Feed Saved, a Novel Trait for Selection in Dairy Cattle

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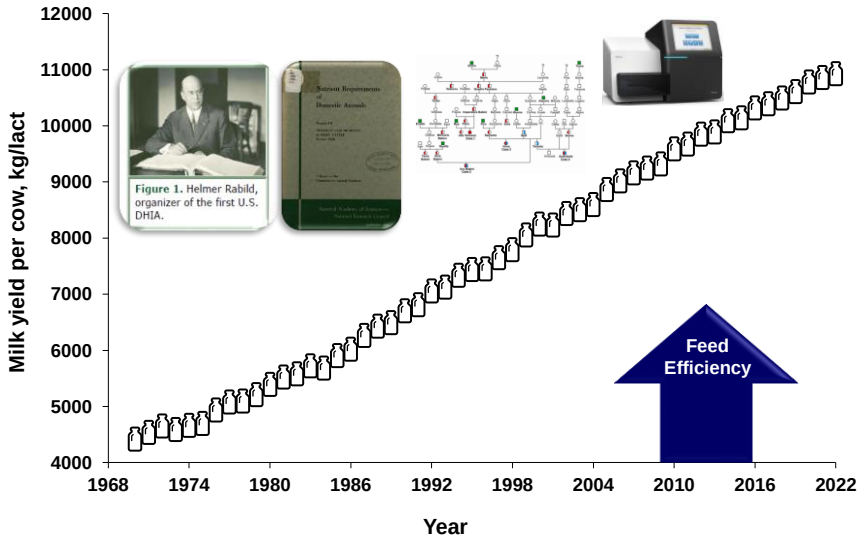
Milk Production Over the Years



USDA-ERS, 2023

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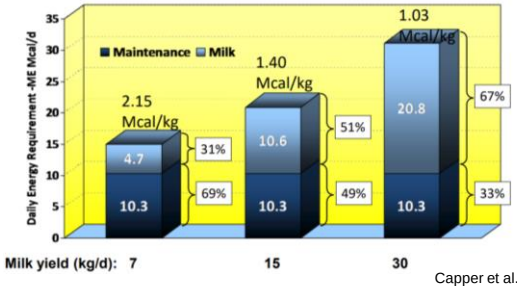
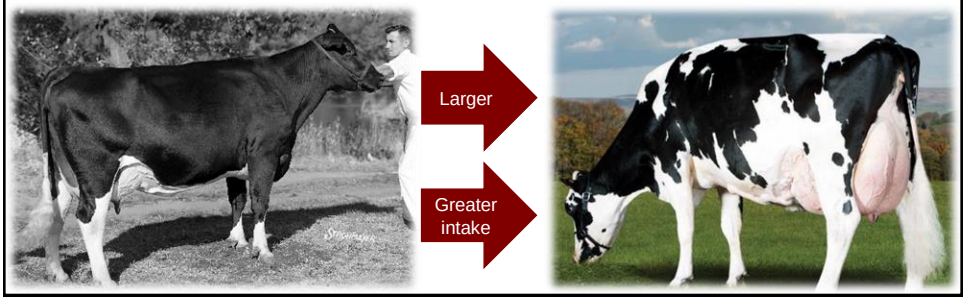
Feed Efficiency Over the Years



Capper et al. (2009) J. Animal Sci. 87:2160

Born 1967 **9,800 lb/lactation** **24,000 lb/lactation** **Born 2018**



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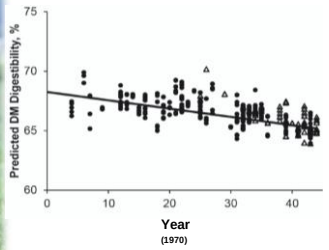
Greater Productivity, Larger Cows, Increased Intake…



Potts et al. (2017) J. Dairy Sci. 100:5400–5410

- ✓ **Maintenance requirements: 700 kg cow**
  - ✓NRC (2001): $700^{0.75} \times 0.08 = 10.9$ Mcal per day (**~ 6.6 kg of DM** of a lactating cow diet)
  - ✓NASEM (2021): $700^{0.75} \times 0.10 = 13.6$ Mcal per day (**~ 8.1 kg of DM** of a lactating cow diet)

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How Can we Improve Feed Efficiency?

