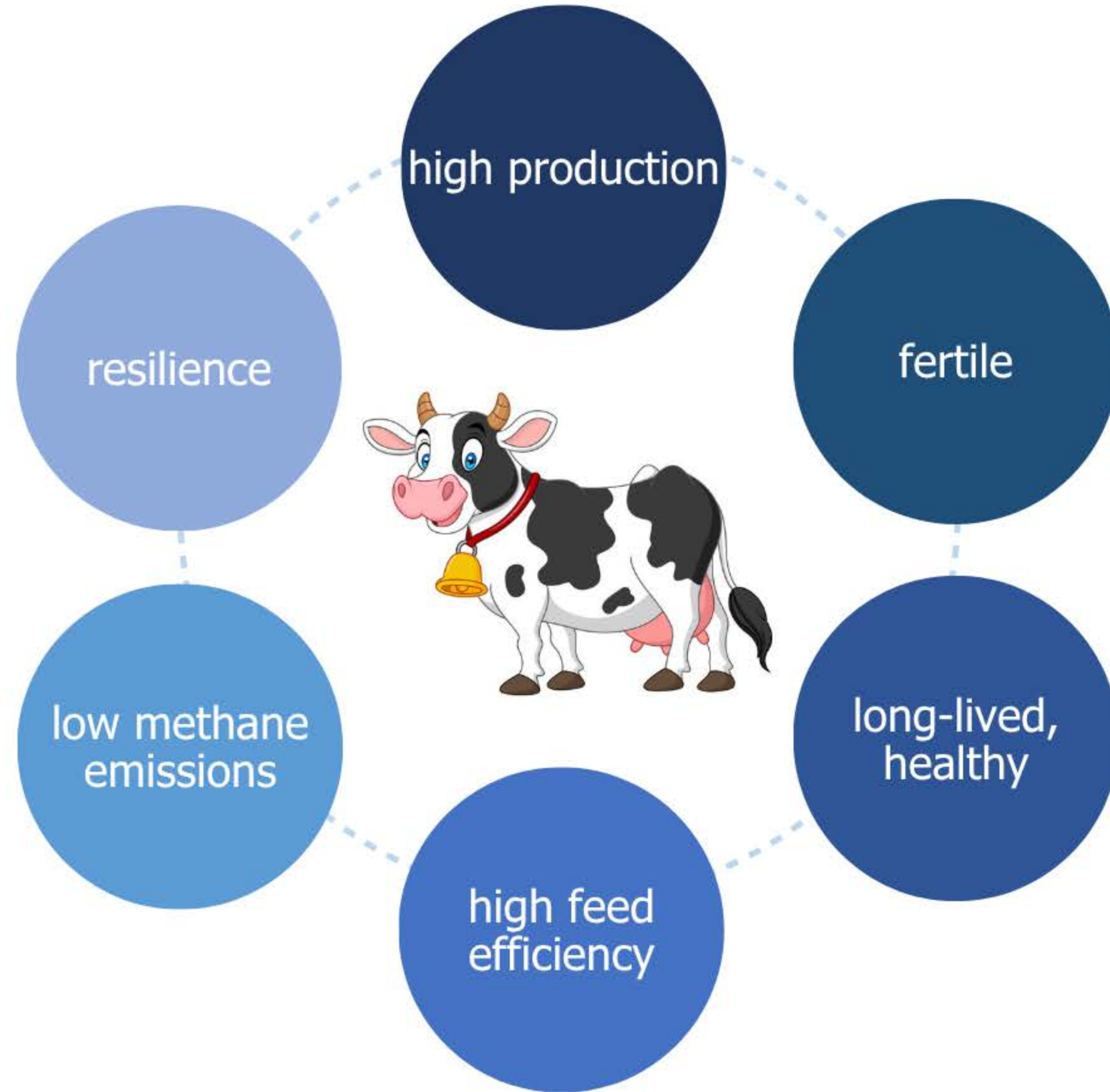


Sustainability

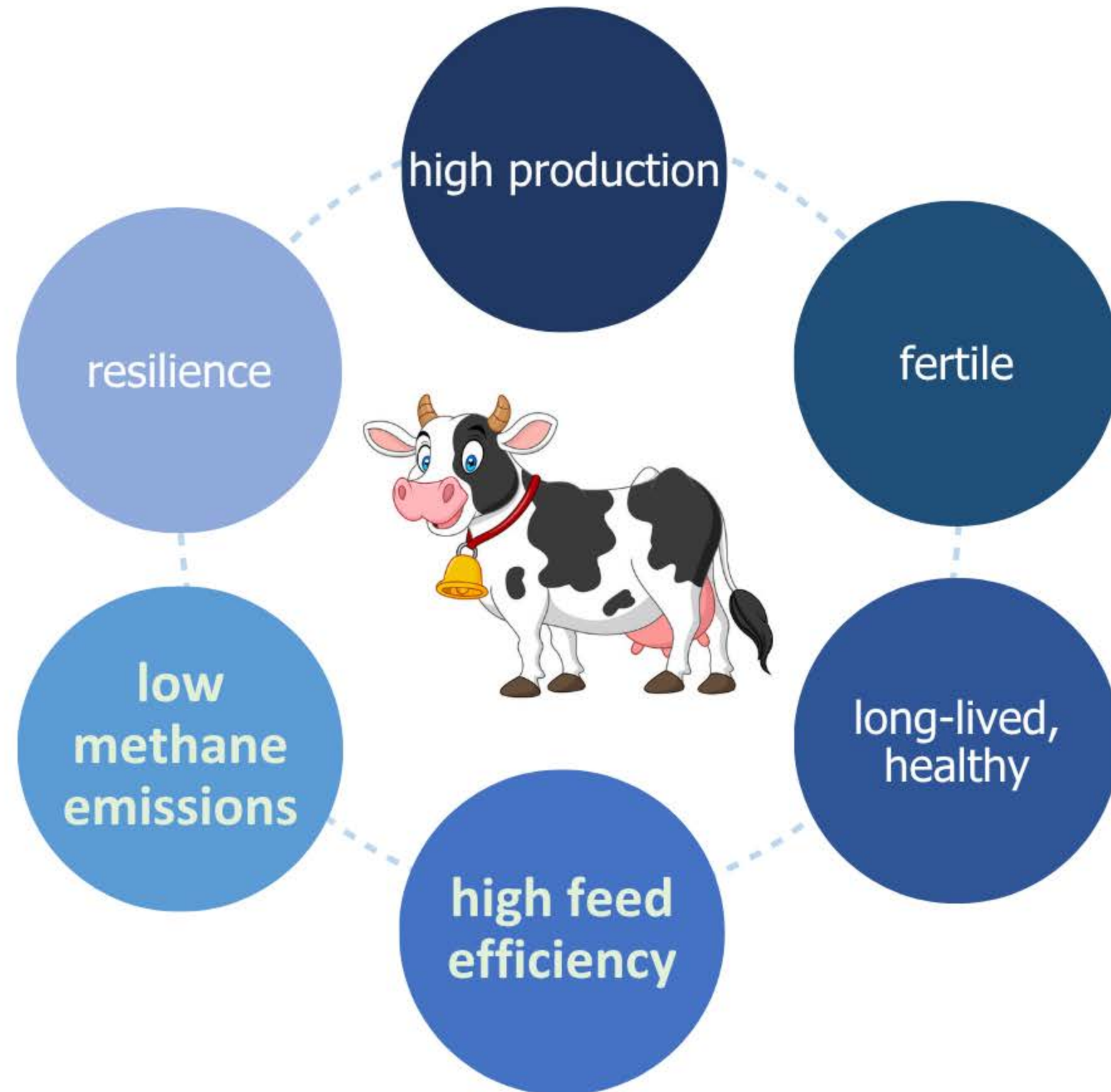
definition: **meeting the needs of the present, without compromising the ability of future generations to meet their own needs**



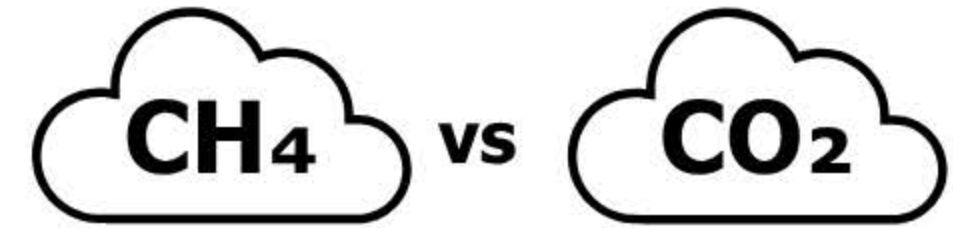
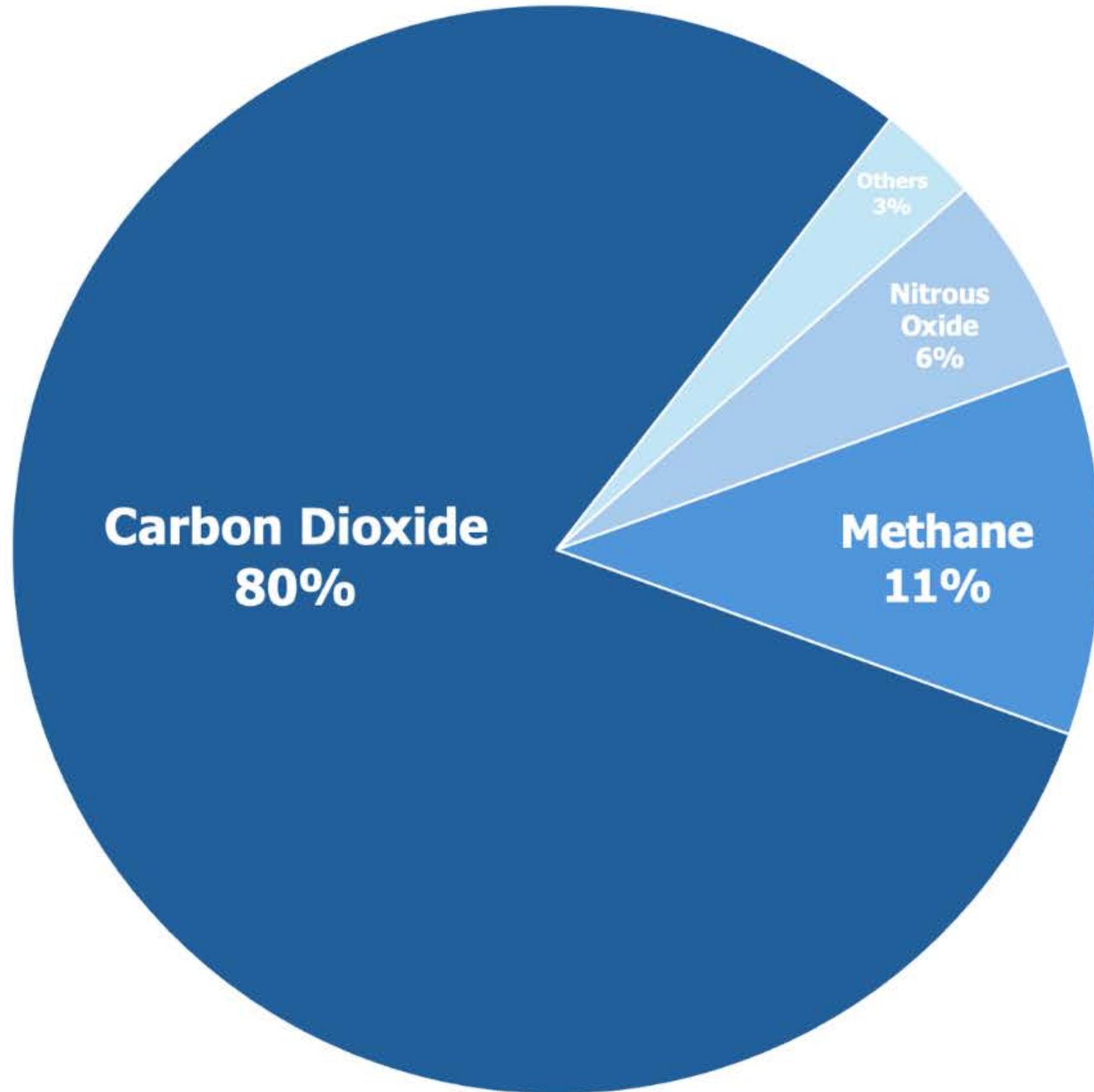
Sustainable dairy farming



Sustainable dairy farming



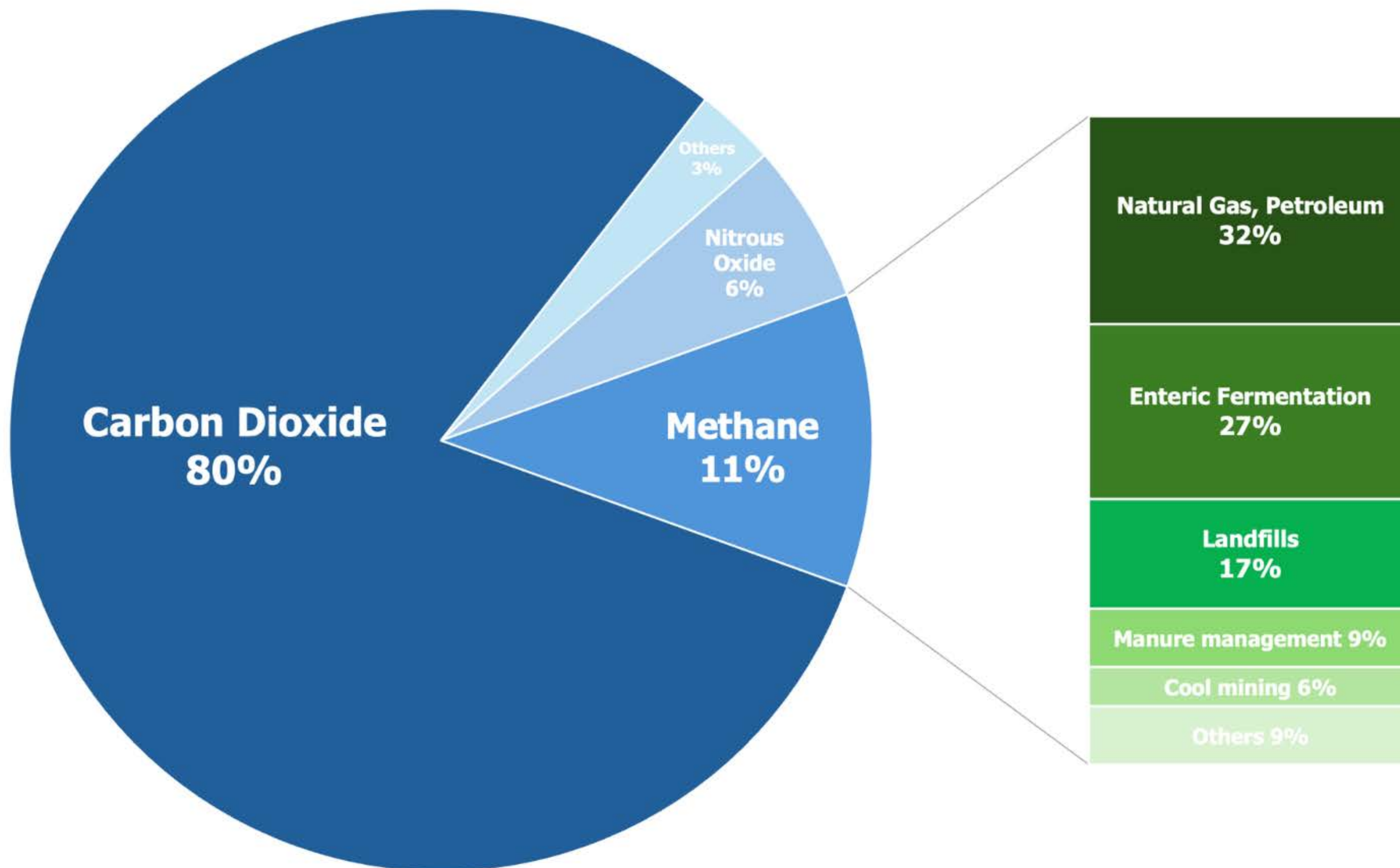
Why methane?



