FLORIDA RUMINANT NUTRITION SYMPOSIA

2024

Proceedings

Improving Energetic and Nitrogen Efficiency when Formulating for Amino Acids – a more Holistic Approach

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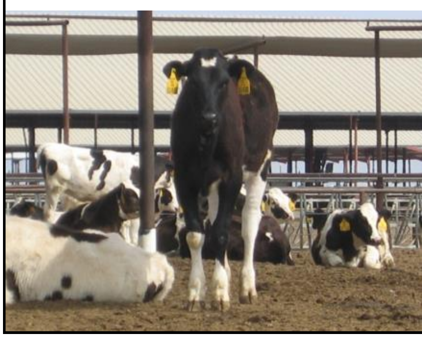

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Today's Talk

- Cows are changing and we need to be conscious of this
- **Protein synthesis** is required for lactose synthesis, fatty acid synthesis and milk protein synthesis
- The concept of N efficiency is energy dependent and, in a ruminant, might be related more to urinary N excretion than intake to milk N
- Thus, the concept of N efficiency is not just related to milk protein output, it is related to energy corrected milk as all components require N

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Efficiency of Use of Intake Nitrogen

- This is a tough metric for ruminants since they require non-protein N for rumen function
- When this is described for non-ruminants the N-currency is amino acids
- On farm N efficiencies (milk N:feed N) range from 20 to 32%
- Theoretical efficiency limit 40 to 45% in lactating dairy cattle (Van Vuuren and Meijs, 1987; Hvelplund and Madsen, 1995)
- Practical limit is ~38 to 40% (high cow groups are achieving this)
- Although it is an ambiguous metric, it can be useful if extended to whole body N metabolism

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Table 1 *Characteristics of the upper and lower quartile based on efficiency of N utilization (ENU) and milk yield*

	ENU (g milk N/100 g N intake)		3.5% Fat corrected milk (kg/day)	
	Low	High	Low	High
EU data set				
ENU (%)	21.0	32.0	24.8	28.7
3.5% FCM (l/day)	26.8	31.2	22.2	35.3
Forage (%)	66.5	56.9	67.4	52.6
Forage CP (%)	20.0	14.8	16.1	14.7
Forage NDF (%)	48.9	59.4	50.5	50.5
DMI (kg/day)	17.9	18.9	15.3	21.1
US data set				
ENU (%)	22.0	32.8	25.5	29.8
3.5% FCM (l/day)	31.8	38.2	27.0	41.6
Forage (%)	53.4	52.6	56.2	51.9
CP (%)	17.9	15.4	15.6	17.4
NFC (%)	31.8	38.2	39.2	42.8
DMI (kg/day)	23.2	23.8	21.0	24.3

FCM = fat corrected milk; DMI = dry matter intake; NFC = non-fibre carbohydrates.

Calsamiglia et al., 2010

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There are cows within groups achieving the theoretical limits of N efficiency

Hardie Family Farm, Lansing NY

High group average production: 120 ± 35 lb/d

Average DMI: 60.2 lb/d, 15.8% CP

Average N efficiency: 38% (productive N:intake N)

Cows at high end of production: ~168 lb/d milk

At estimated intake, N efficiency: 41%

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Efforts to reduce excessive protein feeding

Energetic value of overfeeding nitrogen or nitrogen excretion in urine – impacts on ME allowable milk:

- Reed et al. (2017) determined that overfeeding N increased heat expenditure in cattle, reducing energy for productive function
- In their data metabolizing RDP had a greater impact on heat production than RUP ~ 1.10 Mcal/kg vs 0.78 Mcal/kg
- Overfeeding rumen available protein will reduce the amount of energy available for milk and milk component synthesis
  - Disposal of excessive NH_3 can have a larger impact than RUP/AA

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Efforts to reduce excessive protein feeding

Morris et al., (2021) demonstrated that increasing urinary nitrogen (UN) excretion decreased metabolizable energy content of the diet as calculated from digestible energy:

- Urinary energy (UE) output was 1,390 to 3,160 kcal and UN was 85-220 g/d (20 to 60% of nitrogen intake)
- The best fitting equation was UE =14.6 ± 0.32 x UN (UE is kcals/g and UN is g/d)
- Urinary nitrogen needs to be accounted for when refining the calculation of dietary ME and lower nitrogen intake

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Efforts to reduce excessive protein feeding

- Nichols et al. (2022) review on urea recycling capabilities in ruminants:
  - Levels of rumen degradable protein should be optimized to capture ruminally recycled nitrogen → Improvements in nitrogen use efficiency
  - Excessive dietary urea feeding (>1% DM) elicits deleterious effects on animal (hypophagic effects, ammonia toxicity) and may lead to sequestered urea recycling
  - Increases in post-ruminal protein supply should help improve endogenous urea supply through hepatic production


Contents lists available at ScienceDirect
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Animal
The international journal of animal biosciences
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Review: Unlocking the limitations of urea supply in ruminant diets by considering the natural mechanism of endogenous urea secretion

K. Nichols *, I.P.C. de Carvalho, R. Rauch, J. Martín-Tereso

Trouw Nutrition R&D, P.O. Box 299, 3800 AG Amersfoort, the Netherlands

Formulating closer to nitrogen and amino acid requirements, reducing urinary N excretion, and reliance on endogenous urea recycling leads to improvements in energetic and nitrogen efficiency

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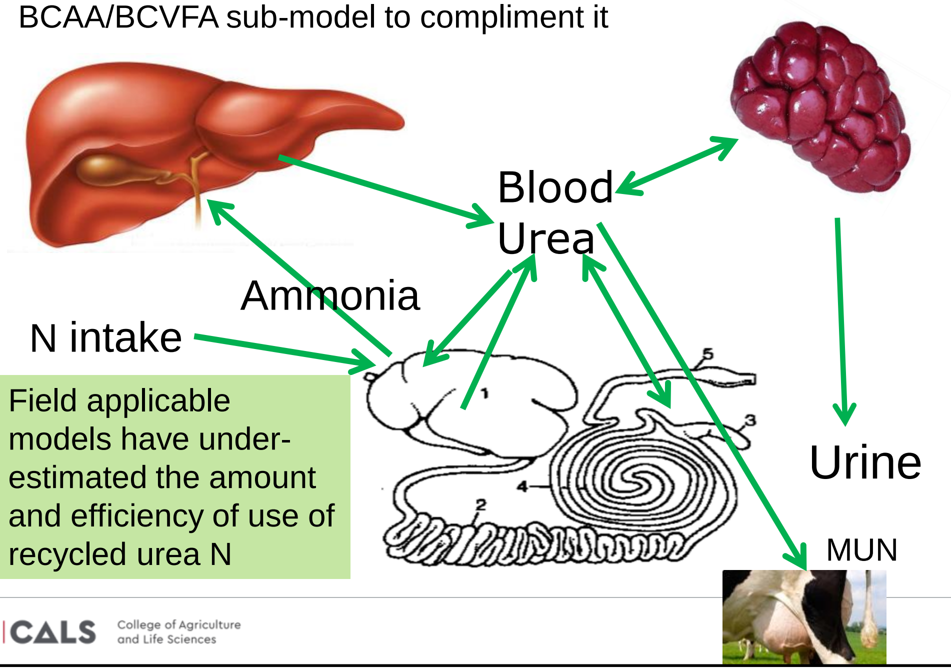
Full urea recycling sub-model and working on a BCAA/BCVFA sub-model to compliment it



Field applicable models have under-estimated the amount and efficiency of use of recycled urea N

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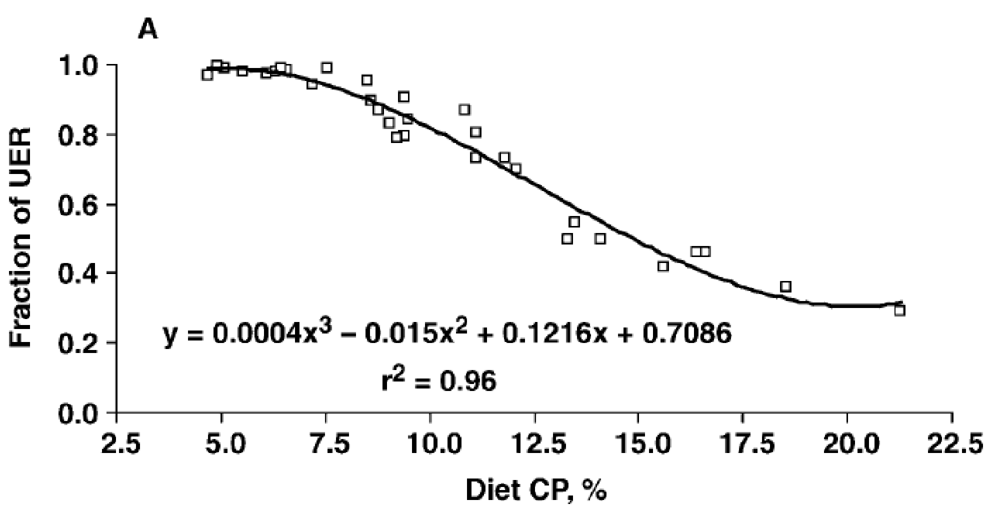
Urea entry rate to GIT



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Reynolds and Kristensen, 2008

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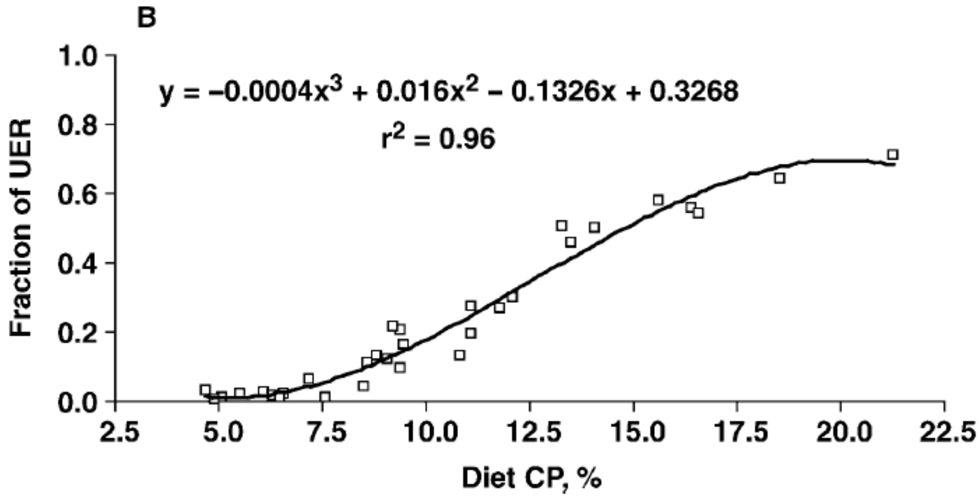
Urea entry rate that is excreted in urine/feces



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Reynolds and Kristensen, 2008

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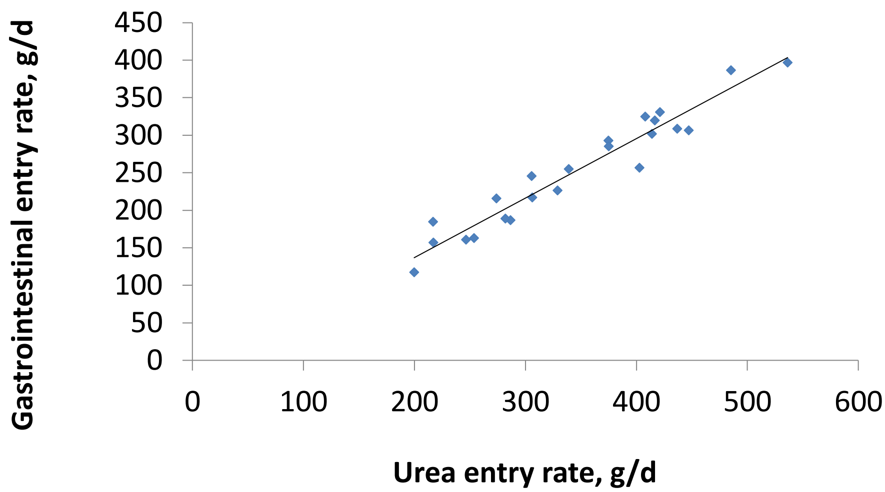
Urea-N entry rate and gastrointestinal urea-N entry rate for each experimental unit across all dietary treatments differing in dietary CP (15.3% and 16.7%), starch, and Rumensin inclusion fed to dairy cattle and continuously infused with $^{15}N^{15}N$ urea-N.



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Recktenwald et al. 2014

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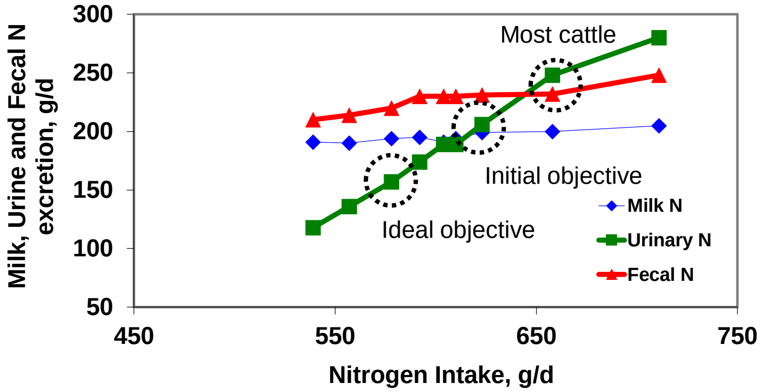
Nitrogen excretion in diets varying in dietary nitrogen



Milk Nitrogen: ~200 g or 1.28 kg (2.81 lb) protein

Urinary N:
- Most Cattle: ~250 g
- Initial Objective: ~200 g
- Ideal Objective : ~150 g

Milk N:Urinary N
- Most Cattle: 0.8
- Initial Objective: 1.0
- Ideal Objective : 1.3

Metrics can be used as a proxy for improvements of Productive N:Urinary N

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Van Amburgh et al. 2015 J. Dairy Sci

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Improving energetic efficiency through nitrogen reduction

- Moving from "most cattle" from 0.7:1.0 on productive N:urinary N to a 1:1 ratio results in a 660 g- 610 g = 50 g reduction in intake N and a proportional reduction in urinary N (1.5 lb soybean meal equivalent)
- Using the equation from Morris et al. 2021, reducing N excretion by 50 g would result in a retention of energy of 0.73 Mcals
  - Could be partitioned to milk or milk components
  - Reduce the environmental impact of milk production
  - Reduce feed costs improving IOFC
  - Results in an improvement in energetic efficiency of cattle

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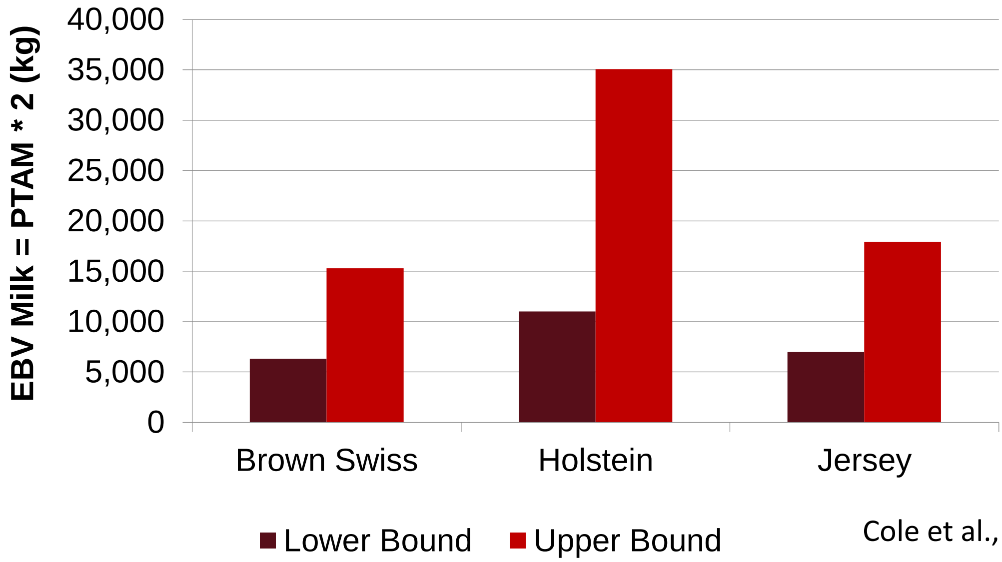
Genetic Potential: upper and lower bounds for Brown Swiss, Holstein and Jersey cattle



Cole et al., 2010

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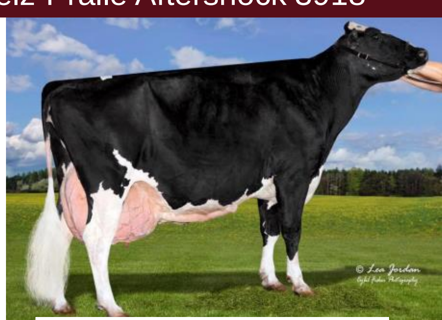
What are the limits? Two world record holders as examples

Selz-Pralle Aftershock 3918	Ever-Green-View My Gold - ET



PTA Milk = 228 kg
EBV Milk = 456 kg

35,467 kg + 34,601 kg=**70,068 kg**
Lower bound = **46,003 kg**

PTA Milk = 216 kg
EBV Milk = 431 kg

35,154 kg + 34,627 kg = **69,781 kg**
Lower bound = **46,170 kg**

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Chad Dechow, 2019

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Perspective

- Based on evaluations by J. Cole and C. Dechow, the genetic capacity for milk yield for Holsteins is approximately 75,000 lb
  - There are cows on commercial farms in Central NY in high performing herds that are peaking in milk yield between 186 to 214 lb/d (>44,0000 lb/lactation)
- My perspective is that many cows in a herd have this capacity.
- Leads to the question, what are we doing, and when, that either detracts from or fails to "turn on" that ability and when is that communicated to the animal?

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Cow 6028 4th lactation record

- 41,150 lb milk, 1,739 lb fat, 1,370 lb protein in 367 days of lactation
- She averaged 103 lb/d for the lactation

PEN	4	CALF1	7980	SID	11H11665	DID	5252
MILK	89	PCTF	4.0	PCTP	3.3	RELV	131

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	1-10	9/17/18	11/15/18	6/21/19	21030	892	698	31530	101	59	277	56
2	2-9	8/16/19	10/10/19	5/29/20	29990	1166	952	37990	122	55	287	44
3	3-8	7/12/20	10/16/20	5/28/21	34190	1415	1146	37840	117	96	320	53
4	4-8	7/20/21	12/09/21	7/22/22	41150	1739	1370	38760	120	142	367	53
5	5-10	9/13/22	2/09/23	-	41570	1669	1285	41890	131	149	340	0
TOT					167930	6881	5451					

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Cow 5973 3rd lactation record

- 41,849 lb milk, 1,724 lb fat, 1,338 lb protein in 356 days of lactation
- Averaged 117.4 lb milk per day

PEN	3	CALF1	0	SID	11H11437	DID	5155
MILK	109	PCTF	3.9	PCTP	3.4	RELV	132

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	2-0	10/01/18	4/06/19	11/08/19	38730	1423	1192	37330	116	187	403	69
2	3-4	1/16/20	6/25/20	2/05/21	44470	1498	1343	40940	126	161	386	43
3	4-6	3/20/21	7/28/21	3/11/22	41850	1725	1338	37710	119	130	356	54
4	5-7	5/04/22	-	-	56140	2079	1723	41990	132	472	472	0
TOT					181190	6725	5596					

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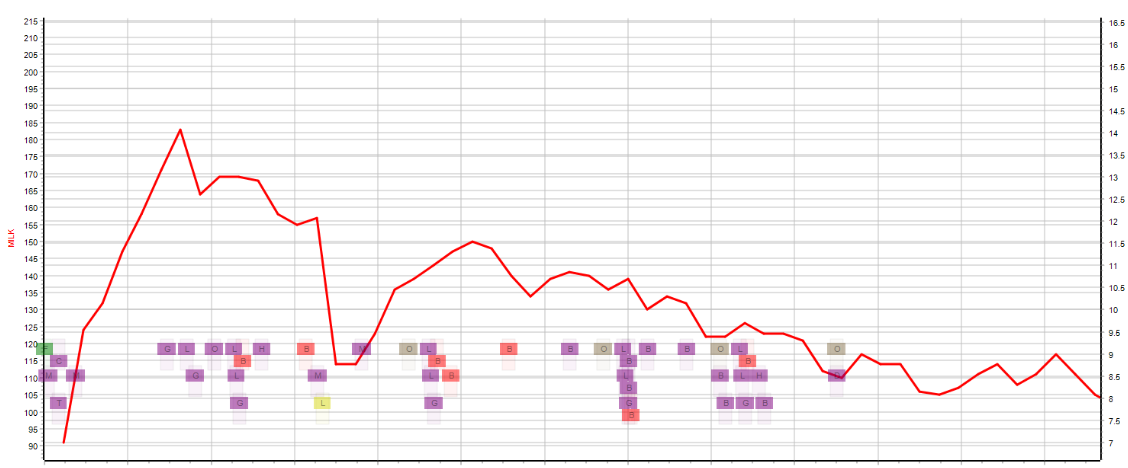
Cow 5973

- Peaked at 183 lb milk per day



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Cow 6389 3rd lactation

- 47,060 lb milk, 2,144 lb fat, 1,653 lb protein
- Averaged 117 lb/d 404-day lactation

PEN	3	CALF1	7962	SID	11H11815	DID	5582
MILK	130	PCTF	5.4	PCTP	3.5	RELV	119

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	1-10	7/04/19	10/03/19	5/08/20	30570	1318	997	42570	136	91	309	56
2	2-10	7/03/20	10/23/20	6/04/21	39100	1747	1322	43940	136	112	336	51
3	3-11	7/25/21	2/13/22	9/02/22	47060	2144	1653	41870	127	203	404	78
4	5-2	11/19/22	-	-	31580	1325	1015	38090	119	273	273	0
TOT					148310	6534	4987					

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Cow 4291 3rd lactation

- 51,600 lb milk, 2,063 lb fat, 1,668 lb protein
- 124 lb milk per day – 4% Fat, 3.23% protein
- 417 day lactation

PEN	3	CALF1	0	SID	11H11462	DID	5281
MILK	120	PCTF	4.5	PCTP	3.4	RELV	126

L#	AGE	FDAT	CDAT	DDAT	TOTM	TOTF	TOTP	305ME	RELV	DOPN	DIM	DDRY
1	1-11	11/02/18	2/19/19	9/27/19	34690	1181	1062	41900	134	109	329	61
2	2-11	11/27/19	4/25/20	12/04/20	42150	1536	1303	40830	125	150	373	59
3	4-1	2/01/21	8/29/21	3/25/22	51600	2062	1669	42410	134	209	417	64

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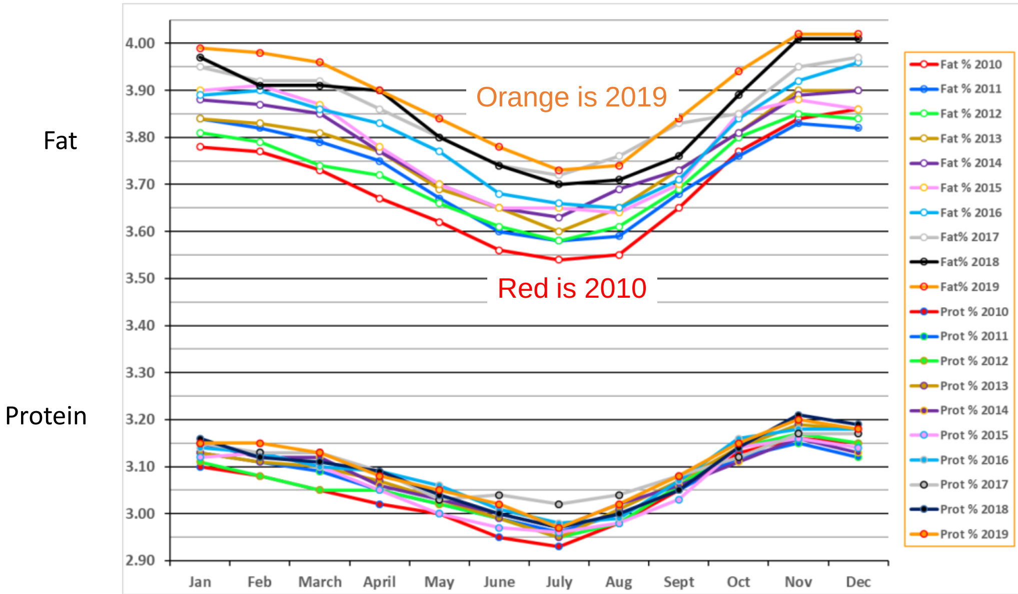
Northeast U.S. FMMO 1 Milk Fat and Protein % -- 2010 to 2019



Slide courtesy of Clay Zimmerman

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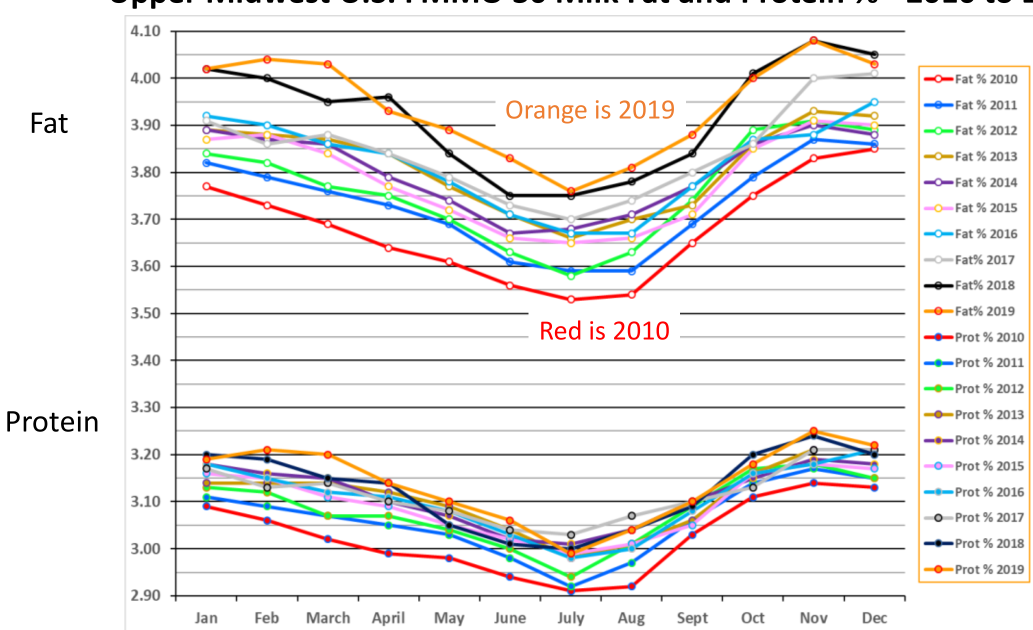
Upper Midwest U.S. FMMO 30 Milk Fat and Protein % - 2010 to 2019



Source: Zimmerman, Balchem Corporation - 2020

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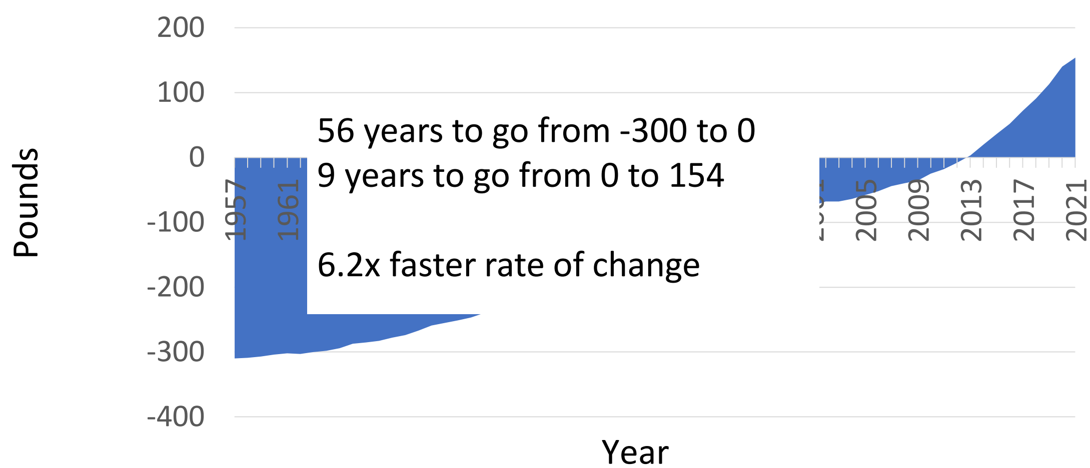
US Sire Breeding Value for Fat 1957-2021



Dechow, 2023; https://webconnect.uscdcb.com/#/summary-stats/genetic-trend

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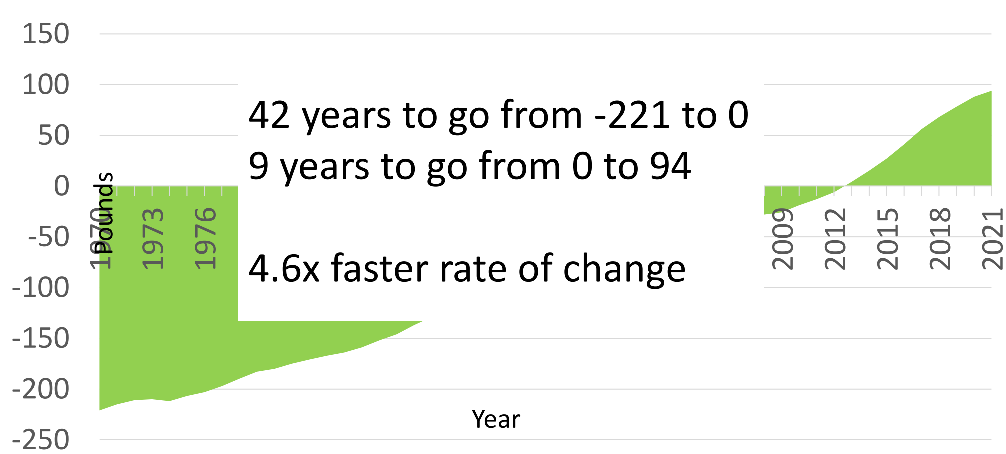
US Sire Protein Breeding Values over 51 years



Dechow, 2023; https://webconnect.uscdcb.com/#/summary-stats/genetic-trend

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Swine Requirements: Lysine as a function of Energy and Other Essential AA as function of Lysine

Table 1. Minimum standardized ileal digestible lysine and amino acid to lysine ratio for growing pigs and sows

	Growing pigs weight range, lb						Sows[4]	
SID amino acids[1]	15 to 25	25 to 55	55 to 130	130 to 175	175 to 220	220 to 285	Gestating	Lactating
Lysine, %[2]	1.35	1.25	1.08	0.88	0.78	0.70	0.60	1.05
Amino acid to lysine ratio, %[3]								
Methionine	28	28	28	28	28	28	28-29	28-29
Methionine + Cysteine	56	56	56	56	57	58	68-70	53-54
Threonine	62	62	62	62	63	64	74-76	63-64
Tryptophan	19	19	18	18	18	18	19-21	19-21
Isoleucine	52	52	52	52	52	52	58	56
Valine	67	67	68	68	68	68	71-76	64-70

[1]Minimum levels based on the NRC (2012) ingredient loading values.
[2]Minimum lysine levels considering a diet with 1,150 kcal NE/lb for growing pigs, 1,130 kcal NE/lb for gestating sows, and 1,160 kcal NE/lb for lactating sows.
[3]Minimum ratios to achieve approximately 95% of maximum growth performance. Minimum ratios of threonine, tryptophan, isoleucine, and valine can be greater depending on diet formulation.
[4]Data on amino acid requirements for contemporary sows is limited.

- These are adjusted based on genotype thus the relationship between Lysine and energy changes with increased capacity for growth
- What about cows and their increased capacity for components?