- ✓ Increase productivity relative to intake
  - ✓ Management strategies
    - ✓ E.g.:
      - Provide evaporative cooling
  - ✓ Reducing risk of disease
    - ✓ Reduction of DMI
    - ✓ Alter partition of consumed nutrients
  - ✓ Diet formulation
    - ✓ E.g.:
      - Highly digestible forage source
      - Supplementation of fatty acids in the diet
- ✓ Select for animals with an innate capacity to improve nutrient utilization
  - ✓ Medium to long-term alternative
  - ✓ It is permanent in the selected individuals and has an additive effect

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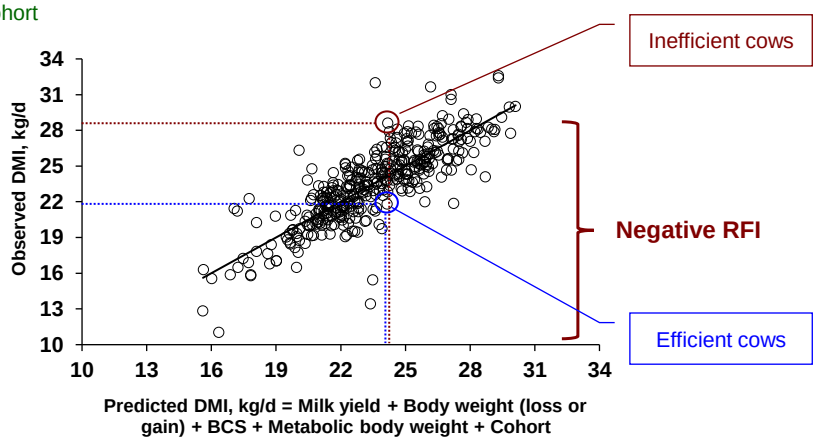
Residual Feed Intake

- ✓ Residual feed intake (RFI) is a trait that measures feed conversion efficiency adjusting for other factors
- ✓ Differs from gross feed efficiency (ECM/DMI):
  - ✓ Energy required for production, maintenance, tissue accretion/loss, and adjusted for cohort



Nehme Marinho et al. (2021) J. Dairy Sci. 104: 5493-550

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Why Selection for RFI is Promising?

Feed represents more than 50% of total costs in a dairy farm (USDA, 2023)

Reduction of land used for feed production, fossil fuels, fertilizer, water, and GHG emissions

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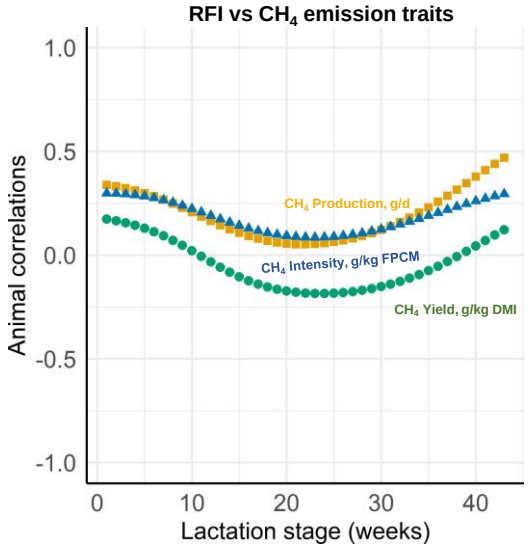
Residual Feed Intake and CH_4 emission throughout the lactation

- ✓ CH_4 data from 107 Holstein cows throughout lactation
- ✓ Both CH_4 production and intensity are favorably correlated with RFI, as is CH_4 yield during the first half of lactation
- ✓ Correlations between RFI and CH_4 yield was low and varied from positive to negative
  - ✓ From 0.17 to -0.18



Fresco et al. (2024) *Animal:* 101110

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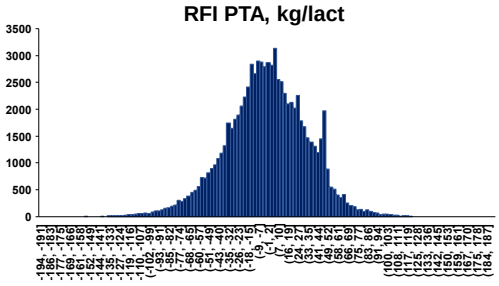
Residual Feed Intake: A Selectable Trait