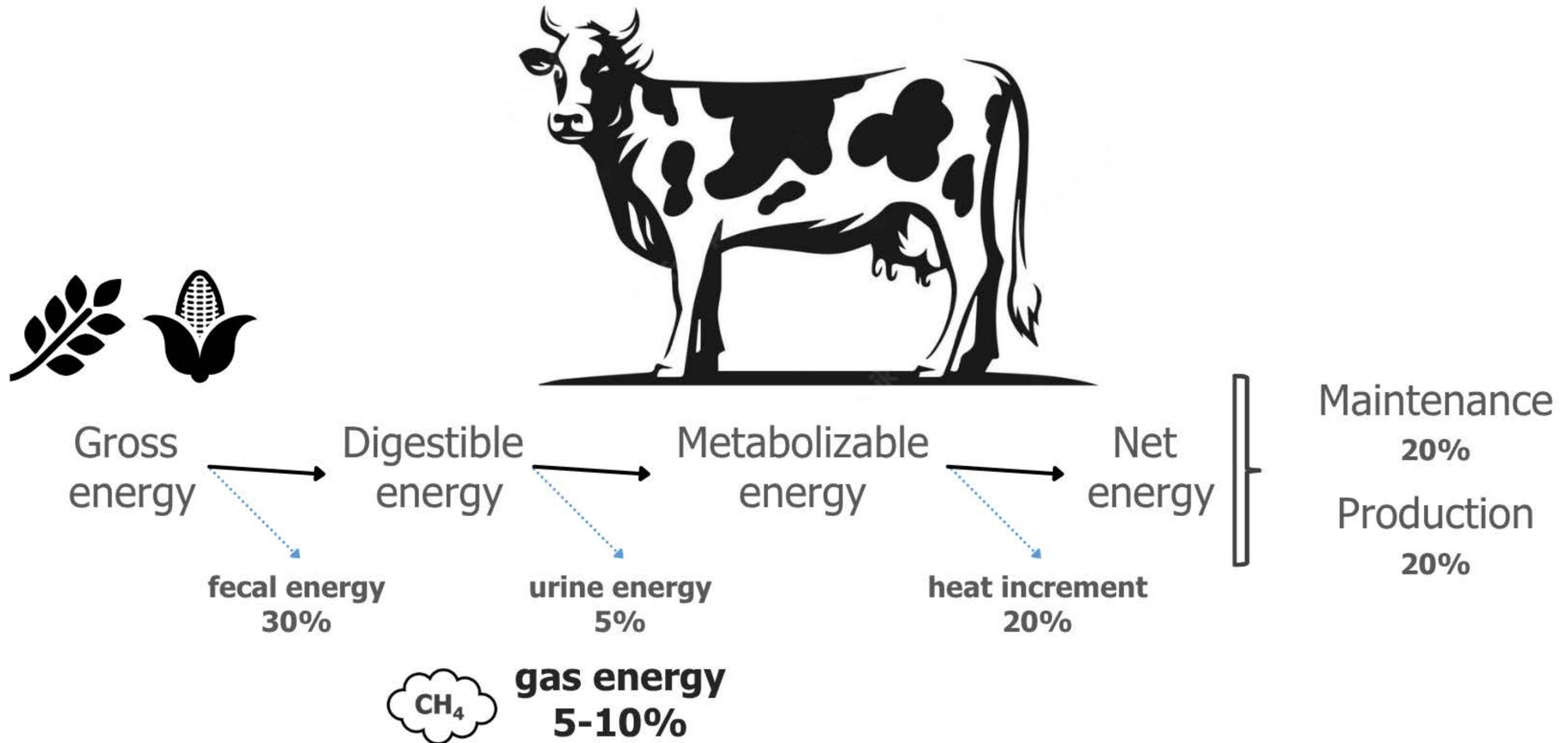
CH₄: more warming power
CH₄: shorter atmospheric lifetime

CH₄, reverse global warming

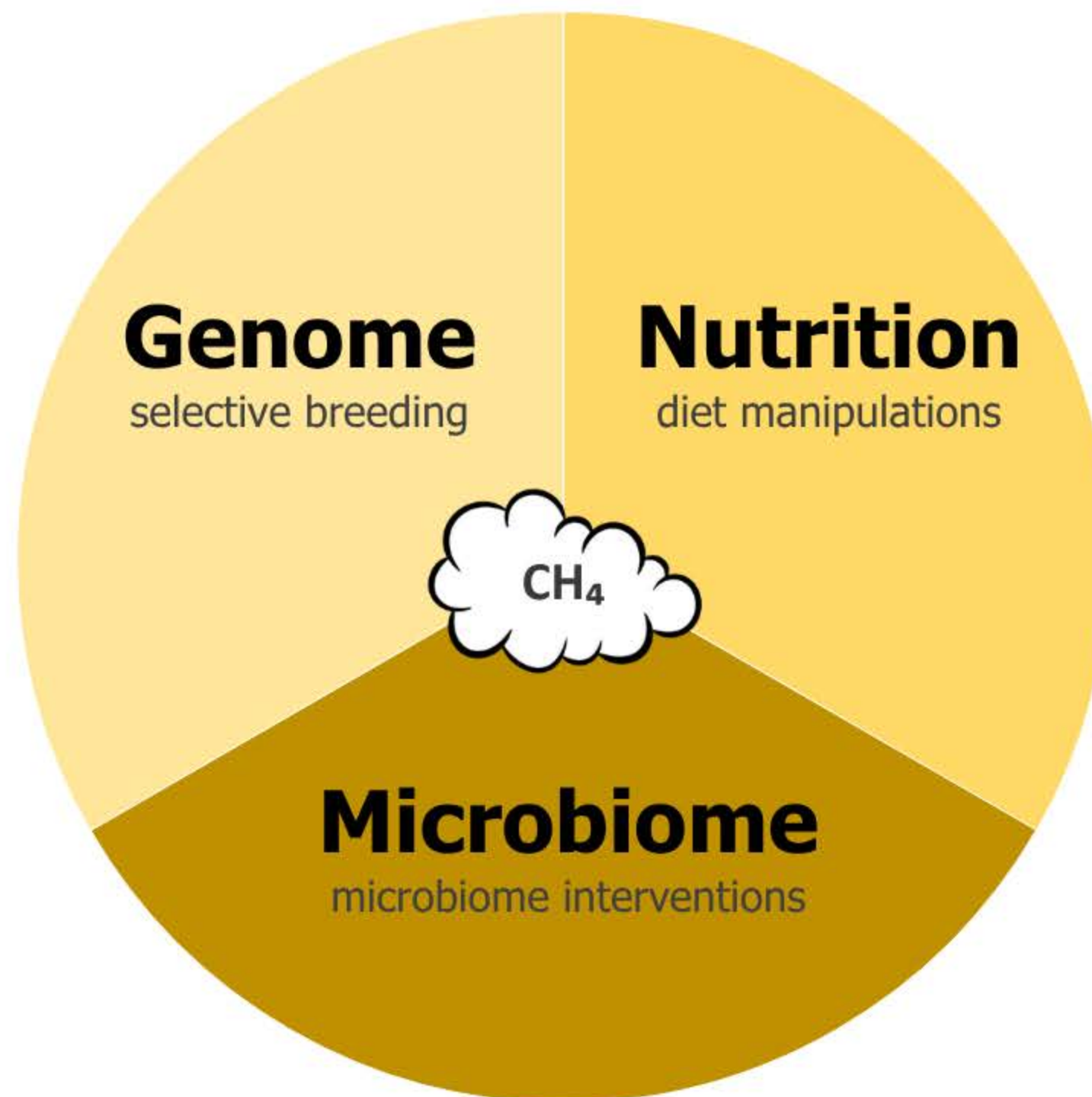
Why methane + livestock?



Methane as energy loss



Mitigation strategies



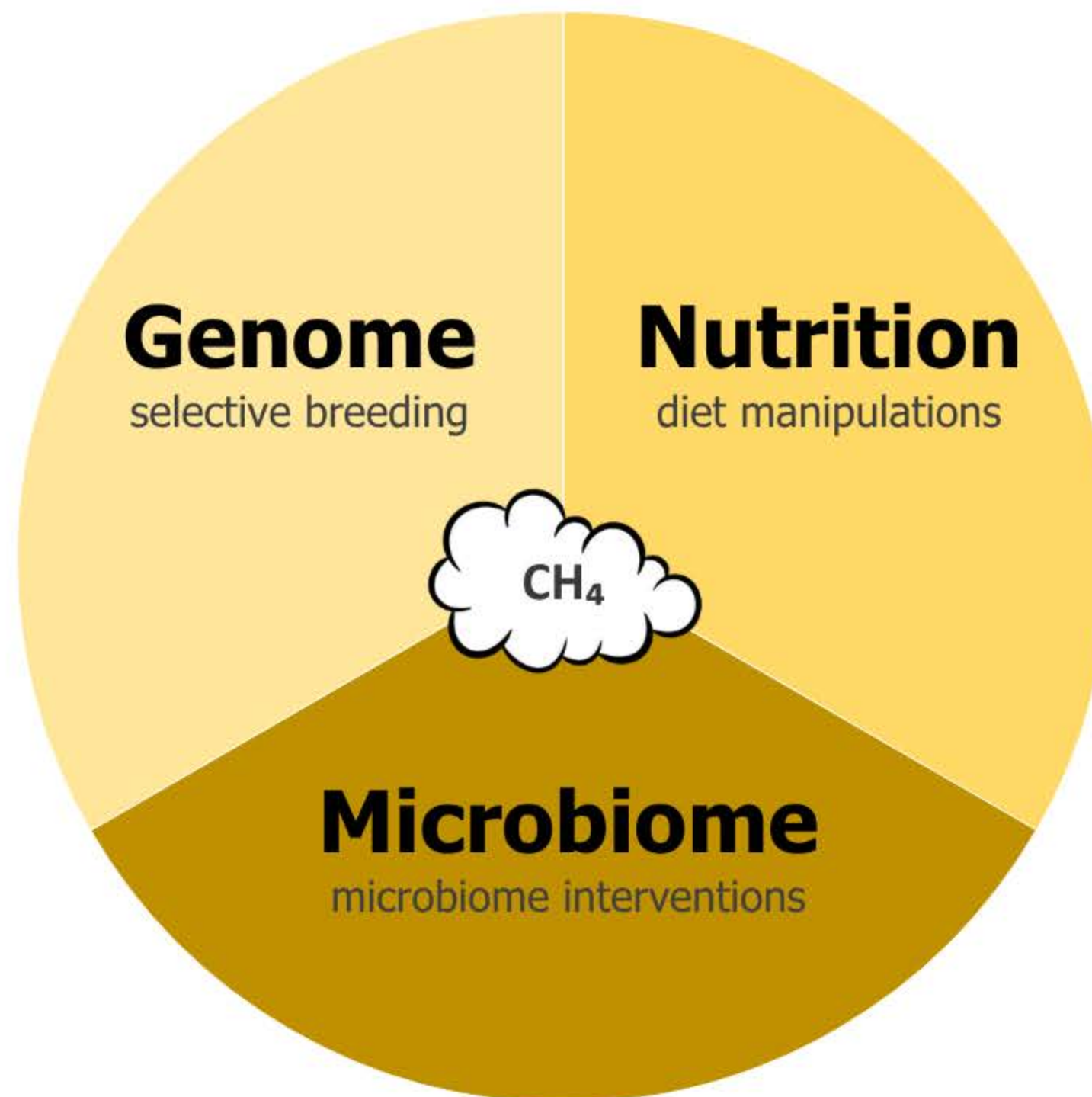
Mitigation strategies

Claudia Arndt et al. (2022) Proc Natl Acad Sci USA



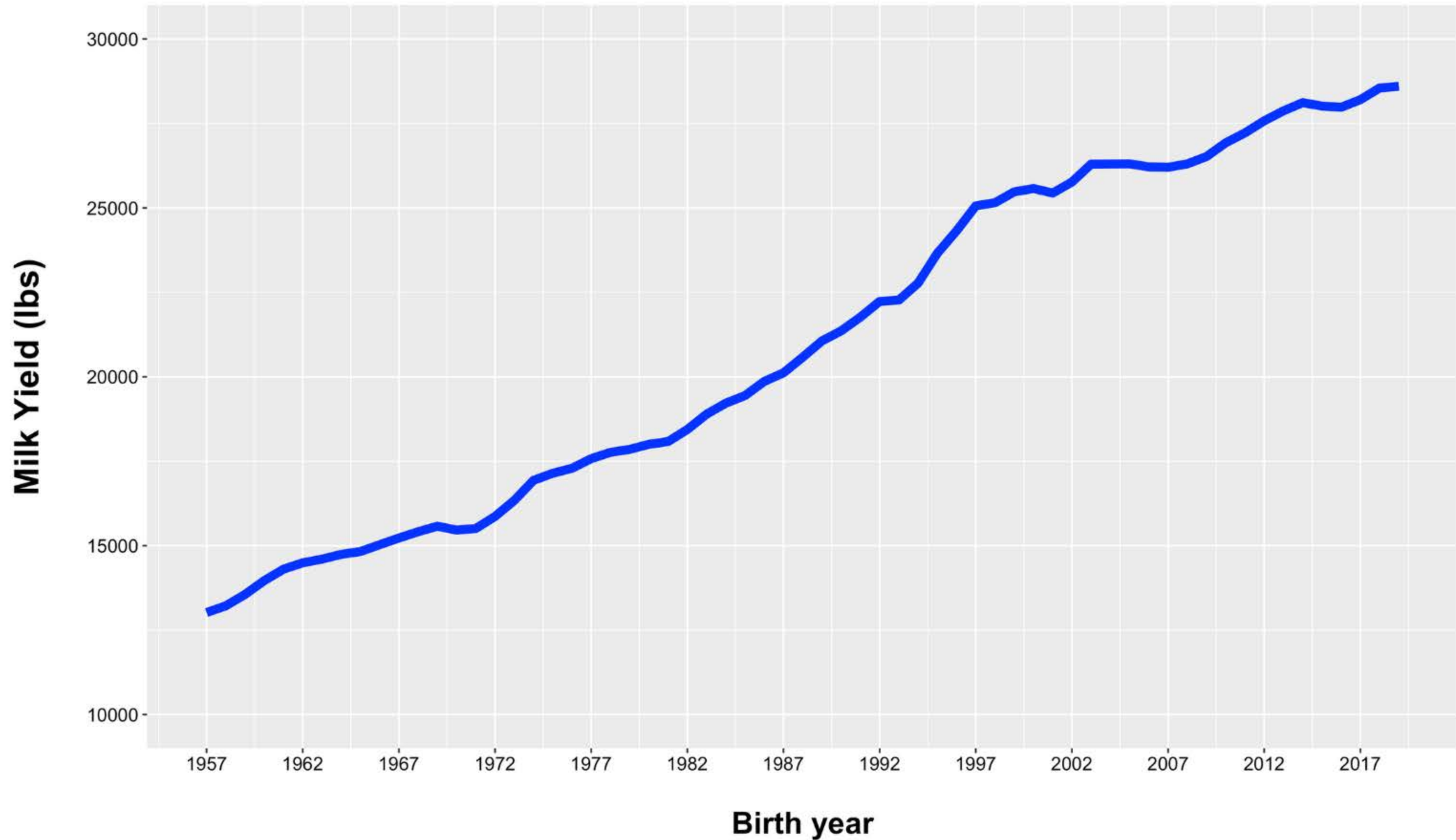
- **meta-analysis:** 430 peer-reviewed studies (1963 to 2018)
- **98 different enteric methane mitigation options**
 - animal and feed management, diet formulation, and rumen manipulation
- **most options (63/98) are not successful in mitigating methane**
- **only 8 options can reduce methane without impacting performance**
- **many challenges remain in identifying effective strategies**
- **any strategy should meet both farmers needs and consumers demands**

Mitigation strategies



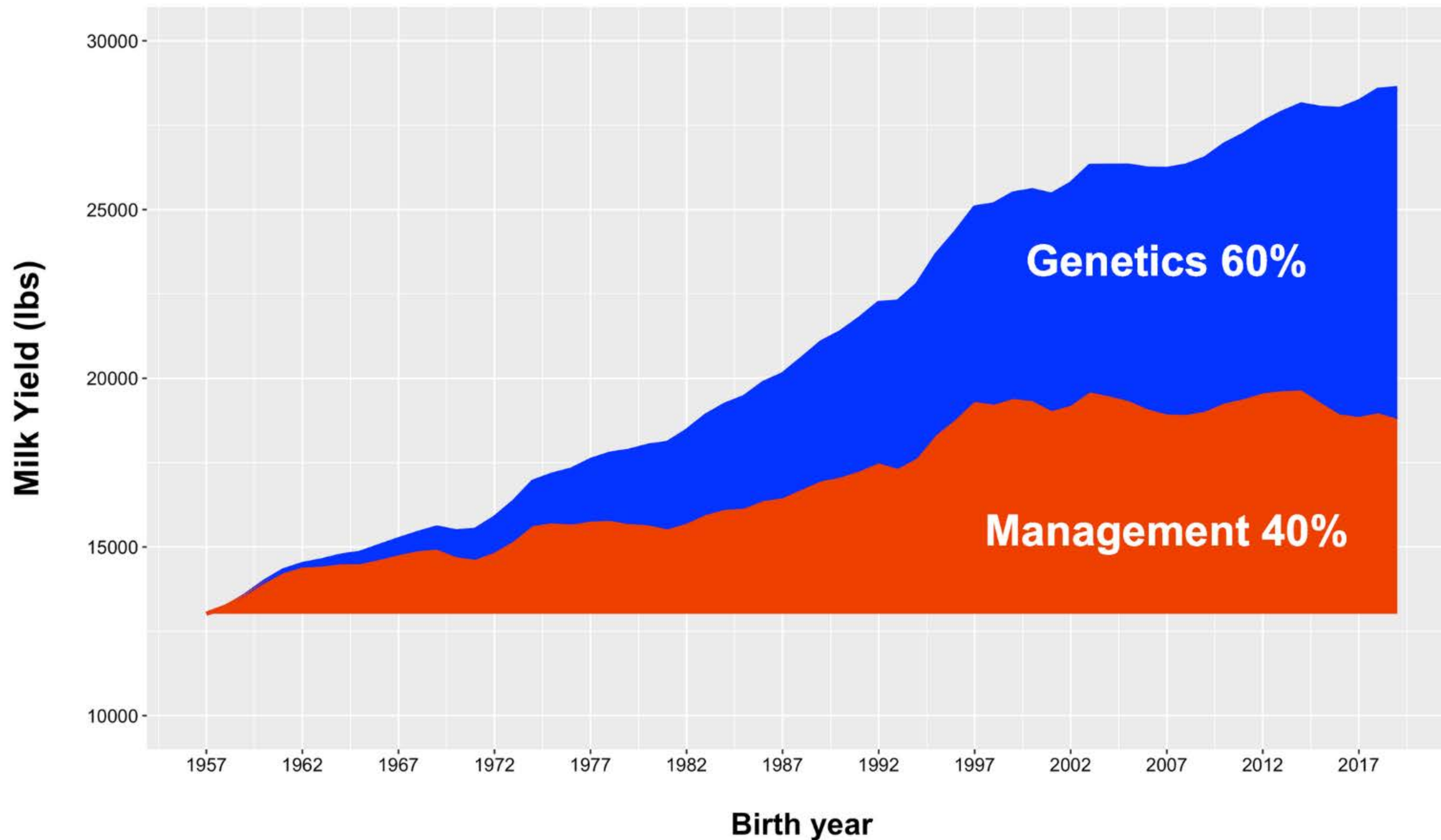
How important is genetic selection?