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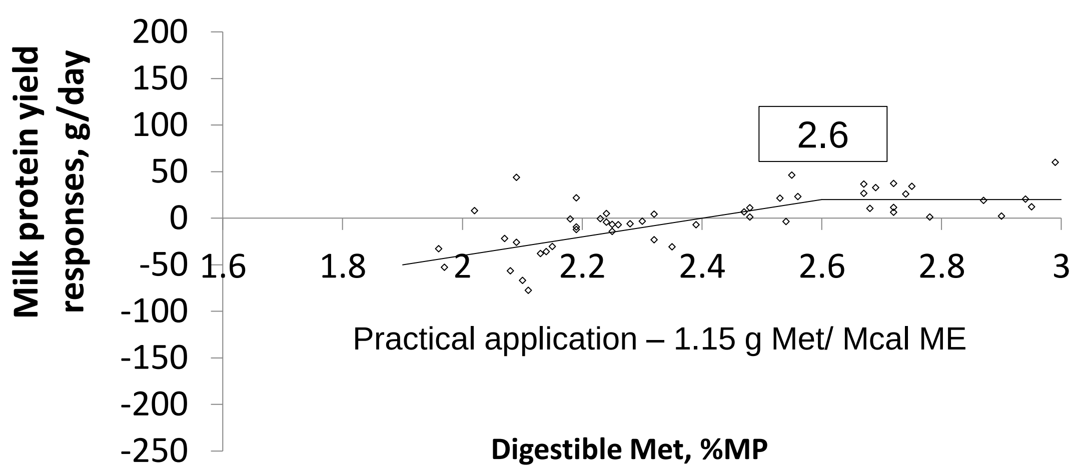
Balancing for met – updated aa profiles – milk protein yield CNCPS v6.55 (NDS/AMTS)



Van Amburgh et al., JDS 2015

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Optimum Supply Of Each EAA Relative To Metabolizable Energy – CNCPS v7.0 – Approach incorporates all productive functions

AA	R^2	Efficiency from our evaluation	Lapierre et al. (2007)	**g AA/ Mcal ME**	% EAA
Arg	0.81	0.61	0.58	**2.04**	10.2%
His	0.84	0.77	0.76	**0.91**	4.5%
Ile	0.74	0.67	0.67	**2.16**	10.8%
Leu	0.81	0.73	0.61	**3.42**	17.0%
Lys	0.75	0.67	0.69	**3.03**	15.1%
Met	0.79	0.57	0.66	**1.14**	5.7%
Phe	0.75	0.58	0.57	**2.15**	10.7%
Thr	0.75	0.59	0.66	**2.14**	10.7%
Trp	0.71	0.65	N/A	**0.59**	2.9%
Val	0.79	0.68	0.66	**2.48**	12.4%

Lys and Met requirements 14.9%, 5.1% - Schwab (1996) 2.9:1

Lys and Met requirements 14.7%, 5.3% - Rulquin et al. (1993) 2.77:1

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Amino Acids and De Novo FA Synthesis

- Lys increased enzymes related to de novo FA synthesis (ACS, ACC, FAS) through upregulation of FABP and SREBP1 (Li et al., 2019)
  - Further increased when supplemented with palmitic acid and oleic acid
- Additionally, Met and Leu increase expression of SREBP1– important regulator of enzymes for milk FA synthesis (Li et al., 2019).
- Arg increased de novo and mixed FA synthesis and expression of ACC, SCD, DGAT1 (Ding et al., 2022)

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Fatty Acid Synthetase (FAS)

- FAS synthesizes de novo FA by elongating FA carbon chain
- Active sites with AA essential for function and transfer of intermediates during elongation of de novo FA
  - His, Lys, Ser, Cys (Smith et al., 2003; Wettstein-Knowles et al., 2005)
- FAS expression decreased in His- and Lys-deficient human liver cell medium (Dudek and Semenkovich, 1995)
  - This was reversible when His and Lys were reintroduced
- Expression of FAS increased by adding both NEAA and EAA compared each treatment individually (Fukuda and Iritani, 1986)
  - FAS complex likely has requirement for both types of AA

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Review of recent experiment evaluating nutrient use efficiency

Dose titration of rumen modifier – nothing to do with amino acids, except the diets were formulated using the latest information related to AA levels

192 cows were used in a replicated pen study

16 cows per pen, milked 3x per day

Prior to the experiment, the cows were producing 42 kg, 4.1% fat and 3.1% true protein

Benoit et al., JDS abstract 2022

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	DM kg
Corn silage	8.85
Haylage - MML	4.90
Corn ground fine	4.54
SBM	1.72
SoyPass	1.45
Citrus Pulp	1.13
Wheat midds	1.13
Dextrose	0.40
Blood meal	0.25
Bergafat 100	0.15
Energy Booster 100	0.15
Sodium bicarb	0.10
Smartamine M	0.03
Smartamine ML	0.03
Levucell SC	0.01
Vitamins and Minerals	0.41
Total	25.27

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Rumen modifier study diet chemistry – formulated

DM, %	45.1
CP, %	15.75
Sol CP, %CP	31.5
aNDFom, %	31.6
Sugar, %	4.92
Starch, %	26.33
EE, %	4.4
ME, mcal/kg	2.65
ME, Mcal @25.5 kg DMI	68
Forage, % DMI	54.3
Forage, %BW	0.93
Methionine, g/Mcal ME	1.19
Lysine, g/Mcal ME	3.03
Methionine, g	82
Lysine, g (methionine x 2.7)	222

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Diet/Intake related information – Methionine and Lysine levels

Cows consumed approximately **71-72 mcals** per day

Methionine @ 1.19g/Mcal = 1.19* 71.5 = **85 g**

Lysine @ 2.7 times Met = 85g * 2.7 = **229 g**

Histidine similar to Methionine

These levels are what we consider the true requirement to be based on the last 10 years of research

Meeting the requirements should improve energetic efficiency and milk component yields

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Milk, energy corrected milk, feed efficiency and body weight of cows fed four levels of rumen modifier

	Treatment					
Item	0	11g	14.5g	18g	SEM	P-Value
DMI, kg/d	26.9	26.8	26.7	27.7	0.31	0.21
Milk Yield, kg/d	39.1	39.9	39.6	39.6	0.4	0.33
ECM, kg/d,	45.9	46.9	47.1	46.8	0.51	0.11
Feed Efficiency, ECM/feed	1.71	1.74	1.76	1.70	0.02	0.93
BCS	2.9	3.1	3.0	2.9	0.2	0.7
BW, kg	693	690	693	692	2.3	0.96
PUN, mg/dL	9.13	9.23	9.19	8.88	0.16	0.36

Benoit et al., 2022

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Milk fat, protein and urea nitrogen of cows fed four levels of rumen modifier

	Treatment					
Item	0	11g	14.5g	18g	SEM	P-Value
DMI, kg/d	26.9	26.8	26.7	27.7	0.31	0.21
Milk Yield, kg/d	39.1	39.9	39.6	39.6	0.4	0.33
ECM, kg/d,	45.9	46.9	47.1	46.8	0.51	0.11
Milk fat, %	**4.60**	**4.67**	**4.72**	**4.67**	0.05	0.2
Milk fat, kg	1.79	1.83	1.85	1.83	0.02	0.02
Milk true protein, %	**3.35**	**3.38**	**3.37**	**3.39**	0.01	0.07
Milk protein, kg	1.30	1.33	1.32	1.33	0.01	0.15
MUN, mg/dL	8.92	10.20	9.65	9.56	0.12	<0.01

Benoit et al., JDS abstract 2022

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Fatty acid profile of milk from cows fed four levels of rumen modifier

	Treatment					
Item	0	11g	14.5g	18g	SEM	P-Value
De novo fatty acid, g/100g	**1.131**	**1.157**	**1.168**	**1.156**	**0.01**	**0.03**
De novo fatty acid, kg	0.44	0.45	0.46	0.46	0.005	0.32
Mixed fatty acid, g/100g	**1.856**	**1.881**	**1.918**	**1.897**	**0.02**	**0.02**
Mixed fatty acid, kg	0.73	0.74	0.75	0.75	0.009	0.39
Preformed fatty acid, g/100g	1.34	1.33	1.38	1.35	0.02	0.23
Preformed fatty acid, kg	0.52	0.52	0.54	0.53	0.007	0.29
Fatty acid chain length	14.6	14.5	14.5	14.5	0.01	0.83
Double Bonds	0.23	0.23	0.23	0.23	0.002	0.42

Benoit et al., 2022

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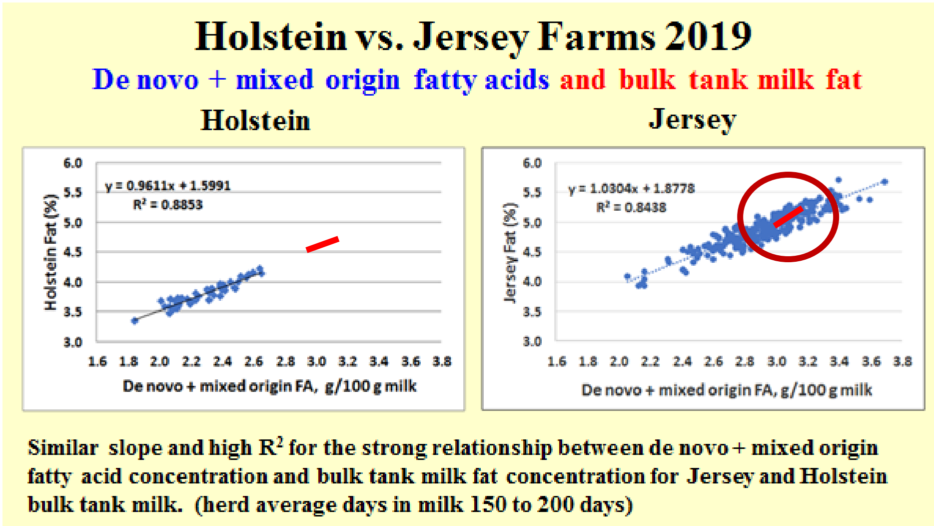
Milk de novo and mixed fatty acids from this study compared to Jersey milk components



Barbano et al. Proc Cornell Nutr. Conf. 2019

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Calculations around Nitrogen and Energetic Efficiency

Change in N efficiency was 8.1% from the initial diet to the study diet

More importantly, the change in energetic efficiency was 8.1% (95.5 lb to 103.2 lb ECM)

	Productive N	Urinary N	Ratio
Initial diet	209	233	0.9
Treatment diet	226	215	1.05

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Effect of Rumen Protected Methionine and Lysine on Energy Corrected Milk Yield (and don't forget about Histidine…)

- 144 cows assigned to a replicated pen study
- Three levels of rumen protected Methionine
- Lysine was held constant at 3.2 g metabolizable AA per Mcal ME
- Histidine was similar to the highest Methionine level

- Methionine was fed at 0, 1.05 and 1.19 g metabolizable Met per Mcal ME

- 14-day covariate, 84-day treatment; 75% multiparous, 25% primiparous cattle per pen

Danese et al. unpublished

41

144 cows, replicated pen, 16 cows/pen	Diet, g Metabolizable Met/Mcal ME				
Parameter	0.86	1.05	1.19	SEM	P value
Body Weight, kg	698	705	701	3.3	0.30
Delta BW, kg	16.4	23.9	9.8	6.8	0.35
Dry Matter Intake, kg	26.4	26.5	26.1	0.3	0.59
Milk Yield, kg	44.6	45.3	44.8	0.38	0.38
ECM, kg	48.8[a]	50.2[b]	50.4[b]	0.44	0.02
ECM to DMI	1.87	1.88	1.92	0.017	0.21
Milk True Protein, g/100g Milk	3.09[a]	3.24[b]	3.34[c]	0.010	< 0.01
Milk True Protein, kg	1.38[a]	1.46[b]	1.49[b]	0.011	< 0.01
Milk Fat, g/100g Milk	4.21[a]	4.25[a]	4.36[b]	0.026	< 0.01
Milk Fat, kg	1.88	1.92	1.94	0.023	0.16
MUN, mg/dL	11.20	11.44	11.09	0.120	0.12

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Diet, g Metabolizable Met/Mcal ME

Milk Fat, g/100g Milk	0.86	1.05	1.19	SEM	P value
De novo	1.14[a]	1.17[b]	1.20[b]	0.010	< 0.01
Mixed	1.65[x]	1.67[xy]	1.70[y]	0.015	0.07
Preformed	1.16	1.15	1.19	0.013	0.20
Milk Fat, % Milk Fat					
De novo	28.79[a]	29.33[b]	29.34[b]	0.088	< 0.01
Mixed	41.83	41.61	41.56	0.148	0.40
Preformed	29.33	29.08	29.07	0.166	0.43

Danese et al. unpublished

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Diet, g Metabolizable Met/Mcal ME

	0.86	1.05	1.19	SEM	P value
N Intake, g	669	671	673	5.9	0.91
Productive N, g	235[a]	241[b]	250[c]	1.7	< 0.01
Urinary N, g	193[y]	189[xy]	181[x]	3.6	0.09
Productive:Urinary N	**1.22**	**1.28**	**1.38**		

At the 1.19 supplementation level, the difference between milk volume and ECM was 9.4 to 13 lb demonstrating a 4% increase in energetic efficiency

In this study, between the same treatments, the increase in N efficiency was 6.4%

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Observations from these studies

- Milk components can be greatly enhanced even in mid-lactation if requirements for various nutrients are met
- Data demonstrate that meeting the amino acid requirements can enhance energetic efficiency as much or more than N efficiency
- Holstein cattle can produce milk fat like Jersey cattle if fed an appropriate diet – meeting the requirements
- These cows are more environmentally efficient because they are producing more components per unit of intake reducing the intensity of greenhouse gas emissions

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Some Steps to Optimize Energetic Efficiency

- Determine the most limiting nutrient – energy or protein – do cows and model agree?
- Evaluate the rumen N balance and urinary N excretion – if high, then work to reduce the soluble protein – within CNCPS rumen NH_3 balance between 120-140%
- If grams MP is in excess, then decrease MP from feed in small increments
- Once you have ME and MP in balance and are happy with rumen N balance, focus on AA
- Met – use 1.15-1.19 g MP Met per Mcal ME (CNCPS v6.55)
- Lys – maintain a Lys:Met of ~ 2.7:1
- Pay attention to aNDFom digestibility and allocate the highest digestibility forages to the fresh and high cows
- Don’t overfeed fatty acids, add some sugar and use high digestible aNDFom

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Thank you for your attention and for all the students who helped develop this work and the sponsors who keep it going.

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Amino Acid Supply in the Ruminant

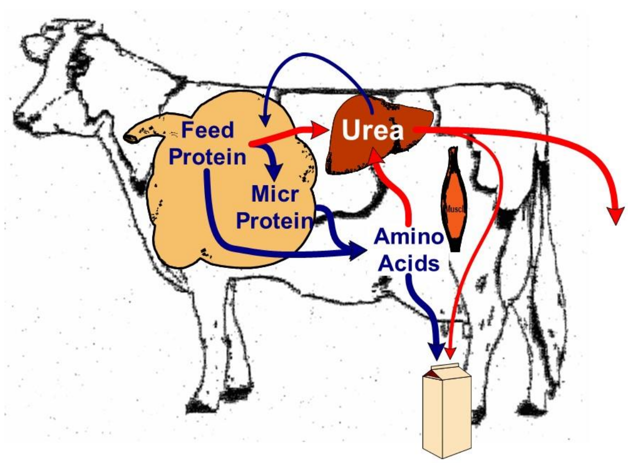
M. D. Hanigan, K. Estes, X. Huang, J. Prestegaard
School of Animal Sciences

VirginiaTech
Invent the Future

1

N and Amino Acid Supply in Ruminants

DAIRY SCIENCE



- Nutrient Intake
- Ruminal Metabolism
  - Escape to SI
  - Capture in Micr
  - Fermentation to other products
  - Absorption
- Abomasum/SI
  - Digestion
  - Absorption
- Large Intestine
  - Digestion
  - Fermentation
  - Absorption

2

Integrated Milk Protein Predictions

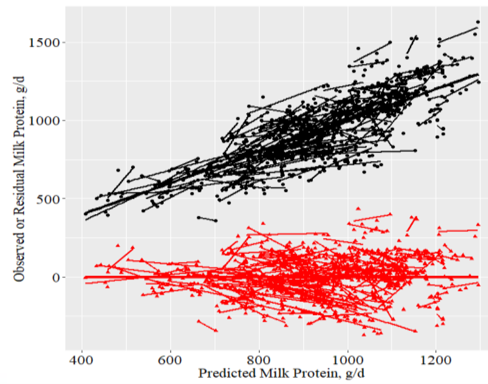
$$mPrt = \beta His + \chi Ile + \delta Leu + \varepsilon Lys + \phi Met + \varphi Thr + \lambda DEI + \kappa dNDF + \mu BW + \lambda(\sum EAA^2)$$

Predictors	Intercept	His	Ile	Leu	Lys	Met	Thr	$\Sigma(EAA^2)$	DEInp	dNDF	BW
	g/d	----------------	----------------	----------------	g/g	----------------	----------------	----------------	g/mcal	g/%	g/kg
Estimates	6.3	**2.44**	**1.05**	**0.99**	**1.10**	**1.80**	**2.01**	**-0.0025**	**9.27**	**-3.37**	**-0.26**
SE	102	0.76	0.51	0.29	0.30	0.39	0.75	0.0004	0.68	0.94	0.14

Cross Evaluation Results – 500 Iterations

Variable	Mean	SE
Observed Mean, g/d	924	17
Predicted Mean, g/d	924	13
RMSE	126	7
RMSE, % mean	**13.7**	**0.8**
Mean Bias, % MSE	0.7	0.9
Slope Bias, % MSE	2.8	2.4
CCC	0.78	0.03

- Arg significant but variable
- Trp, Phe, and Val → inadequate data



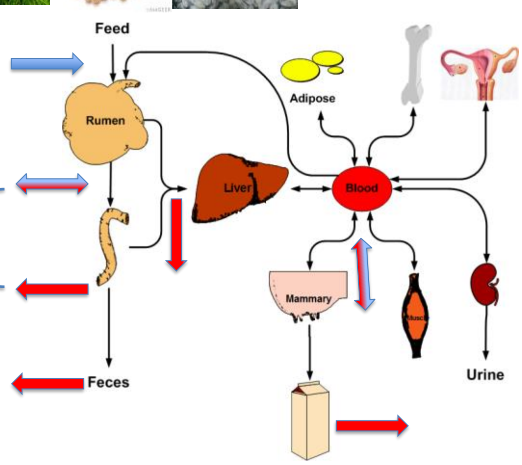
3

Amino Acid Supply Methods



Identity Preservation??

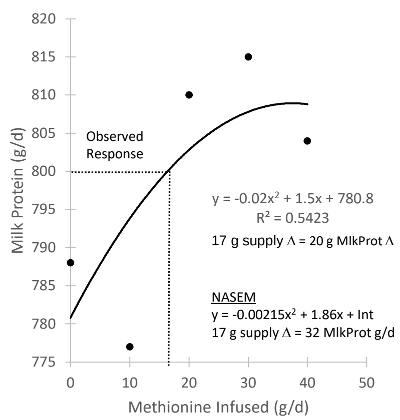
Small Intestine Disappearance



4

Milk Protein Yield Response

Varvikko et al., 1999



- Net delivery to milk from:
  - Infused vs ingredient
- Develop a milk response curve
  - SE_{STD_Curve} = 13.5 g/d
- Include 1 or more Ingr Eval Trt
  - SEM for single point = 20 to 40 g/d
  - 20 g error = 30 g Δ in Met Supply
  - Min Δ Met for STD Curve ≈ 80 g/d
  - Min Sample Δ = 60 g/d
  - Expect 30% SE on Bio Estimate
- Infusion site?
  - Gut
    - replicates dRUP
    - Absorptive losses = 5-15%
  - Jugular
    - Misses loss during absorption

5

Blood Concentration Responses

Dietary MP = 115% of Requirement

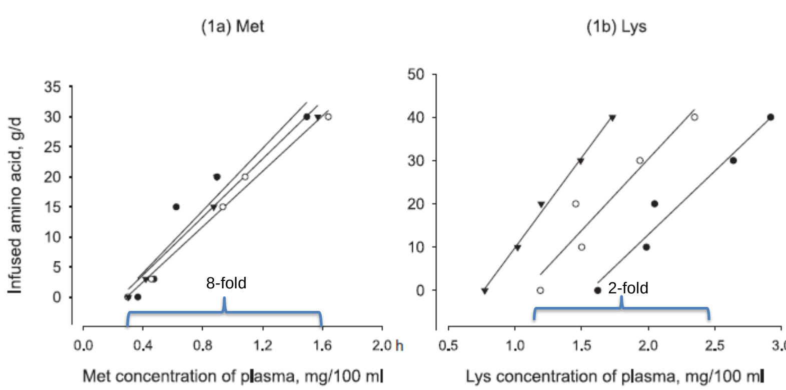


Figure 1. Individual variations of relationships between plasma of Met (1a) or Lys (1b) and amounts infused into the duodenum. Milk protein yield of cows: ● Cow 1 = 189 g/d; ○ Cow 2 = 249 g/d; ▼ Cow 3 = 358 g/d

Rulquin, H. and J. Kowalczyk. 2003

6

Blood Concentration

Rulquin, H. and J. Kowalczyk. 2003.

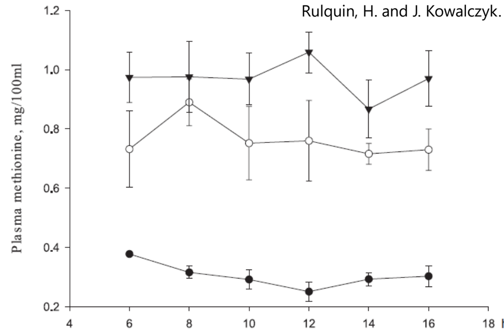


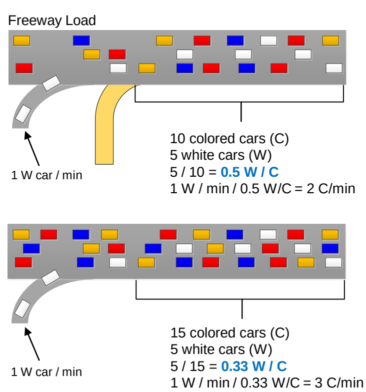
Figure 2. Diurnal variations of plasma methionine concentrations of cows supplied with graded doses of Smartamine ML™: —●— 50 g SmartamineML™, —○— 88 g SmartamineML™, —▼— 132 g Smartamine ML™

Methionine and lysine bioavailability in Smartamine M™ and Smartamine ML™

Indices	Smartamine M™		SED	Smartamine ML™			SED
Product, g/d	30	40		50	88	132	
Met, g/d	23.4	31.2		8.4	14.8	22.2	
Lys, g/d				19.7	34.7	52	
Bioavailability, %							
Met	75.1	75.1	3.43	95.3	79.7	77.7	10.5
Lys				106.3	84.0	109.3	18.2

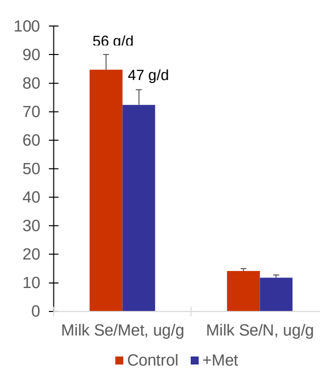
7

Efficacy by Dilution



Challenges
- Need constant clearance of marker
- Loss of label via alternative exit and alternative entry points
- Se specific to Met

Infused 9 g Met
12.2 mg Se/g / 84.7 = 14.4% change in Met supply
SEM = 5.3 mg/g =43% SE



Weiss and St-Pierre, 2009

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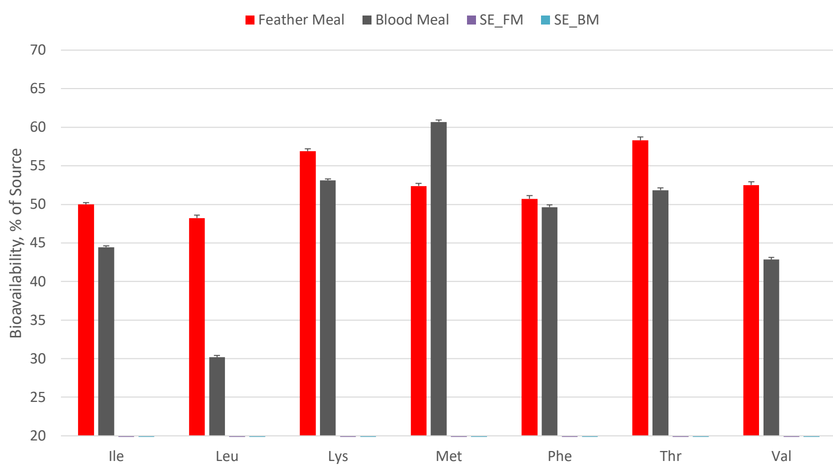
Ingredient EAA Bioavailabilities



Estes et al., 2018

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Stable Isotope Results – Prestegaard and Fernandes (Virginia Tech)

RP-AA	Plasma Appearance (%)[1]	Bioavailability (%)[2]
AminoShure®-XM	51.2	55.0
RP-Lysine Prototype 1	59.8	64.0
RP-Lysine Prototype 2	44.0	47.1
RP-Histidine Prototype 1	68.7	73.5
RP-Histidine Prototype 2	51.9	55.6

[1]Percent of AA appearance in plasma. Calculated as the grams of AA absorbed into blood per 100 grams of AA fed
[2]Predicted bioavailability corrected for 7% loss during first pass

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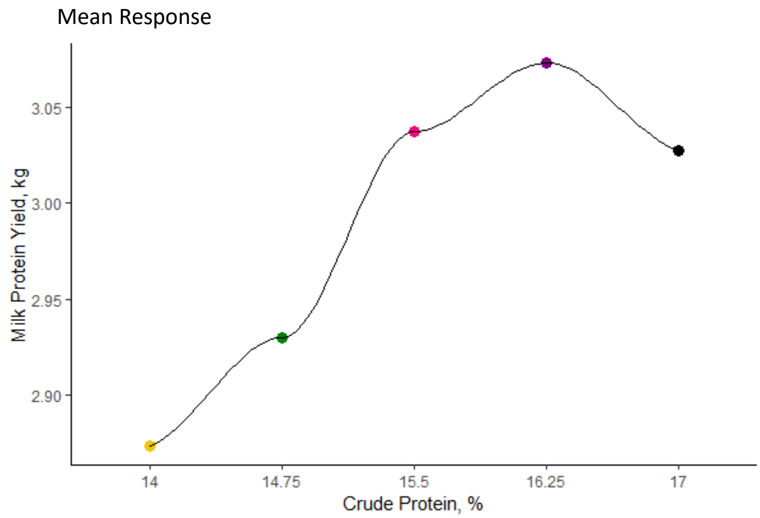
Within Cow Milk Protein Responses to MP



Campos et al., in progress
VT/Univ. Tn. Collaboration

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Conclusions

- Several Valid Methods of Assessment
- Variance is not equal across methods
  - Reduced by greater Ingr feeding and replicating observations
  - Milk Protein Response
    - ± 30% if 90 g Met/d fed
    - Double Lys fed for similar error
  - Blood Concentrations
    - ± 12% units for Met at 100 g/d
    - ± 18% units for Lys
    - e.g. 70% bioavailabilty ± 18%
  - Se-Met Dilution
    - ± 15% units
    - Met only
  - Isotope Dilution
    - ± 12% Units
    - All EAA

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Histidine – a limiting amino acid for dairy cows

Alex N. Hristov
Distinguished Professor, Department of Animal Science
The Pennsylvania State University

35th Annual Florida Ruminant Nutrition Symposium, Feb 26 - 28, 2024, Gainesville, FL

1

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Talk outline

- How it all started - feeding reduced-protein diets to dairy cows
- Why Histidine?
- Early research
- Penn State research
- Conclusions

2

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Low-protein diets - Why?

- What is a low-protein diet?
  - Diets supplying MP below requirements?
  - Diets with CP below “industry standards”?
  - Several surveys showed average CP in dairy diets being around **17%; now many diets tend to be closer to 16%**
- **Reasons for feeding low-protein diets:**
  - Reduced feed cost
  - Striving for efficiency
  - Reduced N emissions (originally, NH_3 was the target)
  - Protein overfeeding and reproduction

3

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Environmental concerns with N

- Eutrophication of water bodies
- Ground water quality
- Air pollution

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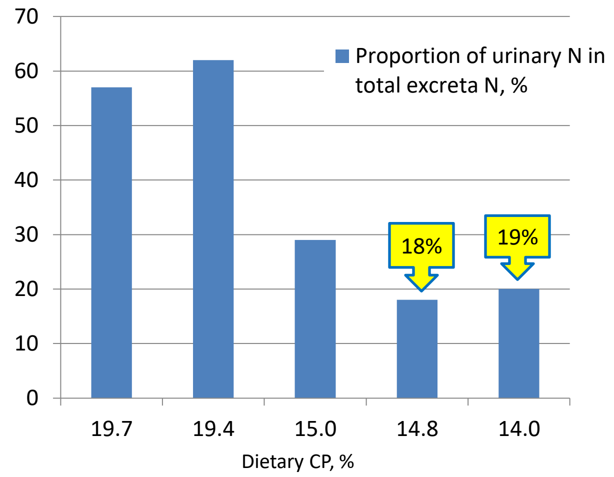
Penn State and Idaho data

Urinary N is the problem



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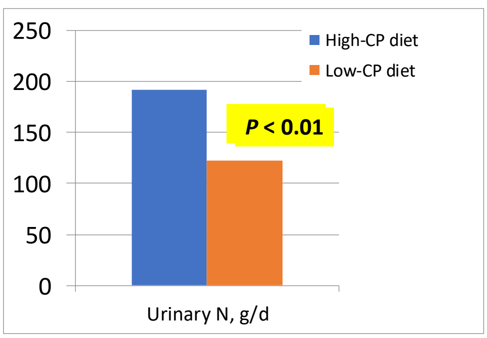
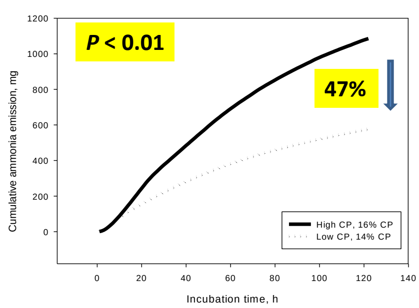
Lee et al., 2010

Decreasing urinary N/urea excretion decreases manure ammonia emissions





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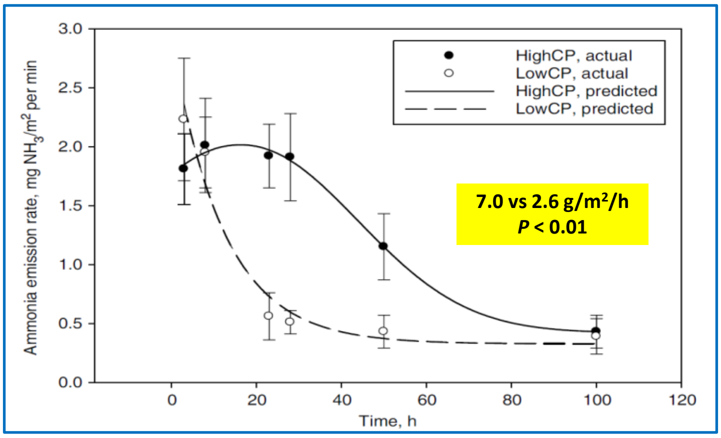
Lee et al., 2016

Dietary CP influences manure ammonia emissions as well



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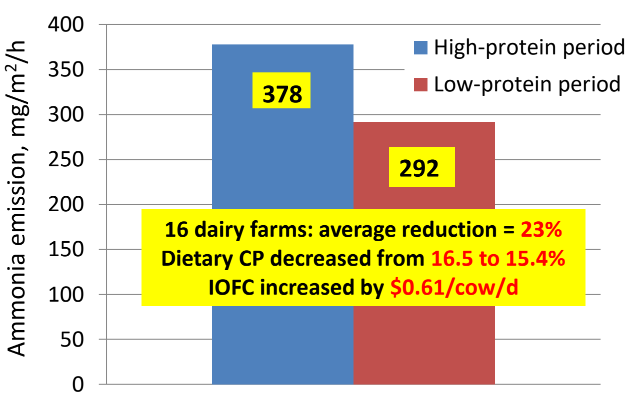
1%-unit reduction in CP can have a large effect on ammonia emission from manure



Hristov et al., 2015

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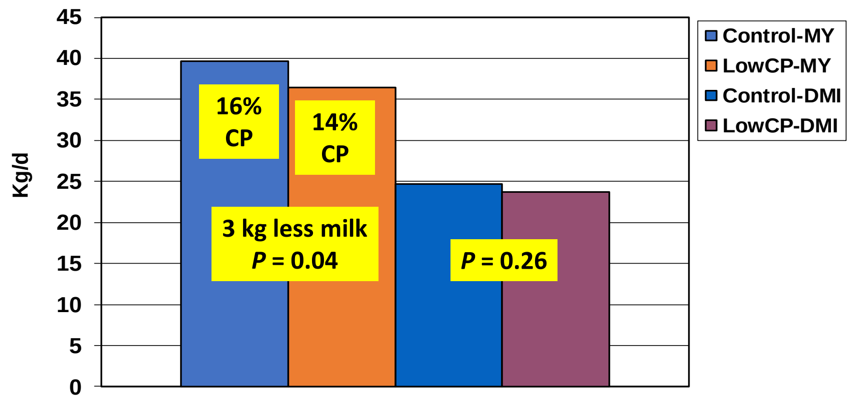
Due to deficiency of specific AA or RDP, MP balance of -12 to -13% will likely decrease DMI, milk yield & components



Penn State data

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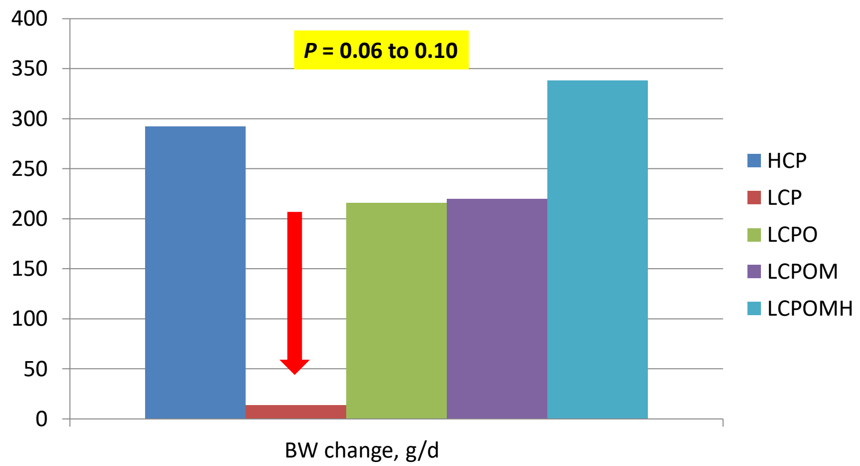
Giallongo et al., 2014

Or cows will lose BW



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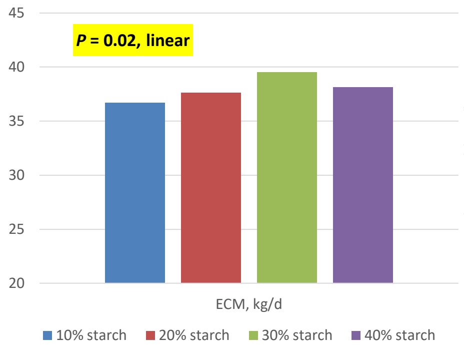
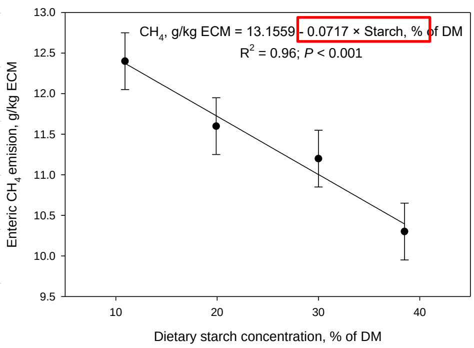
Cueva et al., 2024

More recently, enteric methane became a target: low-protein, high-starch diets?

Milk fat % decreased but milk protein and ECM yields and ECM feed efficiency increased with increasing dietary starch concentration





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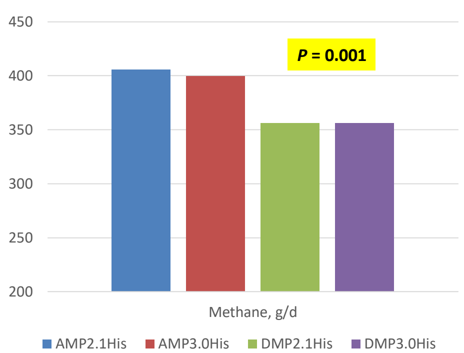
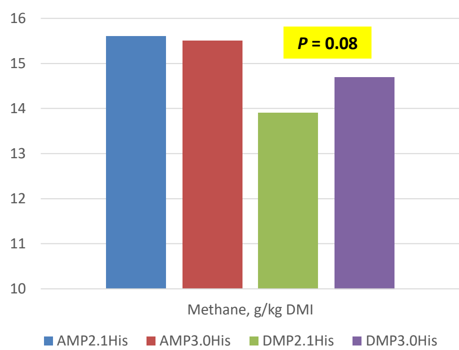
Räisänen et al., 2022

Effect of an approx. 1%-unit decrease in CP on enteric methane emissions

Starch replaced RUP; 16.7 vs 15.4% CP; 110% vs 96% of MP requirements; 23.2 vs 25.0% starch





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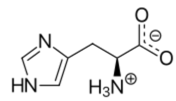
Histidine



- Unique among EAA with an imidazole side chain
- Similar to Met, a Group 1 AA (extracted by the liver with post-liver supply approx. equal to mammary uptake and output in milk)
- Which would suggest that requirements for His should be similar to those for Met
- However, variability in estimates for His requirements have been large: 2.2 to >3% of MP
  - Major reasons for this are endogenous His depots: carnosine and blood hemoglobin
  - And lower His than Met in microbial protein

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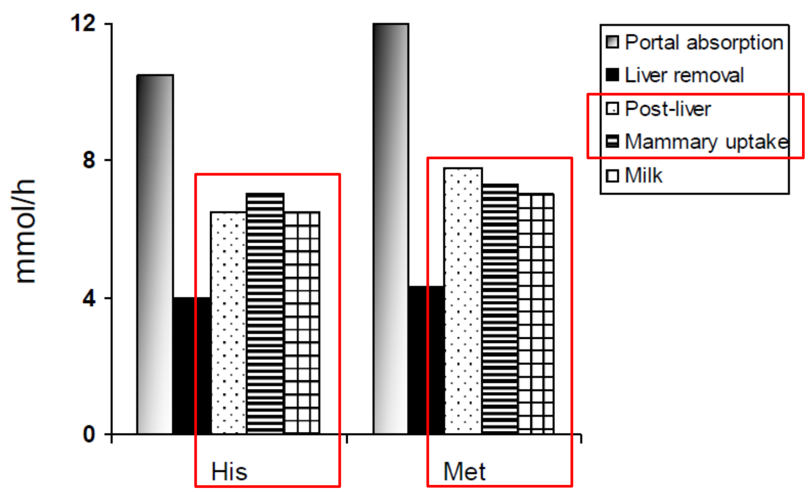
Net flux of Met and His



Lapierre et al., 2008

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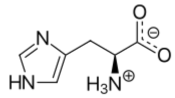
Histidine



- Catabolic pathways:
  - Incorporation into protein
  - Synthesis of carnosine
  - Decarboxylation of histidine to histamine by histidine decarboxylase
  - Buffering role of histidine and histidine-related compounds
- Controversial effects of His on feed intake regulation
  - Reports with lab animals and non-ruminants indicate stimulatory effect on feed intake: perhaps through acting on the anterior prepyriform cortex, the brain's AA "chemosensor" (no stimulation when His was infused in the jugular veins vs. the carotid arteries)
  - Other reports suggest the opposite effect – His depresses feed intake through its conversion into histamine in the hypothalamus; the released histamine acts on food intake through histamine H1 receptors activation of histamine neurons

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Räisänen et al., 2023

Histidine research

Table 1. Characterization of publications used in the meta-analysis

Source	Design[1]	Method of His supplementation[2]	Basal diet	MP-level[3]	Other supplemental AA
Vanhatalo et al. (1999)	LS	Infusion	Grass silage	MPD	Lys, Met
Kim et al. (1999)	LS	Deletion	Grass silage	MPA	Lys, Met, Trp
Kim et al. (2000)	LS	Infusion	Grass silage	MPA	Lys, Met
Korhonen et al. (2000)	LS	Infusion	Grass silage	MPA	—
Kim et al. (2001)a[4]	LS	Infusion	Grass silage	MPA	—
Kim et al. (2001)b	LS	Infusion	Grass silage	MPA	Lys, Met, Trp
Huhtanen et al. (2002)a	LS	Infusion	Grass silage	MPD	Leu
Huhtanen et al. (2002)b	LS	Infusion	Grass silage	MPD	—
Hadrová et al. (2012)	LS	Deletion	Corn silage	MPD	Leu, Lys, Met
Lee et al. (2012)	RCB	RPHis	Corn silage	MPD	RPLys, RPMet[5]
Giallongo et al. (2015)	RCB	RPHis	Corn silage	MPD	RPLys, RPMet
Giallongo et al. (2016)	RCB	RPHis	Corn silage	MPA	RPLys, RPMet
Giallongo et al. (2017)	RCB	Basal diet[6]	Corn silage	MPA	RPLys, RPMet
Zang et al. (2019)	LS	RPHis	Corn silage	MPA	RPMet
Morris and Kononoff (2020)a	LS	RPHis	Corn silage	MPA	—
Morris and Kononoff (2020)b	LS	RPHis	Corn silage	MPA	RPLys
Lapierre et al. (2021)a	LS	Deletion	Corn silage	MPD	Free AA, casein profile
Lapierre et al. (2021)b	LS	Deletion	Corn silage	MPD	Free AA, casein profile
Räisänen et al. (2021a)	LS	RPHis	Corn silage	MPA	RPLys, RPMet
Räisänen et al. (2021b)	LS	RPHis	Corn silage	MPD	RPLys, RPMet
Räisänen et al. (2022)a	RCB	RPHis	Corn silage	MPA	RPLys, RPMet
Räisänen et al. (2022)b	RCB	RPHis	Corn silage	MPA	RPLys, RPMet

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Real Science Exchange | EP94

Journal Club: Lactational performance effects of supplemental histidine in dairy cows: A met...