- ✓ **Genetic variation:**
- ✓ Genotyped Bulls = 81883
  - ✓ Min = -194
  - ✓ Max = +191
  - ✓ Std = 35
  - ✓ Average = -0.7



(CDCB, 2023)

- ✓ **RFI Heritability: 0.19**

Trait	Heritability
Milk	0.20
Fat	0.20
Productive life	0.08
SCS	0.12
Udder composite	0.27
BW composite	0.40
Cow conception rate	0.02
Daughter pregnancy rate	0.04
Mastitis	0.031

VanRaden et al. (2021); USDA AIPL report

⛔ **Problem: Low Reliability**

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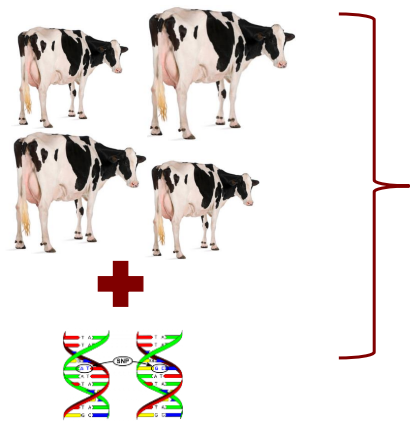
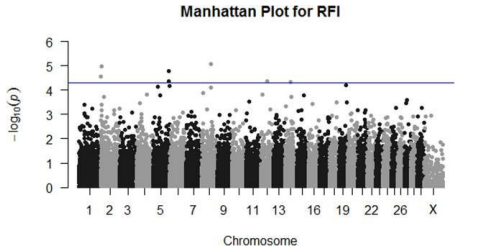
Can We Select for RFI?





Higgins et al. (2018) Sci. Rep 8:1301

Prediction Equation
Breeding value = t1x1 + t2x2 + t3x3 + …

Eggen. (2012) Anim. Front. 2:10-15.

- ✓ **Build a reference population: Phenotype + Genotype**
  - ✓ Michigan State Univ., Univ. of Wisconsin, Iowa State Univ., Univ. of Florida, the USDA Beltsville, and the Animal Improvement Program Laboratory of the USDA
- ✓ **Identify regions/SNPs that explain a large variability in RFI phenotype**
  - ✓ Whole genome scan (E.g.: GWAS)
- ✓ **Use a prediction equation to estimate the genomic breeding value**
  - ✓ Apply equation to the selected candidate sires to identify the best animals

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Feed Saved (FS)

- ✓Includes the economic values of cow body weight composite (**BWC**) with residual feed intake (**RFI**)
- ✓Selection for Feed Saved will result in efficient cows with moderate body size
- ✓**Formulas:**
- ✓$PTA\ FS = -1(PTA\ RFI) - 151.8\ (PTA$ BWC)
  - ✓ **BWC =** $(0.23\ x\ stature) + (0.72\ x\ strength) + (0.08\ x\ body\ depth) + (0.17\ x\ rump\ width) - (0.47\ x\ dairy\ form)$:
    - ✓Each unit represents 35 lb of mature BW
- ✓FS PTA represents the expected pounds of feed saved per lactation above or below the breed average

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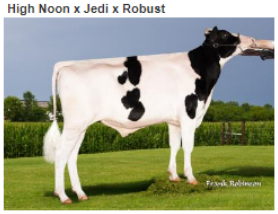
Selecting for More Efficient Animals

551HO03797 TAMPA

Reg: HO840003132350683 DOB: 01/23/2018
RHA: % DMS: 123.234 aAa: 243 AB A2A2 HU1F

EcoFeed®heifer: 94 - 91% R. Cow: 104 - 86% R.