Change in milk yield in the last 60 years



How important is genetic selection?

Change in milk yield in the last 60 years



Current traits under selection



Production	milk yield protein yield & percentage fat yield & percentage milking speed
Fertility	daughter pregnancy rate heifer/cow conception rate age at first calving
Longevity	productive life cow livability heifer livability
Health	SCS mastitis ketosis retained placenta metritis DA milk fever
Calving ability	calving ease stillbirth rate gestation length
Conformation	body weight composite feet and leg composite udder composite type
Feed efficiency	residual feed intake feed saved

Mothers	Not yet, but we're working on it!
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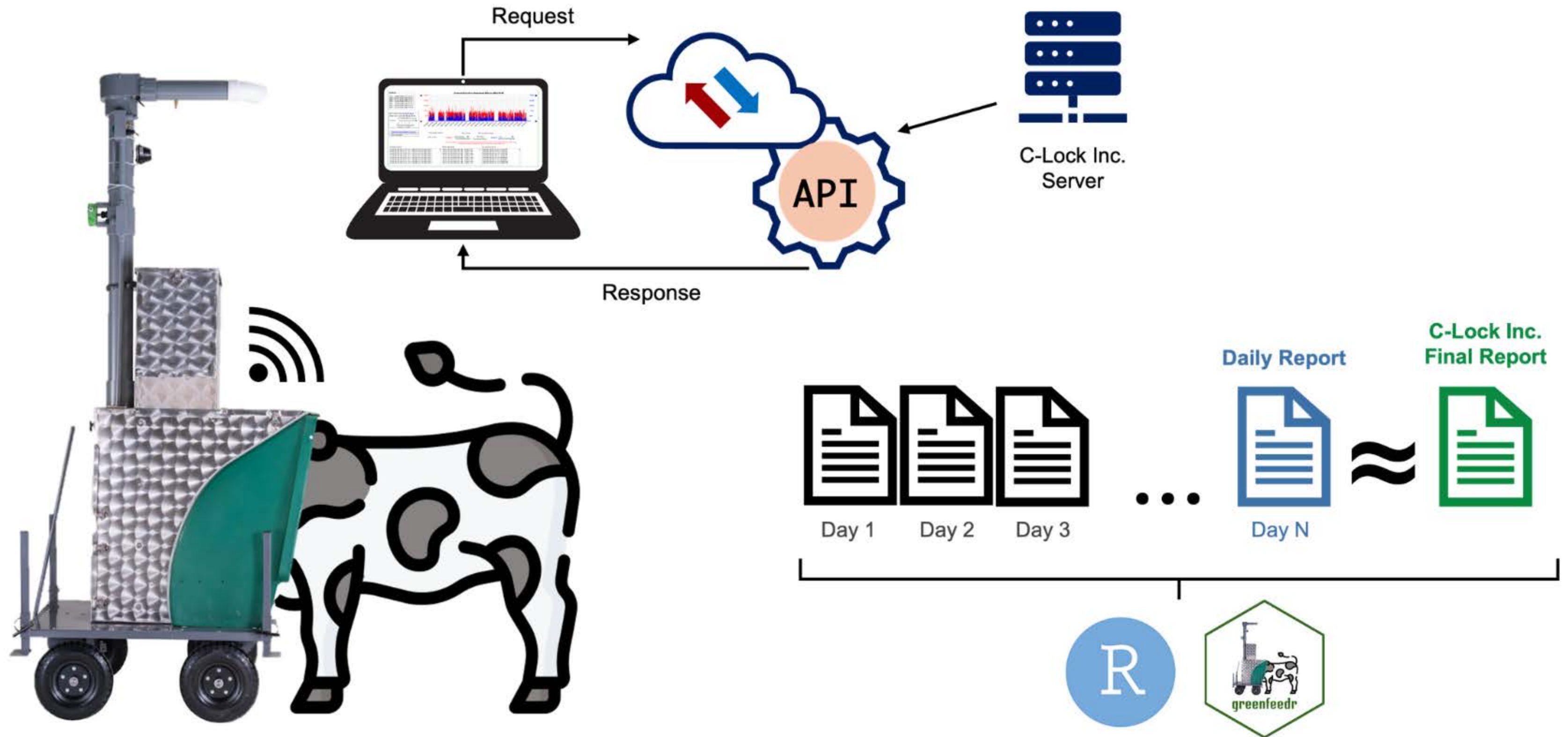
Phenotyping CH4

GreenFeed system, research and commercial farms



greenfeedr R-package

downloading, processing, reporting GreenFeed data



GreenFeed (C-Lock Inc.)

Trait definition

Alternative methane emission traits

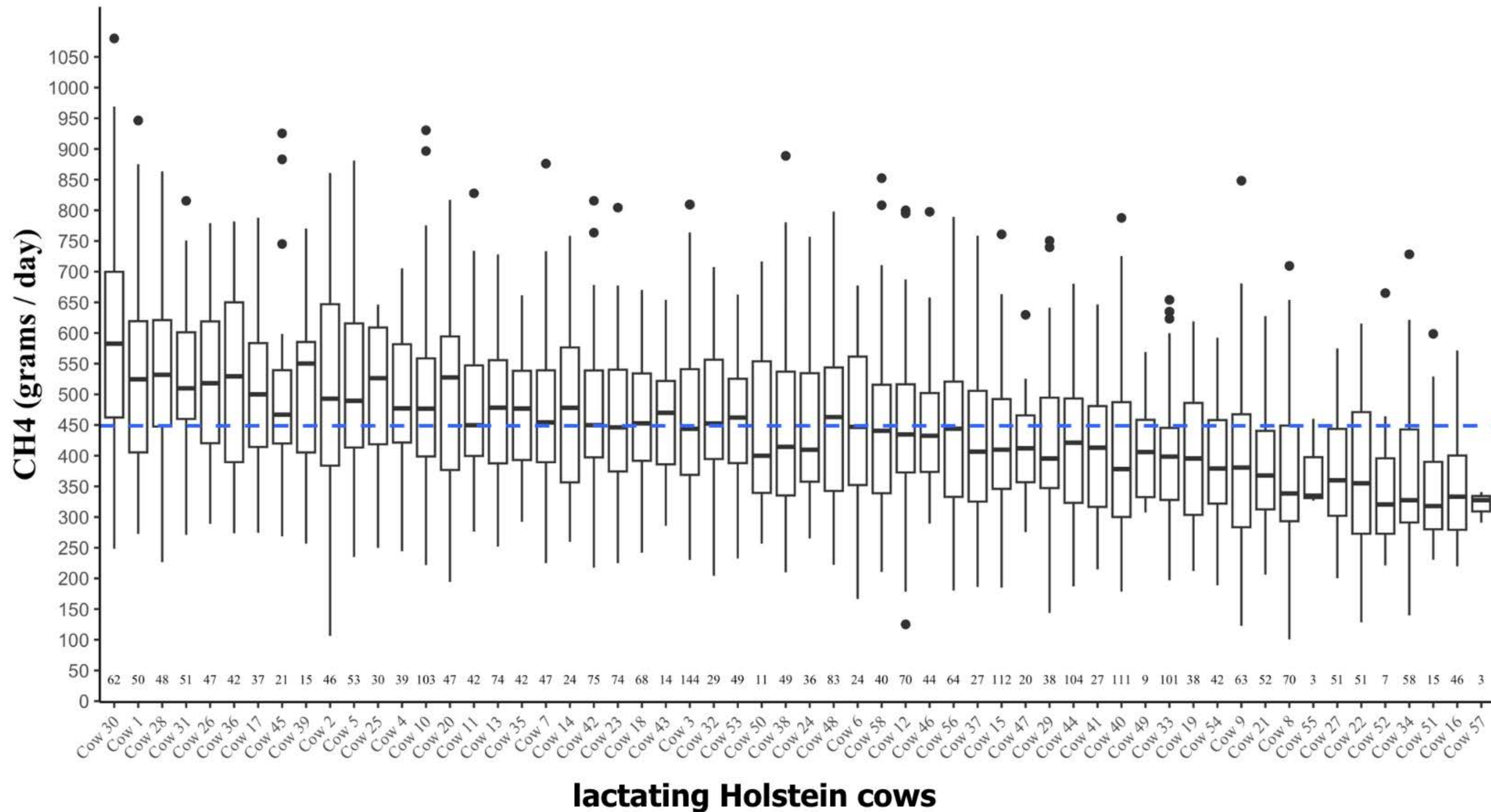


- **methane production** (grams CH₄ per day)
- **methane yield** (grams CH₄ per kg of dry matter intake)
- **methane intensity** (grams CH₄ per kg of energy-corrected milk)
- **residual methane**

residual methane intensity (CH₄ regressed on milkE and mBW)

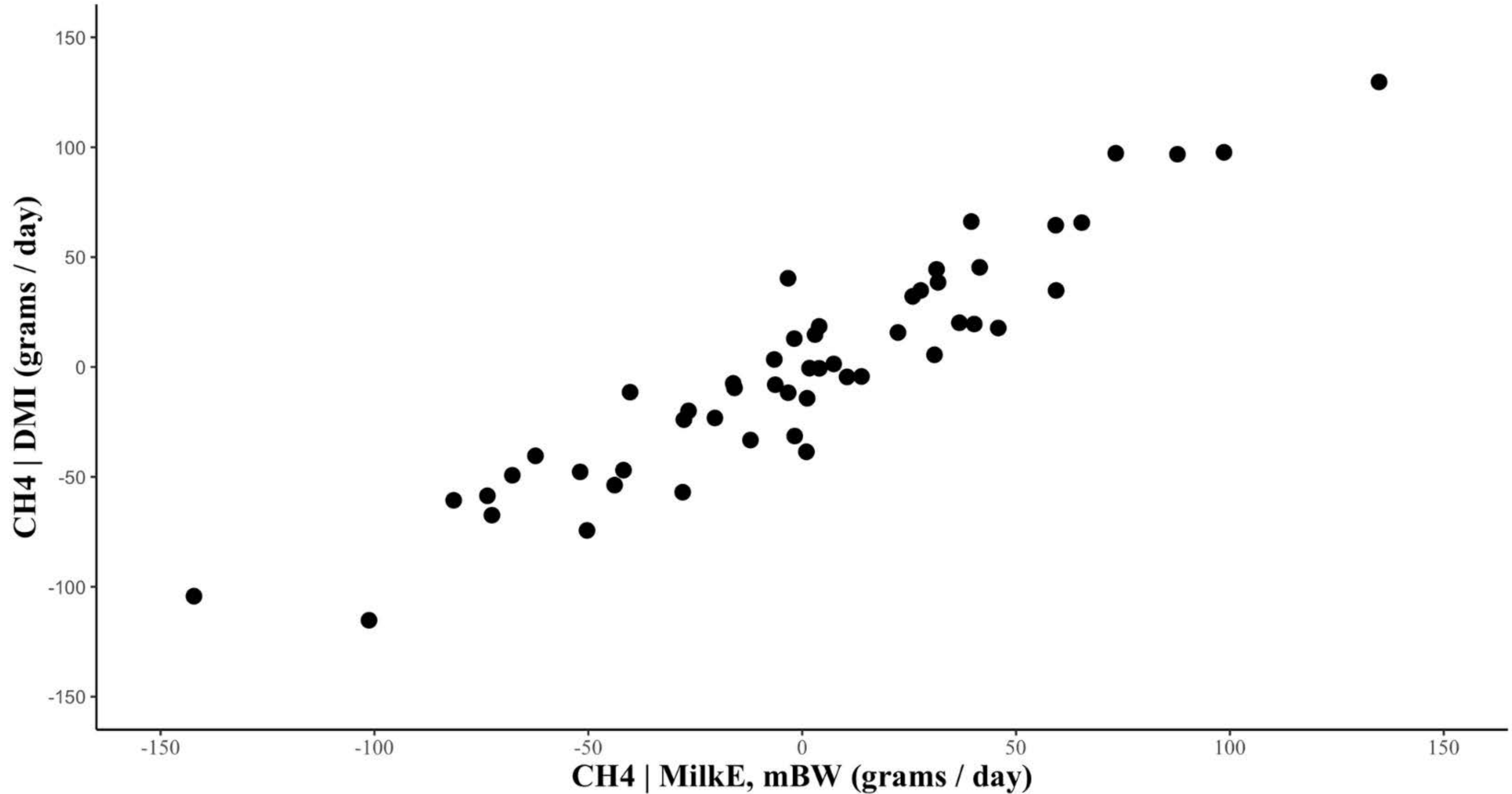
residual methane yield (CH₄ regressed on DMI)

Variability in CH₄ production



Residual CH4 production

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



Are CH4 traits heritable?

Data: CH4, milk energy, body weight, intake | 3500 cows, 12 farms



Heritability	CH4 Production	Residual CH4 Intensity	Residual CH4 Yield	Residual Feed Intake
CH4 Production	0.28 0.04			
Residual CH4 Intensity		0.23 0.04		
Residual CH4 Yield			0.21 0.05	
Residual Feed Intake				0.18 0.05

Are CH4 traits correlated?