00:00 48:43 1X PRIVACY SHARE SUBSCRIBE

Guests: Dr. Bill Weiss, The Ohio State University; Dr. Helene Lapierre, Sherbrooke Reasearch and Development Center; Dr. Susann Räisänen, ETH Zurich

Episode 94: Journal Club-effects of supplemental histidine in dairy cows: A meta-analysis

Timestamps:

Dr. Räisänen completed this research during her Ph.D. at Penn State. The meta-analysis included 17 different studies published between 1999 and 2022 investigating supplemental histidine for lactating dairy cows. They divided the type of supplemental histidine between infused histidine and rumen-protected histidine and the basal diets between corn silage-based and grass silage-based. (4:34)

Primary response variables measured in the meta-analysis included dry matter intake, milk production, milk composition, and milk component yields. The researchers also calculated the efficiency of utilization of histidine and other amino acids supplied to the cow by the diets. Lastly, they calculated marginal recovery of histidine and evaluated the interaction between histidine supply and energy supply and how that impacts the efficiency of utilization. (7:38)

Dr. Lapierre gives a little history of histidine research. When recommendations were coming out about lysine and methionine requirements, the different studies recommended relatively similar amounts of lysine and methionine based on the proportion relative to MP supply. On the other hand, recommendations for histidine varied widely depending on the study, ranging from less than 2% to almost 4%. As emphasis has been placed on reducing the footprint of dairy production, interest has risen in feeding lower-protein diets. In this scenario, we would expect an increase in the microbial protein; however, microbes are relatively low in histidine content. If we look at the proportion of histidine relative to MP, as the crude protein concentration of a diet decreases, this proportion of histidine decreases. (8:34)

The meta-analysis revealed a clear response to histidine in milk production, dry matter intake, and milk true protein yield. Susanna and Helene are not sure if the dry matter intake response was due to a pulling effect because of increased milk and milk protein yield or if histidine has an independent impact on the brain, as has been observed in some monogastric studies (16:15)

Clay asks the guests what they think the histidine requirement is, and both agree that providing one number is not practical given the other interactions from basal diet to the efficiency of utilization to the concentration of other amino acids in the diet. (32:01)

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Milk Production of Cows on Protein-Free Feed

Studies of the use of urea and ammonium salts as the sole nitrogen source open new important perspectives.

Artturi I. Virtanen

Science, 1966

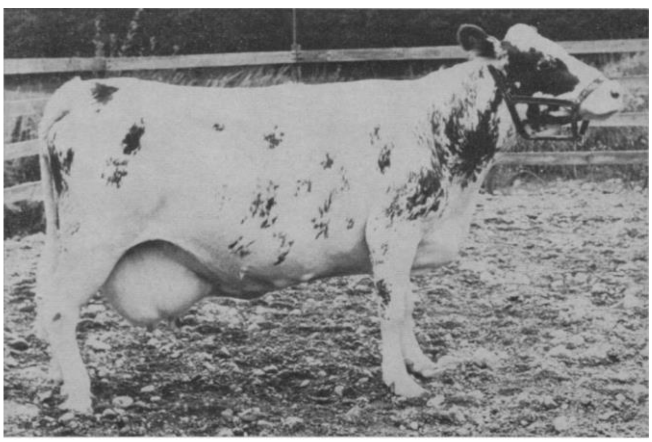

Fig. 3. Test cow Metta after being on test feed 370 days from calving.

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A. I. Virtanen; Science, 1966

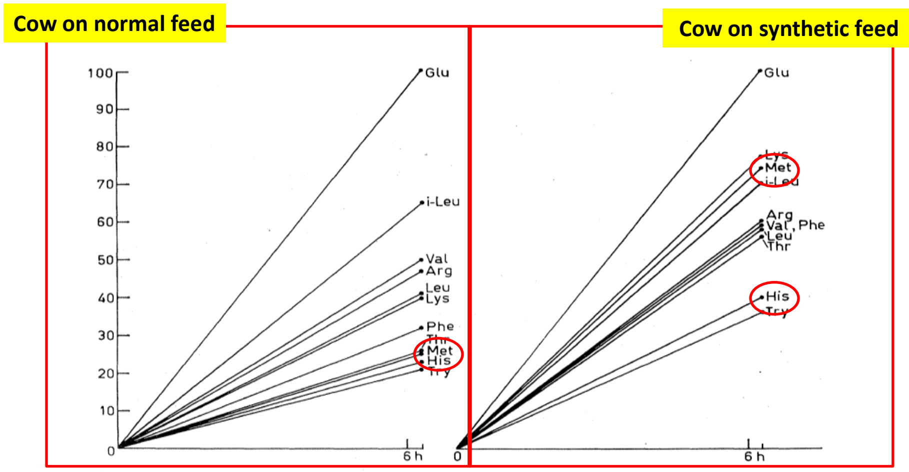

Fig. 1. Labeling of the essential amino acids of total milk protein 6.3 hours after the cow had been fed a single dose of ^{15}N-urea. The results are expressed as a percentage of the labeling of glutamic acid. At left, results of a feeding experiment with a cow on normal feed (17 March 1966); at right, results of a feeding experiment with a test cow (20 October 1962) 6 months after the start of the experimental feeding. Histidine and tryptophan have the lowest labeling in both experiments, but the increase in their labeling in the cow on the experimental feed is remarkable. [Determinations by M. Kreula and T. Moisio]

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Broderick, 1972

Ranking of AA limiting milk production of a cow milking 35 kg/d with 3.30% CP

Table 3. Estimated Order of Limitation for Digestible Essential Amino Acids (EAA) for Model Lactating Cow.

Essential amino acids	Milk EAA composition[1] (gm/16 gm N)	Milk EAA[2] (A) (gm/day)	Dig. EAA[3] (gm/day)	Effect of utilization[4]	Utilizable EAA (gm/day)	(B/A)	Order of Limitation[6]
Arginine	3.5	40	108	.62	67	1.68	10
Histidine	2.7	31	46	.76	35	1.13	3
Isoleucine	6.5	73	120	.72	86	1.18	4
Leucine	9.9	112	176	.81	143	1.28	6
Lysine	8.0	90	145	.70	101	1.12	2
Cystine	0.9	10	25	(.72)[5]	(18)	(1.80)	
Methionine	2.4	27	44	.57	25	.93	1
Sulfur[7]	3.3	37	69	(.65)[5]	(45)	(1.22)	
Phenylalanine	5.1	58	101	.75	76	1.31	7
Tyrosine	4.9	55	88	(.72)[5]	(63)	(1.15)	
Aromatic[8]	10.0	113	189	(.73)[5]	(139)	(1.23)	
Threonine	4.7	53	102	.80	82	1.55	9
Tryptophan	1.3	15	25	.82	21	1.40	8
Valine	6.7	76	120	.75	90	1.18	4

[1] Values from Block and Weiss (1956).
[2] Assuming milk production of 35 kg/day, 3.3% protein and 6.38 gm protein/gm N.

Based on these calculations, Broderick concluded that Met is 1st limiting with Lys and His closely 2nd and 3rd. Apart from Leu and Phe, other EAA are unlikely to be limiting.

[8] Phenylalanine + tyrosine.

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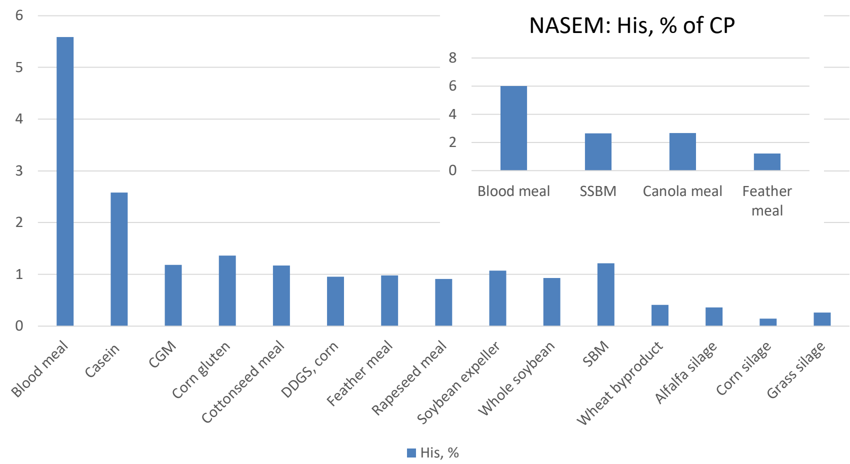
Histidine content in feeds



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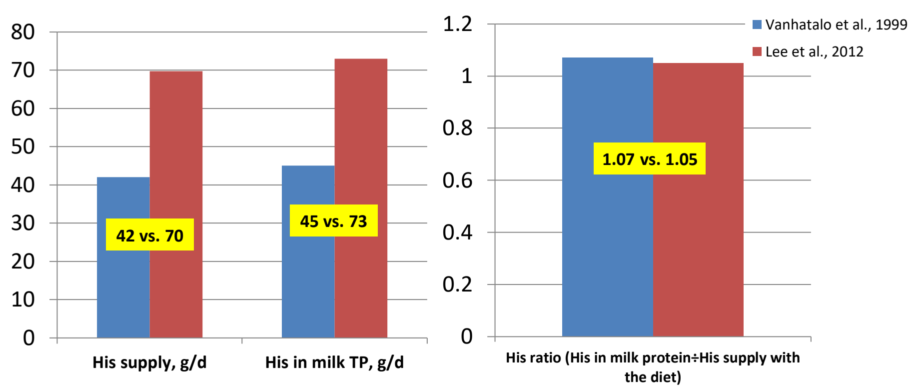
Can His be limiting on CS-based diets?

His supply ÷ output in grass- vs. corn silage-based diets



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Histidine work at Penn State

J. Dairy Sci. 99:6702–6713
http://dx.doi.org/10.3168/jds.2015-10673

Effects of slow-release urea and rumen-protected methionine and histidine on mammalian target of rapamycin (mTOR) signaling and ubiquitin proteasome-related gene expression in skeletal muscle of dairy cows

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J. Dairy Sci. 95:6042–6056
http://dx.doi.org/10.3168/jds.2012-5581

Rumen-protected lysine, methionine, and histidine increase yield in dairy cows fed a metabolizable protein-deficient die

C. Lee,* A. N. Hristov,*[1] T. W. Cassidy,* K. S. Heyler,* H. Lapierre,† G. A. Varga,* M. J.
and C. Parys#

J. Dairy Sci. 98:3292–3308
http://dx.doi.org/10.3168/jds.2014-8791

Effects of slow-release urea and rumen-protected meth and histidine on performance of dairy cows

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A. Gehman,# and C. Parys‖
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J. Dairy Sci. 104:9902–9916
https://doi.org/10.3168/jds.2021-20188

Histidine dose-response effects on lactational performance and plasma amino acid concentrations in lactating dairy cows: 1. Metabolizable protein-adequate diet

S. E. Räisänen,[1] C. F. A. Lage,[1,2] J. Oh,[1,3] A. Melgar,[1,4] K. Nedelkov,[1,5] X. Chen,[1,6] M. M
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J. Dairy Sci. 106
https://doi.org/10.3168/jds.2022-22966

Lactational performance effects of supplemental histidine in dairy cows: A meta-analysis

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J. Dairy Sci. 99:4437–4452
http://dx.doi.org/10.3168/jds.2015-10822

Effects of rumen-protected methionine, lysine, and histidine on lactation performance of dairy cows

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J. Dairy Sci. 100:2784–2800
https://doi.org/10.3168/jds.2016-11992

Histidine deficiency has a negative effect on lactational performance of dairy cows

F. Giallongo,* M. T. Harper,* J. Oh,* C. Parys,† I. Shinzato,‡ and A. N. Hristov*[1]

J. Dairy Sci. 104:9917–9930
https://doi.org/10.3168/jds.2021-20189

Histidine dose-response effects on lactational performance and plasma amino acid concentrations in lactating dairy cows: 2. Metabolizable protein-deficient diet

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J. Dairy Sci. 105:170–187
https://doi.org/10.3168/jds.2021-20800

Lactational performance and plasma and muscle amino acid concentrations in dairy cows fed diets supplying 2 levels of digestible histidine and metabolizable protein

S. E. Räisänen,[1]* C. F. A. Lage,[1,2]† C. Zhou,[1,3] A. Melgar,[1,4] T. Silvestre,[1] D. E. Wasson,[1] S. F. Cueva,[1] J. Werner,[5] T. Takagi,[6] M. Miura,[6] and A. N. Hristov[1]‡
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Histidine work at Penn State

- Observed a consistent apparent drop in plasma His with long-term feeding of low-CP diets
- His is unique among EAA: depots of labile His in muscle dipeptides and blood cholesterol
- Hypothesis: on low-CP diets, microbial protein is becoming an increasingly important source of AA for the cow
  - However, compared with Met, microbial protein is a poorer source of His

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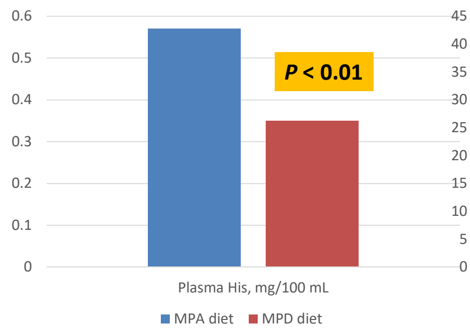
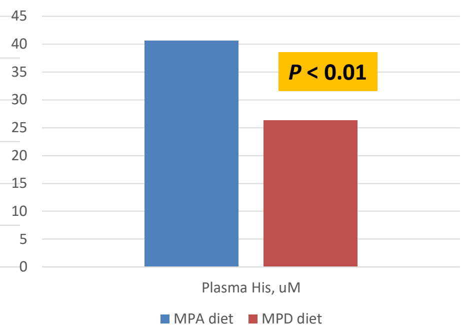
Lee et al., 2012; Giallongo et al., 2016

A couple of examples of the effect of dietary CP/MP on plasma His





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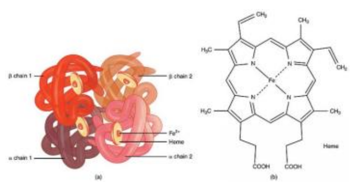
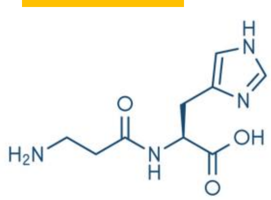
Endogenous sources of His



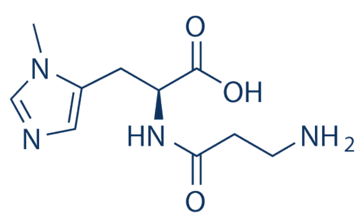
Hemoglobin

Giallongo et al., 2017:

- Blood hemoglobin = 380 g mHis
- Muscle carnosine & anserine = 270 g mHis
- These could supply mHis for about 7 wks (at approx. – 6 g mHis/d deficiency)



Carnosine



Anserine

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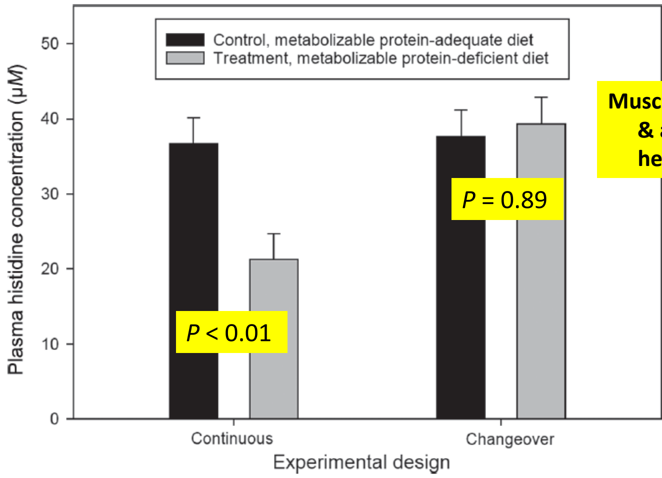
Hristov et al., 2019 (data from Lee et al., 2012, 2015)

Body reserves can hide temporary His deficiencies



Muscle carnosine & anserine, hemoglobin

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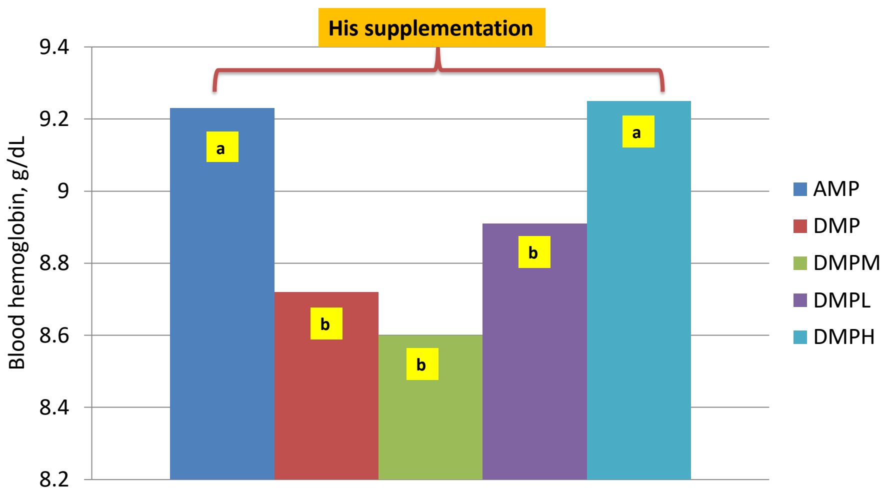
Giallongo et al., 2015

His and blood hemoglobin



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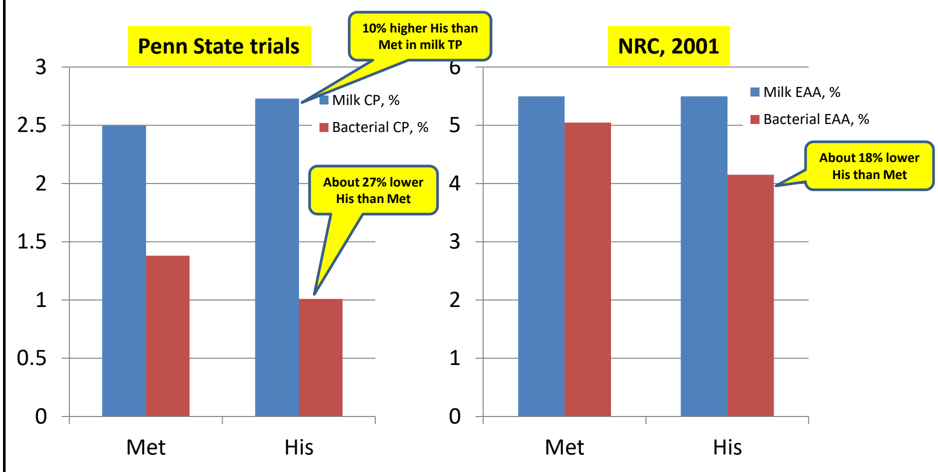
Met and His in milk protein vs. bacteria



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NASEM (2021) AA composition of microbial protein

	g AA_{corr}/100 g CP	g AA_{corr}/100 g TP[a]				g AA_{calc}/100 g TP[b]
AA	Duodenal Endogenous	Microbial[c]	Scurf	Whole Empty Body	Metabolic Fecal	Milk
Ala	4.69	7.38	[illegible]	[illegible]	6.32	3.59
Arg	4.61	5.47	[illegible]	[illegible]	5.90	3.74
Asx	4.75	13.39	[illegible]	[illegible]	7.56	8.14
Cys	2.58	2.09	[illegible]	1.74	3.31	0.93
Glx	11.31	14.98	14.69	15.76	15.67	22.55
Gly	5.11	6.26	21.08	14.46	8.45	2.04
His	2.90	2.21	1.75	3.04	[illegible]	2.92
Ile	4.09	6.99	2.96	3.69	[illegible]	6.18
Leu	7.67	9.23	6.93	8.27	[illegible]	10.56
Lys	6.23	9.44	5.64	7.90	7.61	8.82
Met	1.26	2.63	1.40	2.37	1.73	3.03
Phe	3.98	6.30	3.61	4.41	5.28	5.26
Pro	4.64	4.27	12.35	9.80	8.43	10.33
Ser	5.24	5.40	6.45	5.73	7.72	6.71
Thr	5.18	6.23	4.01	4.84	7.36	4.62
Trp	1.29	1.37	0.73	1.05	1.79	1.65
Tyr	3.62	5.94	2.62	3.08	4.65	5.83
Val	5.29	6.88	4.66	5.15	7.01	6.90

16% lower His than Met

Only 4% difference

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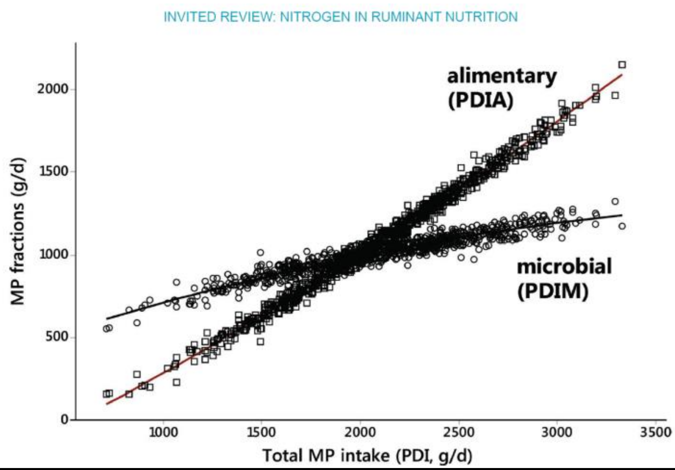
INRA data from Hristov et al., 2019

The relative contribution of microbial protein to the total MP supply is higher with low MP diets



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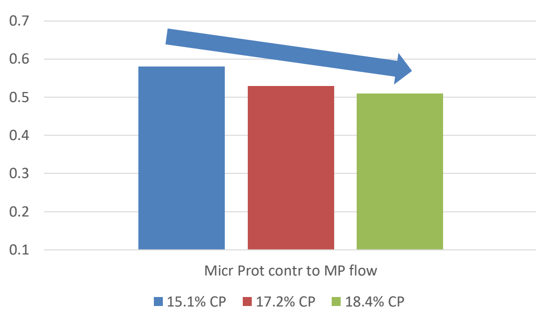
NASEM 2021 simulations

Mature, 700 kg BW Holstein cow, 100 DIM, 55 kg milk/d, 3.30% fat, 2.80% TP, 28 kg/d DMI

Diet CP, %	Proportion of microbial MP	Total mHis, g/d	mHis efficiency (target is 0.75)	N excretions, g/d
15.1	0.58	56	1.04	402
17.2	0.53	67	0.87	488
18.4	0.51	73	0.80	539



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J. Dairy Sci. 100:2784–2800
https://doi.org/10.3168/jds.2016-11992

Histidine deficiency has a negative effect on lactational performance of dairy cows

F. Giallongo,* M. T. Harper,* J. Oh,* C. Parys,† I. Shinzato,‡ and A. N. Hristov*[1]
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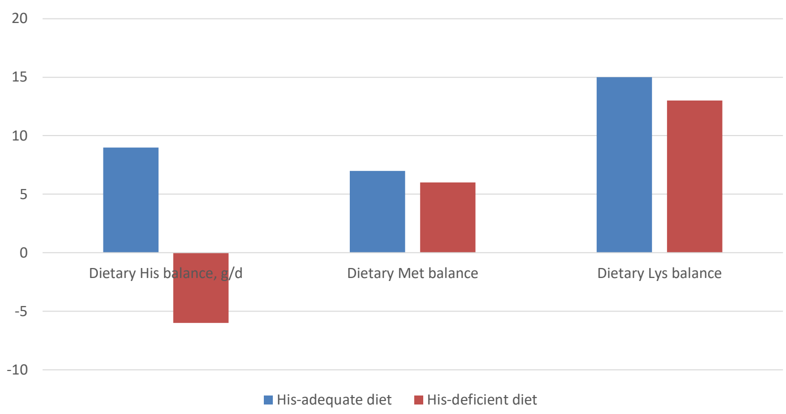

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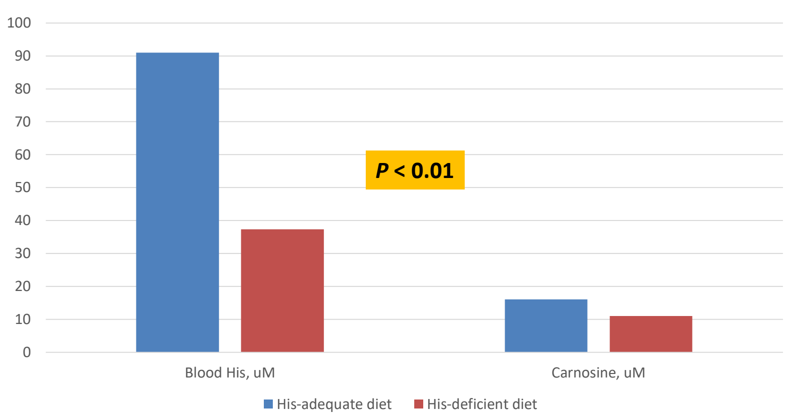

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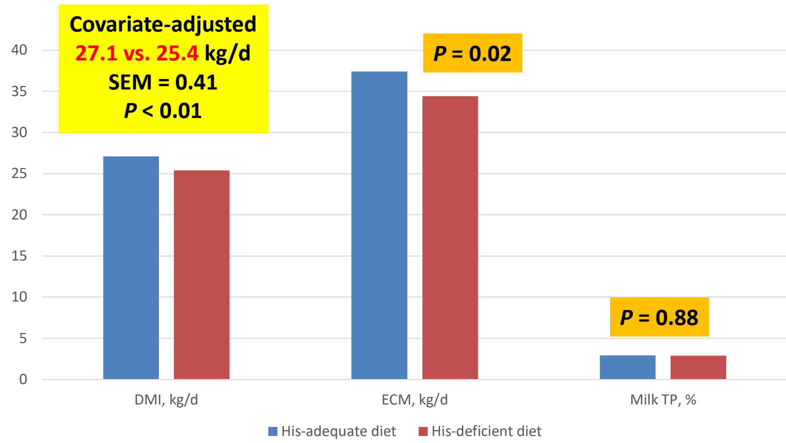

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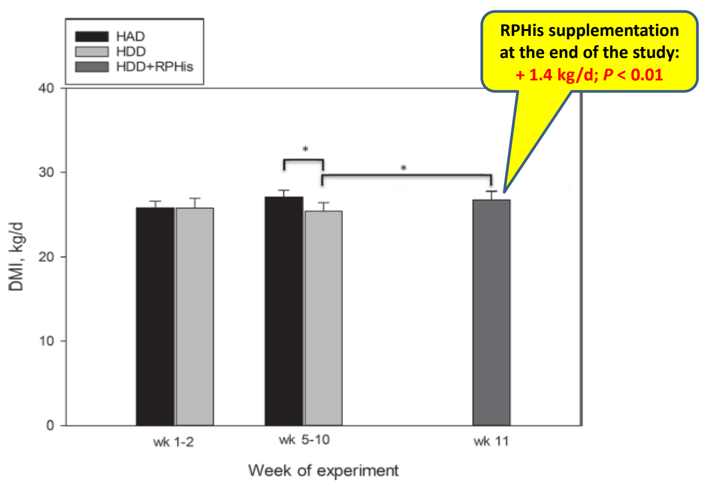

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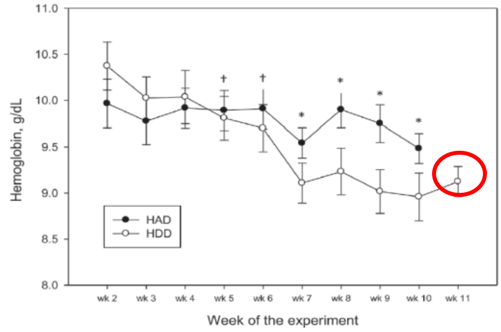
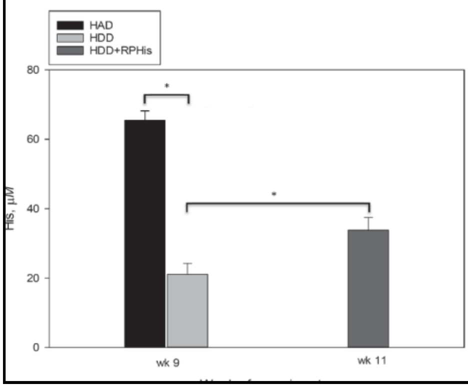
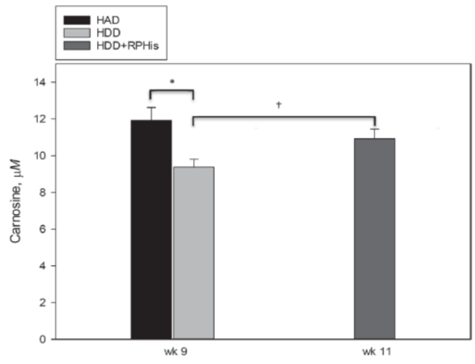
Giallongo et al., 2017

Blood hemoglobin, His, and carnosine as affected by His deficiency







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J. Dairy Sci. 104:9917–9930
https://doi.org/10.3168/jds.2021-20189

Histidine dose-response effects on lactational performance and plasma amino acid concentrations in lactating dairy cows: 2. Metabolizable protein-deficient diet

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[5]University of Chinese Academy of Sciences, Beijing 100049, P. R. China
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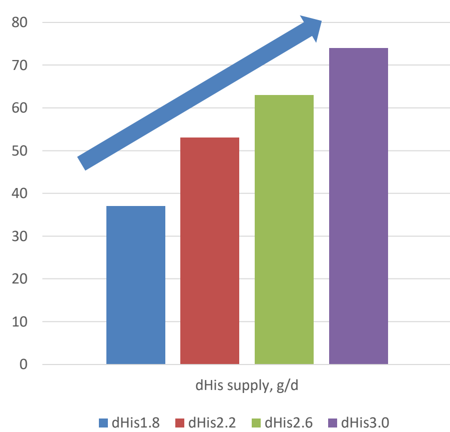
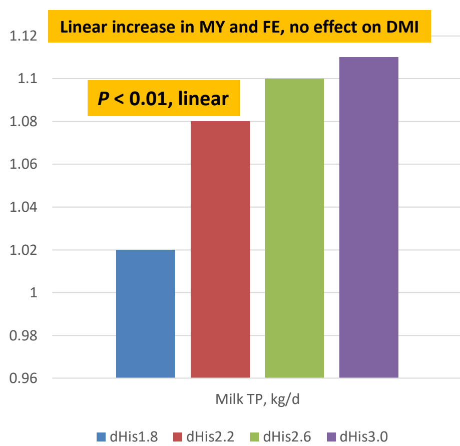
Lactational performance was optimized at dHis supply of 74 g/d (or 3.0% of MP)
No effect on MTP in the MPA diet trial





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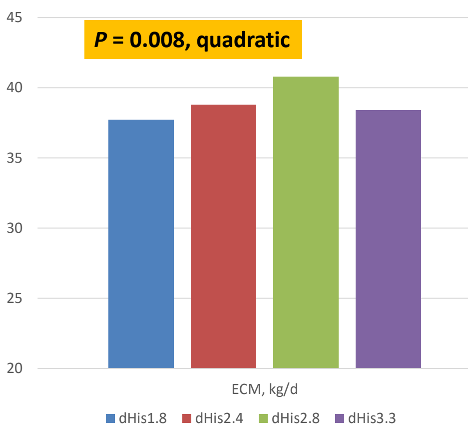
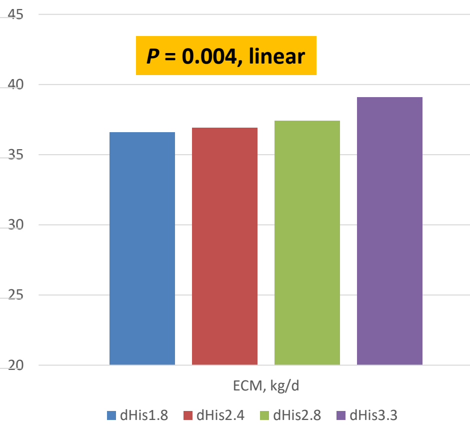
Räisänen et al., 2021; 2022

Dose-response studies with RPHis: ECM yield effect with MP-adequate and -deficient diet





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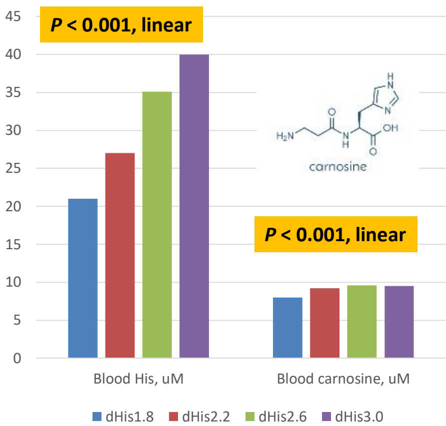
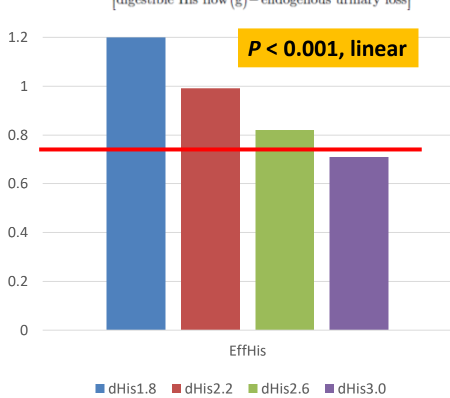


$$\mathrm{Eff}_{\mathrm{His}} = \frac{\text{sum of His in true exported proteins (g)}}{[\text{digestible His flow (g)} - \text{endogenous urinary loss}]},$$