Delicious H-Noon Tampa-ET TC TR
High Noon x Jedi x Robust



04/2023	CDCB SUMMARY GENOMIC			NM$ +1046
Milk	+1919	99%R	Cheese Merit $	+1053
Fat	+64	-0.03%	FM$ +991	GMS +1037
Protein	+69	+0.03%	Gestation Len. +1	MSP +101
CFP	+133		EFI 10.1% gEFI 11.4%	
SCS	2.95	97%R	Mastitis +1.0	Fert. Index +2.5
PL	+7.0	89%R	Livability +3.2	Heifer Liv. +0.7
DPR	+1.7	91%R	HCR +5.3	CCR +4.1
RFI	-144		29431m 4.0% 1187f 3.3% 958p	
Feed Saved	+306	54%R	1022 Dtrs 50 Herds 100% US	

04/2023	CALVING SUMMARY		SCE 1.5 %
Sire Calving Ease	1.5%	96%R	1032 Obs
Daughter Calving Ease	2.1%	88%R	380 Obs
Sire Stillbirth	5.7%	91%R	1001 Obs
Daughter Stillbirth	5.7%	89%R	373 Obs

04/2023	HA TYPE SUMMARY	TPI +2940
PTAT +0.53 98%R UDC+1.01 FLC+0.97 BSC -1.07 385 D / 20 H		

Sire: Mr Detour High Noon-ET TL TV TD
Dam: Ms Delicious Jedi 35127-ET

MGS: S-S-I Montross Jedi-ET
MGD: Miss Ocd Robst Delicious-ET VG-87 GMD DOM 02-05 2x 365d 33780m 3.3 1121f 3.1 1047p
MGGS: Roylane Socra Robust-ET TR TV TL TD
MGGD: OCD Planet Danica-ET EX-93 DOM 03-01 3x 365d 39240m 3.5 1384f 3.0 1166p

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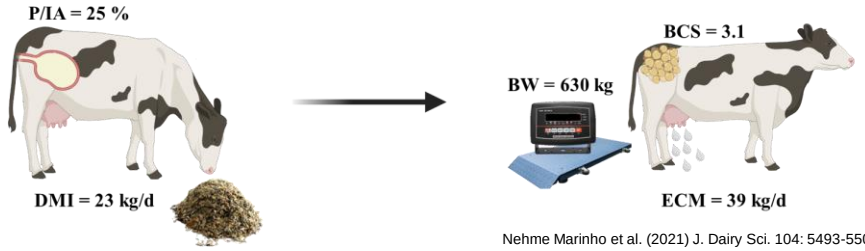
Is it Safe to Select for Negative RFI?

✓ **More efficient Holstein cows had reduced dry matter intake with no associated detrimental impacts on health, production and reproduction**



Nehme Marinho et al. (2021) J. Dairy Sci. 104: 5493-5507
Nehme Marinho and Santos (2022) Front. Anim. Sci. 3:847574

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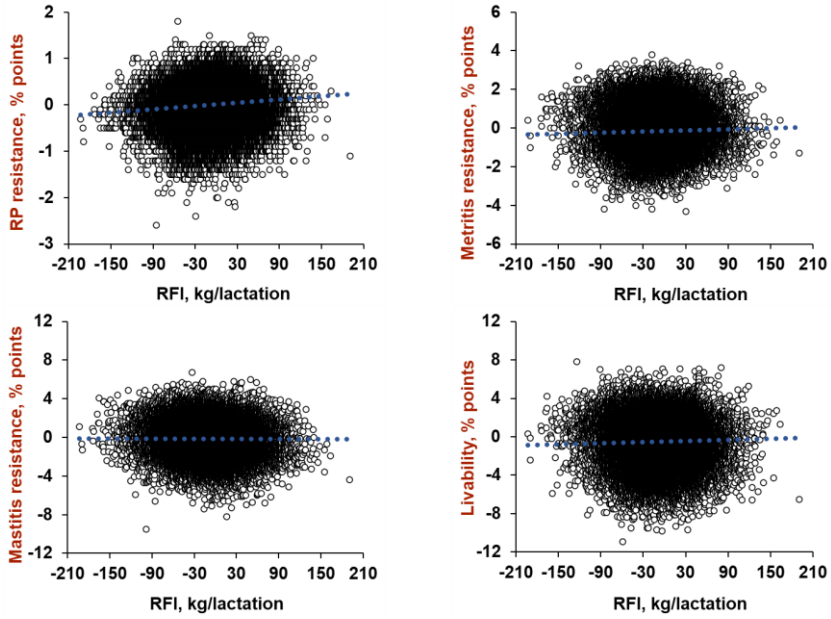