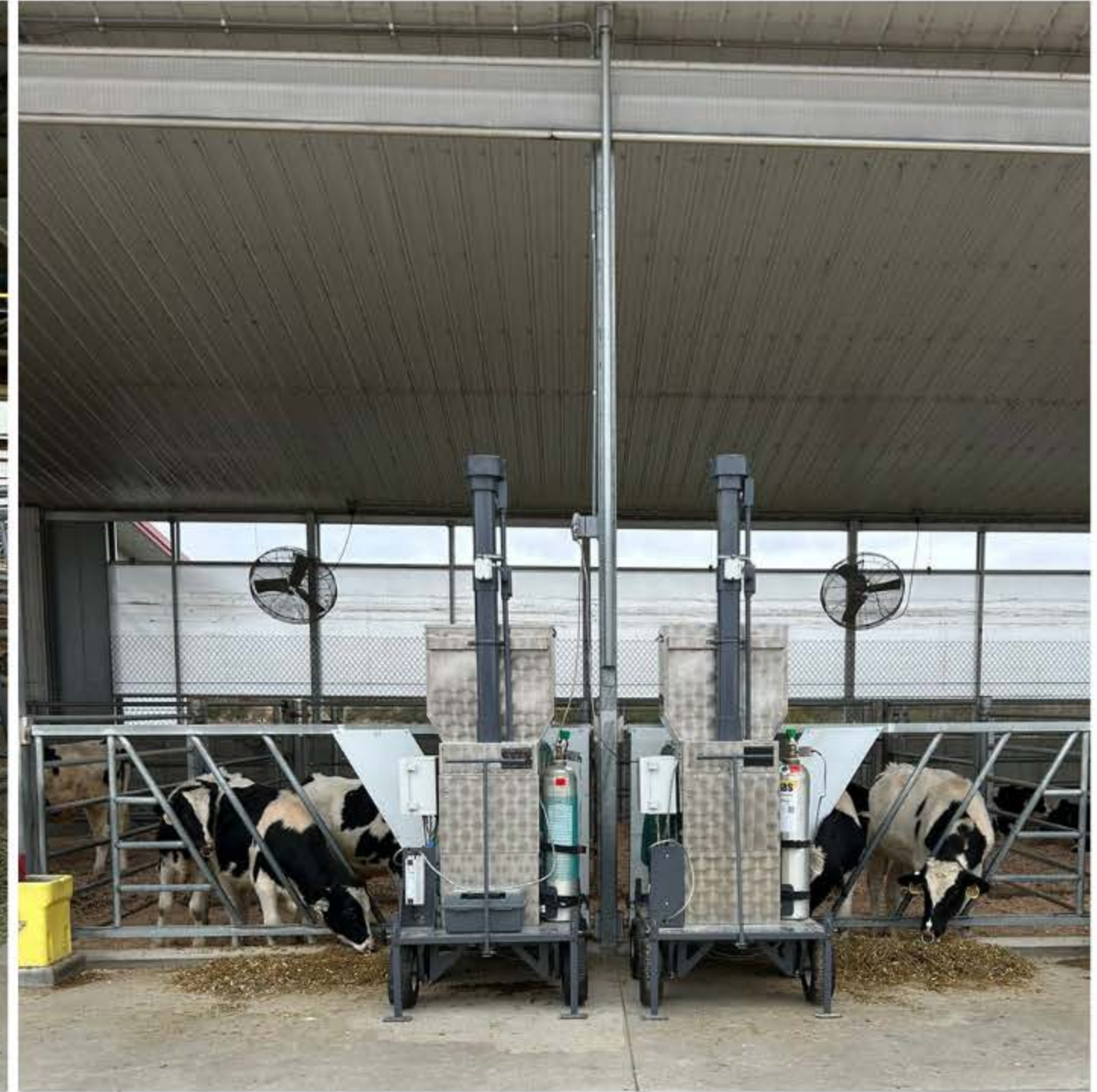
Data: CH4, milk energy, body weight, intake | 3500 cows, 12 farms



Genetic correlation	CH4 Production	Residual CH4 Intensity	Residual CH4 Yield	Residual Feed Intake
CH4 Production	0.28 0.04	0.93 0.01	0.89 0.07	0.40 0.12
Residual CH4 Intensity		0.23 0.04	0.97 0.01	
Residual CH4 Yield			0.21 0.05	
Residual Feed Intake				0.18 0.05

Can we speed up the process?

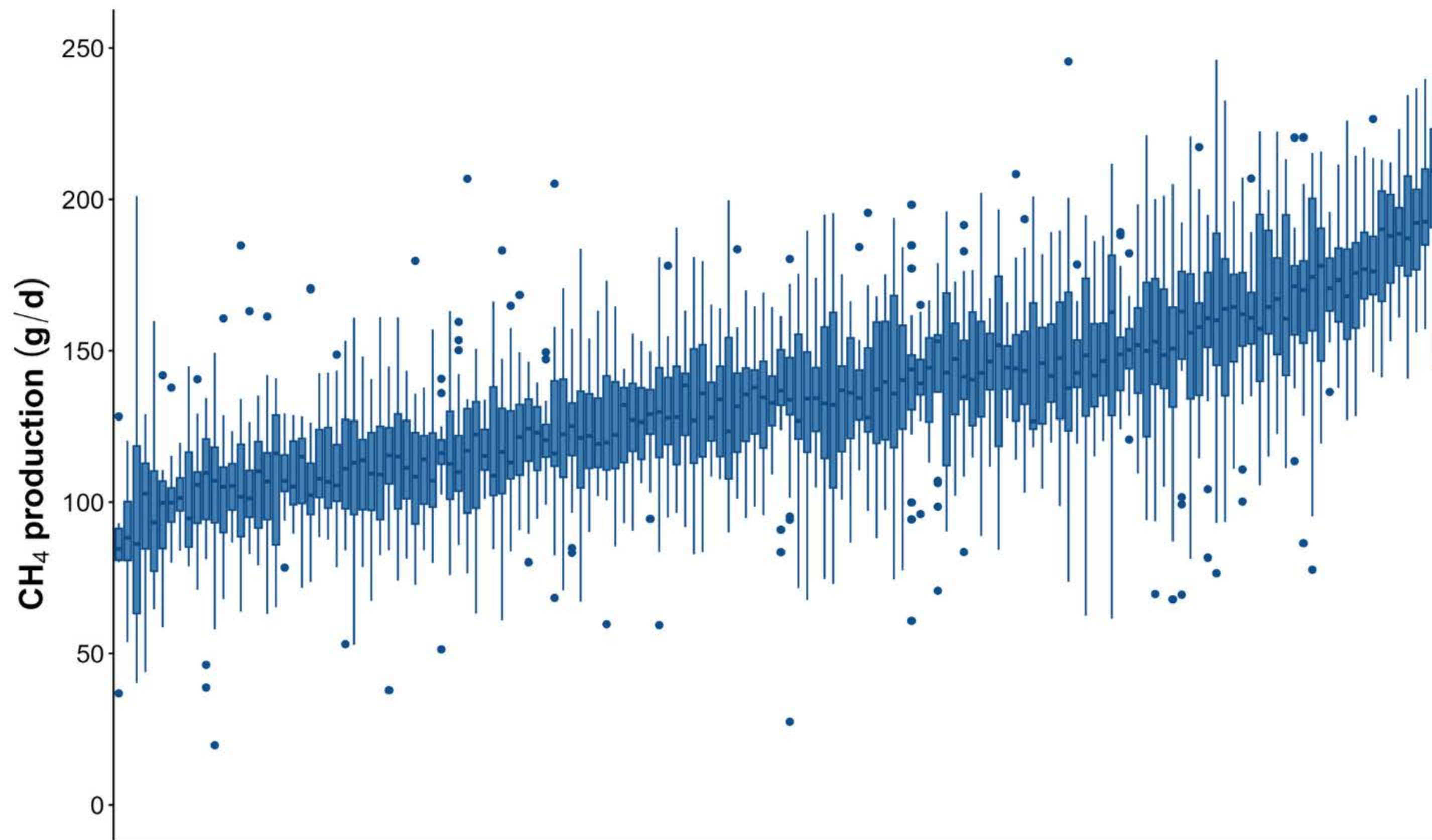
Phenotyping Holstein bulls, 5-6 months old, 3 weeks of records



Q: what's the correlation (CH₄ in young bulls, CH₄ in lactating cows)?

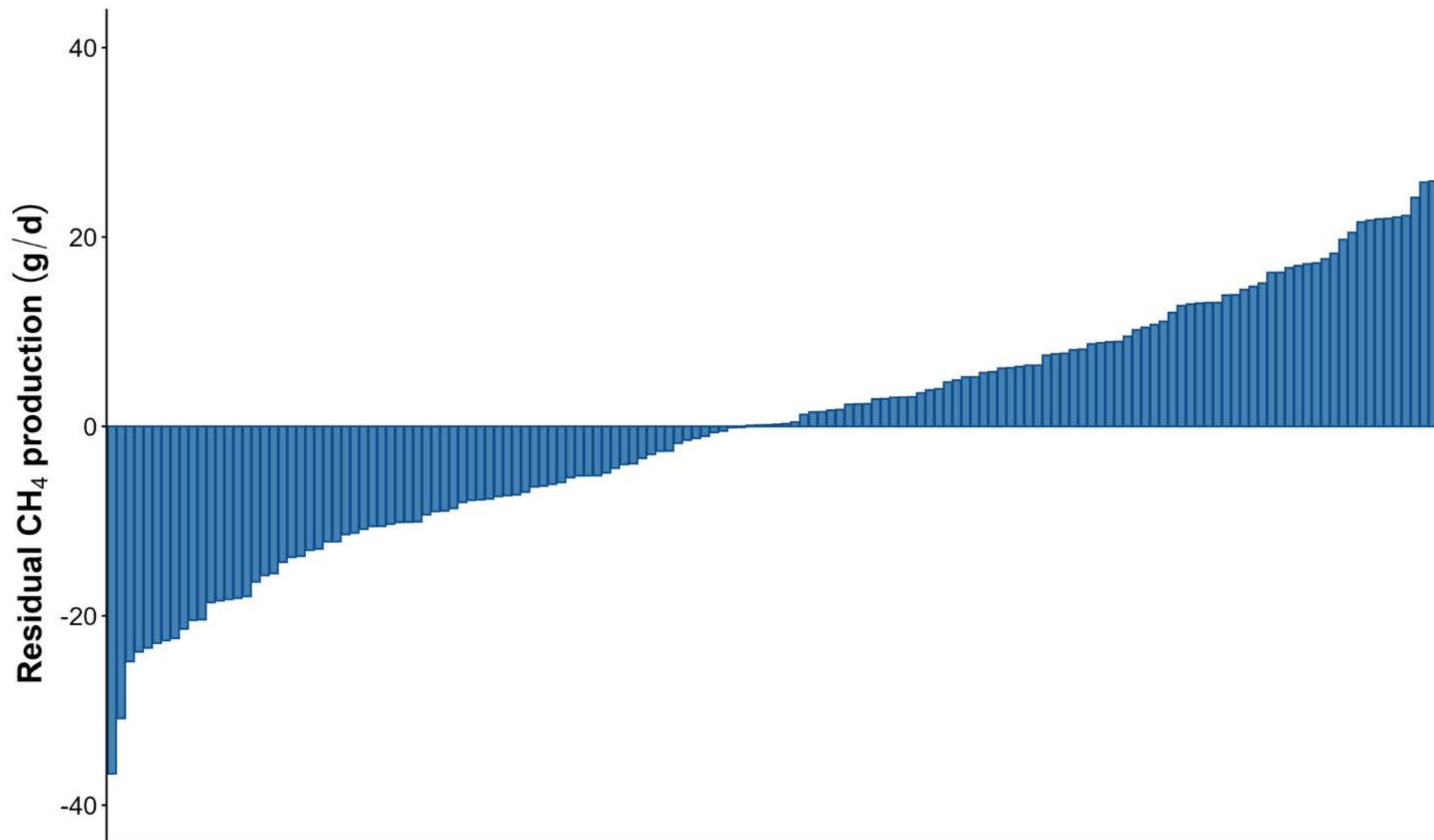
CH₄ production

Preliminary results: 150 Holstein bulls, 5-6 months old, 3 weeks of records



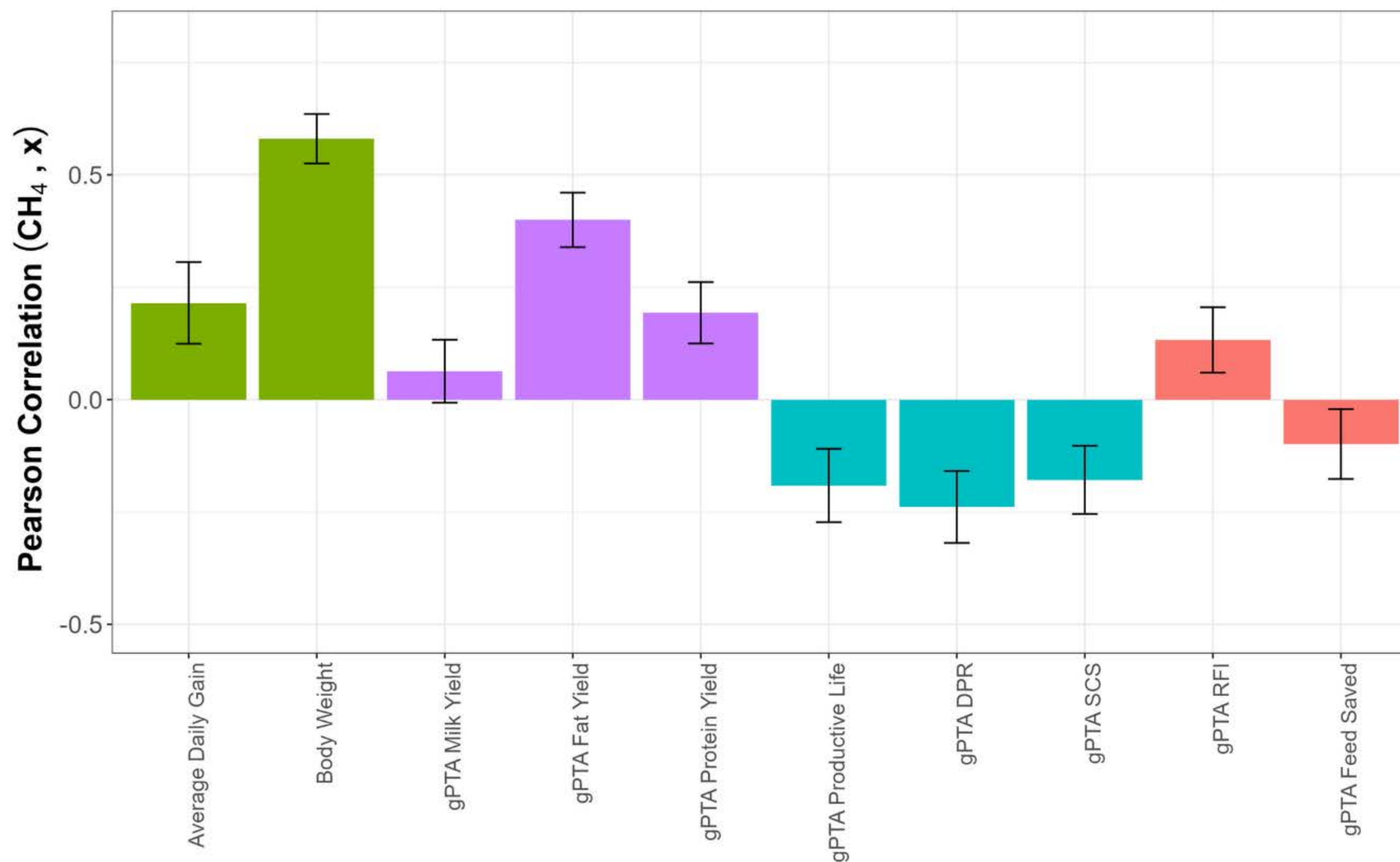
Residual CH₄ production

Preliminary results: 150 Holstein bulls, 5-6 months old, 3 weeks of records

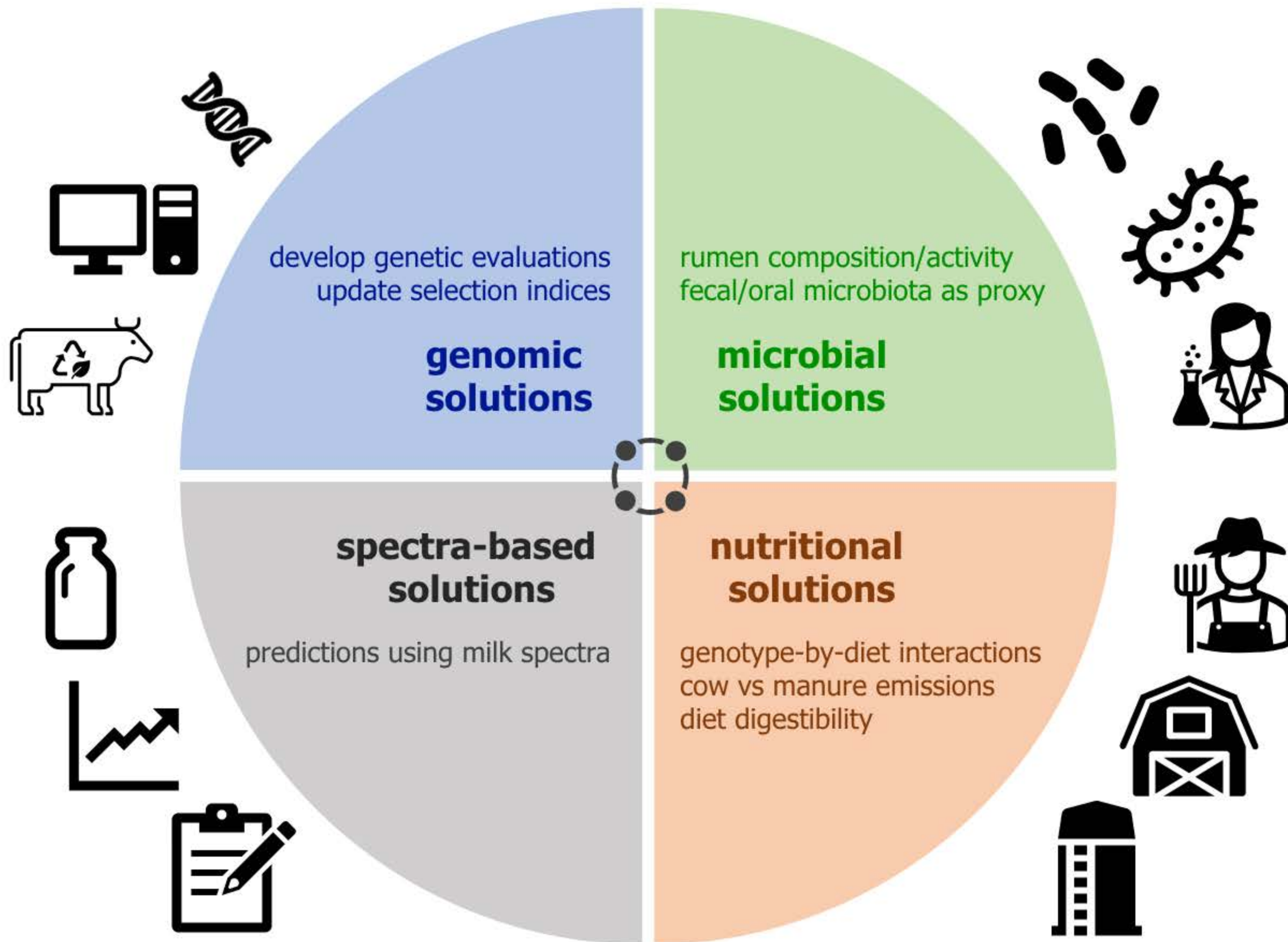


Correlations (CH₄, gPTA)