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Histidine dose-response effects on lactational performance and plasma amino acid concentrations in lactating dairy cows: 1. Metabolizable protein-adequate diet

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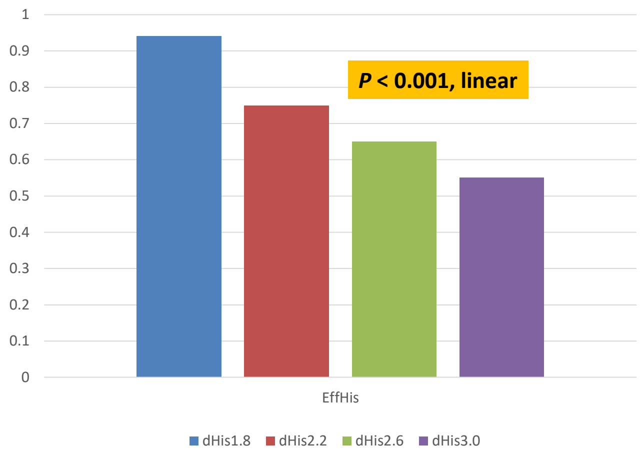
Similar trend as for the MP-deficient diets, but at considerably lower efficiency level



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Lactational performance effects of supplemental histidine in dairy cows: A meta-analysis

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Table 1. Characterization of publications used in the meta-analysis

Source	Design[1]	Method of His supplementation[2]	Basal diet	MP-level[3]	Other supplemental AA
Vanhatalo et al. (1999)	LS	Infusion	Grass silage	MPD	Lys, Met
Kim et al. (1999)	LS	Deletion	Grass silage	MPA	Lys, Met, Trp
Kim et al. (2000)	LS	Infusion	Grass silage	MPA	Lys, Met
Korhonen et al. (2000)	LS	Infusion	Grass silage	MPA	—
Kim et al. (2001)a[4]	LS	Infusion	Grass silage	MPA	—
Kim et al. (2001)b	LS	Infusion	Grass silage	MPA	Lys, Met, Trp
Huhtanen et al. (2002)a	LS	Infusion	Grass silage	MPD	Leu
Huhtanen et al. (2002)b	LS	Infusion	Grass silage	MPD	—
Hadrová et al. (2012)	LS	Deletion	Corn silage	MPD	Leu, Lys, Met
Lee et al. (2012)	RCB	RPHis	Corn silage	MPD	RPLys, RPMet[5]
Giallongo et al. (2015)	RCB	RPHis	Corn silage	MPD	RPLys, RPMet
Giallongo et al. (2016)	RCB	RPHis	Corn silage	MPA	RPLys, RPMet
Giallongo et al. (2017)	RCB	Basal diet[6]	Corn silage	MPA	RPLys, RPMet
Zang et al. (2019)	LS	RPHis	Corn silage	MPA	RPMet
Morris and Kononoff (2020)a	LS	RPHis	Corn silage	MPA	—
Morris and Kononoff (2020)b	LS	RPHis	Corn silage	MPA	RPLys
Lapierre et al. (2021)a	LS	Deletion	Corn silage	MPD	Free AA, casein profile
Lapierre et al. (2021)b	LS	Deletion	Corn silage	MPD	Free AA, casein profile
Räisänen et al. (2021a)	LS	RPHis	Corn silage	MPA	RPLys, RPMet
Räisänen et al. (2021b)	LS	RPHis	Corn silage	MPD	RPLys, RPMet
Räisänen et al. (2022)a	RCB	RPHis	Corn silage	MPA	RPLys, RPMet
Räisänen et al. (2022)b	RCB	RPHis	Corn silage	MPA	RPLys, RPMet

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Table 4. Effect size[1] and heterogeneity for the effect of His supplementation on lactational performance of dairy cows

		Effect size and 95% CI					Heterogeneity	
Item	N[2]	Random	SE	Lower limit	Upper limit	P-value	Q-value[3]	P-value
DMI, kg/d	22	0.241	0.097	0.050	0.432	0.01	21.4	0.44
Milk yield, kg/d	22	0.888	0.192	0.512	1.26	<0.001	69.4	<0.001
ECM yield,[4] kg/d	14	0.187	0.115	−0.039	0.413	0.11	8.78	0.85
Milk true protein, %	22	0.246	0.104	0.041	0.450	0.02	23.9	0.30
Milk true protein, kg/d	22	0.674	0.147	0.386	0.962	<0.001	42.8	0.003
Milk fat, %	22	−0.427	0.119	−0.660	−0.195	<0.001	29.7	0.10
Milk fat, kg/d	22	−0.009	0.096	−0.197	0.178	0.92	12.6	0.92
Milk lactose, %	20	0.004	0.121	−0.234	0.241	0.97	27.1	0.10
Milk lactose, kg/d	20	0.425	0.101	0.227	0.623	<0.001	43.7	0.001
Plasma His, mM	22	1.81	0.251	1.39	2.37	<0.001	92.3	<0.001

[1]Computed as standard mean difference = raw mean difference of treatment and control means divided by the pooled SD of the means; values of <0.2, 0.2 to 0.7, and >0.7, were considered small, moderate, or large, respectively.
[2]Number of studies.
[3]Chi-squared (Q) test for heterogeneity and variation among the study level.
[4]Six studies were excluded from the analysis due to lack of ECM data and respective SD in the publication.

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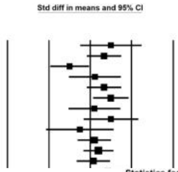
DMI

Study name	Statistics for each study						
	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Vanhatalo et al. (1999)	1.000	0.750	0.563	-0.470	2.470	1.333	0.182
Kim et al. (1999)	0.667	0.419	0.176	-0.155	1.489	1.589	0.112
Kim et al. (2000)	-1.000	0.474	0.225	-1.930	-0.070	-2.108	0.035
Korhonen et al. (2000)	0.222	0.634	0.402	-1.021	1.466	0.350	0.726
Kim et al. (2001)a	0.667	0.419	0.176	-0.155	1.489	1.589	0.112
Kim et al. (2001)b	1.000	0.433	0.188	0.151	1.849	2.309	0.021
Huhtanen et al. (2002)a	0.200	0.634	0.402	-1.043	1.443	0.315	0.752
Huhtanen et al. (2002)b	1.000	0.671	0.450	-0.315	2.315	1.491	0.136
Hadrova et al. (2012)	-0.500	0.829	0.688	-2.125	1.125	-0.603	0.546
Lee et al. (2012)	0.200	0.409	0.168	-0.602	1.002	0.489	0.625
Giallongo et al. (2015)	0.395	0.369	0.136	-0.327	1.118	1.072	0.284
Giallongo et al. (2016)	0.149	0.409	0.167	-0.652	0.950	0.364	0.716
Giallongo et al. (2017)	0.850	0.426	0.182	0.014	1.686		
Zang et al. (2019)	-0.200	0.501	0.251	-1.182	0.782		
Morris and Kononoff (2020)a	0.000	0.408	0.167	-0.800	0.800		
Morris and Kononoff (2020)b	0.172	0.409	0.167	-0.629	0.974		
Räisänen et al. (2021a)	-0.158	0.354	0.125	-0.852	0.536		
Lapierre et al. (2021)a	0.333	0.637	0.406	-0.915	1.582		
Lapierre et al. (2021)b	0.778	0.599	0.359	-0.396	1.951		
Räisänen et al. (2021b)	0.043	0.316	0.100	-0.576	0.663		
Räisänen et al. (2022)a	0.145	0.409	0.167	-0.656	0.946		
Räisänen et al. (2022)b	0.014	0.408	0.167	-0.786	0.815		
Pooled	0.241	0.097	0.009	0.050	0.432		

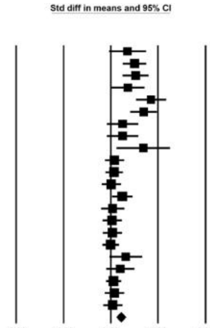
Std diff in means and 95% CI



Milk yield

Study name	Statistics for each study						
	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Vanhatalo et al. (1999)	1.400	0.789	0.623	-0.146	2.946	1.774	0.076
Kim et al. (1999)	2.000	0.500	0.250	1.020	2.980	4.000	0.000
Kim et al. (2000)	2.091	0.556	0.309	1.001	3.181	3.760	0.000
Korhonen et al. (2000)	1.444	0.710	0.504	0.053	2.836	2.034	0.042
Kim et al. (2001)a	3.400	0.638	0.408	2.149	4.651	5.326	0.000
Kim et al. (2001)b	2.778	0.572	0.327	1.656	3.899	4.855	0.000
Huhtanen et al. (2002)a	1.000	0.671	0.450	-0.315	2.315	1.491	0.136
Huhtanen et al. (2002)b	1.000	0.671	0.450	-0.315	2.315	1.491	0.136
Hadrova et al. (2012)	2.750	1.139	1.297	0.518	4.982	2.415	0.016
Lee et al. (2012)	0.314	0.411	0.169	-0.491	1.119	0.764	0.445
Giallongo et al. (2015)	0.275	0.367	0.135	-0.444	0.994	0.749	0.454
Giallongo et al. (2016)	0.034	0.408	0.167	-0.766	0.834	0.083	0.934
Giallongo et al. (2017)	0.967	0.431	0.186	0.121	1.812	2.241	0.025
Zang et al. (2019)	0.158	0.501	0.251	-0.824	1.139	0.315	0.753
Morris and Kononoff (2020)a	0.113	0.409	0.167	-0.688	0.913	0.276	0.783
Morris and Kononoff (2020)b	0.141	0.409	0.167	-0.660	0.942	0.345	0.730
Räisänen et al. (2021a)	-0.009	0.354	0.125	-0.702	0.684	-0.026	0.979
Lapierre et al. (2021)a	1.259	0.692	0.479	-0.098	2.616	1.819	0.069
Lapierre et al. (2021)b	0.805	0.600	0.360	-0.372	1.981	1.341	0.180
Räisänen et al. (2021b)	0.231	0.317	0.101	-0.391	0.853	0.727	0.467
Räisänen et al. (2022)a	0.309	0.411	0.169	-0.496	1.113	0.751	0.453
Räisänen et al. (2022)b	0.170	0.409	0.167	-0.631	0.972	0.416	0.677
Pooled	0.888	0.192	0.037	0.512	1.264	4.626	0.000

Std diff in means and 95% CI



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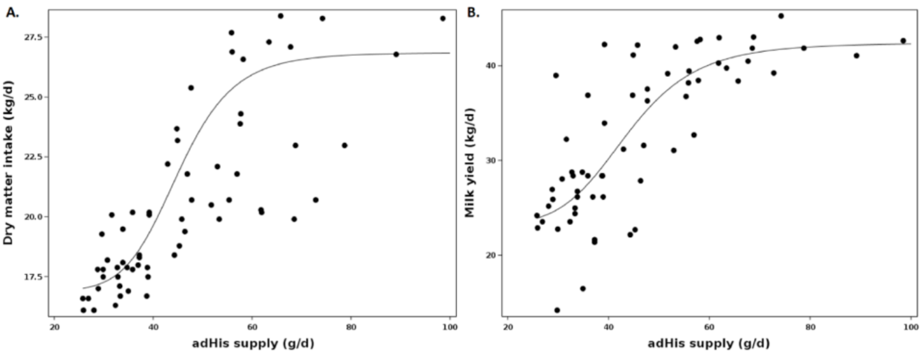
Räisänen et al.: HISTIDINE IN LACTATING DAIRY COWS 6227



Dry matter intake and milk yield across increasing adjusted digestible His (adHis) supply

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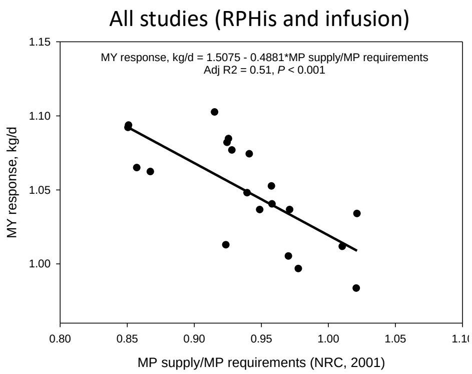
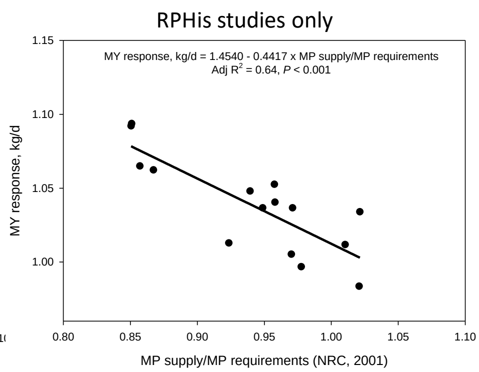
Räisänen et al., 2022

Responses to RPHis supplementation depend on MP supply





Production responses increase as MP deficiency increases

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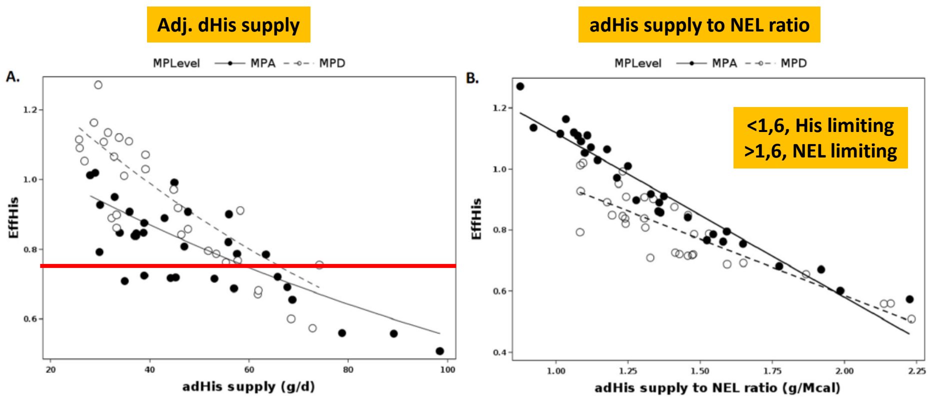

Figure 7. Efficiency of His utilization (Eff_{His}) observations by MP-level and across (A) increasing adjusted digestible His (adHis) supply or (B) ratio of adjusted digestible His (adHis) to NE_L supplies. Metabolizable protein requirements and supply were calculated based on NRC (2001); MP-deficiency (MPD) was defined as MP supplied at or below 95% of NRC (2001) requirements, and MP-adequacy (MPA) above 95% supply of requirements.

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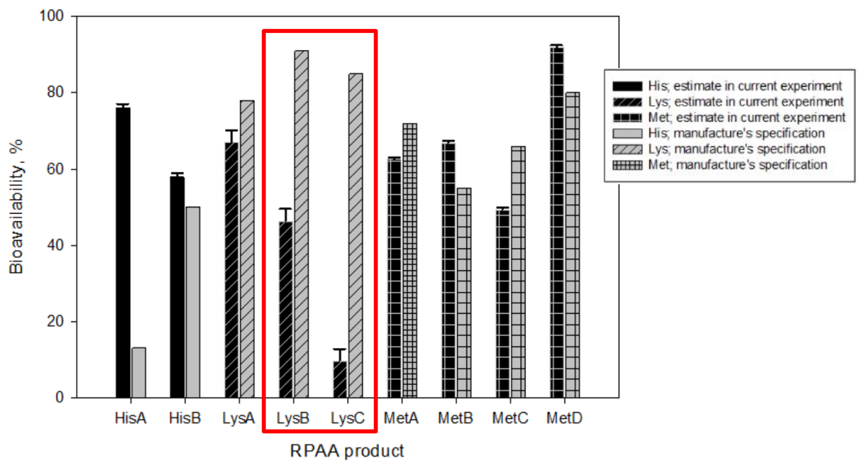
Räisänen et al., 2020

Be aware of incorrect bioavailability data of RPAA!



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Take-home message

- Dietary **protein intake is the most important factor determining nitrogen efficiency**, urinary nitrogen losses, and consequently, nitrate leaching and ammonia and nitrous oxide emissions from dairy cow manure
- Earlier and more recently studies with corn silage-based diets conducted at Penn State indicate that His may be a limiting AA in dairy cow **fed low-protein (< 16% CP) diets**
  - Long-term trials showed that **supplementation of such diets with rumen-protected His increased or tended to increase milk yield and milk protein percent and yield, partially through increasing DMI**
  - **Our data suggest dHis recommendations at around 3.0% of MP, or 70-74 g/d**
  - **Watch for false bioavailability data**
  - **Order and degree of AA limitation will likely depend on EAA profile of RUP**
- The effects of **low-protein, high-starch diets on enteric methane emission** and overall carbon footprint of milk needs to be further examined

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Protein Nutrition of Transition Cows and Amino Acid Balancing in Early Lactation

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ANIMAL SCIENCES

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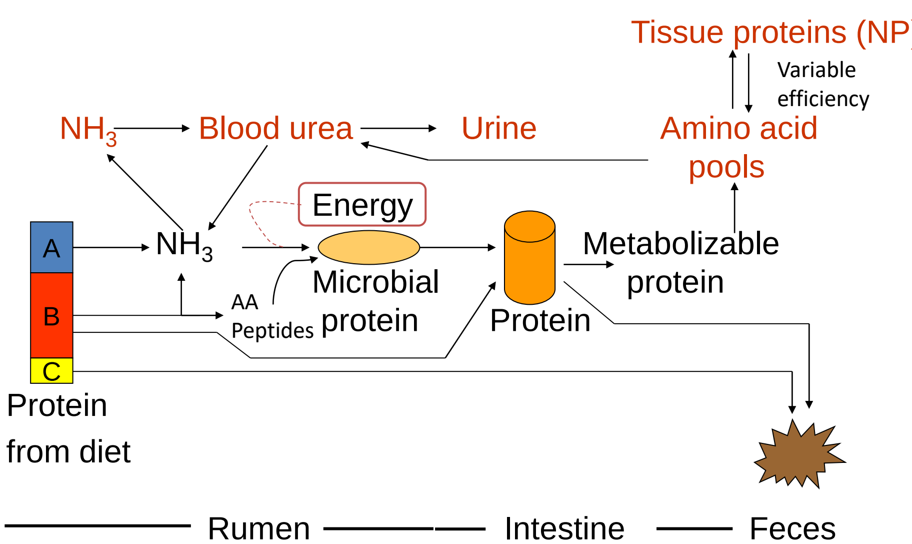
1

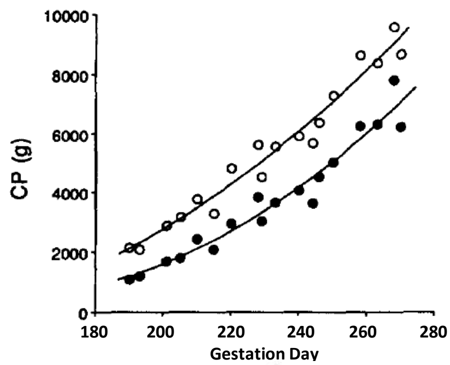
Metabolizable and Net Protein Models

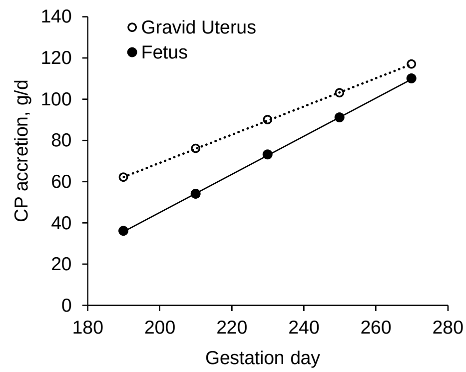


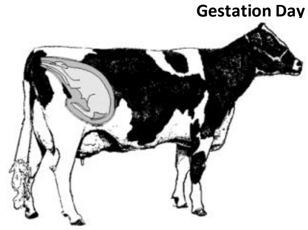
NP = net protein

2

Accretion of CP in Gravid Uterus of Pregnant Cows







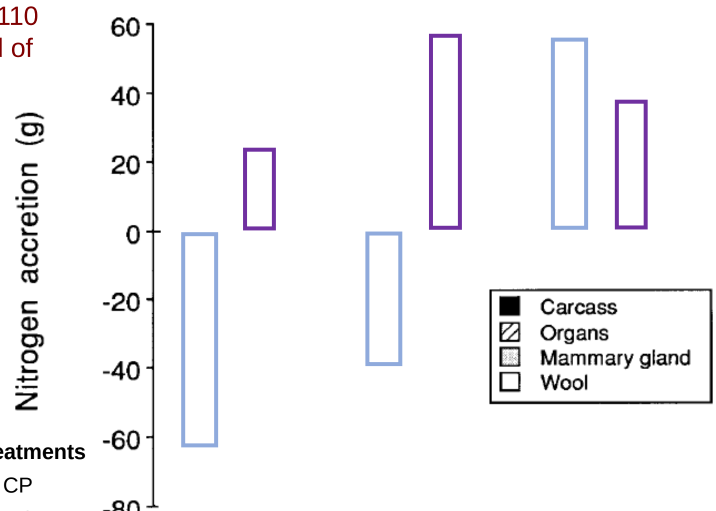
Bell et al. (1995) J. Dairy Sci. 78:1954-1961

3

Tissue N Accretion in Late pregnancy

Incorporation into mammary tissue

Between 110 and 140 d of gestation



Dietary treatments

LP = 7.9% CP

MP = 11.7% CP

HP = 15.9% CP

McNeil et al. (1997) J. Anim. Sci. 75:809-816

4

NASEM 2021

- ✓ 700 kg dry cow requires approximately 480-500 g/d of metabolizable protein for maintenance
  - ✓ Scurf loss
  - ✓ Endogenous urinary loss
  - ✓ Metabolic fecal loss
  - ✓ Frame growth → it is assumed that 86% of the live BW is empty BW, and 11% of the empty body weight is net protein
- ✓ MP for scurf (g/d) = [(0.20 x $BW^{0.60}$) x 0.85]/ 0.69
  - ✓ Where 0.85 is the ratio of true protein to CP in scurf and 0.69 is the efficiency of MP use for NP in tissues
- ✓ MP for endogenous urinary
  - ✓ MP (g/d) = 53 x 6.25 x BW x 0.001 (same as NP as efficiency is 1)
- ✓ MP for endogenous fecal
  - ✓ MP (g/d) = ([11.62 + (0.134 x NDF % DM)] x DMI x 0.73)/0.69
  - ✓ Where 11.62 is the intercept of the equation, 0.134 is the g of MFP per unit of NDF in each kg of DMI, and 0.73 is because 73% of MFP is considered to be true protein, and 0.69 is the efficiency of conversion of MP to NP
- ✓ MP for growth = (live BW gain x 0.85 x 0.11 x 0.86)/0.40
  - ✓ 0.85 is the empty BW relative to live BW; 0.11 represent 11% true protein in empty BW, 0.86 is the ratio of true protein to CP in tissues, and 0.40 is the efficiency of MP use into NP for growth
- ✓ If change in BW is not frame growth, but reserves, then the protein content of reserves is assumed to be 8%, and not 11%

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NASEM 2021

- ✓ Metabolizable protein needed for gravid uterus accretion
  - ✓ 125 g of net protein per kg of gravid uterus gain
  - ✓ 230 d of gestation = 190 g/d
  - ✓ 250 d of gestation = 260 g/d
  - ✓ 270 d of gestation = 360 g/d
- ✓ Efficiency of incorporation of MP into net protein (NP) in the gravid uterus is 33%
- ✓ At 250 days of gestation, the cow would need
  - ✓ 480 g of MP for maintenance
  - ✓ 260 g of MP for pregnancy
  - ✓ Total = 740 g/d of MP (410 g/d of NP)
  - ✓ Plus any additional MP for frame growth replenishment of body reserves
- ✓ At 270 days of gestation, the cow would need
  - ✓ 480 g of MP for maintenance
  - ✓ 381 g of MP for pregnancy
  - ✓ Total = 864 g/d of MP (535 g/d of NP)
  - ✓ Plus any additional MP for frame growth replenishment of body reserves

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NASEM 2021

- ✓ Estimated requirements for metabolizable protein as cows approach calving
  - ✓ 870 g/d to meet maintenance and gravid uterus accretion
- ✓ Estimated additional 120 g/d of metabolizable protein for mammary accretion in nulliparous cows (Capuco et al. JDS 1997; McNeil et al. JAS 1997)
  - ✓ Nulliparous are still growing and have requirements for lean tissue accretion
  - ✓ Late pregnant nulliparous cows might need 1,000 to 1,100 g/d of MP

7

Factorial Protein Needs of a Prepartum Cow

Cow: 50-mo old Holstein, 270 d of gestation, 720 kg BW, 0.1 kg/d frame growth, eating 12.5 kg of DM with 44% NDF

Heifer: 22-mo old Holstein, 270 d of gestation, 620 kg BW, 0.8 kg/d frame growth, eating 11.0 kg of DM with 44% NDF

	Net protein		Metabolizable protein	
Item	Heifer	Cow	Heifer	Cow
Scurf, g/d	8	9	12	13
Endogenous urinary, g/d	205	240	205	240
Metabolic fecal, g/d	138	158	200	230
Frame growth, g/d	77	8	112	12
Body reserves	0	0	0	0
Pregnancy	119	126	360	381
Total	**547**	**541**	**890**	**876**

Very likely there are needs for mammary tissue accretion, particularly in nulliparous
Estimated at 120 g of MP or 89 g of NP/d (Capuco et al. JDS 1997; McNeil et al. JAS 1997)

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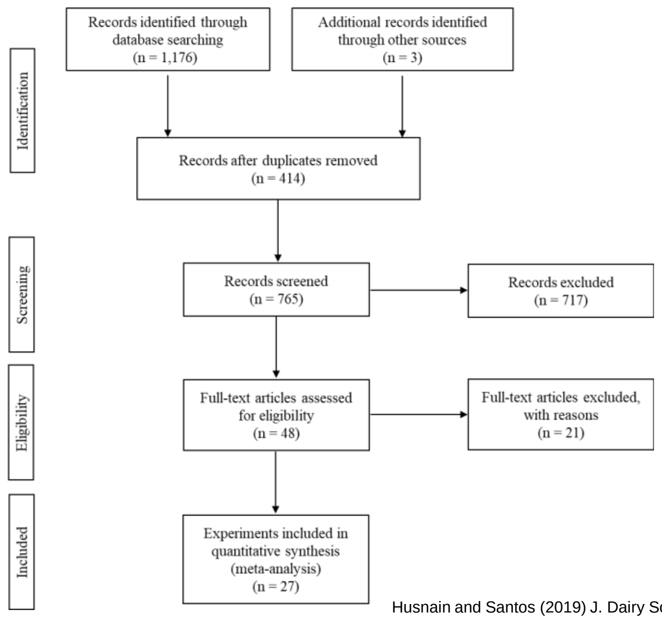
Prisma Diagram



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Meta-Analysis of Published Literature

✓27 randomized experiments

- 125 treatment means and 1,801 cows
- 8 experiments with 27 treatment means reported responses for 510 nulliparous cows

✓Diets entered into the NRC (20021) software using the ingredient composition and nutrient content, and observed prepartum intake for the specific cows

- ✓Net energy for lactation (Mcal/kg)
- ✓Metabolizable protein (g/d)
- ✓Metabolizable amino acids (g/d)
  - ✓ Essential AA
  - ✓ Methionine
  - ✓ Lysine

Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Descriptive Statistics of Protein Inputs

Item	TRT Means, n	Mean	SD	Median	Min	Max
NE_L, Mcal/kg	114	1.59	0.10	1.62	1.25	1.73
CP, %	114	14.3	2.1	14.4	9.0	20.9
RDP, % DM	114	9.6	1.2	9.5	5.5	12.2
RUP, % DM	114	4.7	1.4	4.6	2.7	9.0
CP intake, g/d	114	1,681	407	1,648	745	2,482
Metabolizable, g/d						
Total MP	114	1,100	290	1,091	463	1,733
Microbial CP	114	603	119	601	257	876
RUP	114	446	190	425	159	937
Met	114	22	6	21	9	40
Lys	114	76	18	75	31	120
Total EAA	114	505	125	505	211	766

Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Descriptive statistics of production responses according to parity group

	Nulliparous		Parous	
Item	TRT Means, n	Mean ± SD	TRT Means, n	Mean ± SD
Prepartum				
DMI, kg/d	12	10.1 ± 0.8	76	12.4 ± 2.2
BW, kg	12	606 ± 25	66	700 ± 50
Postpartum				
DMI, kg/d	6	17.0 ± 1.6	70	20.7 ± 2.7
Yield, kg/d				
Milk	25	31.6 ± 3.2	89	38.5 ± 4.6
FCM	25	32.0 ± 3.5	89	40.5 ± 4.6
Milk fat				
%	25	3.65 ± 0.23	89	3.88 ± 0.38
kg/d	25	1.14 ± 0.12	89	1.48 ± 0.18
Milk protein				
%	25	3.21 ± 0.11	87	3.07 ± 0.17
kg/d	25	1.01 ± 0.11	87	1.18 ± 0.12
BW, kg	8	542 ± 26	82	622 ± 31

Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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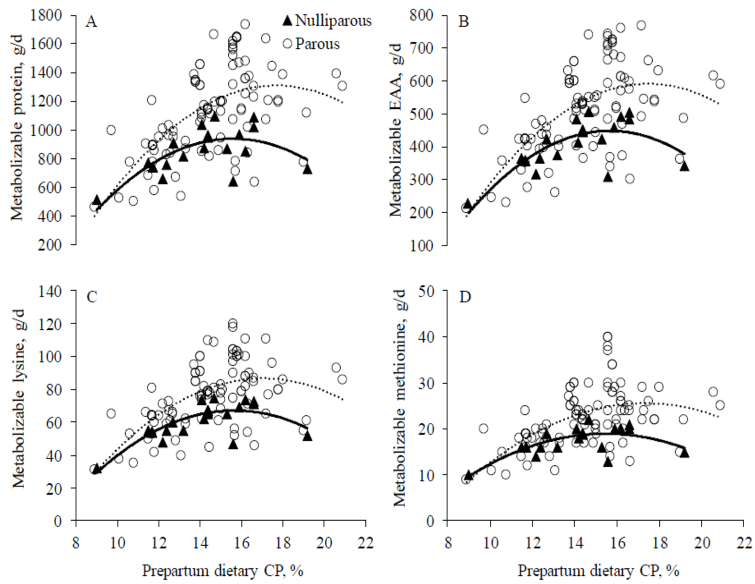
Predicted Supply of Metabolizable Amino Acids According to Prepartum Dietary CP



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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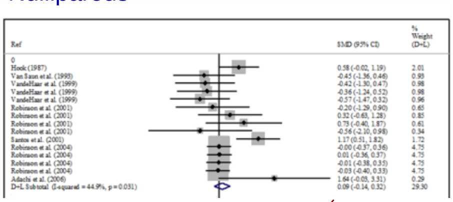
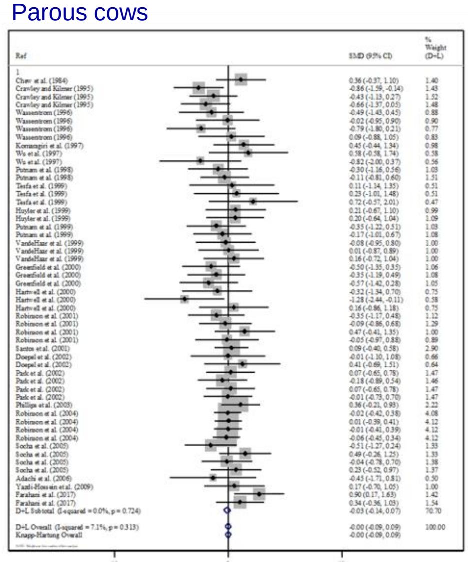
Milk Yield Responses to Increasing Metabolizable Protein Prepartum

Nulliparous



0.09 SD
P = 0.03

Parous cows



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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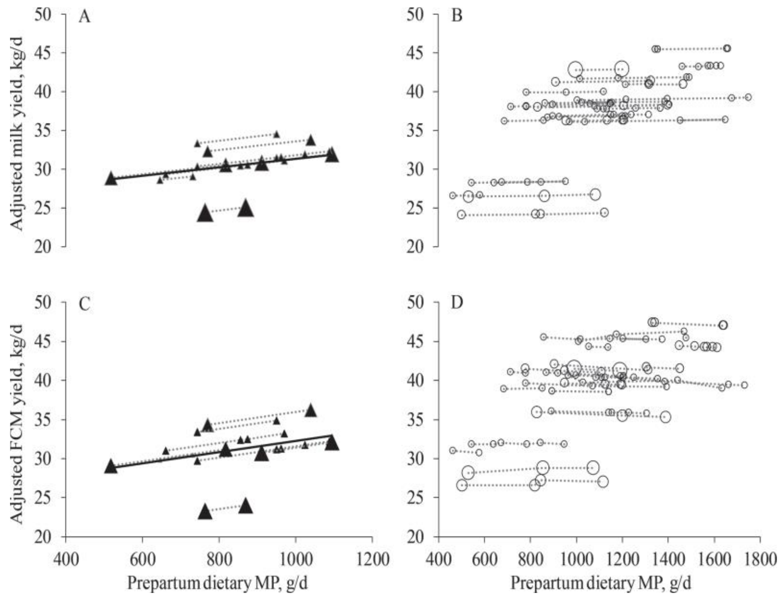
Yields of Milk and FCM



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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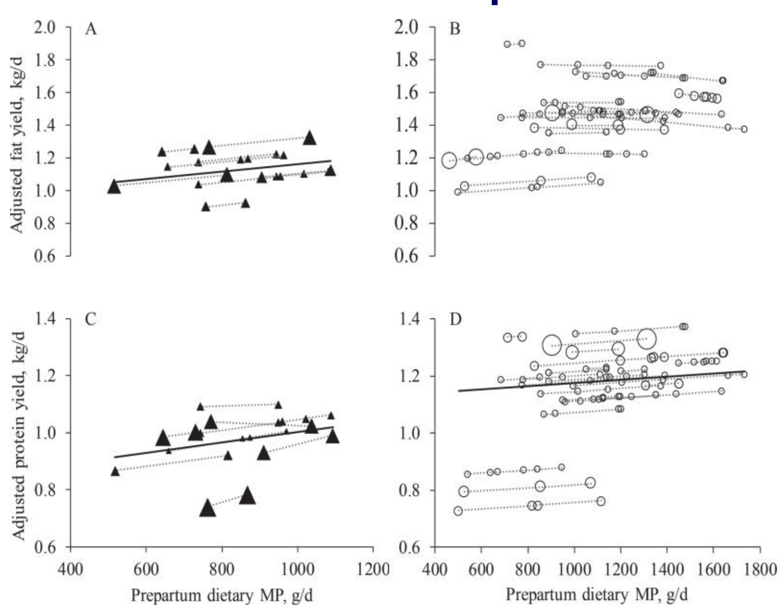
Yields of Milk Components



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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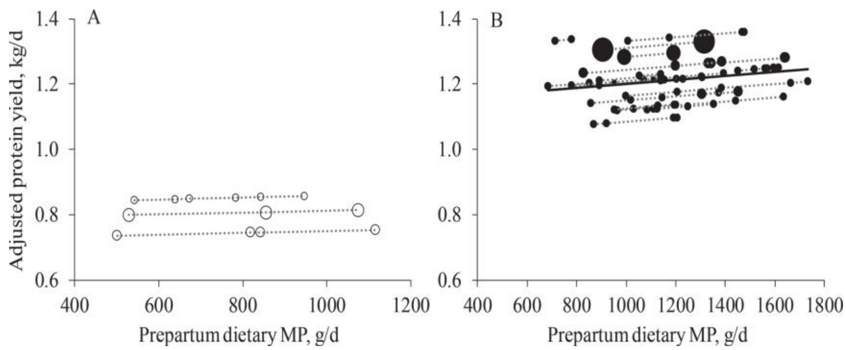
Yields of Milk Components