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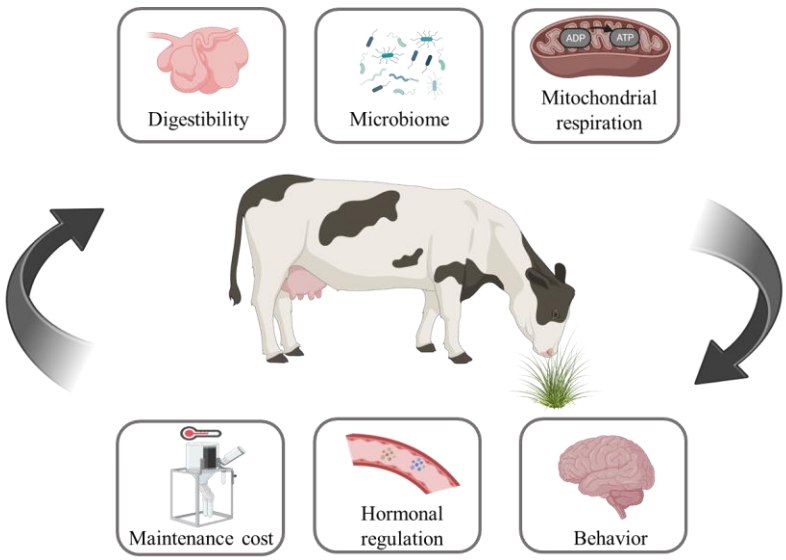
What Makes a Cow More Efficient?



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What Makes a Cow More Efficient?

- ✓**Hypotheses**
  - ✓Cows with improved feed efficiency have altered rumen microbiome, increased nutrient digestibility, and increased coupling of ATP synthesis with oxygen consumption by tissues
  - ✓Phenotypic and genomic RFI have a high degree of agreement
- ✓**Objectives:**
  - ✓To quantify nutrient digestion and characterize rumen microbiome and fermentation
  - ✓Evaluate behavior responses
  - ✓Assess mitochondrial oxygen consumption coupled with ATP synthesis in hepatocytes

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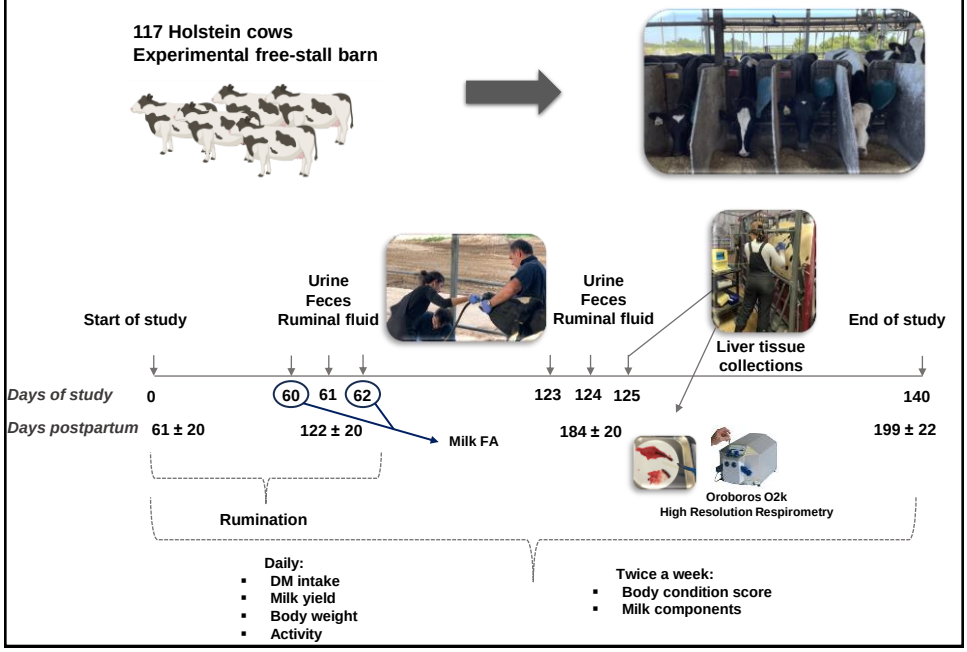
Methods