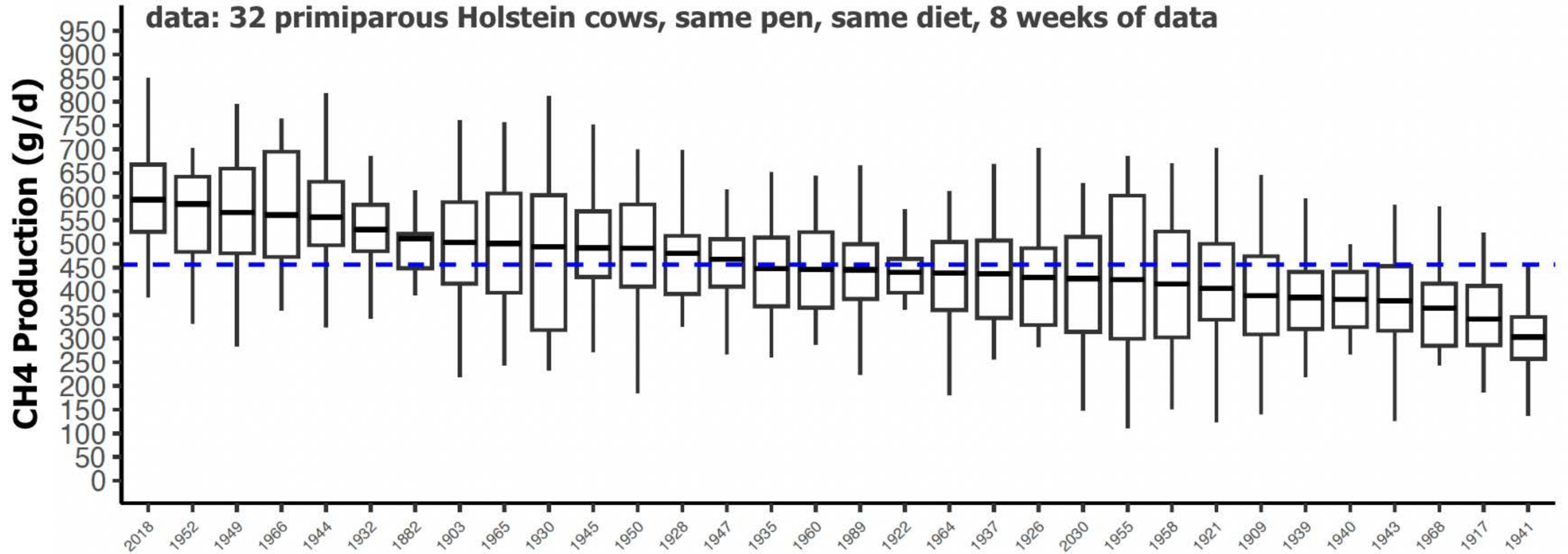
Preliminary results: 150 Holstein bulls, 5-6 months old, 3 weeks of records



Methane emissions: current efforts



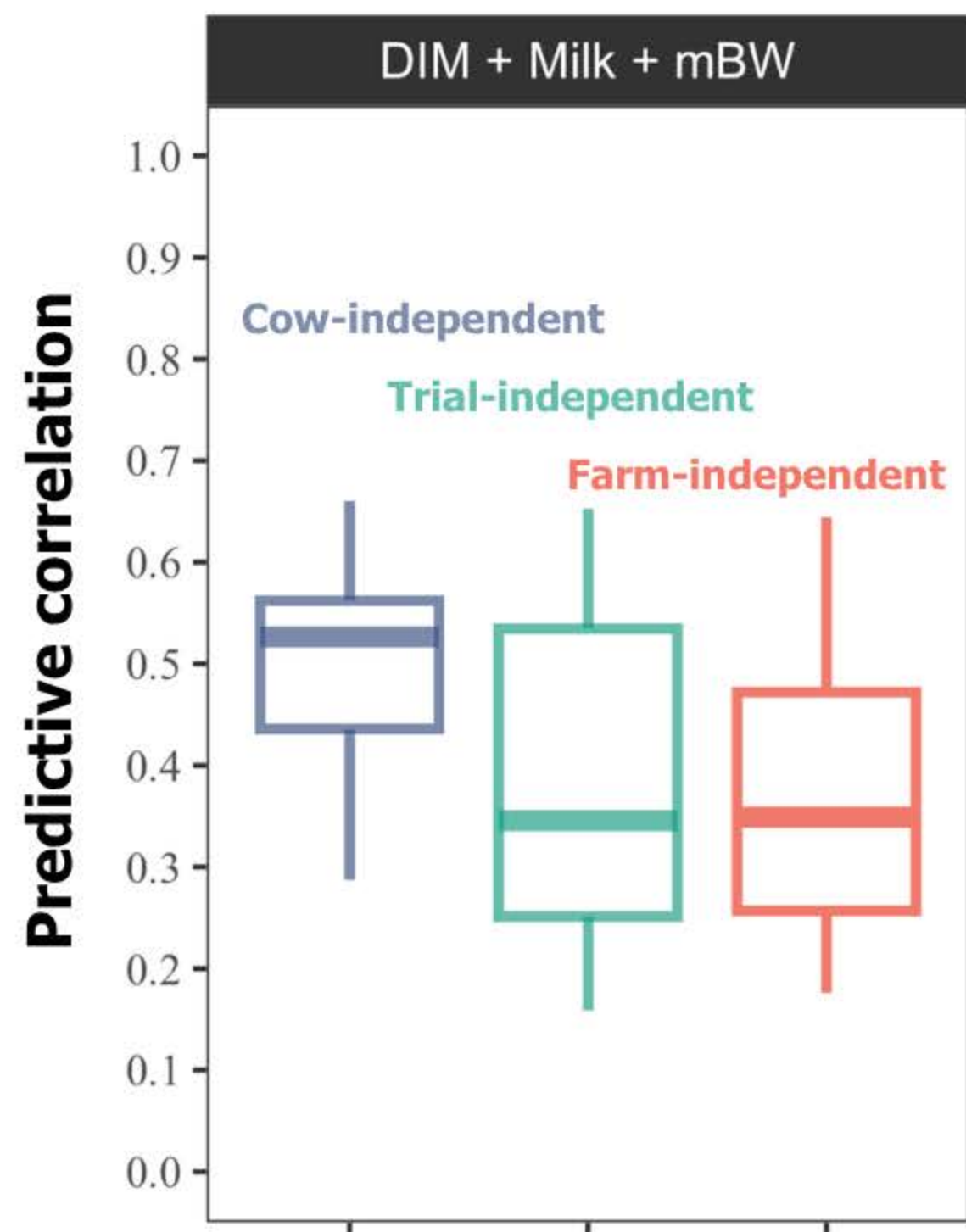
Precision management



Do we have tools to predict CH4 production? **Not yet, but we're working on it!**

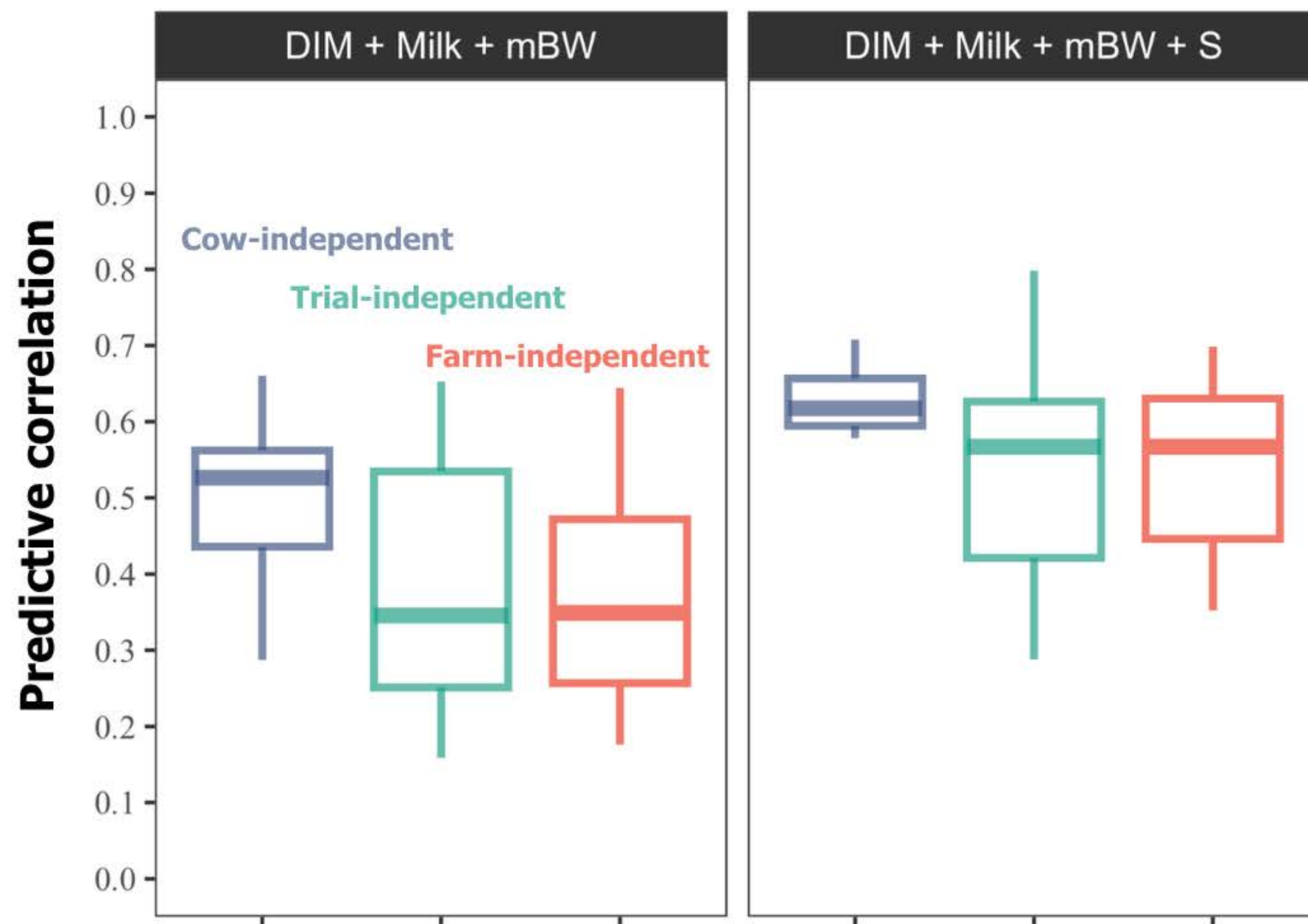
Milk spectra: predicting CH₄ production

Data: CH₄, milk energy, body weight, spectra, genomics



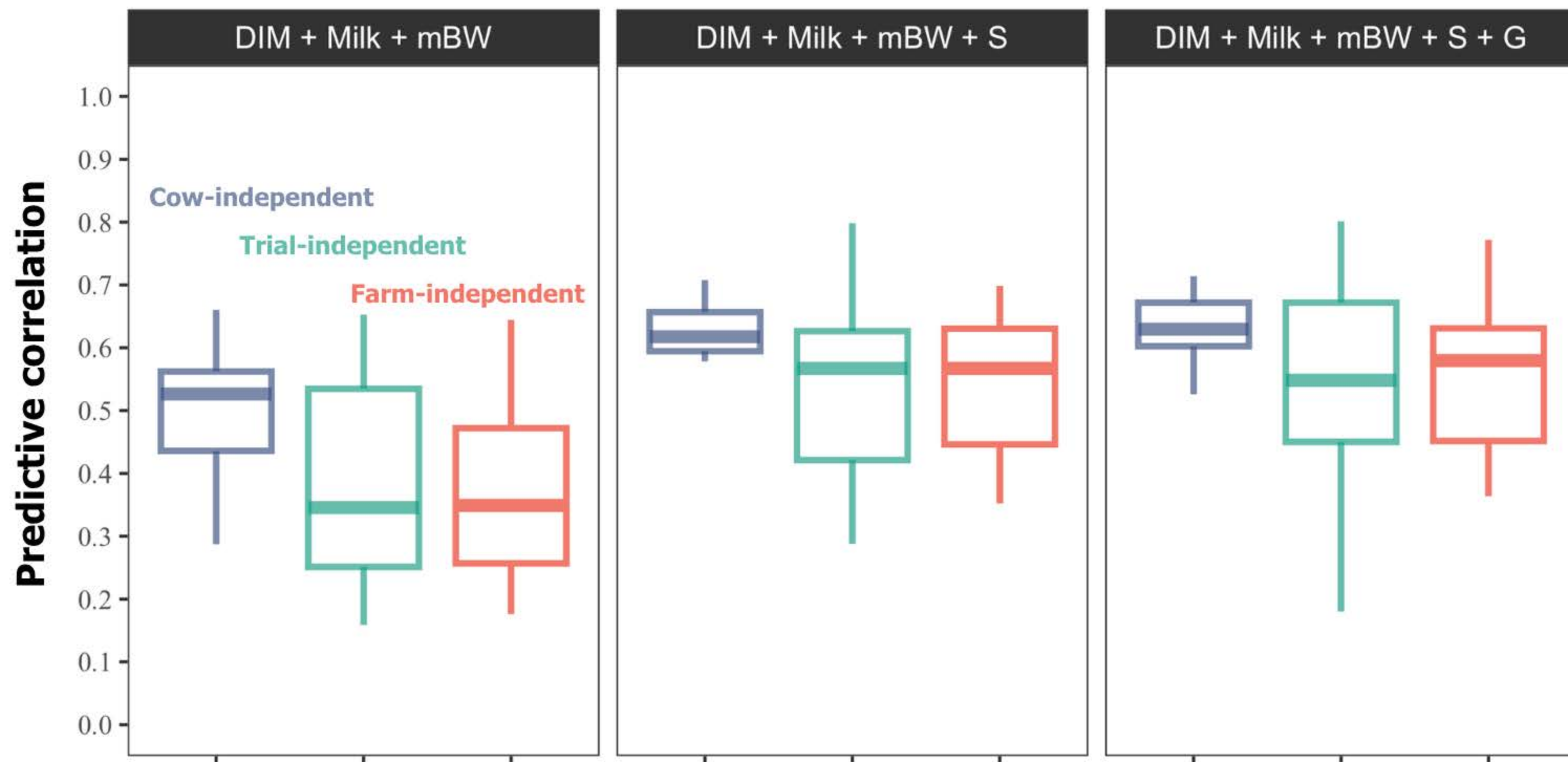
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Milk spectra: predicting CH₄ production

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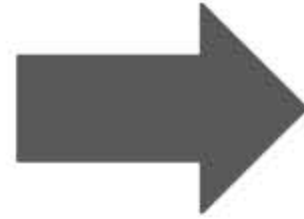