Husnain and Santos (2019) J. Dairy Sci. 102:9791–9813

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Conclusion and Implications

- ✓Formulate diets based on supply of metabolizable protein
  - ✓Parous cows: 800 to 900 g/d seems sufficient to meet the needs and to support postpartum performance (12 to 13% CP is sufficient is adequate intake of DM is achieved)
  - ✓Nulliparous require more than parous cows. At this point, approximately 1,100 g/day (14 to 15% CP is needed, with added undegraded protein source)
- ✓If housed together, feed for the nulliparous cows
- ✓Limited to no data today in the literature to support health effects of manipulating prepartum dietary protein content

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Issues Start Before or Around Calving

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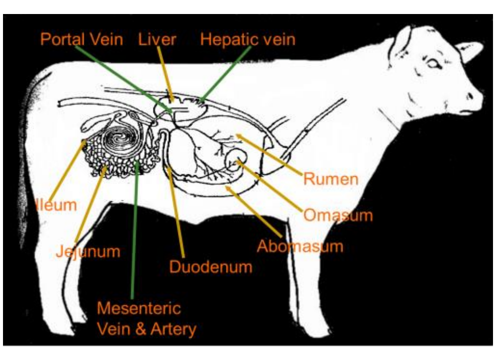
Inflammatory Disease and Nutrient Flux

- ✓ Control
  - ✓ Steers received saline (no inflammation)
- ✓ Challenge
  - ✓ Intra-tracheal challenge with 10 mL containing 1 x 10^9 CFU of *Mannheimia haemolytica* at hour 0



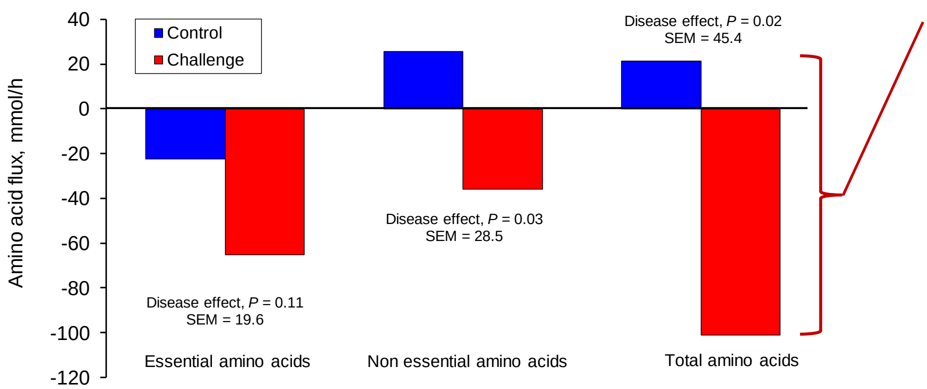
Burciaga-Robles et al. (2009)

20

Amino Acid Hepatic Flux in Steers Without (Control) or with (Challenge) an Intratracheal Challenge with *M. haemolytica*

At 0.69 efficiency, this is equivalent to the true protein in 8 kg of milk (18 lbs)

Difference of 2.6 moles/day → ~ 380 g of AA for a 400 kg steer



Burciaga-Robles PhD Dissertation (2009)

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Protein in Early Lactation

Ingredients	Control	High MP	High MP + AA
	Treatment		
Corn silage	40.0	40.0	40.0
Alfalfa silage + alfalfa hay	17.0	17.0	17.0
Whole cottonseed	9.0	9.0	9.0
Ground corn	15.7	14.0	15.7
Soybean hulls	4.4	1.9	4.4
Soybean meal (48%)	9.0	7.1	8.7
Heat-treated SBM (AminoPlus)	2.0	7.0	---
Corn gluten meal (60%)	---	1.6	---
Blood meal + AA	---	---	2.3
Fat + Minerals and Vitamins	3.0	2.8	2.8
Nutrients			
Crude protein, %	16.3	18.4	17.4
Rumen degradable protein, %	10.7	11.3	10.2
Methionine, % MP	1.85	1.83	2.60
Lysine, % MP	6.68	6.33	7.20
Histidine, % MP	2.25	2.21	2.90

N = 56 cows

Calder and Weiss (2017) J. Dairy Sci. 100:4528–4538

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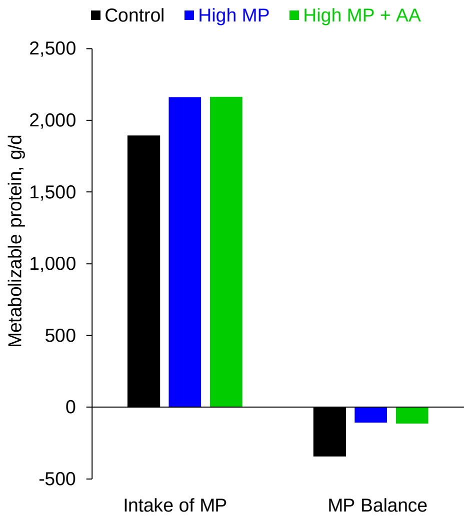
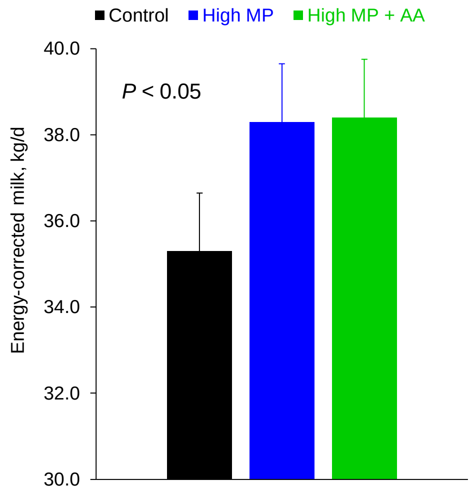
Responses in the First 3 Weeks of Lactation





Calder and Weiss (2017) J. Dairy Sci. 100:4528–4538

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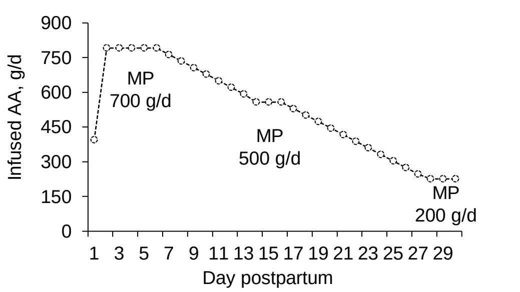
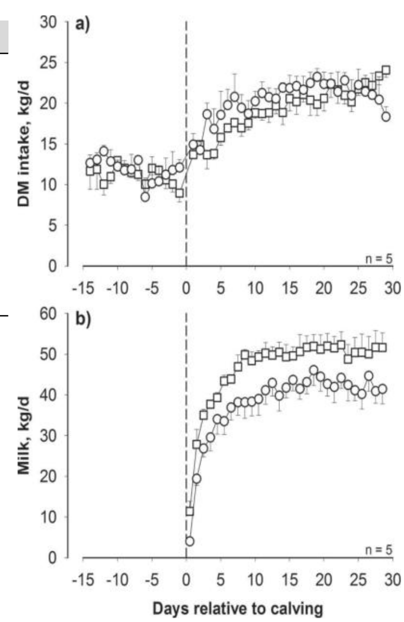
Protein in Early Lactation

Item	Prepartum	Postpartum
NE_L, Mcal/d	17.5	34.0
Crude protein, % DM	14.2	16.4
NDF, % DM	39.5	36.1
ADF, % DM	27.0	23.2
Metabolizable protein, g/d	1153	2365
Microbes	585	1157
Undegraded	511	1108
Endogenous	57	100

Treatment: ± infusion of free AA with similar profile to that of casein (88% metabolizable)





Larsen et al. (2015) J. Dairy Sci. 98:7944–7961

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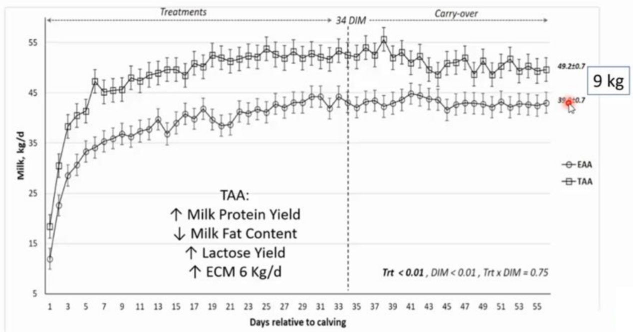
Effect of Abomasal Infusion of EAA or TAA on Production in Early Lactation Cows

Bahloul et al., 2021

- 9 Holstein Cows, Calving to 50 DIM
- 2 Trts: TAA or EAA, Casein AA Profile
- Abomasal infusions



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Synthesis of Milk and Milk Protein are Energy-Driven Processes

Table 1. Least squares means for DMI, milk yield, and milk protein concentration and yield.

Variable	Water	CB	Water+I	CB+I	SEM	P[2] INS
	Treatment[1]					
DMI,[3] kg/d	26.2	27.6	25.1	25.2	1.2	0.09
Milk yield, kg/d	26.5^{b}	27.5^{b}	28.3^{ab}	29.8^{a}	2.4	0.02
Milk protein						
%	3.29^{b}	3.31^{b}	3.52^{a}	3.66^{a}	0.185	0.001
kg/d	0.867^{c}	0.895^{c}	0.995^{b}	1.080^{a}	0.073	0.001

^{a,b,c}Least squares means within rows with different superscripts differ ($P < 0.05$).

Treatments (abomasal infusions)

Water = water

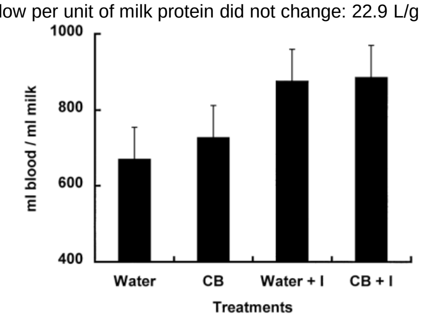
CB = casein and branched chain AA

Water + hyperinsulinemic/euglycemic clamp

CB+I = CB + hyperinsulinemic/euglycemic clamp

Insulin affected absolute MBF: 5.8 vs. 8.2 L/min

Blood flow per unit of milk protein did not change: 22.9 L/g



Mackle et al. (2000) J. Dairy Sci. 83:93–105

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Table 19.3. Relative net fluxes of amino acids across the mesenteric-drained viscera (MDV), the portal-drained viscera (PDV) and small intestinal disappearance (SID) in sheep and dairy cows.

Amino acid	Sheep[a]		Dairy cow[b]	
	MDV:SID	PDV:MDV	MDV:SID	PDV:MDV
Histidine	–	–	1.27	0.75
Isoleucine	1.11	0.55	1.02	0.61
Leucine	1.02	0.64	0.92	0.68
Lysine	1.03	0.56	0.76	0.72
Methionine	–	–	1.01	0.66
Phenylalanine	1.12	0.68	1.00	0.76
Threonine	0.85	0.69	1.15	0.38
Valine	0.76	0.57	1.11	0.46

[a]From MacRae *et al.* (1997b).
[b]From Berthiaume *et al.* (2001).

Bequette et al. (2003) https://doi.org/10.1079/9780851996547.0347

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Hepatic Removal of Amino Acids in Dairy Cows

Table 19.4. Proportion of net portal absorption of amino acids removed by the liver in non-lactating and lactating dairy cows.

Amino acid	Non-lactating cows[a]	Lactating cow[b]
Histidine	0.57	0.28
Isoleucine	0.41	n.r.[c]
Leucine	0.01	n.r.[c]
Lysine	0.16	0.06[d]
Methionine	0.70	0.43
Phenylalanine	0.67	0.50
Threonine	0.72	0.11
Valine	0.12	n.r.[c]

[a]From Wray-Cahen *et al.* (1997), basal periods.
[b]From Blouin *et al.* (2002) and Berthiaume (2000).
[c]Net removal by the liver zero.
[d]Data only from Blouin *et al.* (2002).

Bequette et al. (2003) Mammary uptake and metabolism of amino acids by lactating ruminants

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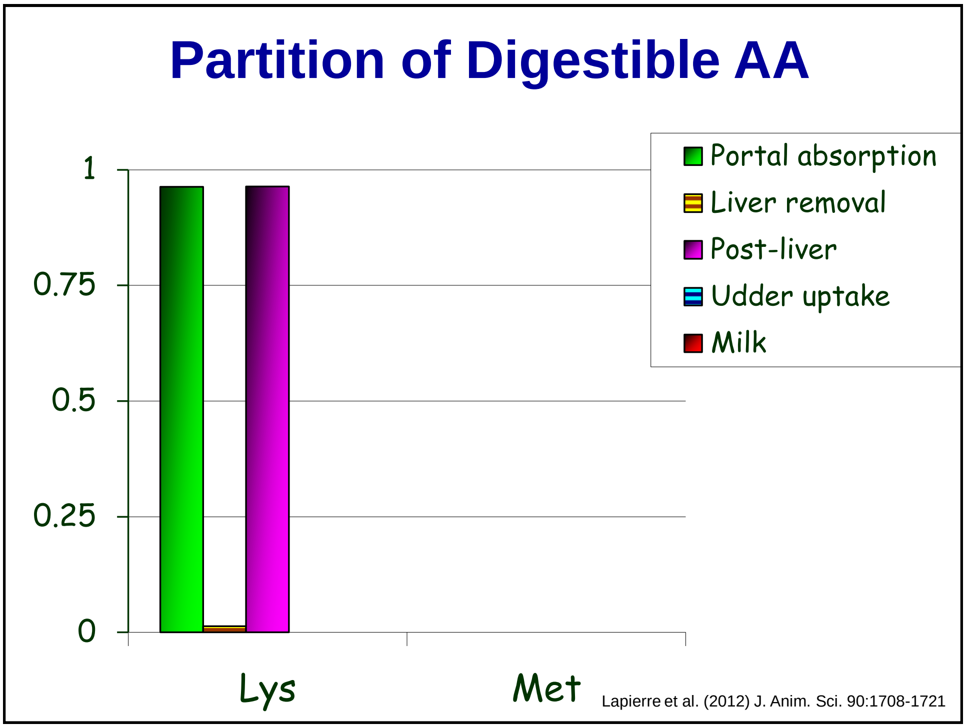
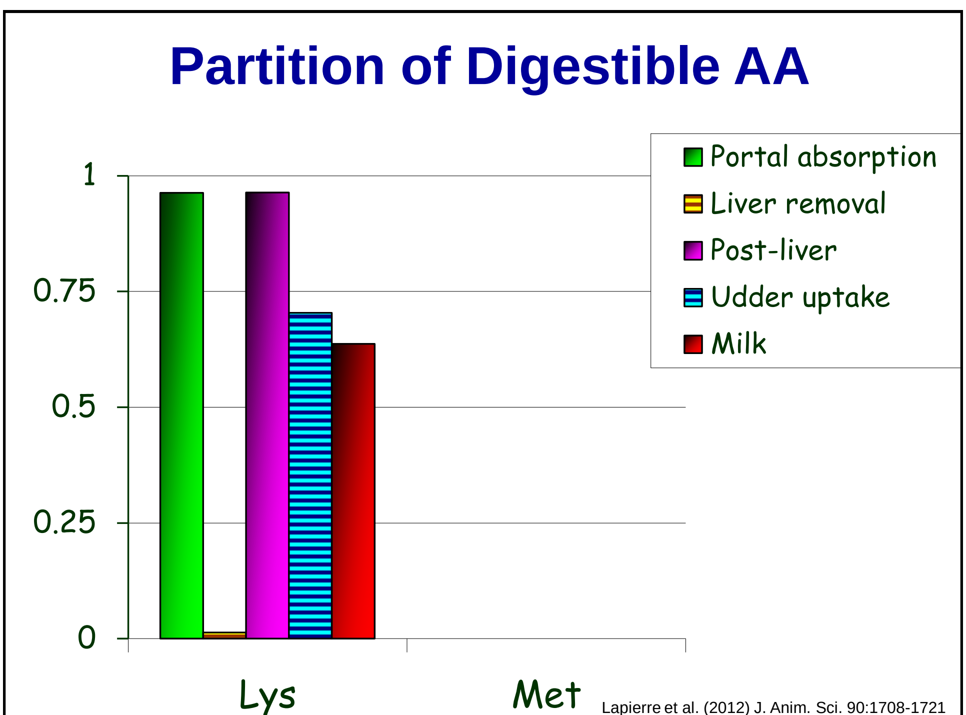

Partition of Digestible AA
1
0.75
0.5
0.25
0
Lys
Met
Portal absorption
Liver removal
Post-liver
Udder uptake
Milk
Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

29


Partition of Digestible AA
1
0.75
0.5
0.25
0
Lys
Met
Portal absorption
Liver removal
Post-liver
Udder uptake
Milk
Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

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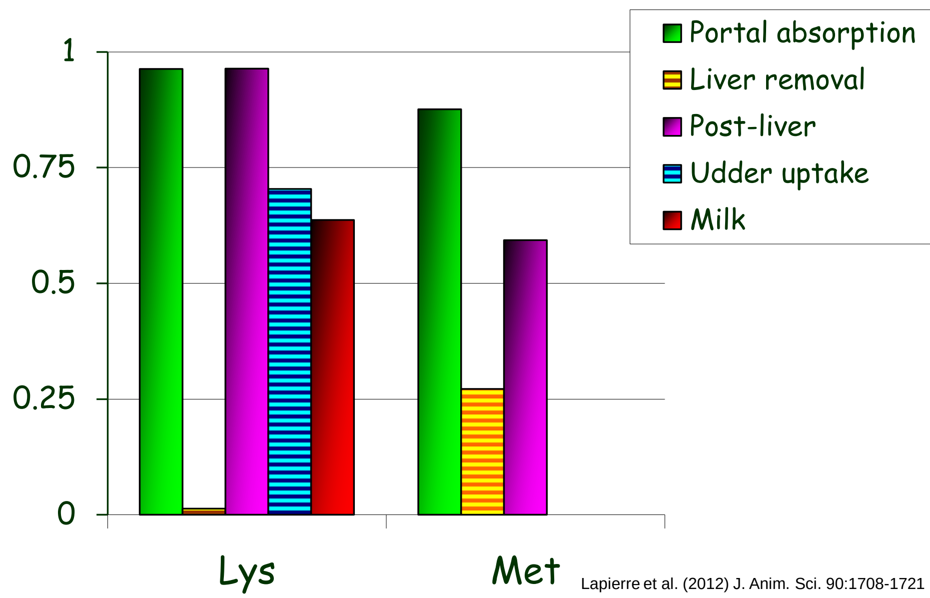
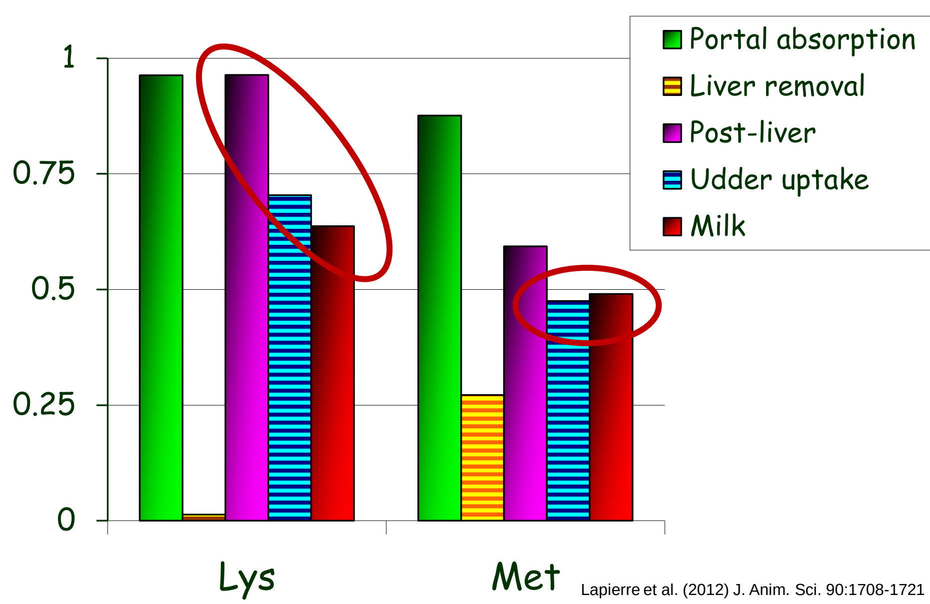
Partition of Digestible AA



Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

31

Partition of Digestible AA



Lapierre et al. (2012) J. Anim. Sci. 90:1708-1721

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Efficiency of Incorporation of Mammary Extracted AA into Milk AA

	Amino acid group (Mepham, 1982)		
	1	2	3
	Histidine	Isoleucine	Alanine
	Phenylalanine	Leucine	Asparagine
	Methionine	Valine	Cysteine
	Tyrosine	Lysine	Glutamine
	Tryptophan	Arginine*	Glycine
		Threonine*	Proline
			Serine
Efficiency (AA-N uptake/ AA-N secreted in milk)	1	> 1.15	< 1.0

* Suggested group according to Lapierre et al. (2012)

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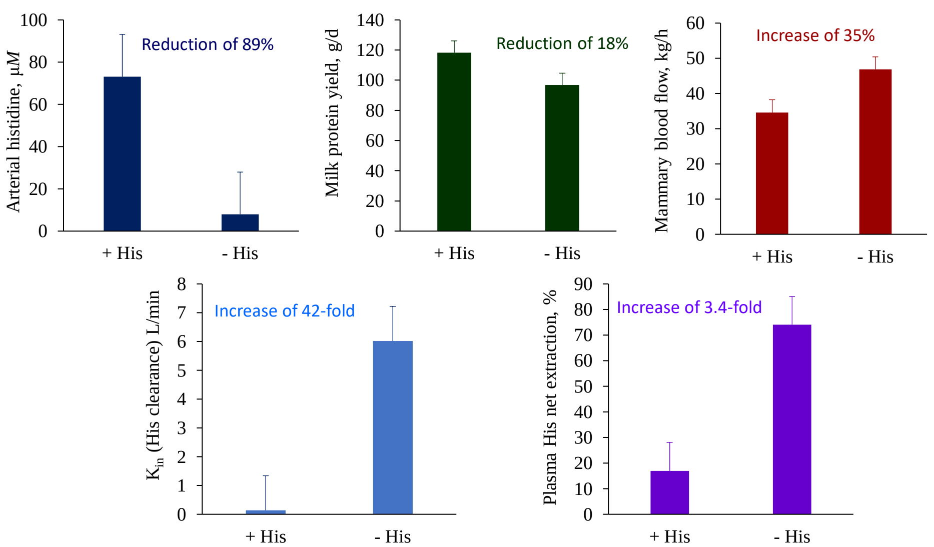
Mammary Gland is Metabolically Flexible



Lactating goats fed a low protein diet (77% of MP needed) and infused abomasally with a mixture of AA (67 g/d) with (+His) or without (-His) 4.4 g/d of histidine

Bequette et al. (2000) J Dairy Sci 83:765–775

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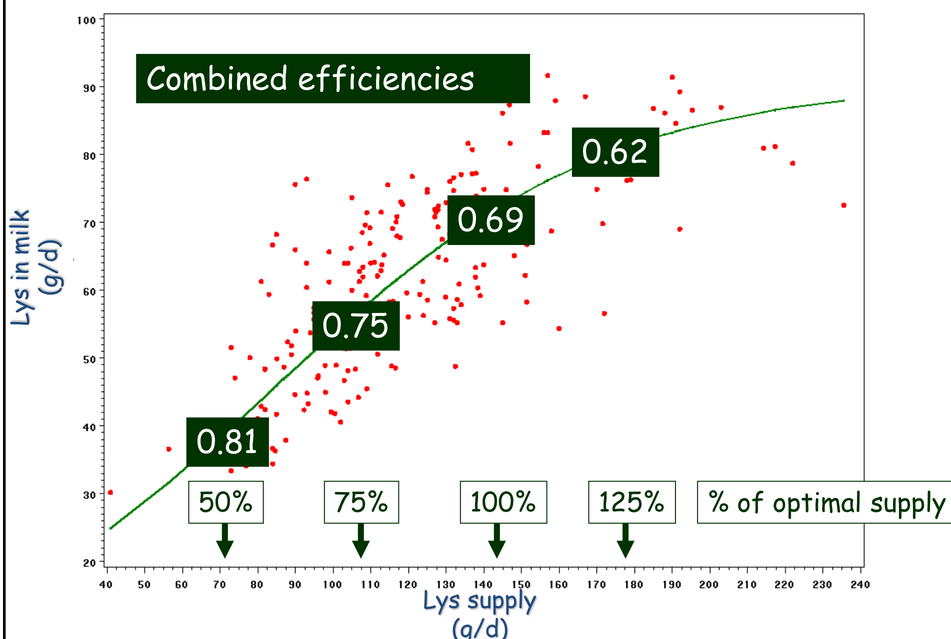

Lapierre et al. (2007) Proc. Cornell Nutr. Conf. Pages 39-59

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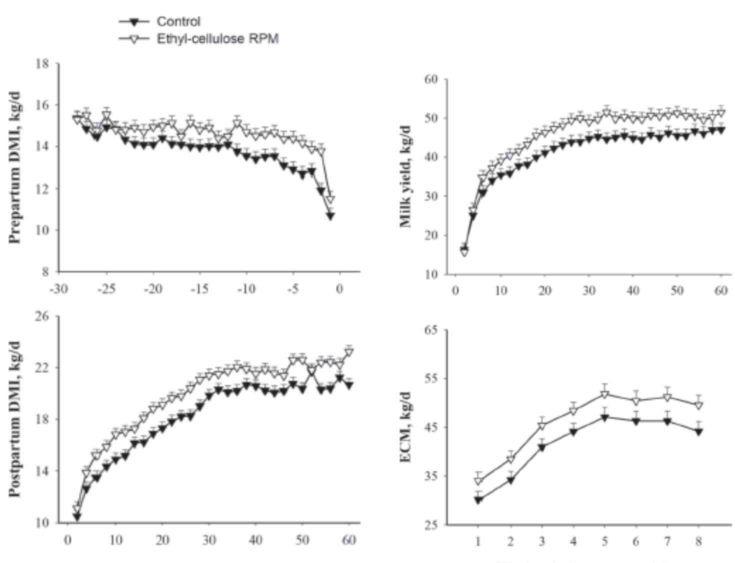
Effect of RP-Met supplementation during the prepartum and early lactation period on Intake and milk yield



Batistel et al. (2017) J. Dairy Sci. 100:7455-7487

36

Colostrum Yield

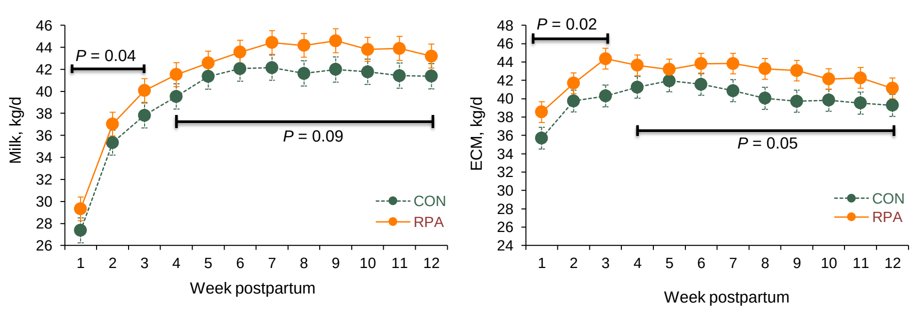
	Treatment							
	CON		RPA			*P*-value		
Item	Null	Parous	Null	Parous	SEM	TRT	Parity	TRT x parity
Yield, kg	5.38	5.16	8.52	7.19	1.23	0.02	0.51	0.69
Fat, kg	0.405	0.256	0.677	0.401	0.07	< 0.001	0.001	0.26
True protein, kg	1.01	1.03	1.33	1.25	0.16	0.03	0.82	0.67
Lactose, kg	0.200	0.184	0.238	0.244	0.03	0.05	0.86	0.68
Total solids, kg	1.71	1.58	2.39	2.02	0.26	0.01	0.29	0.58

[a,b,c] Distinct superscripts in the same row denote differences among LSM ($P < 0.05$)

Simões et al. (2023) J. Dairy Sci. 106 (Abstr.)

37

Yields of Milk and Energy-Corrected Milk



Simões et al. (2023) J. Dairy Sci. 106 (Abstr.)

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Protein in Early Lactation

- ✓ Early lactation
  - ✓ Feed diets with 17 to 18% CP to result in ~11.5 to 12% MP
  - ✓ 11% of the diet DM should be degraded protein
  - ✓ 6 to 7% of the diet DM should be undegraded protein
- ✓ Prioritize high quality rumen undegraded protein sources that complement microbial protein
  - ✓ Blood meal of high intestinal digestibility
  - ✓ Heat-treated soybean meal or canola meal
- ✓ RP Methionine and Lysine should be incorporated into early lactation diets
  - ✓ 2.50% of MP (1.14-1.19 g/Mcal of ME) as methionine and 7.50% of MP (3.03 g/Mcal of ME) as lysine
  - ✓ ~5.5% of EAA as methionine and ~15.0% of EAA as lysine
- ✓ Remember, improving protein supply will stimulate milk synthesis, which will likely increase body fat mobilization in the first 2 to 4 weeks of lactation

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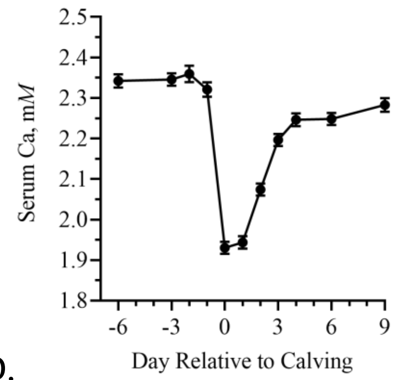
Prevention of Hypocalcemia and Associations with Health and Production

Florida Ruminant Nutrition Symposium
February 27, 2024



Corwin D. Nelson, Ph. D.
Associate Professor of Physiology
Department of Animal Sciences
University of Florida, Gainesville, FL, USA

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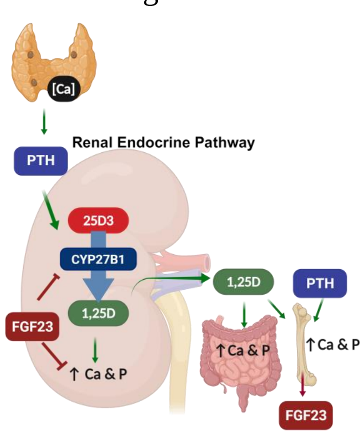
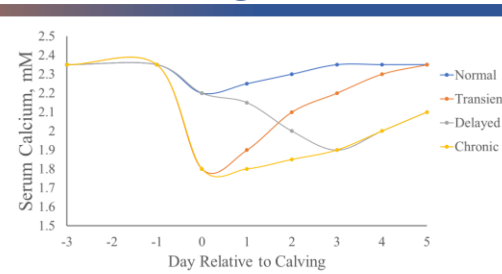
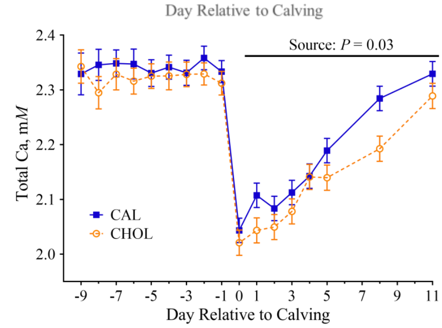
1

Additional Strategies to Control Post-Calving Calcium

1. Endocrine control of Ca and P
2. Dynamics of periparturient Ca
3. Effective control strategies







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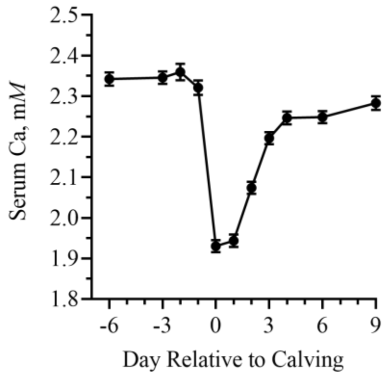
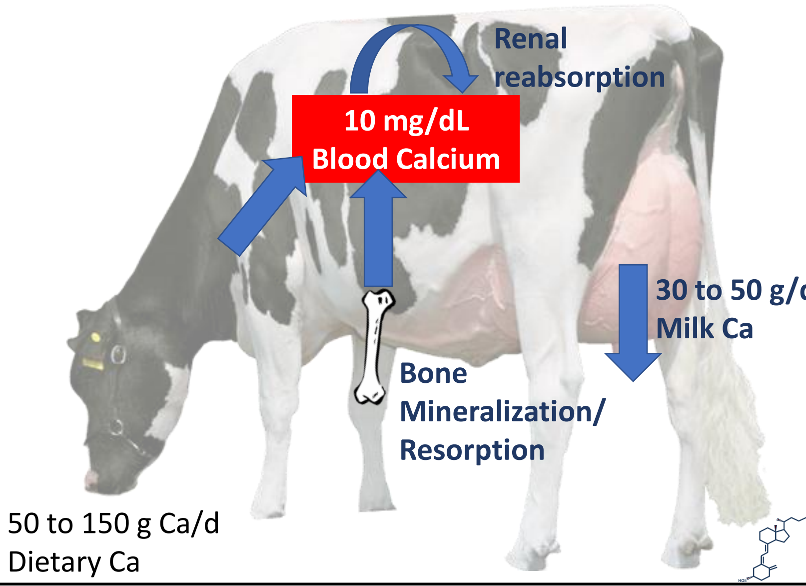
2

Calcium Economy at the Onset of Lactation





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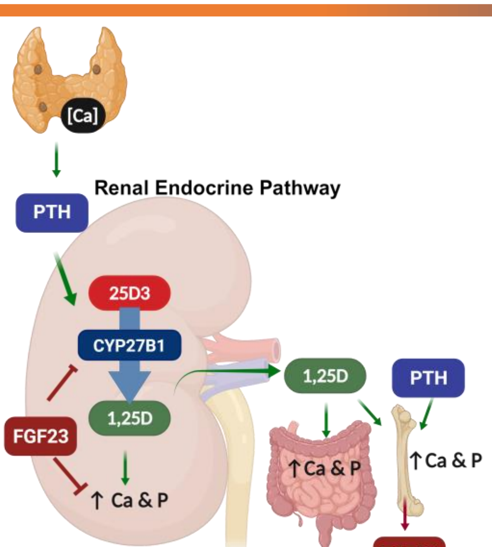
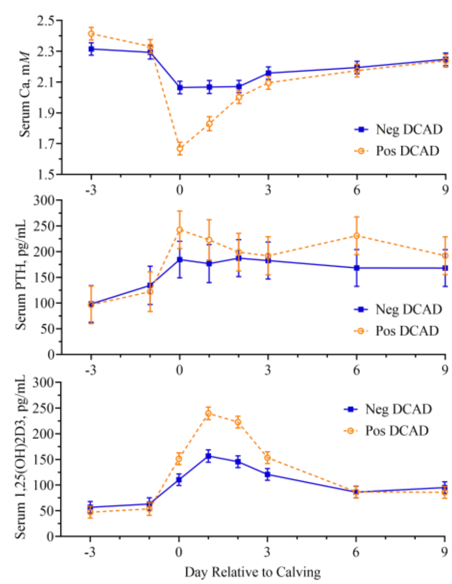
3

Hormonal Control of Calcium





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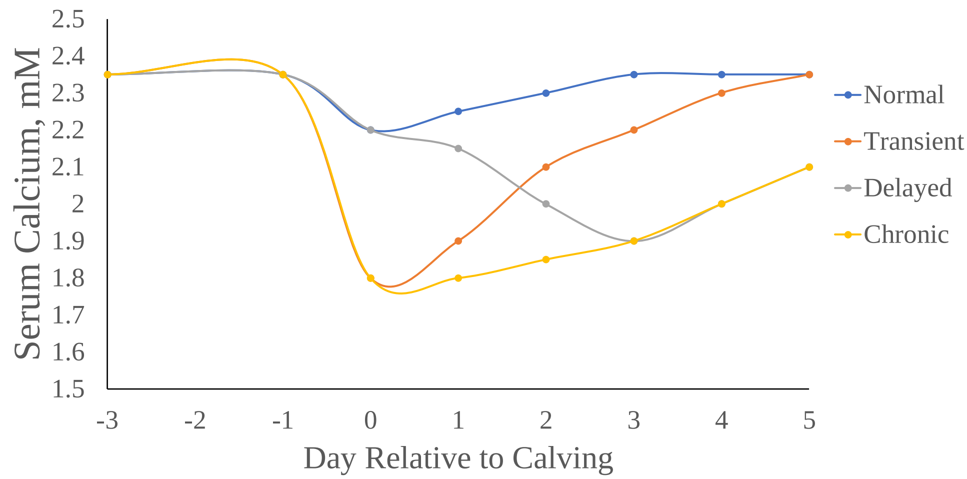
4

Dynamics of Serum Calcium



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5

Association Between Hypocalcemia & Productivity

	Classification of Hypocalcemia				
Variable	Normal	Transient	Delayed	Chronic	SEM
Cows, n	575	239	228	432	
Day 1 Ca, m*M*	2.14	1.70	2.06	1.63	0.02
Day 3 Ca, m*M*	2.37	2.32	2.02	1.95	0.01
Metritis, %	11.0	10.5	26.3	26.2	
Milk Yield, kg/d	53.5	55.1	51.6	54.1	0.6

Plasma Ca and production data from 1,474 multiparous cows

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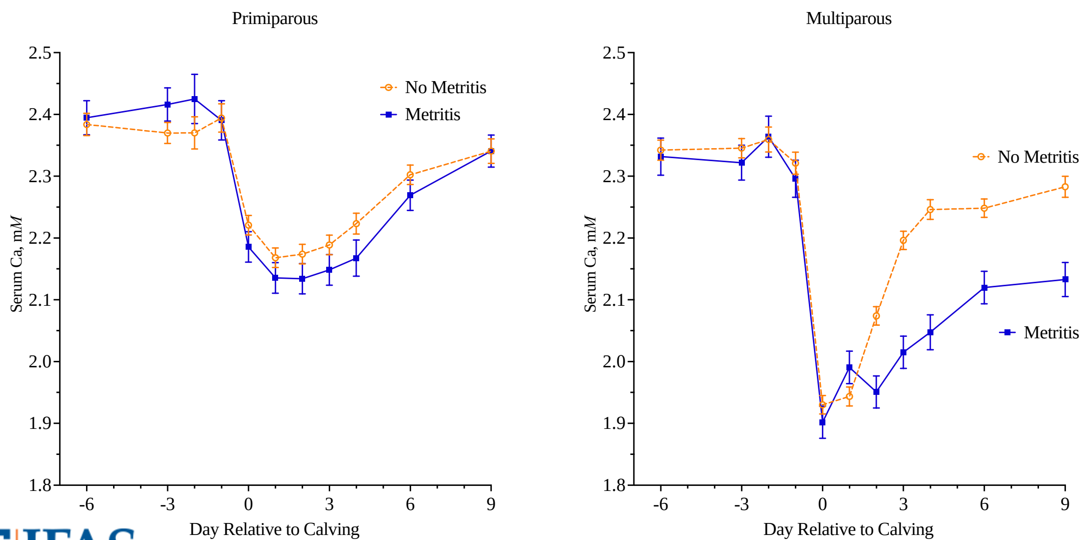
Nelson, CD unpublished data.