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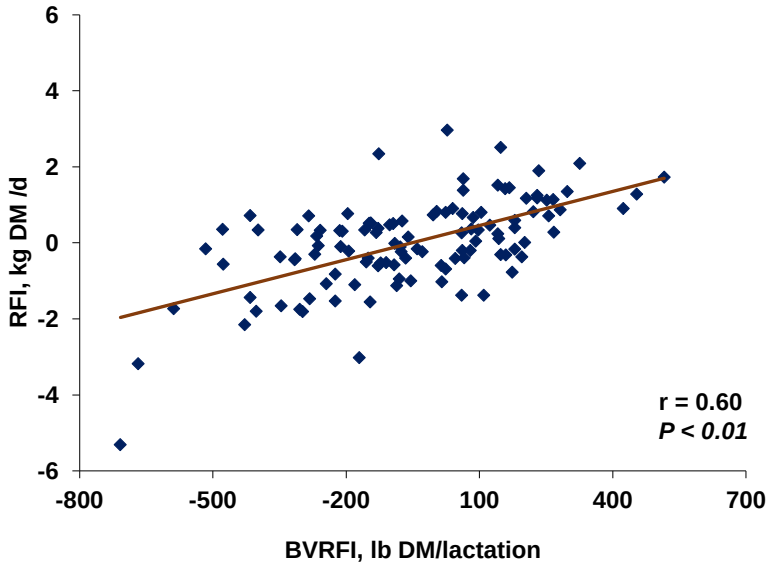
Phenotypic and Genomic RFI Correlation



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Relationship between RFI and Performance

	Feed Efficiency					
Item	Q1	Q2	Q3	Q4	SEM	P-value
DMI, kg/d	21.0	22.3	22.6	24.2	0.4	<0.001§
ECM, kg/d	39.0	39.9	38.2	39.9	1.1	0.64
Fat, %	3.26	3.24	3.31	3.44	0.11	0.55
Protein, %	2.85	2.87	2.91	2.93	0.04	0.37
Lactose, %	4.81	4.87	4.86	4.86	0.03	0.48
BEC, Mcal/d	2.54	2.48	2.19	2.50	0.34	0.88

§ Linear Effect

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Relationship between RFI and Milk Fatty Acids

	Feed Efficiency					
Fatty acids, g/100g	Q1	Q2	Q3	Q4	SEM	P-value
< C 16	24.4	24.8	24.9	25.6	0.5	0.42
C 16	35.3	36.4	36.8	37.4	0.4	< 0.001§
> C 16	39.5	38.0	37.6	36.3	0.7	0.002 §
Saturated	65.9	67.1	67.5	68.3	0.7	0.12 §
Monounsaturated	29.9	28.8	28.2	27.4	0.7	0.007
Unsaturated	33.3	32.2	31.7	30.9	0.7	0.11
Polyunsaturated	3.44	3.48	3.54	3.52	0.07	0.69
trans	4.59	4.52	4.35	4.47	0.25	0.92
Milk fat depressing	0.054	0.059	0.048	0.063	0.006	0.39

§ Linear Effect

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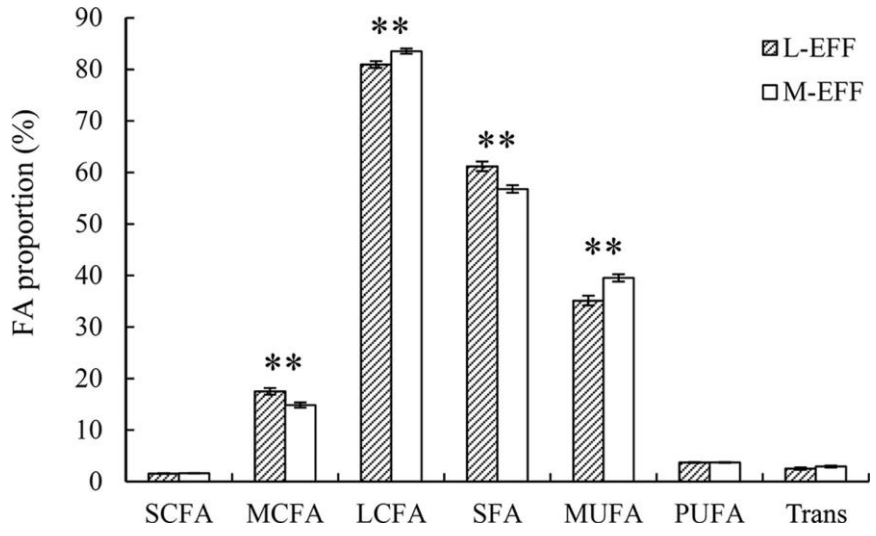
Milk Fatty Acids Profile Changed According to RFI