Microbiome

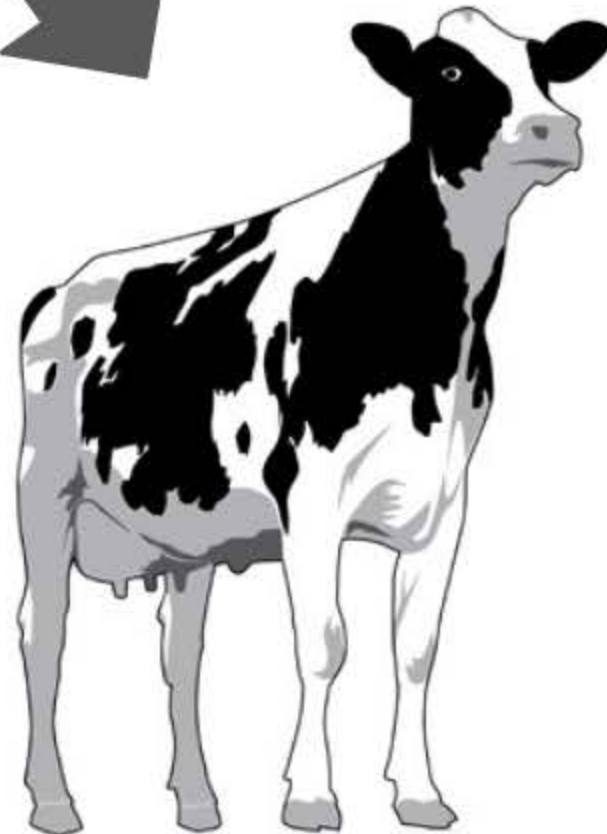
enteric CH₄ is formed exclusively by methanogens in the rumen