6

Association of Metritis and Delayed Hypocalcemia



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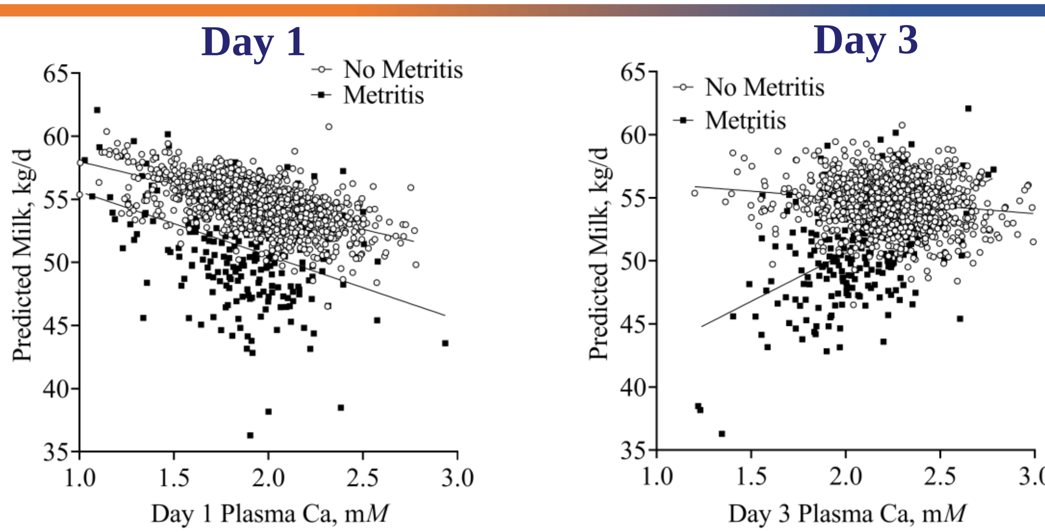
Nelson, CD unpublished data.

7

Relationship Between Ca and Milk – Effect of Day and Metritis



Day 1 Ca, $P < 0.001$; Day 3 Ca, $P < 0.001$; Metritis: $P = 0.007$
Met*Day 1 Ca, $P = 0.003$; Met*Day 3 Ca, $P < 0.001$

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Nelson, CD unpublished data.

8

Relationship Between Day 1 Ca and Milk Yield

Table 1. Effect of plasma Ca concentration <1.9 mM at day 1 postpartum and incidence of metritis on production of multiparous cows.

	Plasma Ca ≥ 1.9 mM		Plasma Ca < 1.9 mM			*P*-values[1]		
Measure	No Met	Met	No Met	Met	SEM	Ca	Met	Ca × Met
Cows, n	687	124	538	139				
Colostrum								
Yield, kg	7.0	7.3	8.0	7.8	0.3	0.01	0.95	0.36
NE, Mcal	9.4	9.5	11.1	10.8	0.5	<0.001	0.86	0.63
Brix, %	23.6	24.0	24.8	24.8	0.3	<0.001	0.66	0.27
Milk yield								
Day 1 to 7, kg/d	44.8	39.9	46.1	40.0	0.5	0.10	<0.001	0.21
Day 1 to 70, kg/d	54.1	50.8	56.1	52.7	0.6	<0.001	<0.001	0.91

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Nelson, CD unpublished data.

9

Relationship Between Day 3 Ca and Milk Yield

Table 2. Effect of plasma Ca concentration <2.2 mM at day 3 postpartum and incidence of metritis on production of multiparous cows.

	Plasma Ca ≥ 2.2 mM		Plasma Ca < 2.2 mM			*P*-values[1]		
Measure	No Met	Met	No Met	Met	SEM	Ca	Met	Ca × Met
Cows, n	735	89	501	178				
Colostrum								
Yield, kg	7.4	7.7	7.7	7.5	0.3	0.71	0.88	0.45
NE, Mcal	10.0	10.4	10.6	10.3	0.5	0.67	0.91	0.45
Brix, %	23.8	24.5	24.8	24.4	0.3	0.14	0.59	0.06
Milk yield								
Day 1 to 7, kg/d	45.6[a]	42.2[b]	45.4[a]	39.0[c]	0.5	<0.001	<0.001	<0.001
Day 1 to 70, kg/d	55.0[ab]	53.2[bc]	55.4[a]	51.3[c]	0.6	0.15	<0.001	0.02

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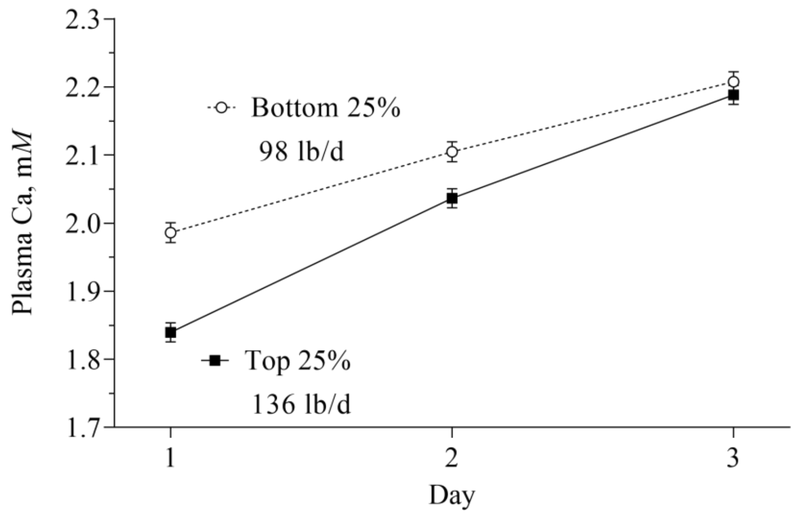
Nelson, CD unpublished data.

10

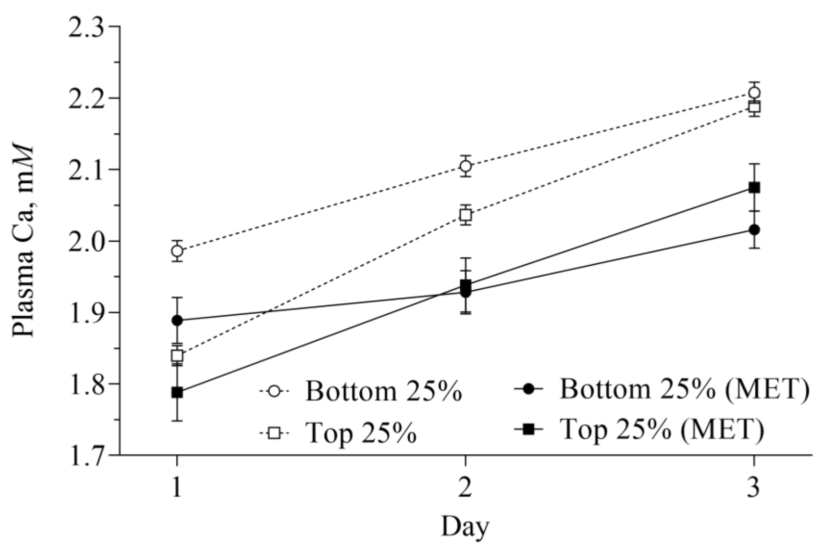
Plasma Ca by Milk Production, Top 25% vs. Bottom 25%



Nelson, CD unpublished data.

11

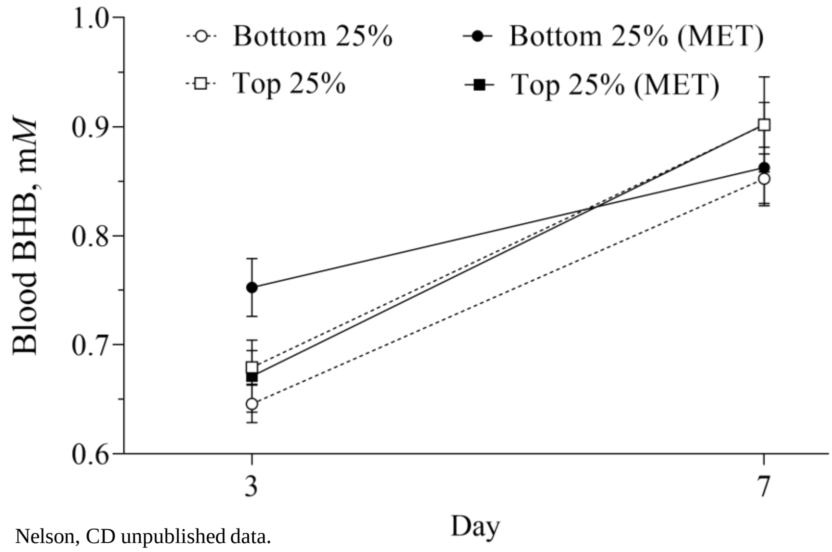
Plasma Ca by Milk Production and Metritis



Nelson, CD unpublished data.

12

Blood BHB by Milk Production and Metritis



Nelson, CD unpublished data.

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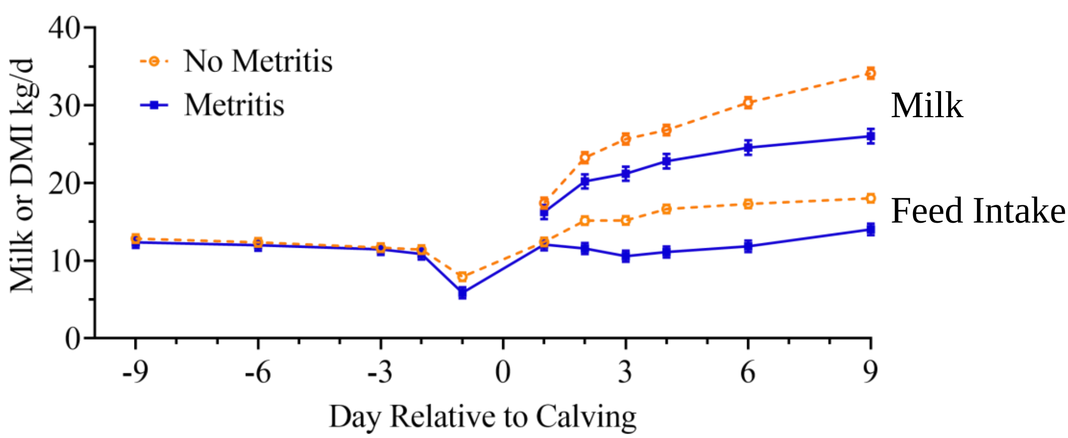
13

Effect of Metritis on Milk and Feed Intake in Week 1



Nelson, CD unpublished data.

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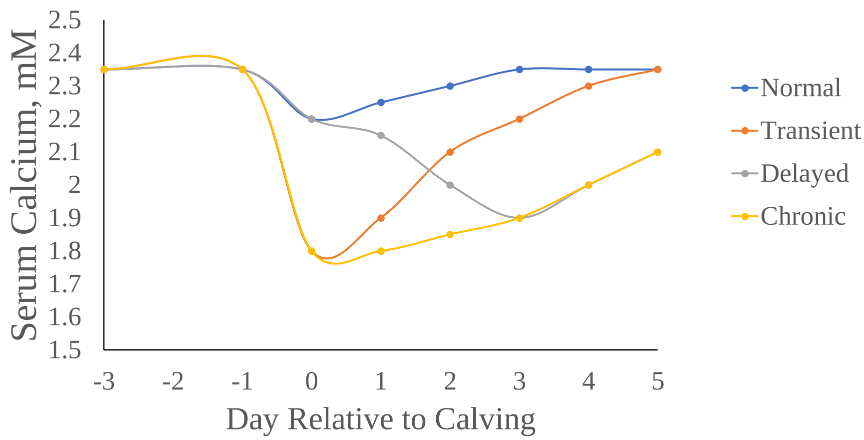
14

Strategies to Improve Calcium Dynamics

- Low DCAD
- Low dietary P
- Zeolite products

- Intravenous Ca
- Oral Ca bolus
- Calcitriol injection



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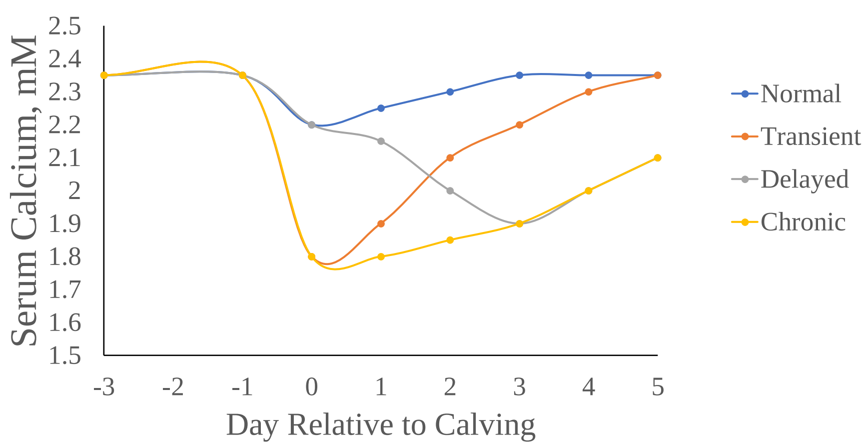
15

Strategies to Improve Calcium Dynamics

- Low DCAD
- Low dietary P
- Zeolite products

- Intravenous Ca
- Oral Ca bolus
- Calcitriol injection



Blanket postpartum Ca treatment **DOES NOT** improve **herd** health and production

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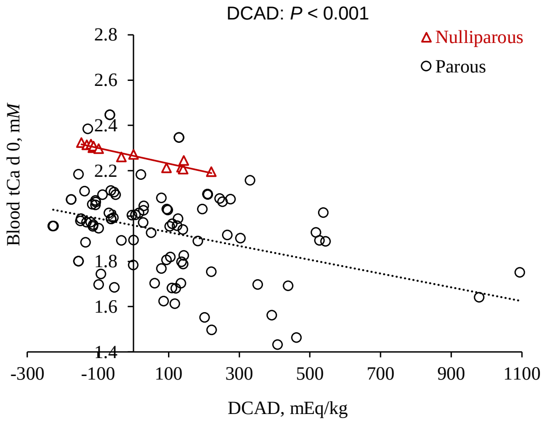
16

Prevention of Postpartum Hypocalcemia with DCAD



Santos et al. (2019) J. Dairy Sci. 102:2134–2154

Meta-analysis of 42 experiments

Feeding multiparous cows -100 vs +200 mEq/kg DM prepartum:

- **Increased milk yield by 2.4 lbs/d**
- **Decreased serum BHB**
- **Decreased incidence of RP and metritis**

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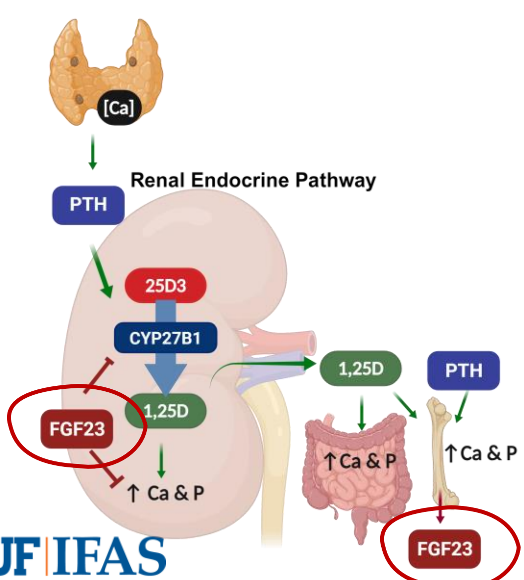
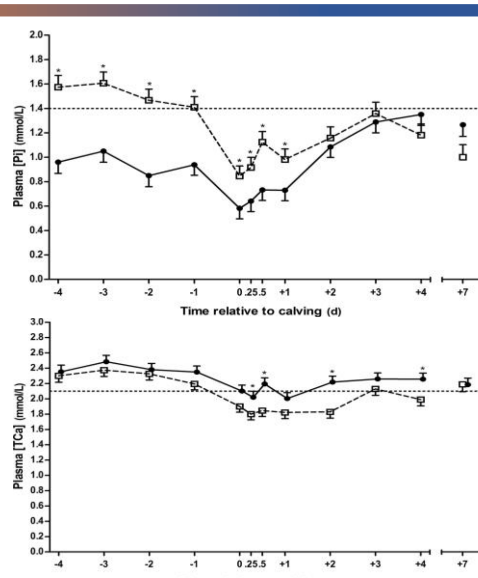
Prevention of Postpartum Hypocalcemia with Low P





Wachter et al. 2022. J. Dairy Sci. 105748-760DOI: (10.3168/jds.2021-20726)

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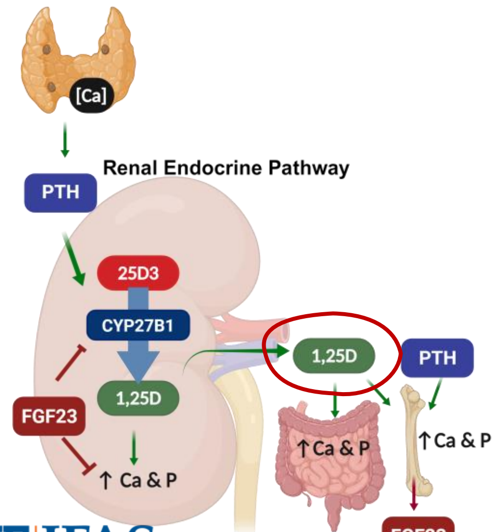
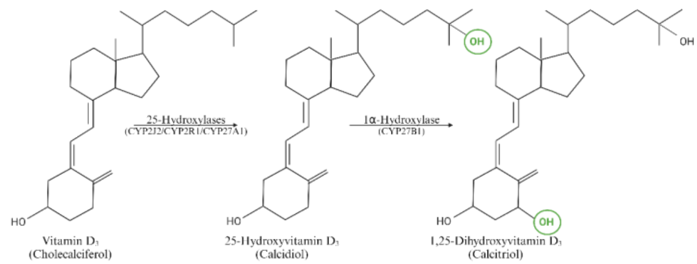
18

Prevention of Hypocalcemia with Vitamin D





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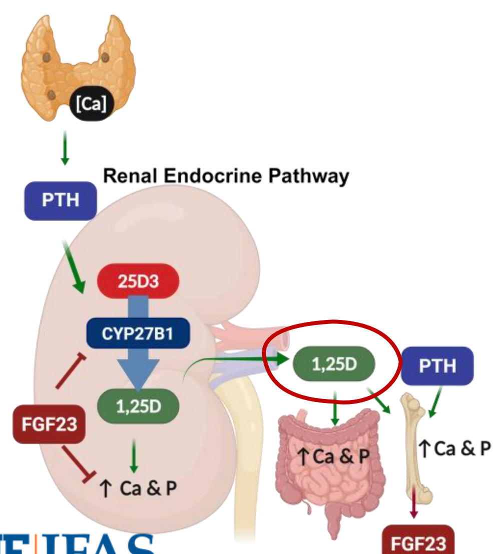
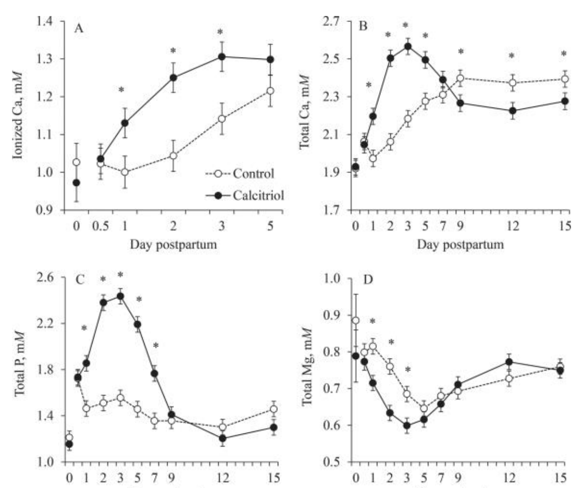
Prevention of Postpartum Hypocalcemia with Calcitriol





Vieira-Neto et al. (2018) J. Dairy Sci. 100:5805–5823

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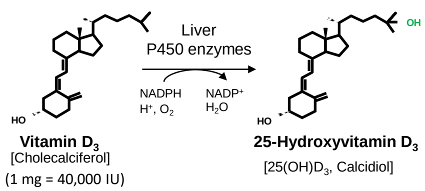
20

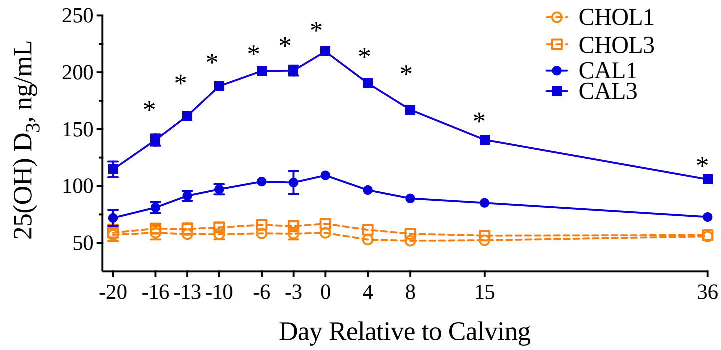
Calcidiol: An Alternative and Effective Vitamin D Source



1 vs. 3 mg/d

1 vs. 3 mg/d

Treatments fed 4 weeks prepartum



Adapted from Poindexter et al., 2023. J. Dairy Sci. 106:954-973.

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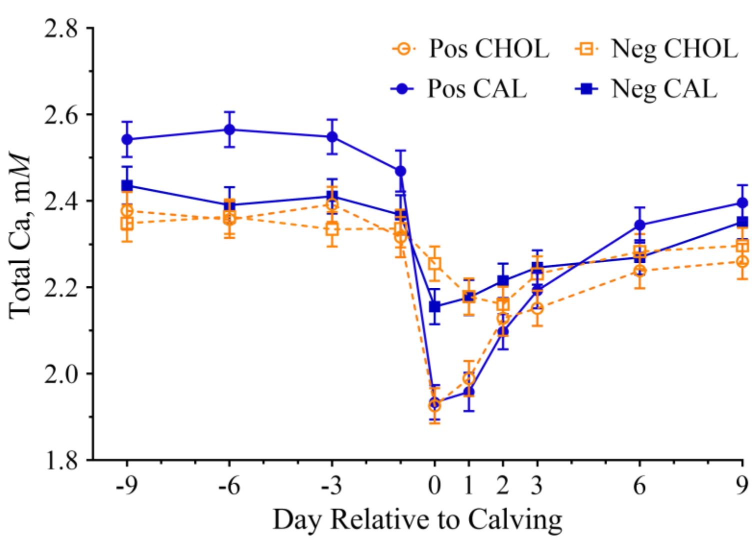
Prepartum DCAD is More Effective Than Calcidiol at Preventing Postpartum Hypocalcemia



Rodney et al. 2018. J. Dairy Sci.

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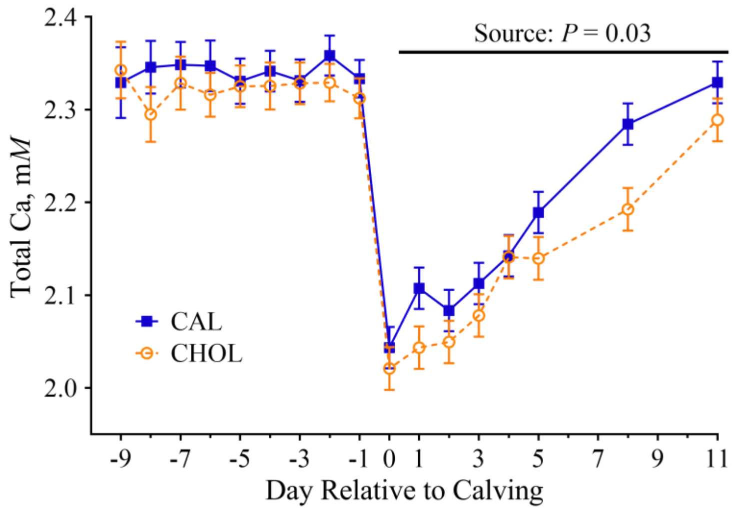
Prepartum Calcidiol Did Not Prevent Hypocalcemia but Restored Postpartum Ca Faster



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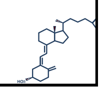
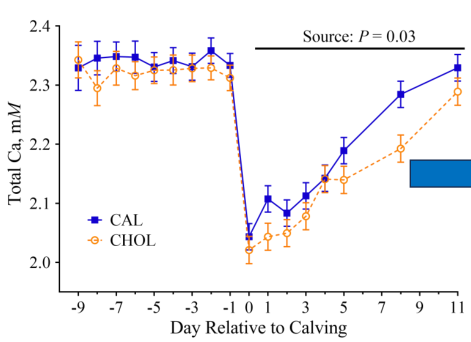
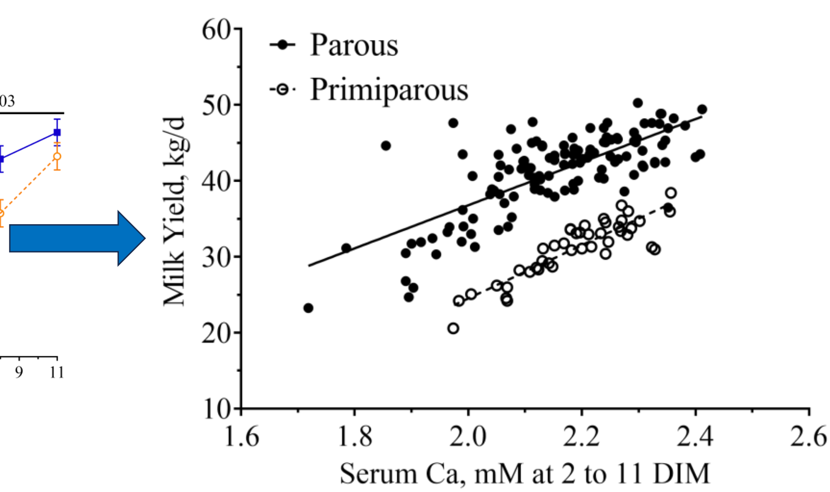
Adapted from Poindexter et al., 2023. J. Dairy Sci. 106:954-973.



23

Prepartum Calcidiol Restored Postpartum Ca Faster: Associated with More Milk





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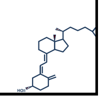
Adapted from Poindexter et al., 2023. J. Dairy Sci. 106:954-973.



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Effect of Prepartum Calcidiol on Energy Corrected Milk, kg/d

Experiment	Cholecalciferol	Calcidiol	*P*-value
Martinez, 2018	35.8	39.5	0.03
Poindexter, 2023	36.3	39.0	0.06

Experiment	Control	Calcidiol	*P*-value
Silva, 2021	29.3	32.4	0.03
Holub, 2023	54.9	56.7	0.04

Martinez et al. 2018. J. Dairy Sci. 101:2544-2562.
Poindexter et al., 2023. J. Dairy Sci. 106:974-989.
Silva et al., 2022. J. Dairy Sci. 105:5796-5812.
Holub, et al., 2023. J. Anim. Sci. 101(Suppl. 3):632-633.

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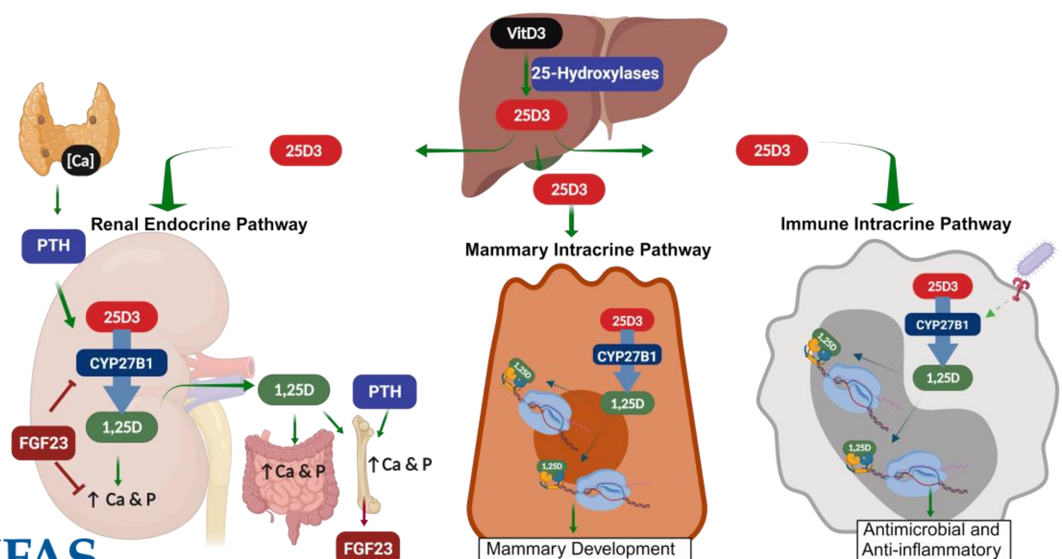
25

Vitamin D Physiology



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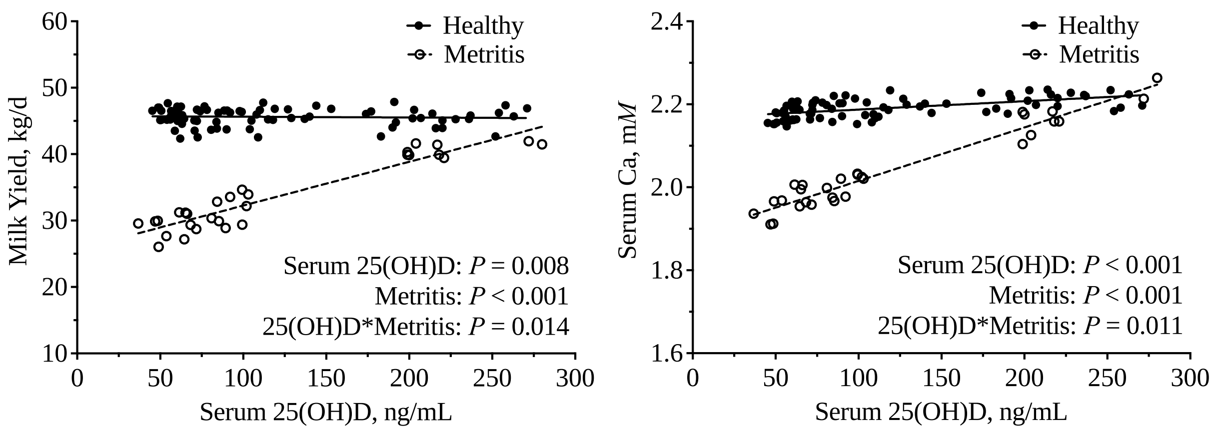
Interaction Between Calcidiol and Metritis



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Adapted from data in Poindexter et al., 2023. J. Dairy Sci. 106:974-989.