Zhang et al. (2022) J. Dairy Sci. 105: 4971-4986

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Relationship between RFI and Total Tract Digestibility

Item	Feed Efficiency				SEM	P-value
	Q1	Q2	Q3	Q4		
DM, %	74.8	74.3	74.6	74.7	0.3	0.77
OM, %	76.8	76.2	76.7	76.8	0.4	0.60
CP, %	72.3	71.4	72.0	72.3	0.7	0.77
NDF, %	44.6	44.2	45.0	45.0	0.6	0.76
Starch, %	98.6	98.8	98.7	98.7	0.1	0.46
Fat, %	82.4	81.1	82.8	82.1	0.9	0.56

Nehme Marinho et al. (2024) in preparation

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Relationship between RFI and Behavior Traits

Item	Feed Efficiency Q1	Q2	Q3	Q4	SEM	P-value
Rumination, min/d	570.0	566.8	585.5	600.3	8.7	<0.01§
Rum/DMI, min/kg	26.2	24.9	25.0	24.1	0.6	0.02§
Rum/NDFI, min/kg	97.6	92.7	93.3	89.8	2.3	0.02§
Activity, step/h	160.5	158.0	156.5	167.1	6.7	0.69

§ Linear Effect

Nehme Marinho et al. (2024) in preparation

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Relationship Between RFI and Ruminal Fermentation

Item	Feed Efficiency Q1	Q2	Q3	Q4	SEM	P-value
pH	6.2	6.2	6.4	6.3	0.1	0.06¶
Acetate, *mmol/L*	71.1	70.3	71.1	70.1	1.0	0.83
Propionate, *mmol/L*	26.1	26.1	26.8	25.6	0.7	0.58
Butyrate, *mmol/L*	16.0	15.0	15.5	15.3	0.4	0.25
Total VFA, *mmol/L*	118.6	116.5	118.8	116.2	1.4	0.49
Ammonia N, mg/dL	10.0	9.3	9.0	8.0	0.5	<0.01§

§ Linear Effect
¶ Cubic Effect

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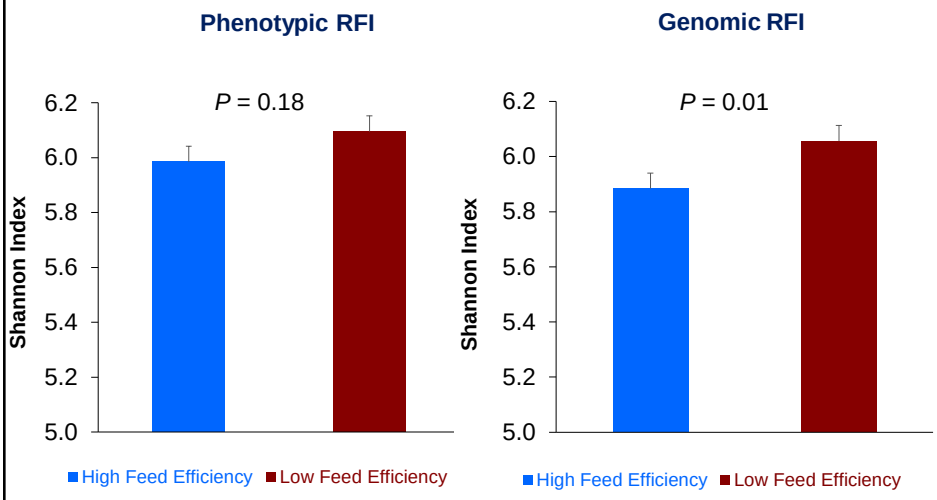
Relationship Between RFI and Rumen Microbiome