**Host
Genome**

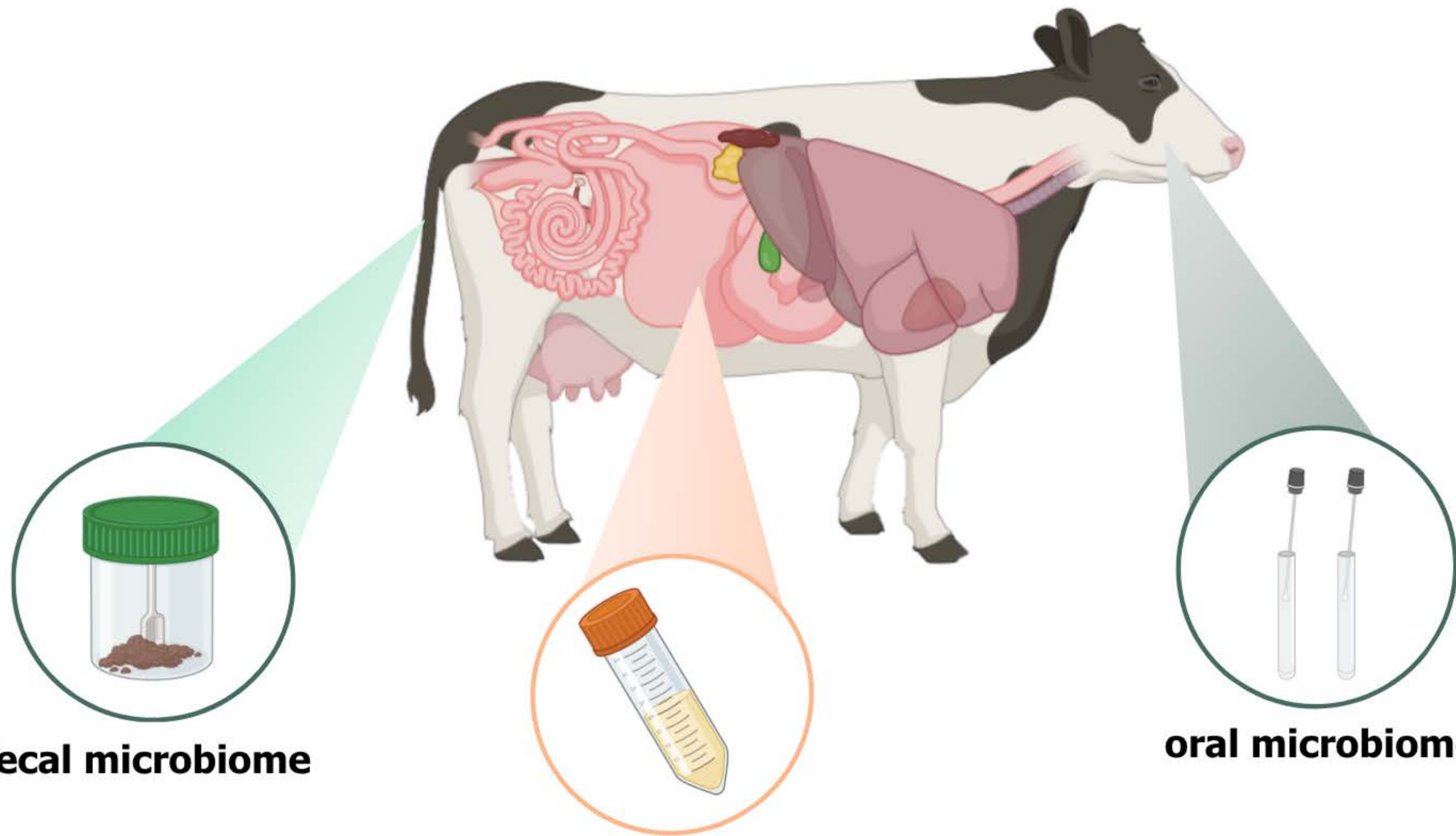


Microbiome



Phenotype

Microbiome collection



fecal microbiome

rumen microbiome

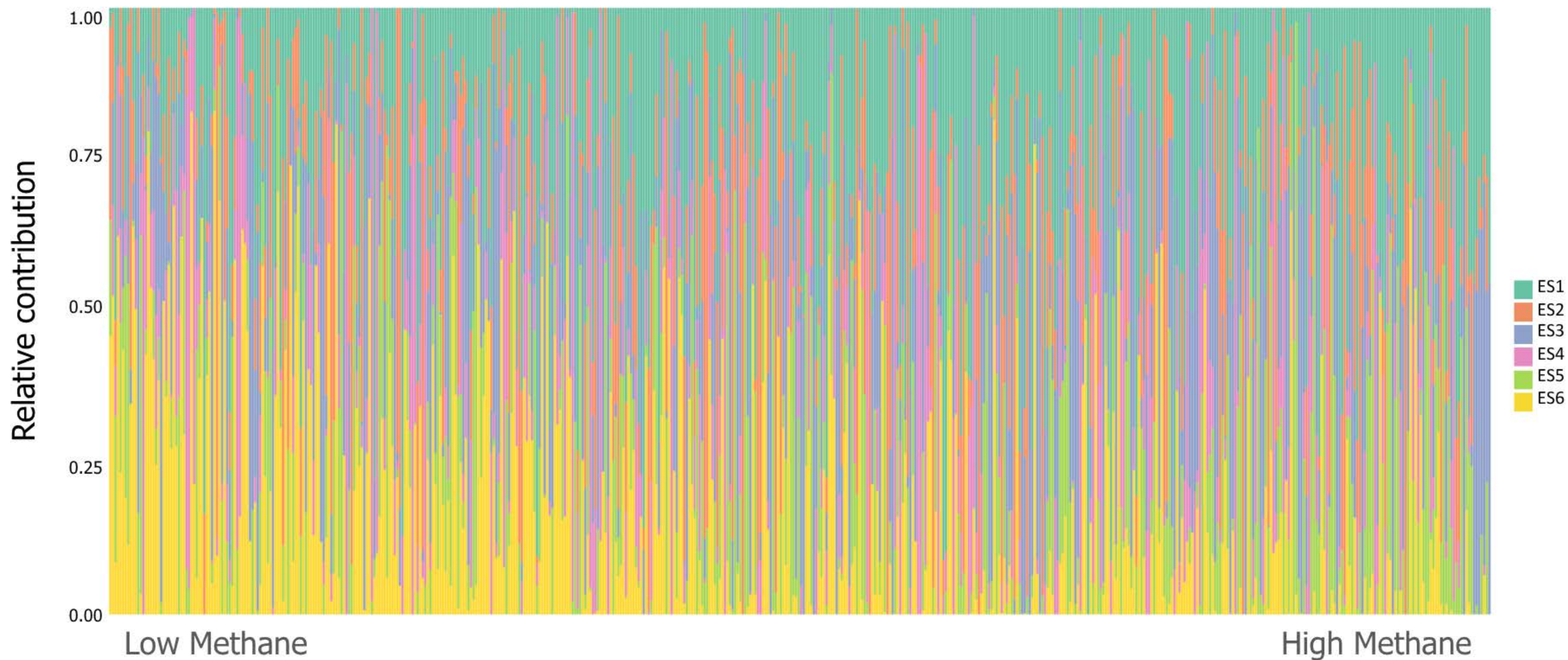
oral microbiome

Fecal Microbiome

Data: CH₄, milk energy, body weight, 16S rRNA seq | 700 cows, 5 farms

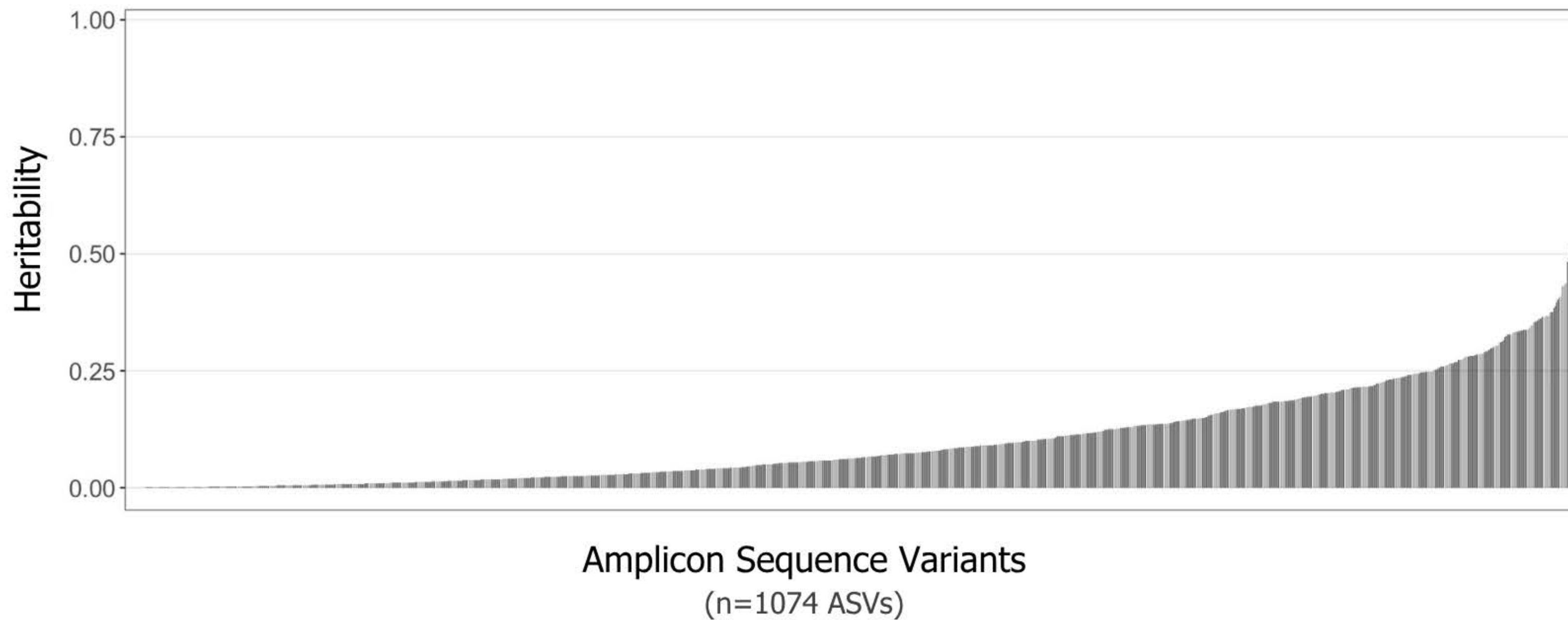


Cows with divergent methane emissions have different fecal microbial profiles



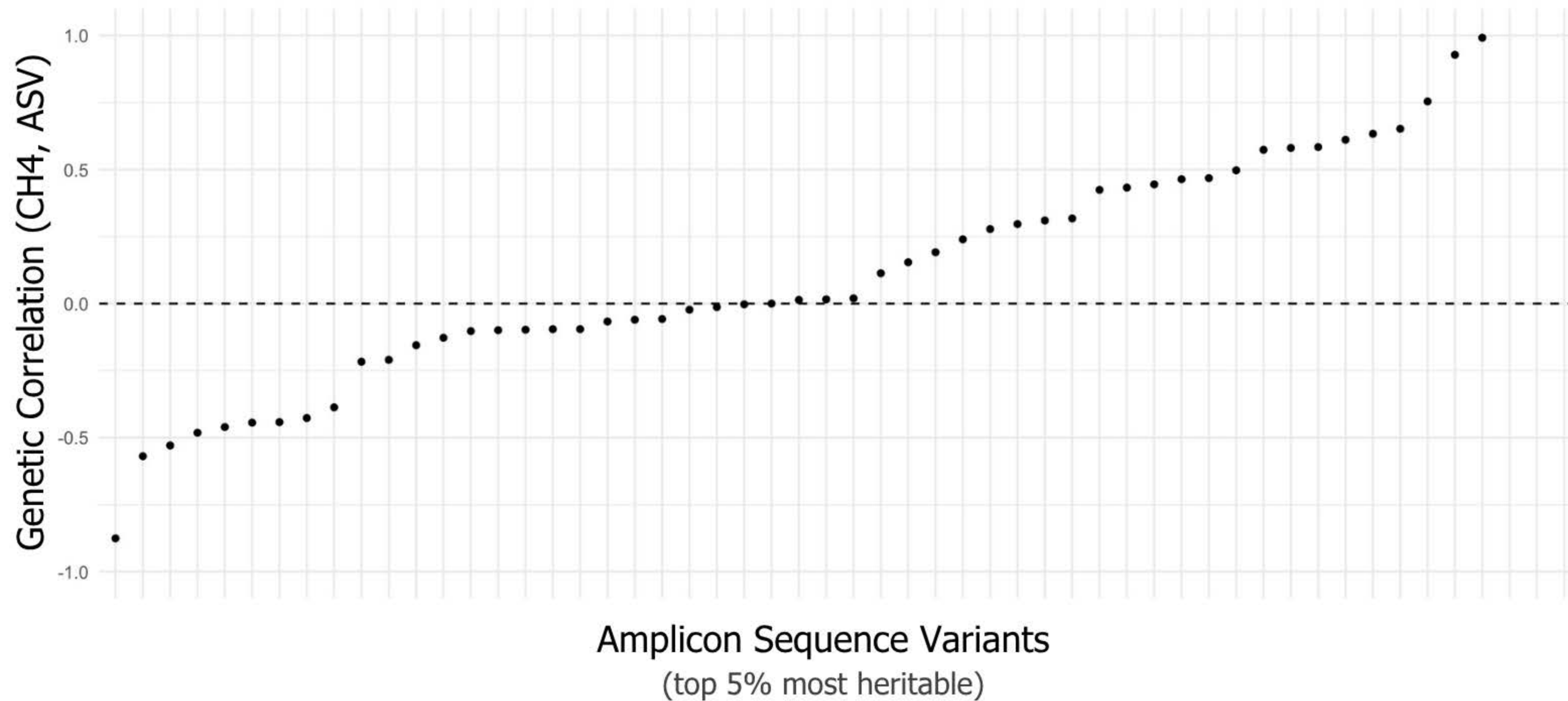
Fecal Microbiome

Data: CH₄, milk energy, body weight, 16S rRNA seq | 700 cows, 5 farms

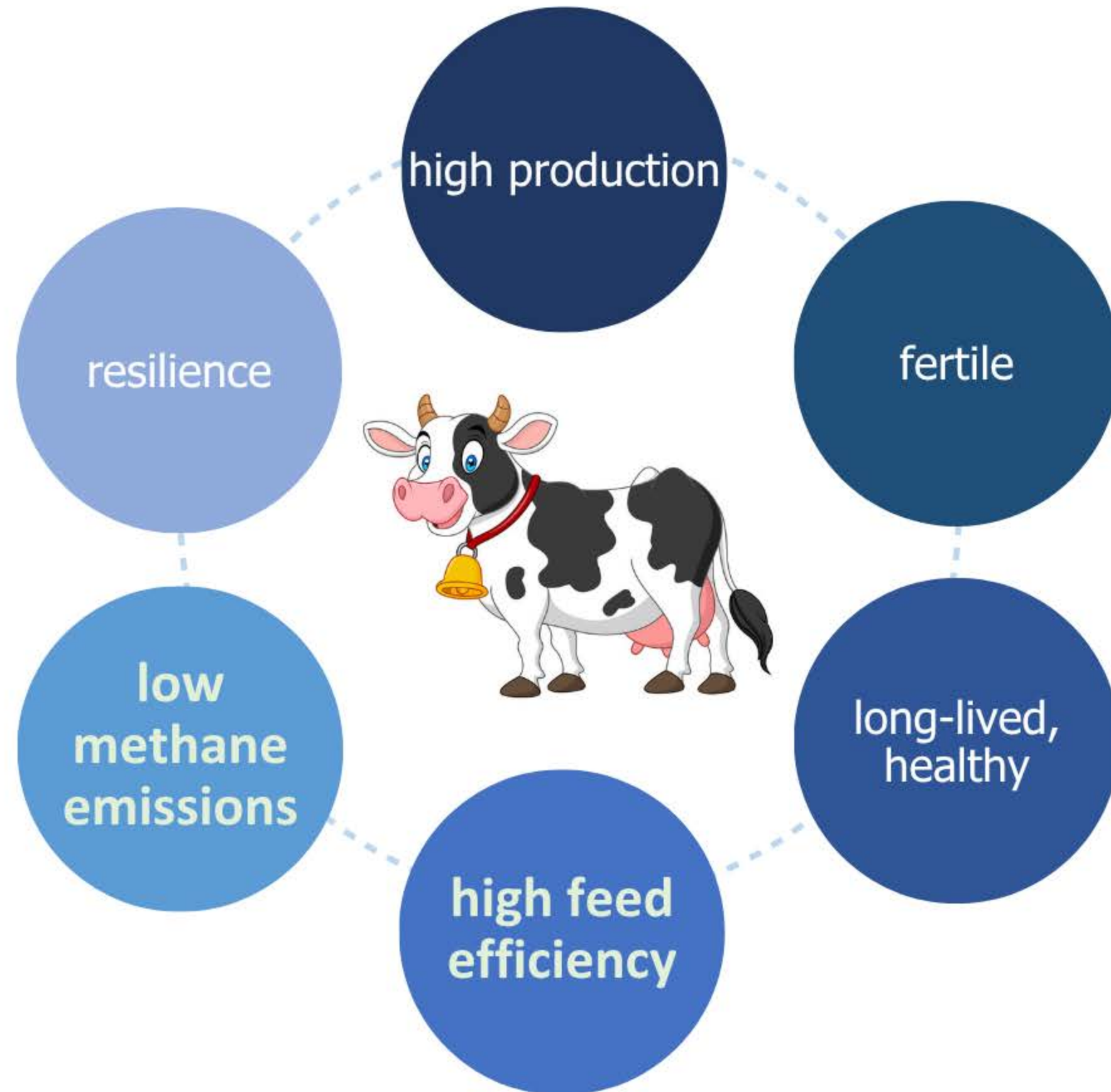


Fecal Microbiome

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Sustainable dairy farming



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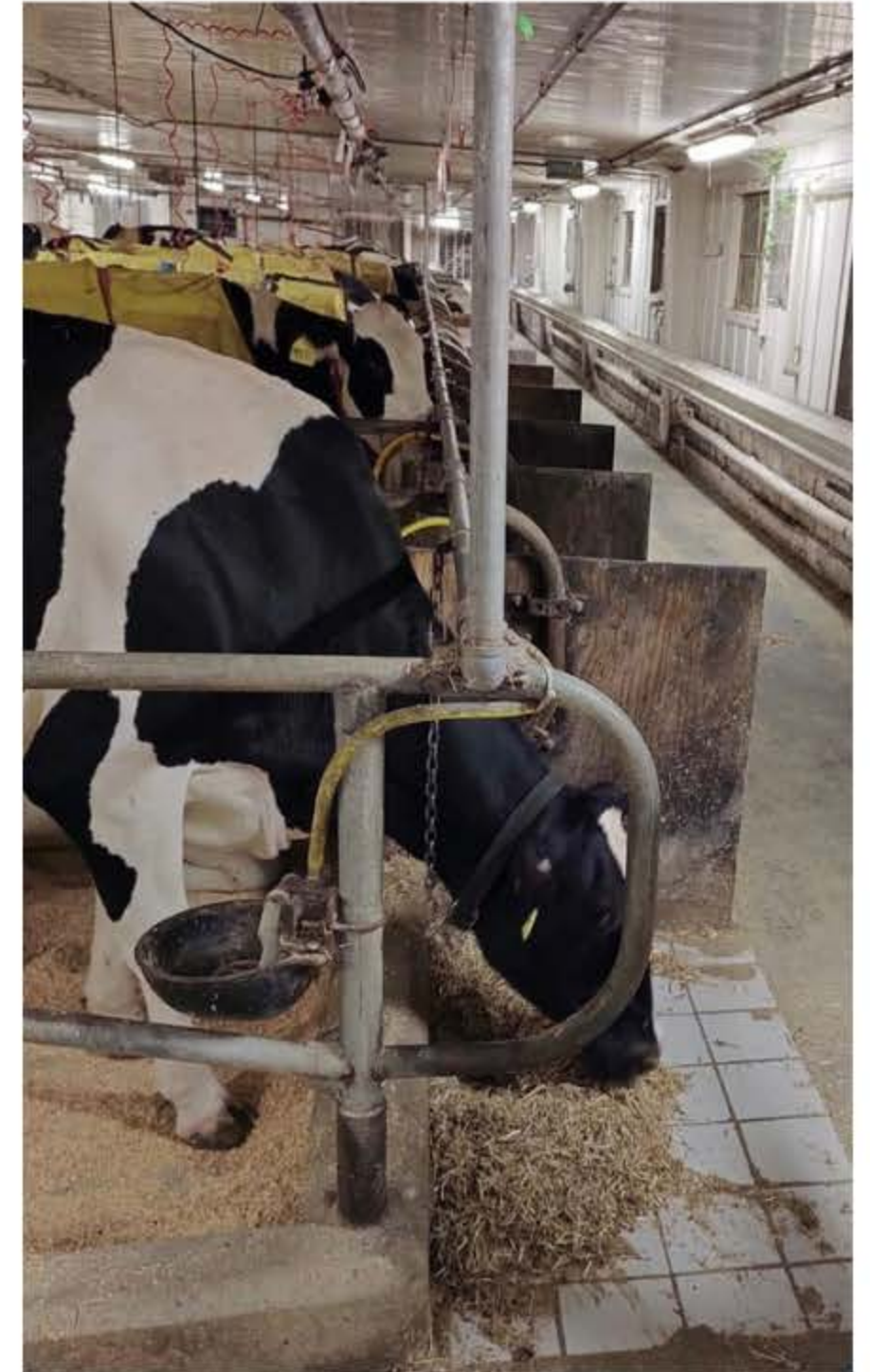
Individual feed intake recording



Insentec Gates



Calan Gates



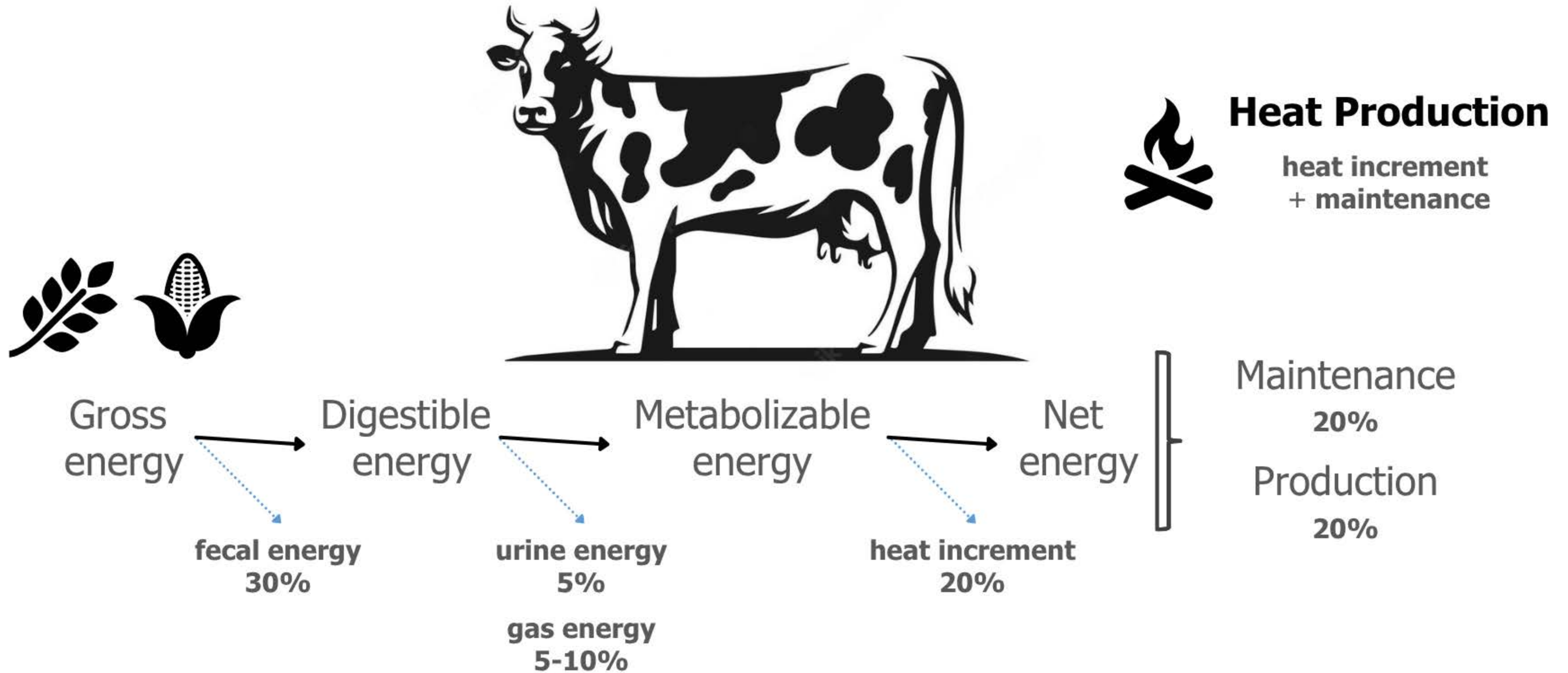
Tie Stalls

Residual feed intake

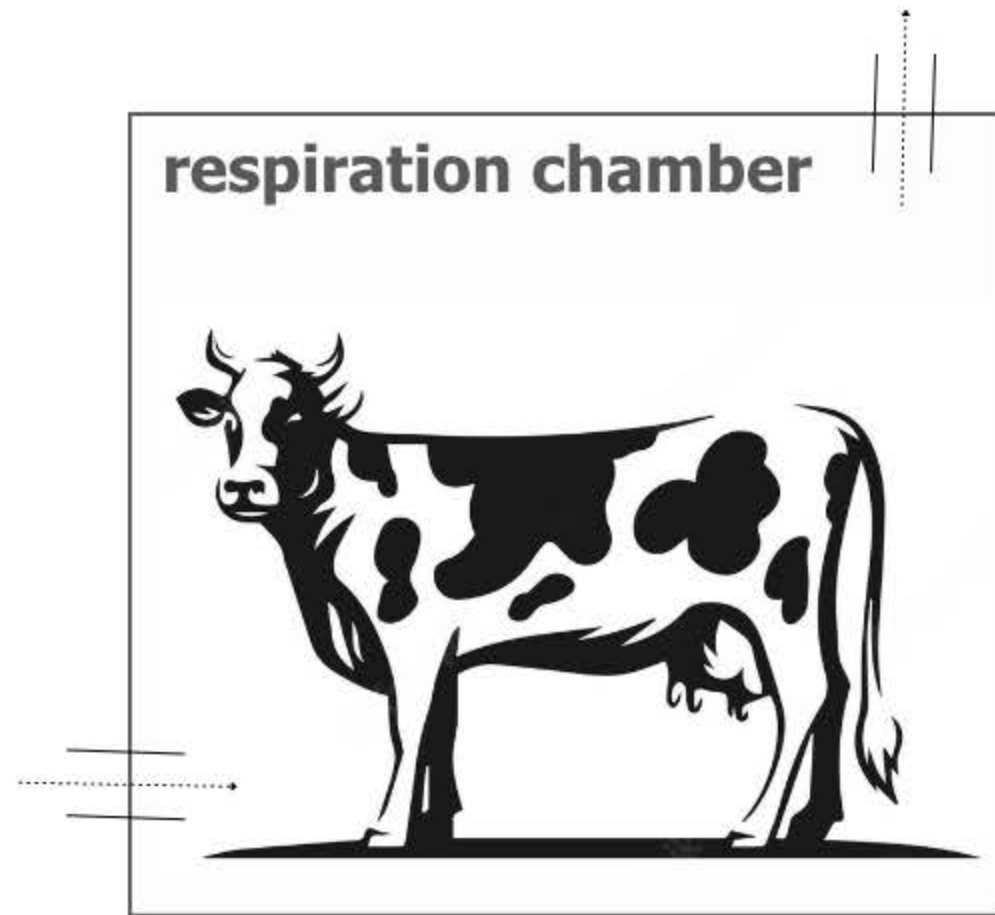


- **feed efficiency impacts production costs and environmental sustainability**
- **residual feed intake:** the most popular index to measure feed efficiency
- **phenotyping RFI is expensive, labor-intensive,** and limited to research facilities
- **RFI does not fully reflect metabolic efficiency**
- **RFI does not fully account for energy partitioning,** maintenance vs production

How else can we quantify efficiency?



How can we quantify heat production?



(Brouwer, 1965)

$$\text{HP} = 16.18 \times \text{O}_2 + 5.02 \times \text{CO}_2 - 5.90 \times \text{N} - 2.17 \times \text{CH}_4$$



Heart Rate



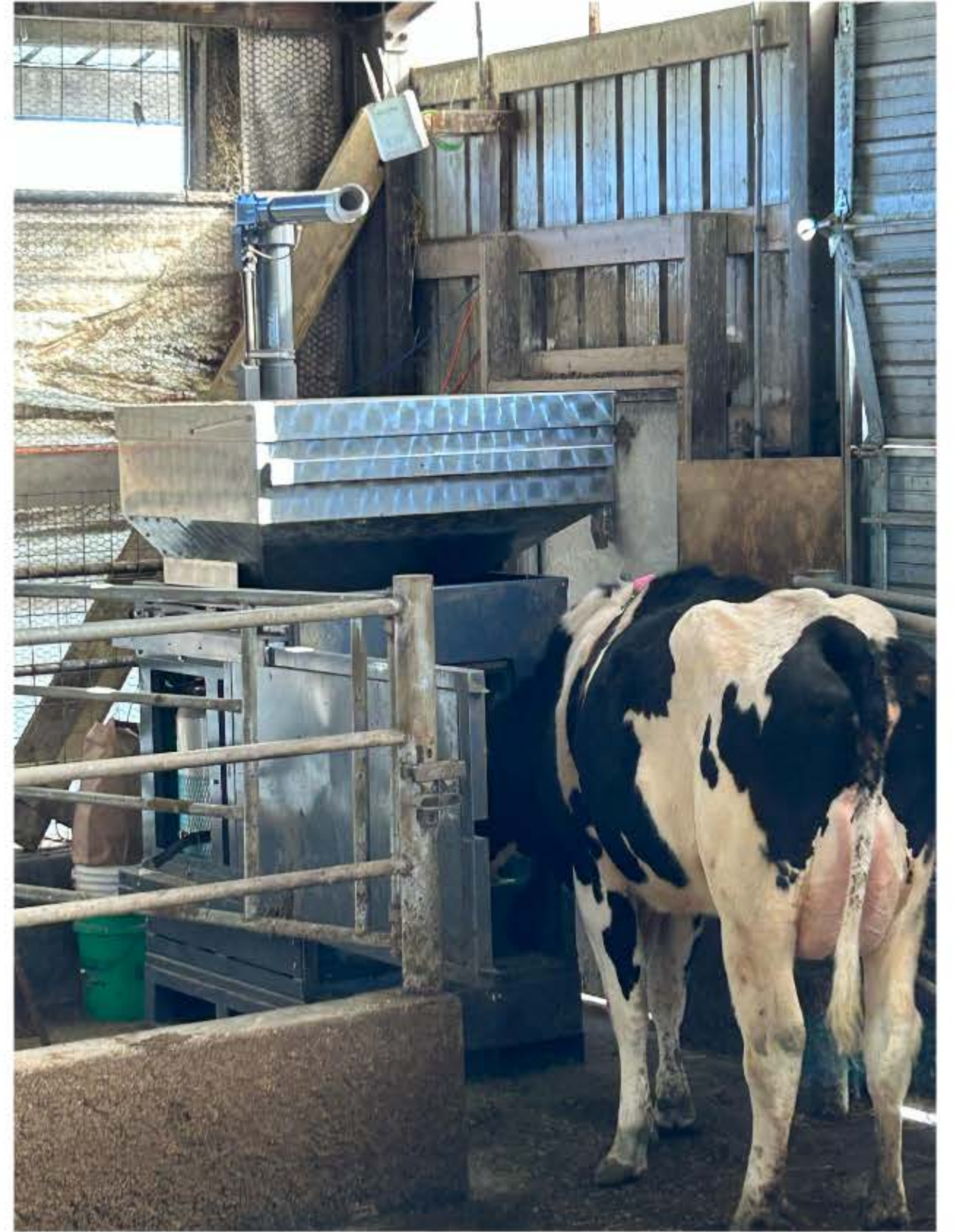
Oxygen Rate

(Brosh, 2007)