27

Summary & Conclusions

- **Interaction between metritis and day 3 postpartum SCH is associated with decreased milk yield**
- **Feeding a low prepartum DCAD prevents milk fever and decreases risk of uterine diseases**
- **Feeding calcidiol prepartum:**
  - **Increased serum Ca from 2 to 9 DIM but not 0 and 1 DIM**
  - **Increased milk yield by 3 to 4 kg/d in first 42 DIM**

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Acknowledgements

University of Florida
- Michael Poindexter
- Achilles Vieira-Neto

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- Teri Wells
- Samantha Bohm
- Roney Zimpel
- Jose Santos

DSM Nutrition
- Pietro Celi
- Mark Engstrom

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https://animal.ifas.ufl.edu/people/corwin-d-nelson/

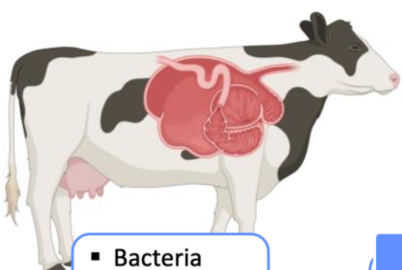
29

Uncovering the Effect of Immunoglobulin A on the Rumen Ecosystem

Fernanda Batistel
Dept. Animal Sciences
University of Florida

1

Rumen Microbes Play a Central Role in Ruminant Nutrition



- Bacteria
- Protozoa
- Fungi
- Archaea

Rumen microbes

Fermentation

- Fiber breakdown
- Nutrient synthesis

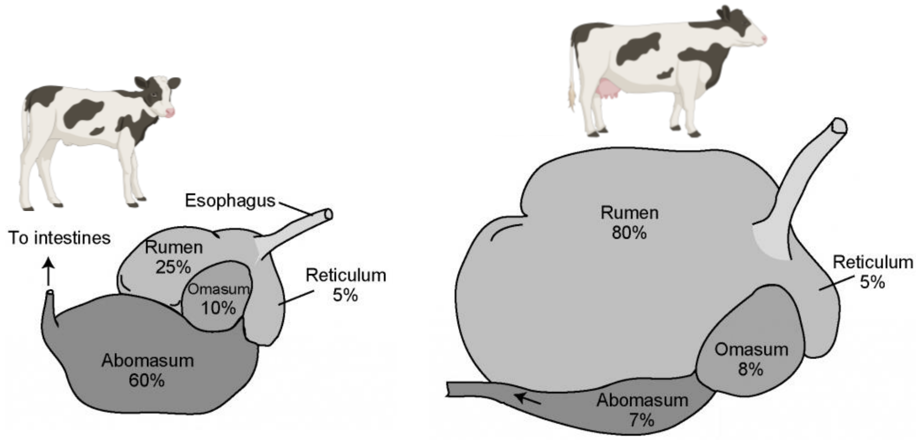
- Energy
- Amino acids

Benefit to the host

2

The Development of the Digestive System in Ruminants

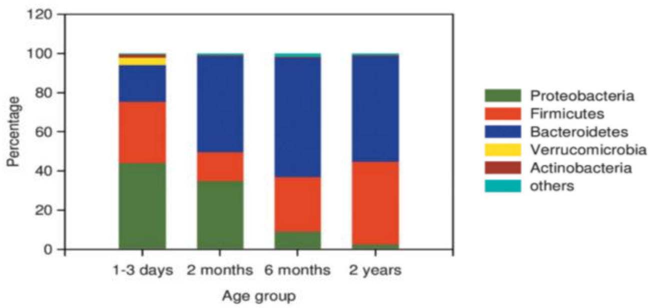
- Rumen and reticulum: allometric growth
- Rumen development and function are closely tied to microbial establishment



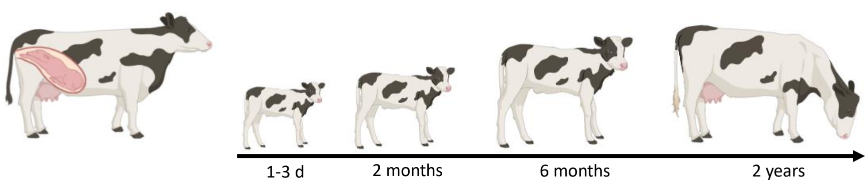
CalfCare.ca

3

The Establishment of the Rumen Microbial Ecosystem



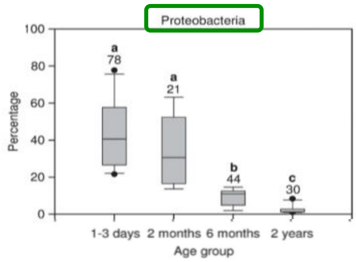
Bacterial phylum distribution in the rumen at different ages.

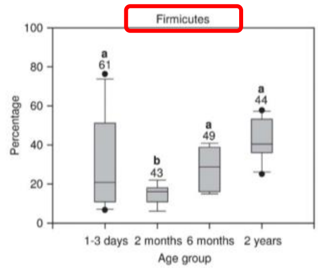


Jami et al. (2013), *ISME J*

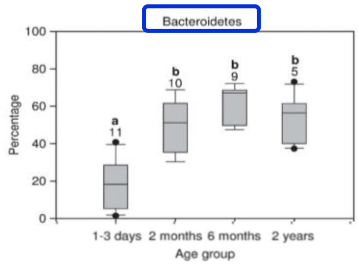
4

The Establishment of the Rumen Microbial Ecosystem





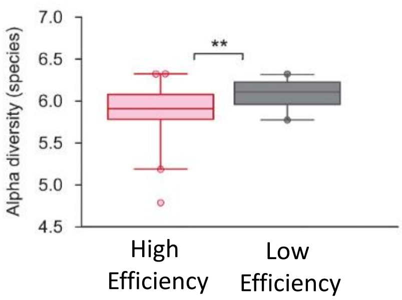
*Diet changes

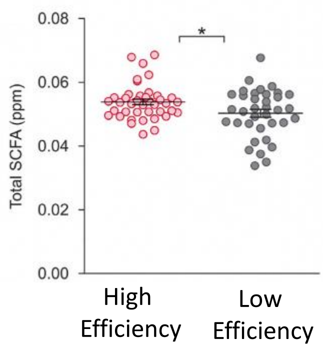


Relative abundance of the three main bacterial phyla in the rumen at different ages.

Jami et al. (2013), *ISME J*

Rumen Microbial Composition and Activity are Associated with Production Efficiency

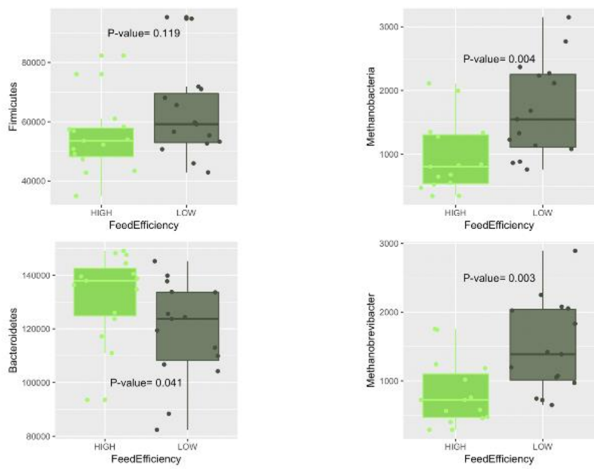




* $P < 0.05$
** $P < 0.01$

Shabat et al. (2016), *ISME J*

Rumen Microbial Composition and Activity are Associated with Production Efficiency



Delgado et al. (2018), *Scientific Reports*

7

Classification of Bacterial Species by Function

In 1953, Bryant & Burkey isolated and characterized 896 strains of bacteria from the rumen of cows fed different diets during six experiments. There fundings are summarized in table:

Classification	% of total population
Anaerobic	98
Glucose users	72
Cellobiose users	62
Xylan (hemicellulose) users	54
Starch users (amylolytics)	39
Protein users (proteolytic)	21
Cellulose users (cellulolytics)	15

8

The Interest in Modulating the Rumen Microbial Ecosystem has been Longstanding

Proc. Nutr. Soc. (1972), **31**, 125 125

PROCEEDINGS OF THE NUTRITION SOCIETY

The Two Hundred and Forty-second Scientific Meeting (Ninety-sixth Scottish Meeting) was held at the Hannah Research Institute, Ayr, on 10 March 1972

SYMPOSIUM ON
'MANIPULATION OF RUMEN FERMENTATION'

Chairman's introduction

By J. A. F. Rook, *The Hannah Research Institute, Ayr KA6 5HL*

Rook (1972), *Proc Nutr Soc*

Stability and Adaptability of the Ruminal Microbial Community in Mature Animals

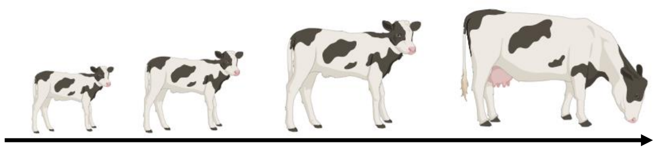
Characteristic	Definition	Likely status in rumen
Inertia	Resistance to change	High, based on dosing studies
Resilience	Ability to restore its structure following acute or chronic disturbances	High, based on exchange studies

- Previous attempts to modulate the mature rumen microbiome: diet, enzymes, prebiotics, probiotics, etc.
- The effects do not persist once the insult is discontinued.

Weimer (2015), *Front Microbiol*

Early-life Attempts to Modulate the Rumen Microbial Ecosystem

- More recent efforts have focused on early-life strategies to modulate the assembly of the rumen microbial community.
  - Imprint a favorable microbial phenotype throughout the animals' lives.
  - Diet and inoculation.



Early-life Attempts to Modulate the Rumen Microbial Ecosystem

- Treatments:
  - Autoclaved rumen fluid
  - Rumen inoculum
- Administration:
  - Day 3: 100 mL
  - Day 7: 200 mL
  - Day 21: 300 mL
  - Day 42: 400 mL
  - Day 50: 500 mL
- No changes in animal performance.

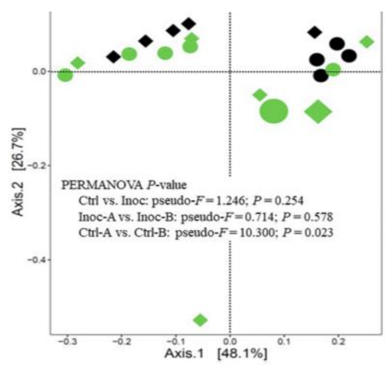
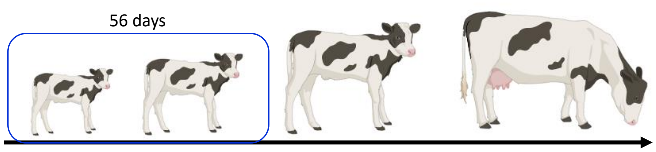


FIGURE 1 | PCoA plot showing the overall comparison of the rumen prokaryotic microbiota. Large green circle, Inoc-A donor; small green circles, Inoc-A calves; large diamond, Inoc-B donor; small green diamonds, Inoc-B calves; small black circles, Ctrl-A calves; small black diamonds, Ctrl-B calves Data of the donors for the control calves were not shown.

Bu et al. (2020), *Front Microbiol*

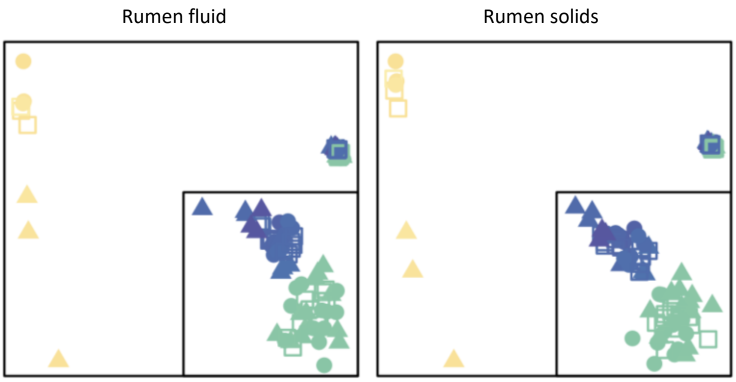
Early-life Attempts to Modulate the Rumen Microbial Ecosystem

- Treatments:
  - Calf starter
  - Corn silage
  - Mixed diet (25% calf starter, 75% corn silage)



Dill-McFarland et al. (2018), Appl Environ Microbiol

Early-life Attempts to Modulate the Rumen Microbial Ecosystem



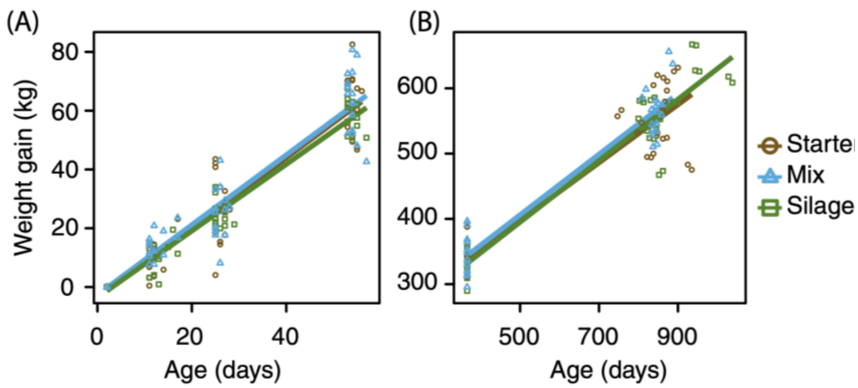
Circle: calf starter
Triangles: corn silage
Squares: Mixed diet

Yellow: 8 wks
Green: 1 year
Blue: 2 years

NMDS plots of Bray-Curtis diversity index values for bacteria.

Dill-McFarland et al. (2018), Appl Environ Microbiol

Early-life Attempts to Modulate the Rumen Microbial Ecosystem



Calf diet effect on weight gain.

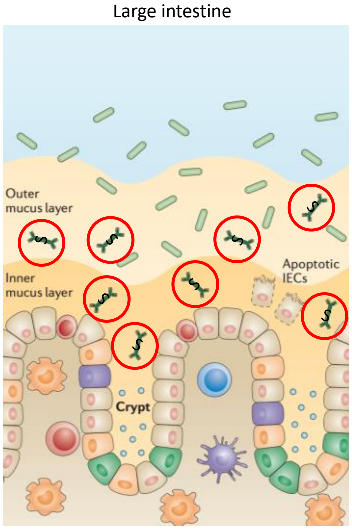
Dill-McFarland et al. (2018), Appl Environ Microbiol

Modulatory Effect of Antibodies on Gastrointestinal Microorganisms

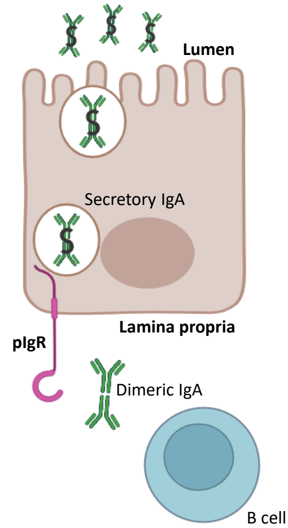
- The lack of response to diet and inoculum in early-life trials indicates that host-dependent mechanisms may contribute to rumen homeostasis.
- Immune system >> antibodies
  - Secretory immunoglobulin A (SIgA)

Secretion of SIgA by the Gastrointestinal Tract

Large intestine



Adapted from Mowat & Agace (2014), *Nat Rev Immunol*

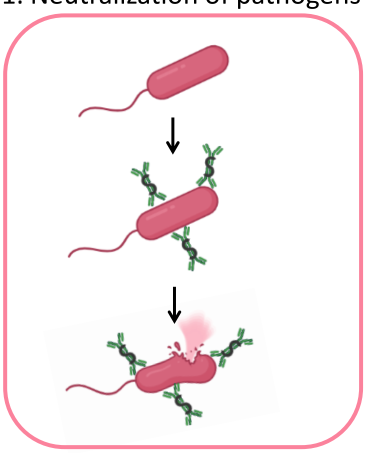


Adapted from Johansen & Kaetzel (2011), *Mucosal Immunol*

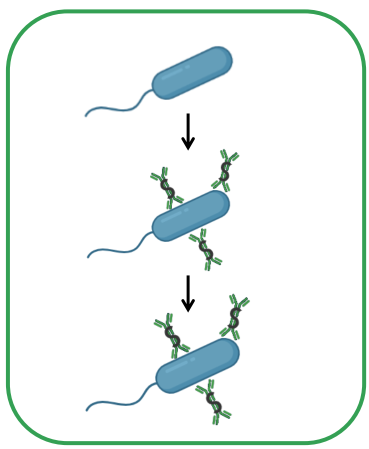
17

Roles of SIgA in Gastrointestinal Microorganisms

1. Neutralization of pathogens



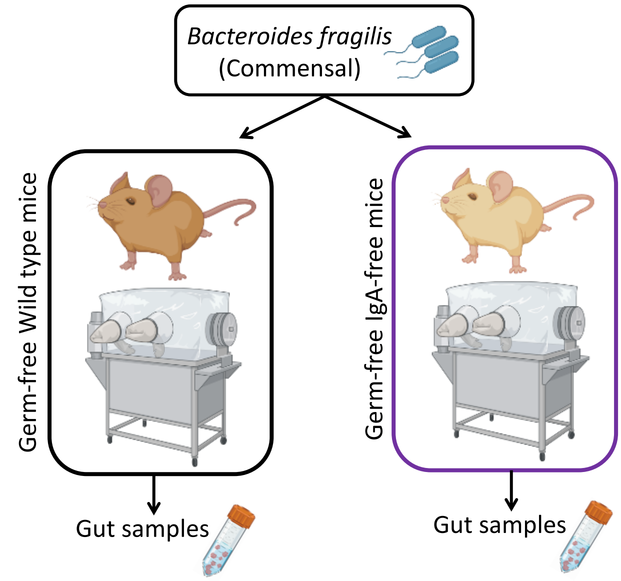
2. Maintenance of commensal bacteria



Adapted from Gutzeit et al. (2014), *Immunol Rev*

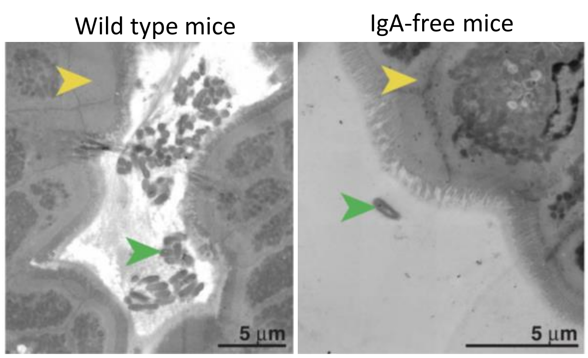
18

SIgA Favors Gut Colonization by Commensal Bacteria in Mice

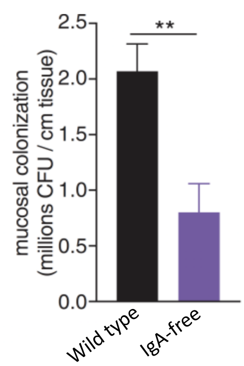


Donaldson et al. (2018), *Science*

SIgA Favors Gut Colonization by Commensal Bacteria in Mice



Transmission electron microscopy images of the colon (yellow arrowhead denotes epithelial cell) in mice colonized with *B. fragilis* (green arrowhead).

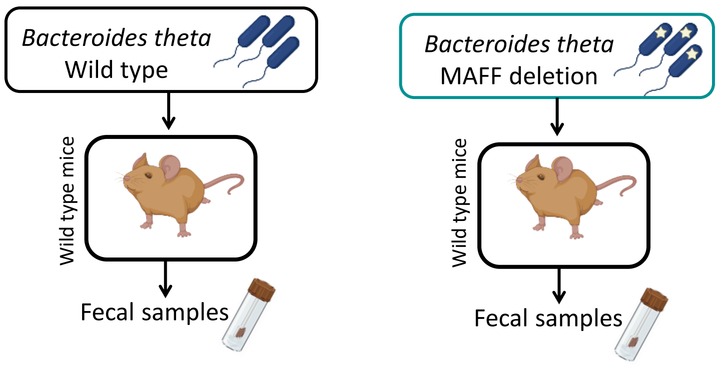


- SIgA is essential for the colonization of commensal bacteria in the gut.
- SIgA plays a role in establishing host-microbial symbiosis.

Donaldson et al. (2018), *Science*

SIgA Alters the Composition and Metabolic Function of the Gut Microbiome in Mice

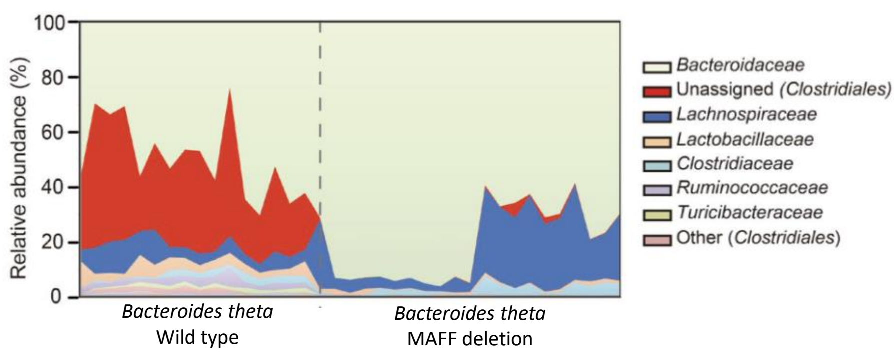
- In mice, *Bacteroides theta* (commensal) were heavily coated with SIgA.
- SIgA influenced the expression of mucus-associated functional factors (MAFF).



Nakajima et al. (2018), *J Exp Med*

21

SIgA Alters the Composition and Metabolic Function of the Gut Microbiome in Mice

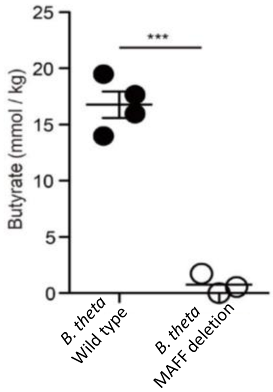


Relative abundance of bacterial families identified with 16S rRNA analysis in the cecum.

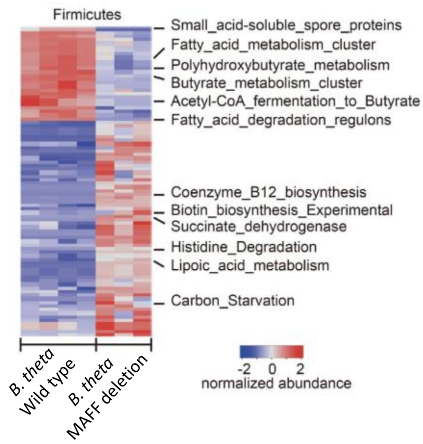
Nakajima et al. (2018), *J Exp Med*

22

SIgA Alters the Composition and Metabolic Function of the Gut Microbiome in Mice



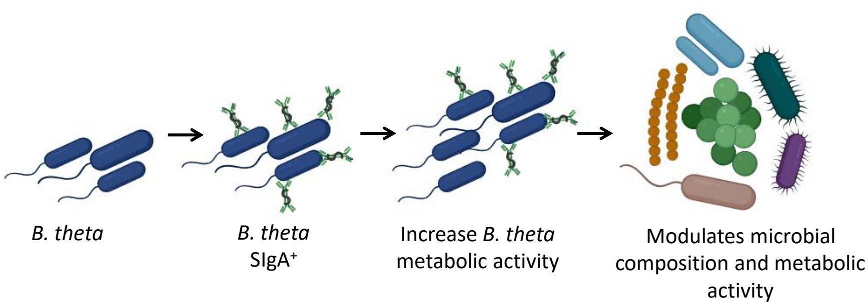
Concentration of butyrate in cecal samples.



Gene expression of Firmicutes from cecal samples.

Nakajima et al. (2018), *J Exp Med*

SIgA Alters the Composition and Metabolic Function of the Gut Microbiome in Mice

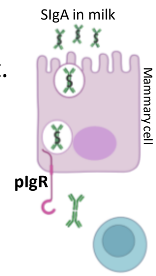


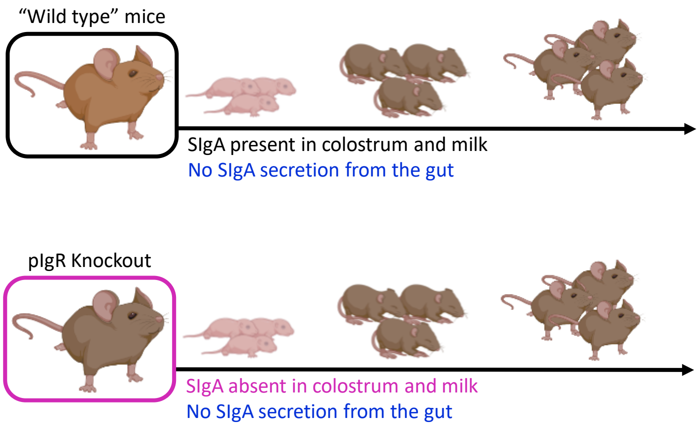
- SIgA directly and indirectly affects gut microbial composition and metabolic activity.

Nakajima et al. (2018), *J Exp Med*

Milk SIgA Promotes Long-Lasting Changes in the Gut Microbiome of Mice

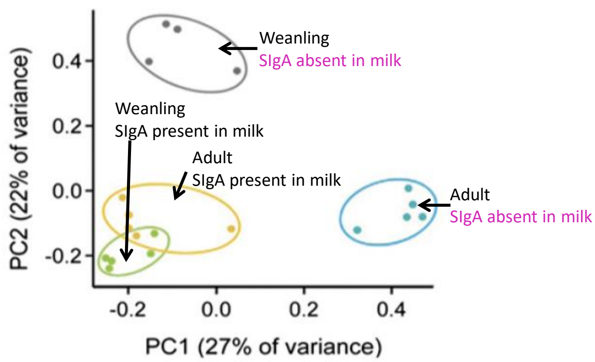
- SIgA is secreted into milk similarly to its secretion into the gut.





Rogier et al. (2014), *Proc Natl Acad Sci*

Milk SIgA Promotes Long-Lasting Changes in the Gut Microbiome of Mice



PCoA illustrating bacterial community structures.

- Milk SIgA induces enduring alterations in the gut microbiome of mice.

Rogier et al. (2014), *Proc Natl Acad Sci*

Summary SIgA Results in Mice

- SIgA modulates gut colonization by commensal bacteria.
- SIgA alters the microbial composition and metabolic function of the microbiome.
- SIgA promotes long-lasting changes in the gut microbiome.

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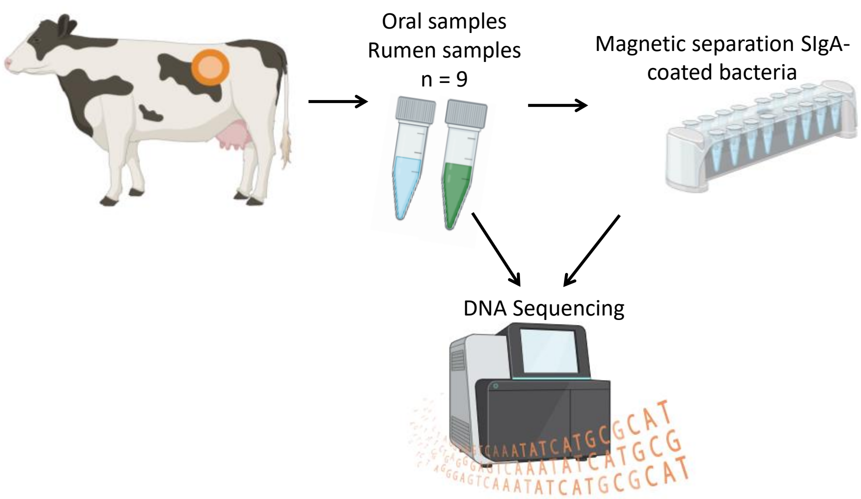
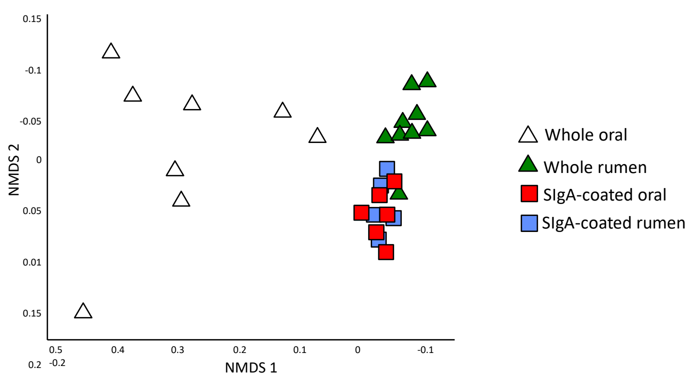
SIgA-coated Oral Microbiome is Correlated with SIgA-coated Rumen Microbiome



Fouhse et al. (2017), *Front Microbiol*

SIgA-coated Oral Microbiome is Correlated with the SIgA-coated Rumen Microbiome



Non-parametric multidimensional scaling (NMDS) ordination plot illustrating bacterial community structures.

- The correlation between the SIgA-coated oral microbiome and the SIgA-coated rumen microbiome suggests a host-derived mechanism impacting commensal colonization.

Fouhse et al. (2017), *Front Microbiol*

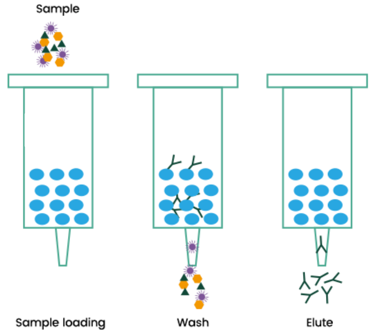
But Correlation Does Not Imply Causation…

31

Effect of Colostrum SIgA on Rumen Bacterial Growth

- We hypothesized that exposure of rumen bacteria to colostrum SIgA would favor bacterial growth.

1st step: Validated a protocol for isolating and purifying SIgA from from colostrum.



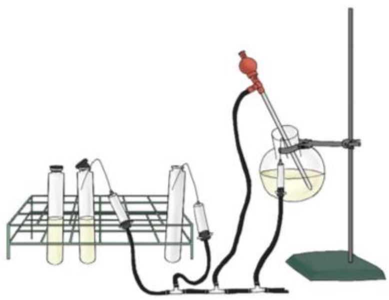
32

Effect of Colostrum SIgA on Rumen Bacterial Growth

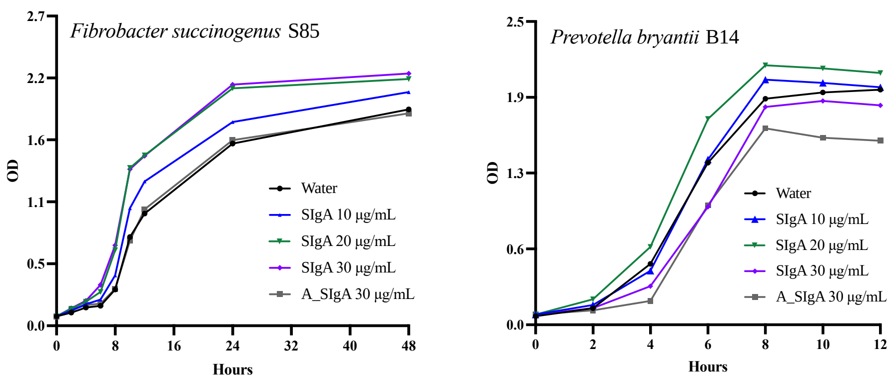
- We hypothesized that exposure of rumen bacteria to colostrum SIgA would favor bacterial growth.

2nd step: The Hungate anaerobic technique was used to investigate the effect of SIgA on pure culture bacteria.

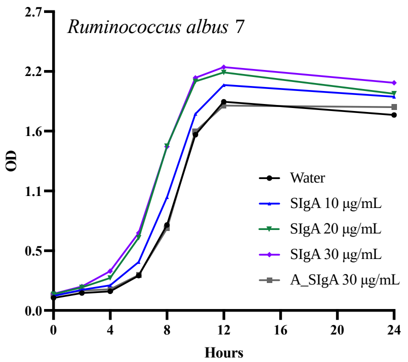
Treatments:
1. Water
2. 10 µg SIgA/mL
3. 20 µg SIgA/mL
4. 30 µg SIgA/mL
5. 30 µg autoclaved SIgA/mL

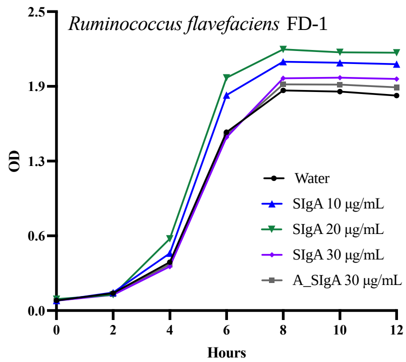


Rumen Bacterial Growth is Induced by Colostrum SIgA



Rumen Bacterial Growth is Induced by Colostrum SIgA





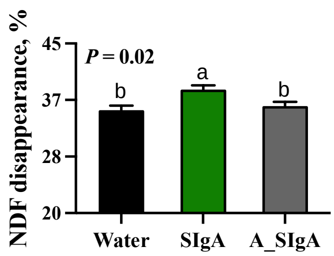
- SIgA derived from bovine colostrum promotes the growth of fiber-digesting bacteria.

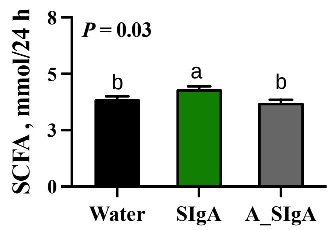
Effect of Colostrum SIgA on Rumen Fermentation

- We hypothesized that SIgA would favor rumen fermentation.

  - Batch culture technique
  - Treatments:
    1. Water
    2. 20 µg SIgA/mL
    3. 20 µg autoclaved SIgA/mL

Colostrum-derived SIgA Improves Fiber Digestion and SCFA Production *In Vitro*





- SIgA derived from bovine colostrum influences the modulation of rumen fermentation.

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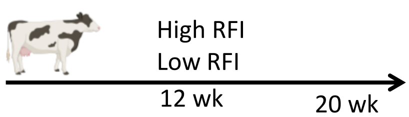
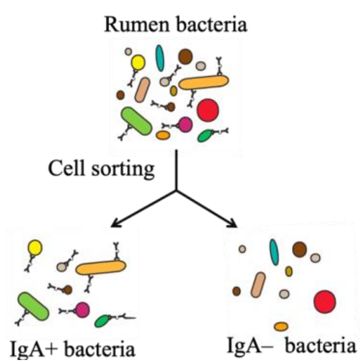
Effect of SIgA-coated Bacteria on Feed Efficiency

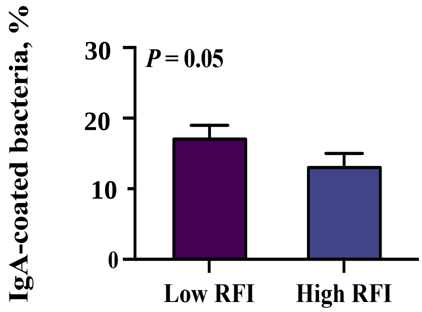
- We hypothesized that feed efficiency is positively associated with the proportion of rumen SIgA-coated bacteria.



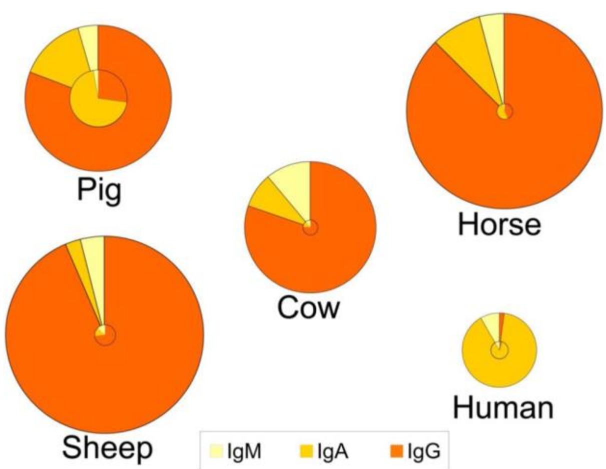


38

There Seems to be an Association Between Feed Efficiency and the Proportion of Rumen Siga-coated Bacteria in Dairy Cattle

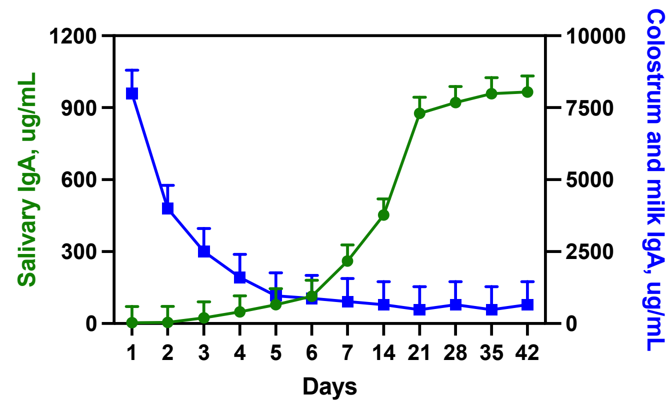


Milk is the Primary Source of SIgA Entering the Rumen During Calves' Early Life



Hurley & Theil. (2011), *Nutrients*

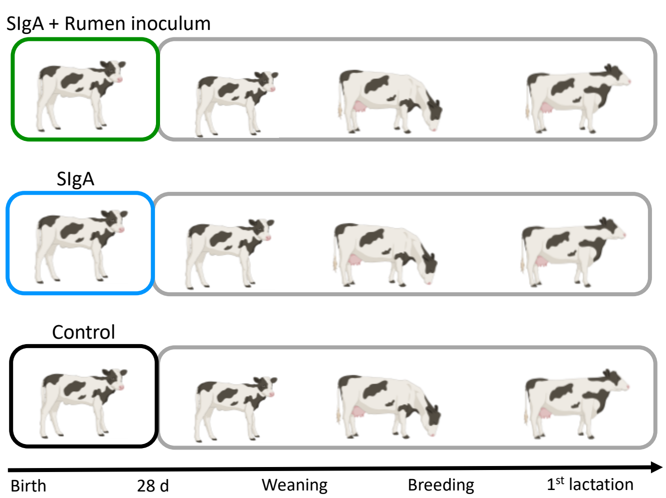
Milk is the Primary Source of SIgA Entering the Rumen During Calves' Early Life



SIgA levels in the saliva of newborn calves and in the colostrum and milk of early-lactating dairy cows.