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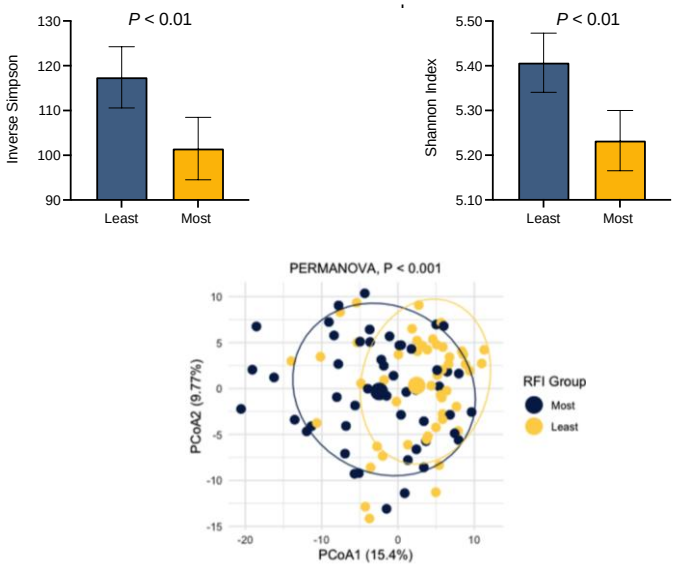
Relationship Between RFI and Rumen Microbiome



Monteiro et al. (2024) Anim. Microb. 6:5

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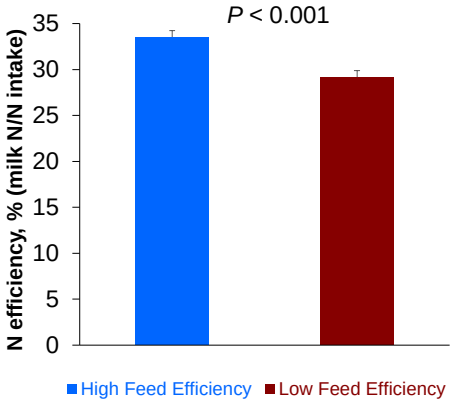
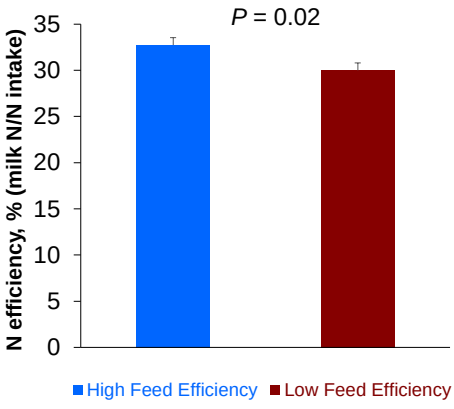
Relationship Between RFI and N Efficiency





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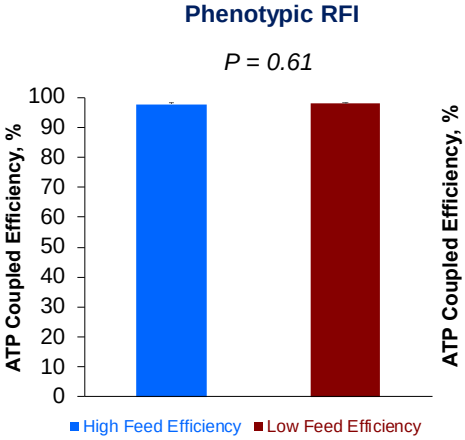
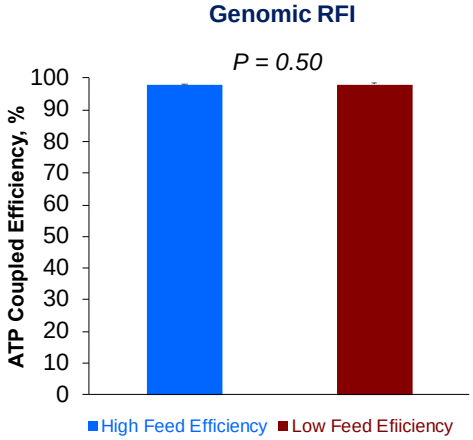
Relationship Between RFI and Hepatic Mitochondrial Respiration





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Conclusions

- ✓Phenotypic and genomic RFI have a high degree of agreement
  - ✓Cows with breeding values that result in negative RFI also have negative phenotypic RFI → more feed efficient
- ✓Mechanisms underlying improved feed efficiency were linked with differences in microbial diversity, and ruminal fermentation which affects pH and ammonia nitrogen concentrations rather than apparent total tract digestibility or hepatic mitochondrial respiration

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