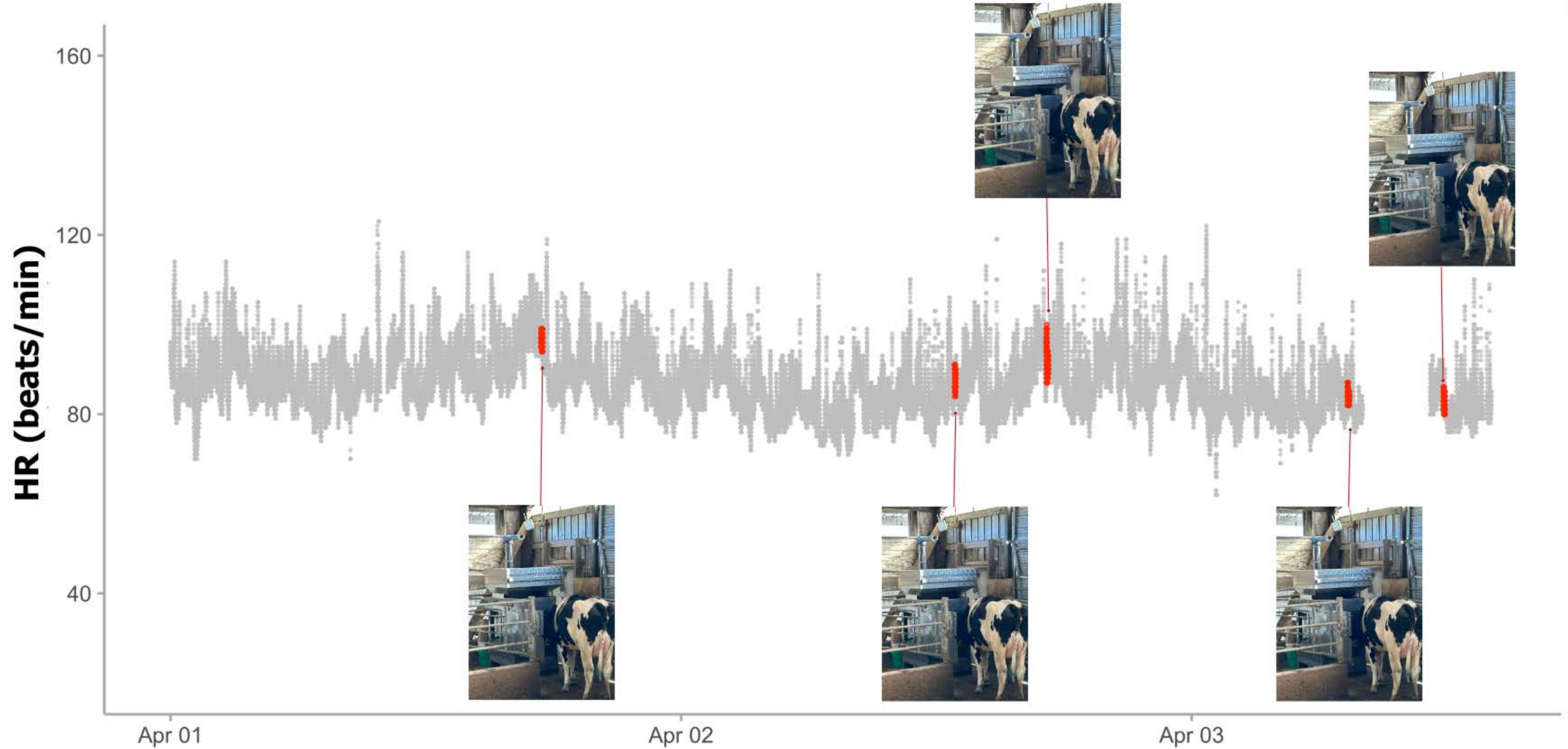
$$\text{HP} = \text{HR} \times \text{O}_2 \text{ pulse} \times \text{constant}$$

(heart beat/d) x (O₂ /heart beat) x 20.47

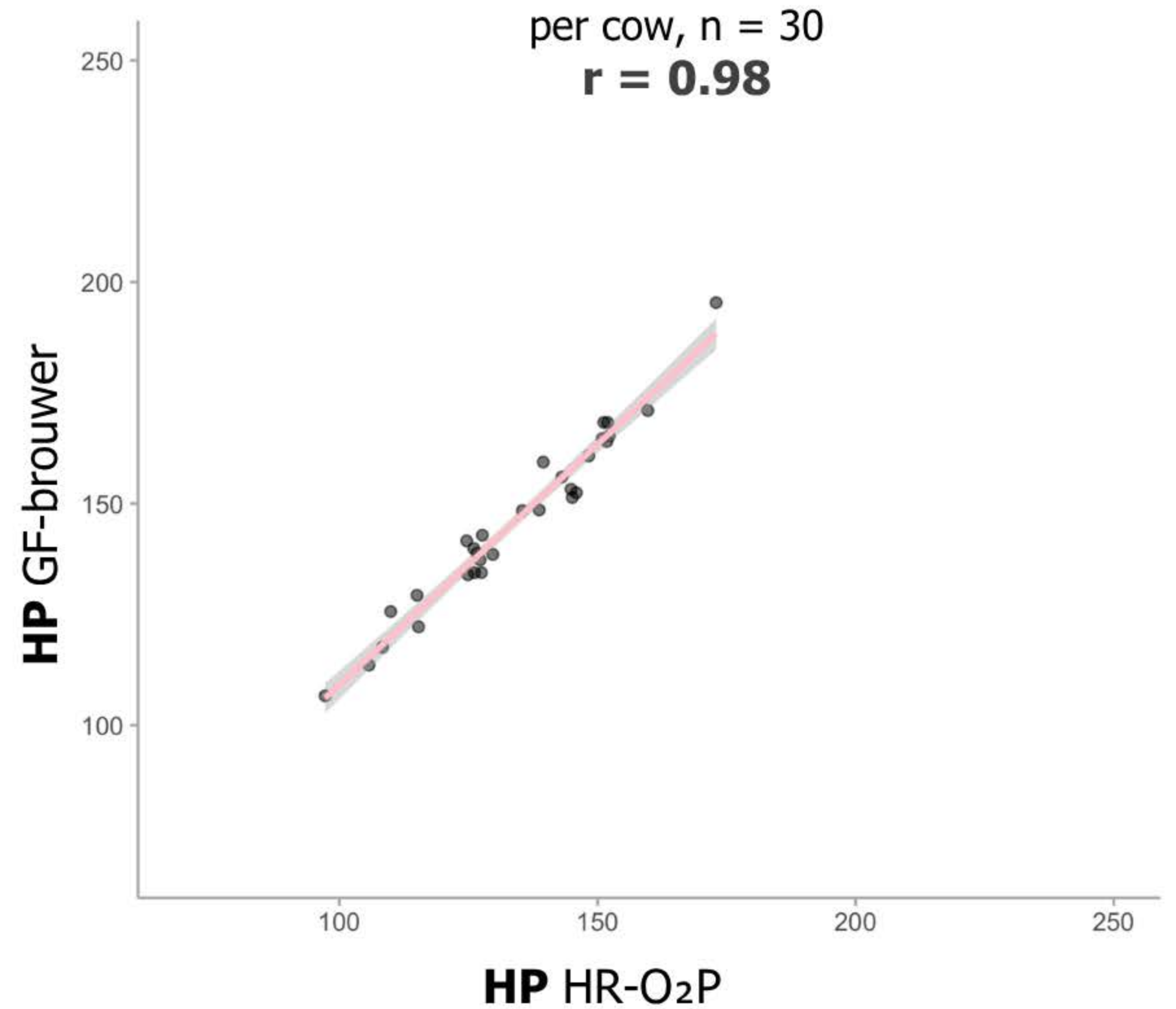
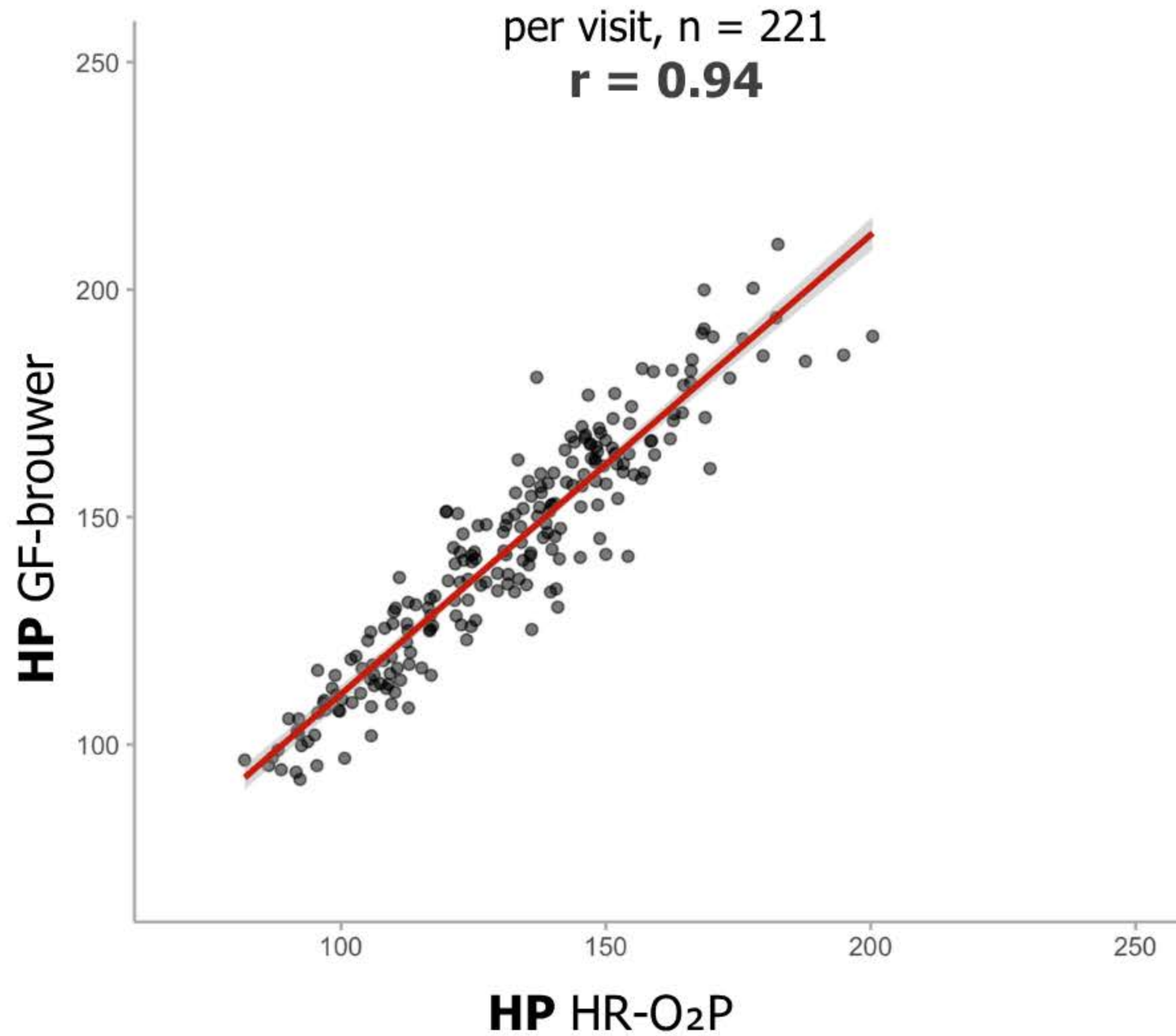
Validation: GF-Brouwer HR-O2pulse



Validation: GF-Brouwer HR-O2pulse



Validation: GF-Brouwer HR-O2pulse



How else can we quantify efficiency?

Residual Feed Intake vs Residual Heat Production

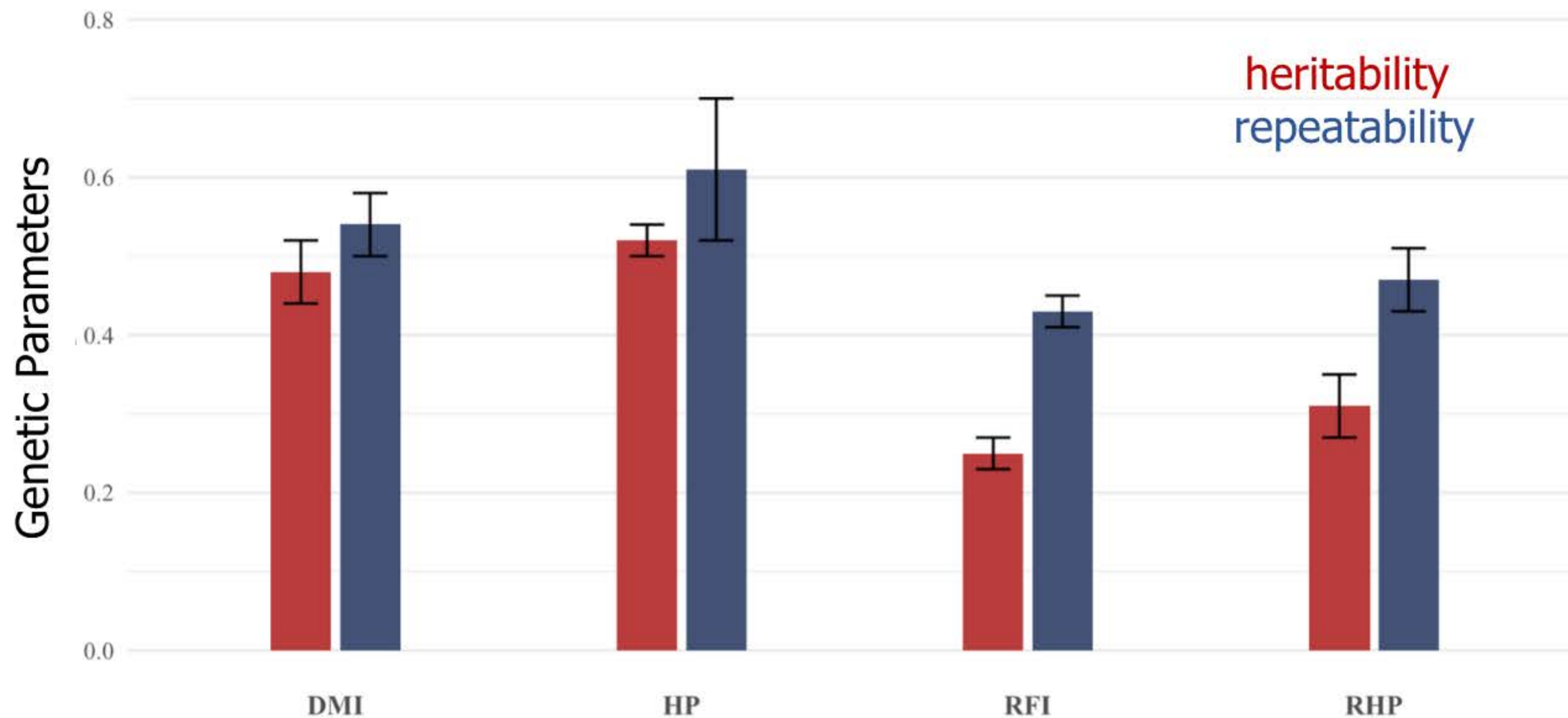


Residual Feed Intake

Residual Heat Production

Efficiency: RFI vs RHP

Data: DMI & RFI 10k cows | HP & RHP 2200 cows



genetic correlations: $rg_{DMI,HP} = 0.78 \square 0.09$ and $rg_{RFI,RHP} = 0.50 \square 0.09$

Final remarks



- **growing public & consumer scrutiny over dairy farming**
animal welfare, environmental impact, pharmacological interventions
- **genetic selection is a critical tool to improve dairy sustainability**
- remember: **in the genomics era, phenotype is king!**
- **any mitigation should meet farmers needs and consumers demands**
- **what's the economic value of reducing methane emissions?**
- **how should we measure dairy cow efficiency?**

Team



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Thanks for your attention!



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