41

Determine the effects of SIgA supply during early life on the rumen microbial ecosystem and animal performance



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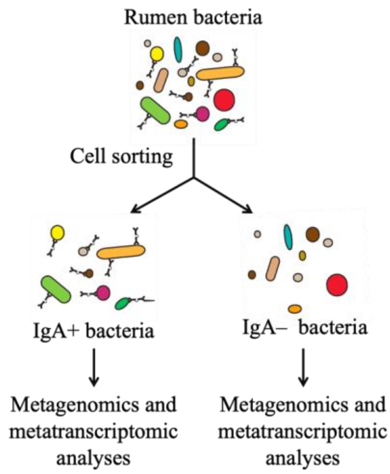
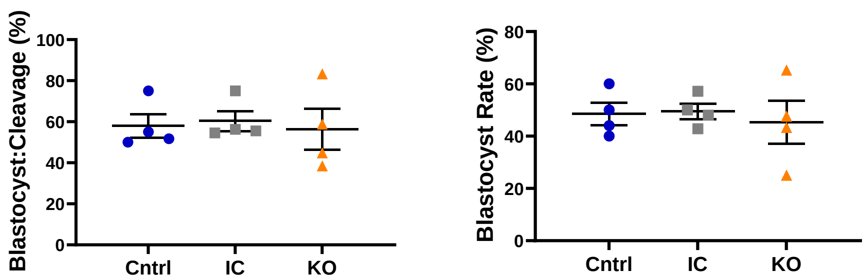
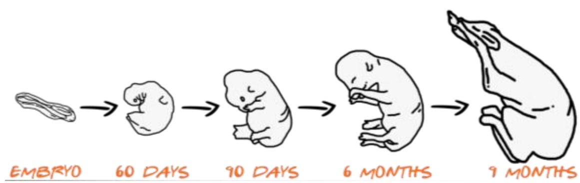
Determine the effects of SIgA supply during early life on the rumen microbial ecosystem and animal performance



We wish to be able to create a bovine pIgR knockout…



- pIgR is not required for blastocyst development.



Preliminary Conclusions

- SIgA derived from bovine colostrum promotes the growth of fiber-digesting bacteria.
- SIgA derived from bovine colostrum influences the modulation of rumen fermentation.
- There seems to be an association between feed efficiency and the proportion of rumen SIgA-coated bacteria in dairy cattle.
- Milk is the primary source of SIgA to young dairy calves.
- Future: We expect to demonstrate that milk SIgA modulated the rumen microbial ecosystem.

45

Acknowledgments

- KC Jeong
- Brad Daigneault/Maura McGraw
- Jeff Firkins
- José E. P. Santos/Mariana Nehme

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  - Daniel de Oliveira
  - Benjamin Schrag
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  - Filipe A. C. Mendonça
  - Derick Rosler

- Funding
  - USDA-AFRI – Batistel & Jeong
  - UF-IFAS Early Career – Batistel & Daigneault

USDA NIFA

United States Department of Agriculture
National Institute of Food and Agriculture

UF IFAS
UNIVERSITY of FLORIDA

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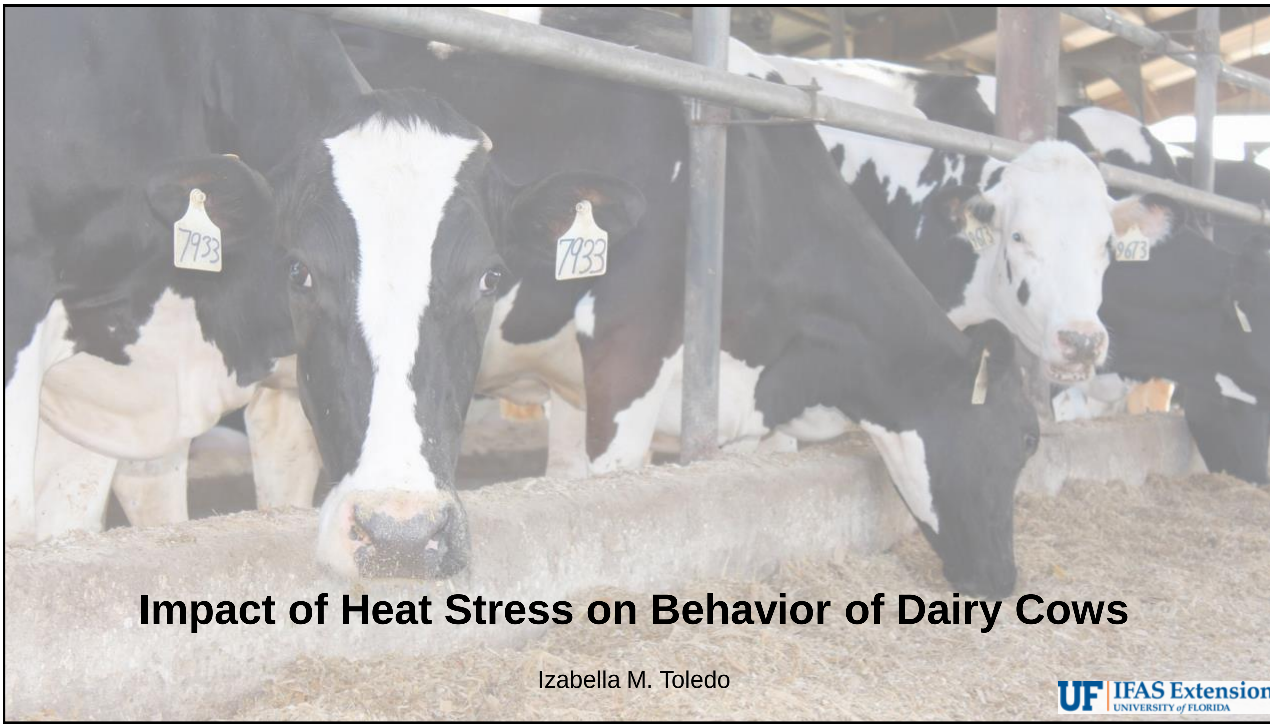
Thank you!

fernandabatistel@ufl.edu



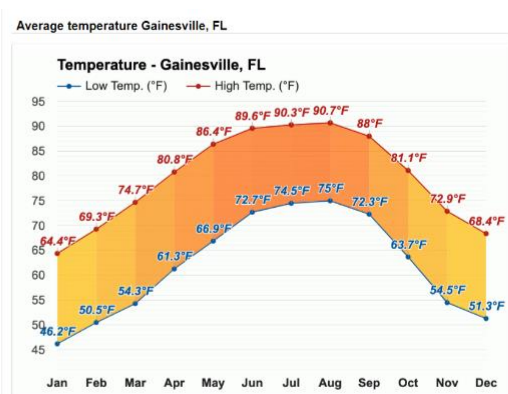
Impact of Heat Stress on Behavior of Dairy Cows

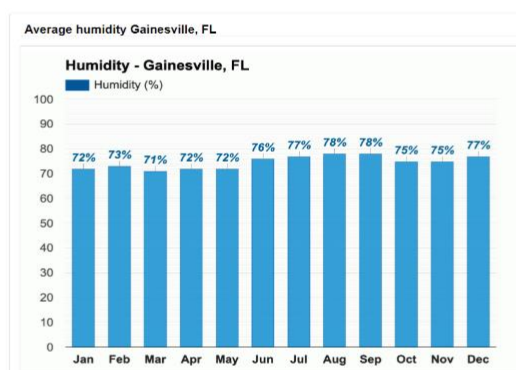
Izabella M. Toledo

UF | IFAS Extension
UNIVERSITY of FLORIDA

1

Florida is Hot!!





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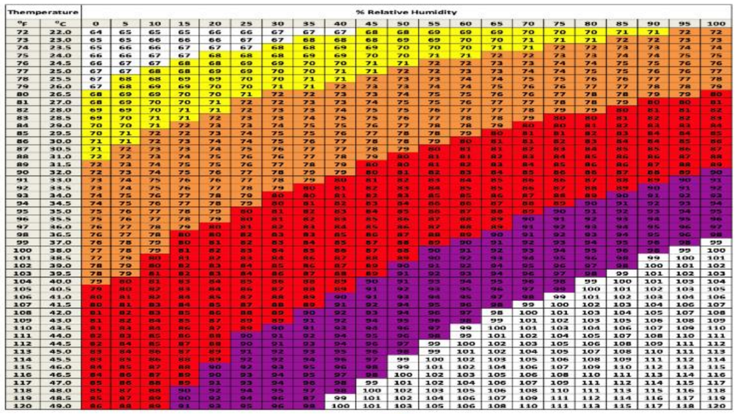
[Weather today - Gainesville, FL (weather-atlas.com)]

2

Temperature-Humidity Index (THI)



Themperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
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94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95	96	98
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
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106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103	104	106
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104	106	107
108	42.0	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
109	43.0	81	82	84	85	87	89	89	91	92	94	95	96	98	99	101	102	103	105	106	108	109
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117	47.0	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	48.0	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	48.5	85	87	89	90	92	94	96	97	99	101	102	104	106	107	109	111	112	114	116	117	119
120	49.0	86	88	89	91	93	95	96	98	100	101	103	105	106	108	110	111	113	115	117	118	120

Stress threshold: Respiration rate exceeds 60 BPM. Milk yield losses begin. Repro losses detectable. Rectal temperature exceeds 38.5°C (101.3°F)

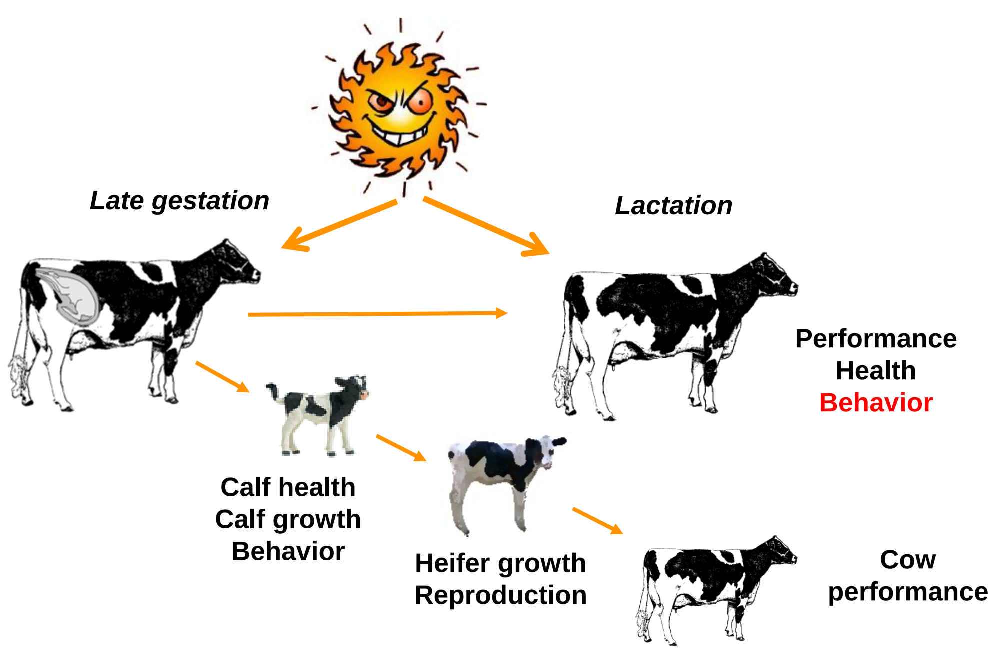
Mid-Moderate Stress: Respiration rate exceeds 75 BPM. Rectal temperature exceeds 39°C (102.2°F)

Moderate-Severe Stress: Respiration rate exceeds 85 BPM. Rectal temperature exceeds 40°C (104°F)

Severe Stress: Respiration rate 120-140 BPM. Rectal temperature exceeds 41°C (106°F)

Collier et al. (2012). Quantifying heat stress and its impact on metabolism and performance. UF-IFAS Ruminant Nutrition Symposium.

3



4

Typical Daily Time Budget of a Lactating Dairy Cow

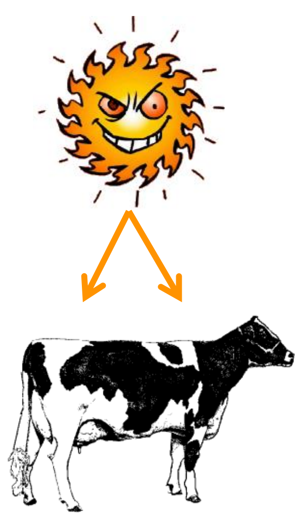
Activity	Time devoted to activity per day
Eating	3 to 5 h (9 to 14 meals/d)
Lying/resting	12 to 14 h
Social interactions	2 to 3 h
Ruminating	7 to 10h
Drinking	30 min
Outside pen (milking, travel time)	2.5 to 3.5 h

(Adapted from Grant and Albright, 2000).

5

Behavioral Coping Strategies in Lactating Cows Exposed to Heat Stress

↓ Activity and Movement



Modified Drinking and Eating Behaviors

↓ Dry Matter Intake

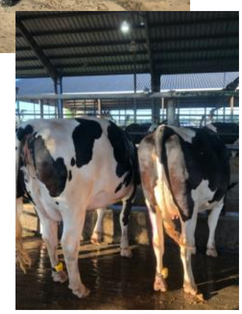
↑ Standing time

↓ Rumination time

6

Behavior Measurements

- **Leg Tag:**
  Measure lying time, standing time, walking and standing events
- **Neck Tag:**
  Measure eating time and rumination time
- **Acclimation Period**



7

Effects of Exposure to Heat Stress During Late Gestation on the Daily Time Budget of Nulliparous Holstein Heifers

Toledo I.M., Ouellet V., Davidson B.D., Dahl G.E., and Laporta J. 2022. Effects of exposure to heat stress during late gestation on the daily time budget of nulliparous Holstein heifers. Front. Anim. https://doi.org/10.3389/fanim.2022.775272

8

Hypothesis

Exposure of pregnant nulliparous Holstein heifers to hyperthermia during late gestation induces behavior modifications that have lingering effects during lactation.

9

Objectives

To characterize natural behaviors of nulliparous Holstein heifers 60 d pre-and postpartum and examine the effects of late gestation heat stress on those behaviors.

10

Design and Management

- 25 multiparous lactating Holstein heifers (~60 d before expected calving)
- Measurements recorded for each cow during 60 d pre and postpartum
- **Temperature and Humidity Index:** was assessed during the entire study period through HOBO devices.
- **Physiological measurements:** Davidson et al., J. Dairy Sci. 104:2357-2368.

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11

Design and Management

Cool Treatment (n=12) ← Sand bedded free stalls → Heat Stress Treatment (n=13)

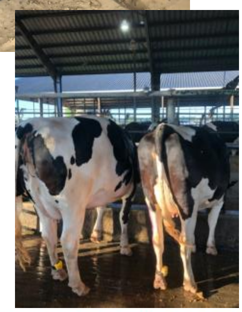
12

Design and Management

- **Leg Tag:**
  Measure lying time, standing time, walking and standing events

- **Neck Tag:**
  Measure eating time and rumination time

- **Acclimation Period:** 7 days after leg and neck tags were placed



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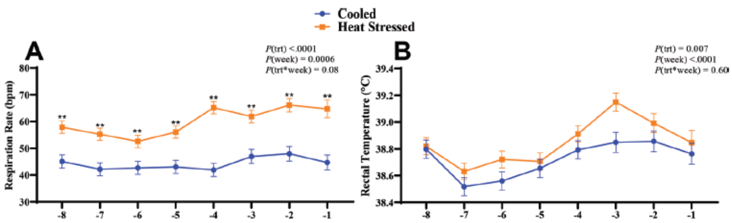
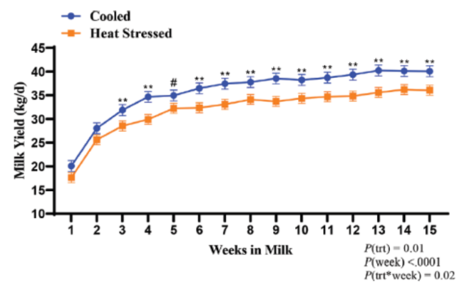
Results

14

Heat Stress Affects Respiration Rate, Rectal Temperature and Milk Yield

THI CL and HT = 77.3

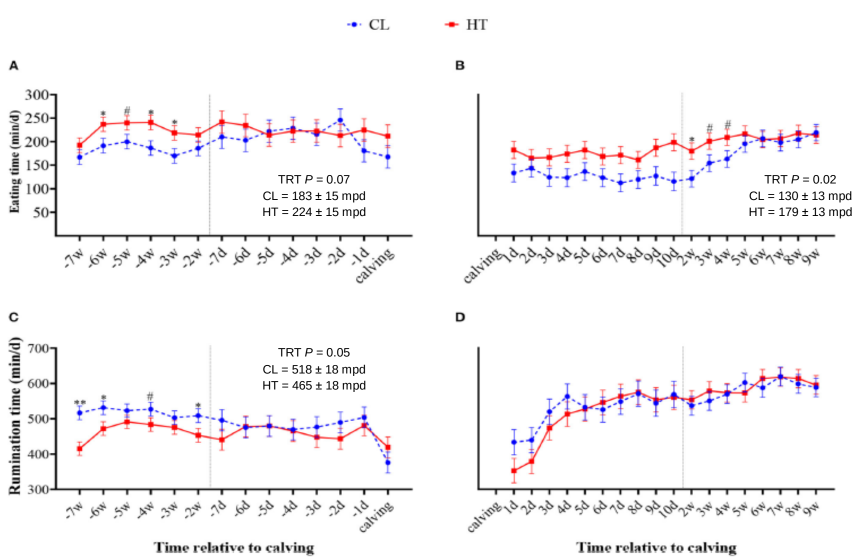




Davidson et al., J. Dairy Sci. 104:2357-2368.

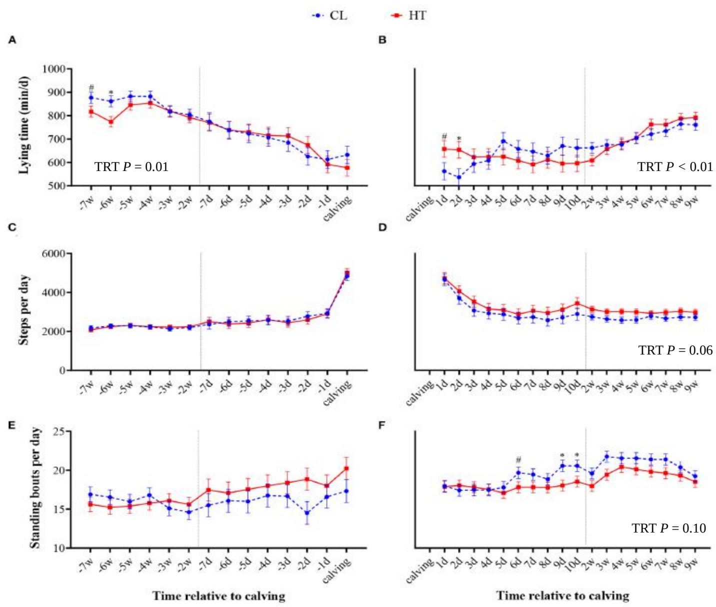
15

Heat Stress Affects Eating and Rumination Times During the Pre and Postpartum Periods

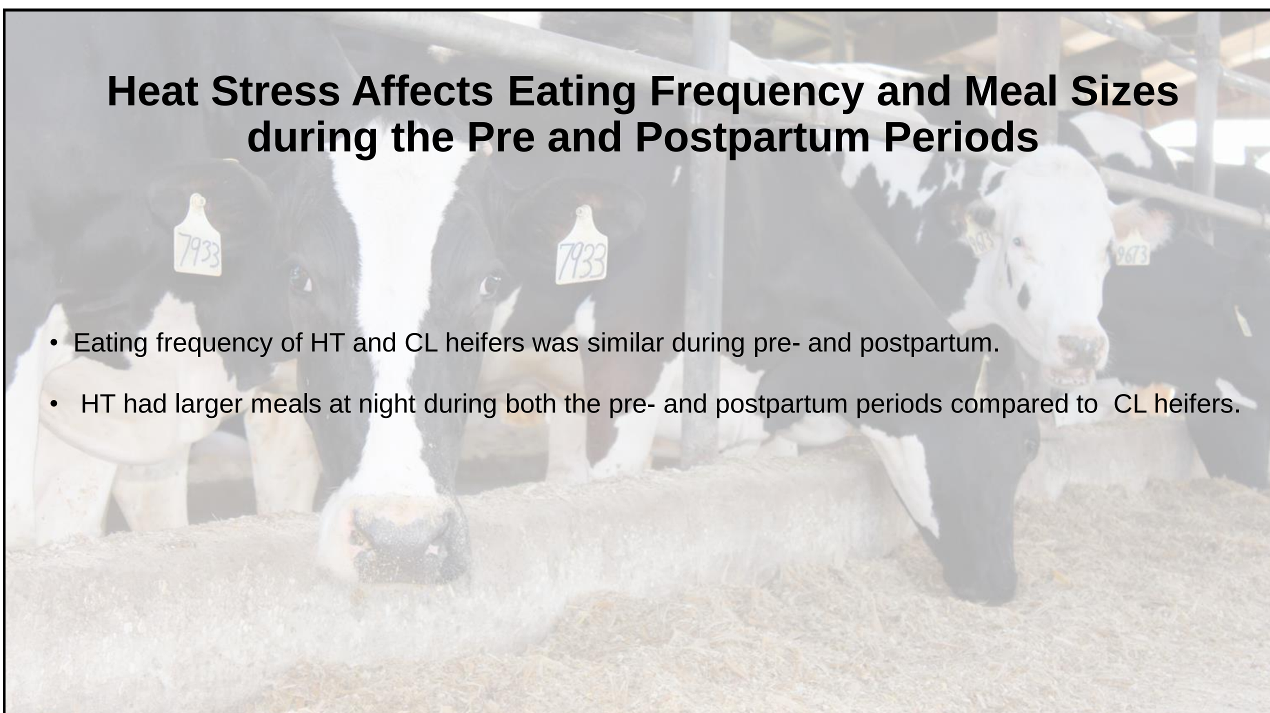


16

Lying Time, Steps by Day and Standing Bouts per Day During the Pre and Postpartum Periods



17



Heat Stress Affects Eating Frequency and Meal Sizes during the Pre and Postpartum Periods

- Eating frequency of HT and CL heifers was similar during pre- and postpartum.
- HT had larger meals at night during both the pre- and postpartum periods compared to CL heifers.

18

Eating, Rumination, and Lying times (min/d) of Late Gestation Nulliparous Heifers and Late Gestation Dry Cows

	Late-gestation Nulliparous Heifers[1]		Calving week Nulliparous Heifers[2]		Late-gestation cows[3]		
Behavior/Treatments[4]	CL/TN	HT	CL/TN	HT	CL/TN	HT	References
Eating, min/d							
	183	224	209	223	166	147	Karimi et al., 2015
					205	–	Schirmann et al., 2013
Rumination, min/d							
	518	465	471	456	655	–	Ouellet et al., 2016
					283	243	Karimi et al., 2015
Lying, min/d							
	854	817	687	689	962	–	Jensen et al., 2012
					1050	966	Karimi et al., 2015
					768	–	Ouellet et al., 2016

[1]Behaviors automatically recorded from 7 to 2 weeks before calving in the present study
[2]Behaviors automatically recorded during the last 7 days before calving in the present study
[3]Behaviors automatically recorded during the 3 weeks before calving or last 7 days before calving retrieved in different studies
[4]CL/TN = animals exposed to active cooling by fans and soakers or housed in thermoneutral conditions; HT = animals deprived of cooling or exposed to high temperature-humidity index

19

Eating, Rumination, and Lying Times (min/d) in Postpartum Nulliparous Heifers and Lactating Cows

	Postpartum Nulliparous Heifers[1]		Calving week Nulliparous Heifers[2]		Lactating cows[3]		
Behavior/Treatments[4]	CL/TN	HT	CL/TN	HT	CL/TN	HT	References
Eating, min/d							
	130	179	180	209	224	–	King et al., 2016
Rumination, min/d							
	511	496	588	593	340–410	–	Pahl et al., 2015
					535–545	493–520	Müschner-Siemens et al., 2020
Lying, min/d							
	637	604	666	638	660–720	–	Cook et al., 2004b
					600	480	Cook et al., 2007
					540	360	Nordlund et al., 2019

[1]Behaviors automatically recorded from 0 to 10 days postpartum in the present study
[2]Behaviors automatically recorded from 2 to 9 weeks postpartum in the present study
[3]Behaviors automatically recorded during in lactating multiparous cows
[4]CL/TN = animals exposed to active cooling by fans and soakers or housed in thermoneutral conditions during the last 60 days of gestation; HT = animals deprived of cooling or exposed to high temperature-humidity index during last 60 days of gestation

20

Summary

- Heat stress during the last 60 d of gestation altered the behavior of nulliparous heifers and had lingering effects after parturition.

- Heat-stressed heifers adapted their behavior by increasing feeding time and meal size at night and by reducing rumination and lying during the *prepartum* period.

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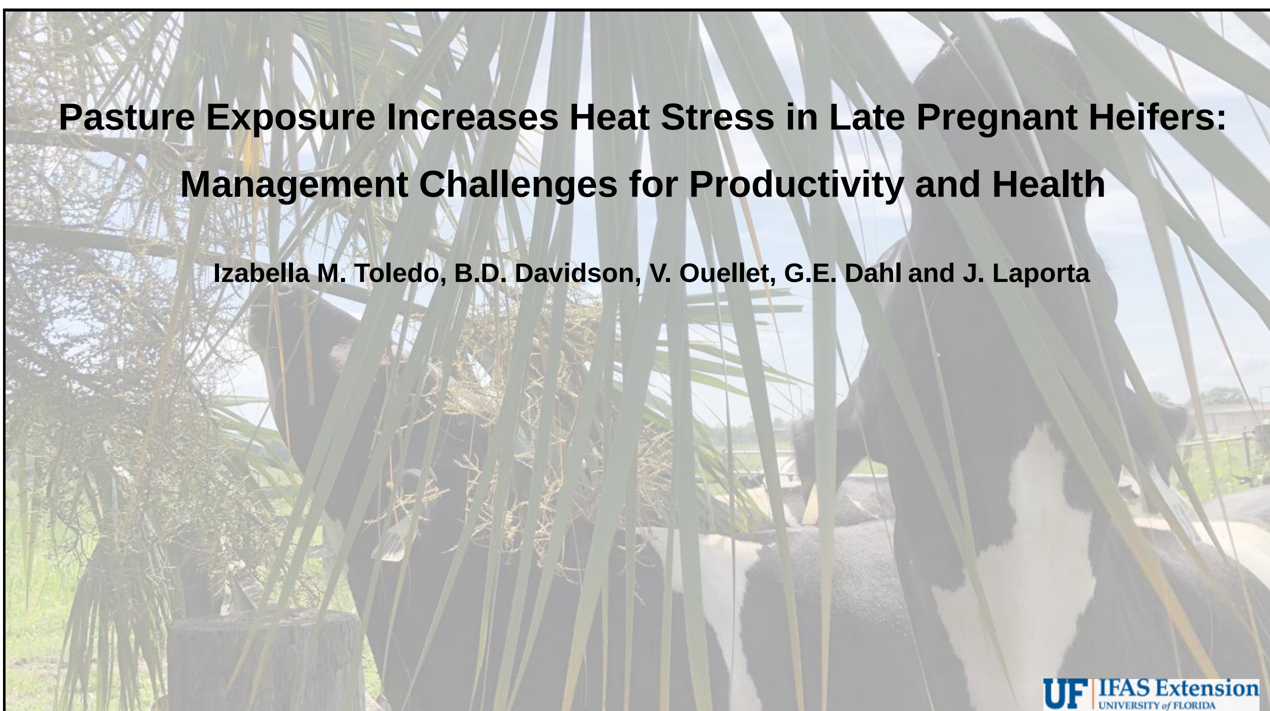

Pasture Exposure Increases Heat Stress in Late Pregnant Heifers: Management Challenges for Productivity and Health

Izabella M. Toledo, B.D. Davidson, V. Ouellet, G.E. Dahl and J. Laporta

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22

Objective

To have a better understanding of how heat stress affects the daily time budget of late gestation dairy heifers in order to adapt management practices in adverse conditions.

23

Design and Management

- 17 Holstein dairy heifers
- Treatments:
  - Pasture (PA; n= 6)
  - Heat Stress (HT; n=6)
  - Cooling (CL; n=5)
- **Study Period:** measurements were recorded for each cow for 14 days
- **Respiration Rate (**breaths/min) were recorded thrice weekly
- **Temperature and Humidity Index** was measured during the entire study through HOBO devices.
- **Black Globe Temperature** was measured during the entire study period by using a black globe temperature sensor.

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Design and Management

Heat Stressed Heifers:
- Sand bedded free stalls

Cooled Heifers:
- Sand bedded free stalls
- Fans over stalls
- Soakers over feedline
- Fans on at 70º F (21.1ºC)
- Soakers on 1 min every 5 min at 72º F

Pastured Heifers:
- Portable shade shelters

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25

Design and Management

- **Leg Tag:**

Measure lying time, standing time, walking and standing events

- **Neck Tag:**

Measure eating time and rumination time

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26

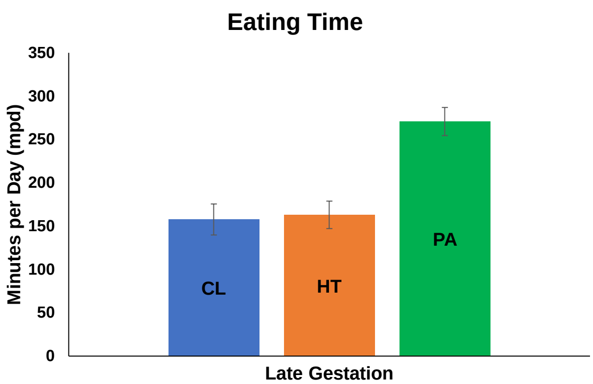
Results

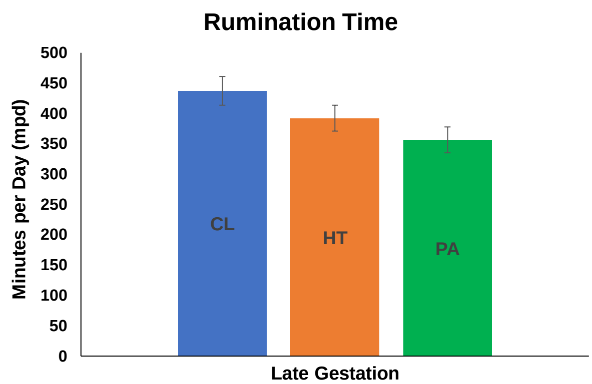
27

Temperature-Humidity Index, Black Globe Temperature and Respiration Rate During the Study Period

- Temperature-Humidity Index averaged 78.0 in the pasture and 77.3 in the free-stall barn
- Black Globe Temperature averaged 29 °C
- Respiration Rates ($P < 0.01$)
  - Cooled Heifers: 48 ± 2.11 bpm
  - Heat Stressed Heifers: 61 ± 8.69 bpm
  - Pastured Heifers: 96 ± 2.14 bpm

28





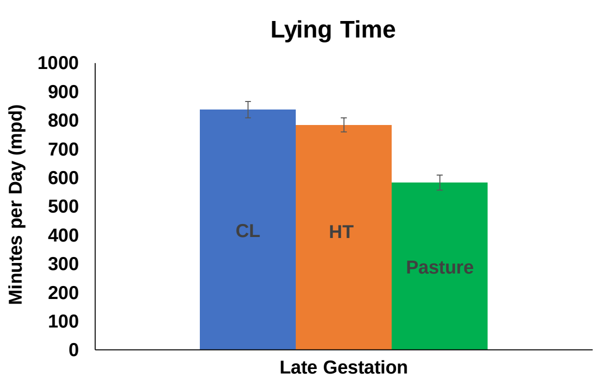
CL vs HT *P* = 0.97
CL vs PA *P* < 0.01
HT vs PA *P* < 0.01

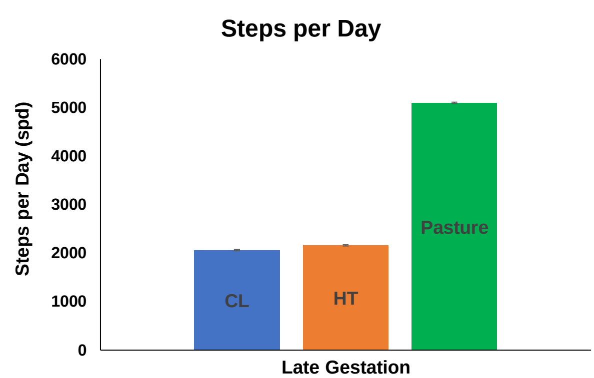
CL = 158 ± 18 mpd
HT = 163 ± 16 mpd
PA = 270 ± 16 mpd

CL vs HT *P* = 0.36
CL vs PA *P* = 0.05
HT vs PA *P* = 0.48

CL = 438 ± 24 mpd
HT = 392 ± 22 mpd
PA = 357 ± 21 mpd

29





CL vs HT *P* = 0.35
CL vs PA *P* < 0.01
HT vs PA *P* < 0.01

CL = 877 ± 28 mpd
HT = 784 ± 24 mpd
PA = 583 ± 26 mpd

CL vs HT *P* = 0.92
CL vs PA *P* < 0.01
HT vs PA *P* < 0.01

CL = 2060 ± 200 spd
HT = 2159 ± 179 spd
PA = 5097 ± 184 spd

30

Summary

- Exposure to heat stress during late gestation affects the daily time budget of first lactation heifers, especially if they are kept in pasture conditions.

- Insights onto heat stress effects in the daily time budget of late gestation heifers may contribute to the development of more effective management strategies to decrease the possible negative effects of heat exposure.

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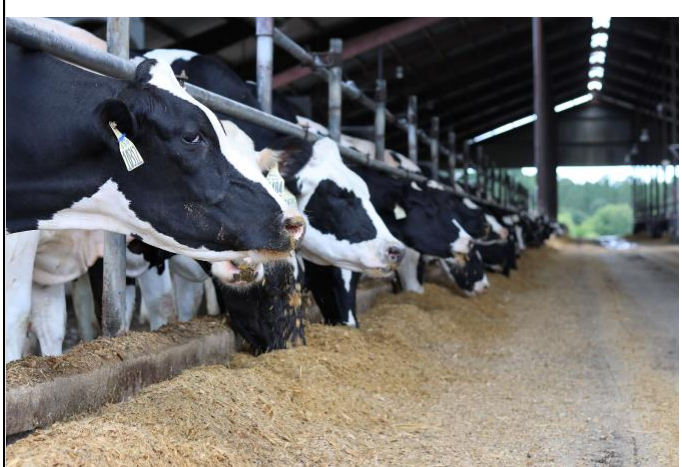
Seasonal Effects on Multiparous Lactating Dairy Cow Behavior

Izabella M. Toledo, L.T. Casarotto and G.E. Dahl



JDS Communications, accepted.

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Hypothesis

Seasonal changes will affect the behavior of multiparous lactating dairy cows housed in free-stall facilities and exposed to active cooling.

33

Objectives

To have a better understanding of how seasonal changes affect the daily activities and the behavior of multiparous dairy cows.

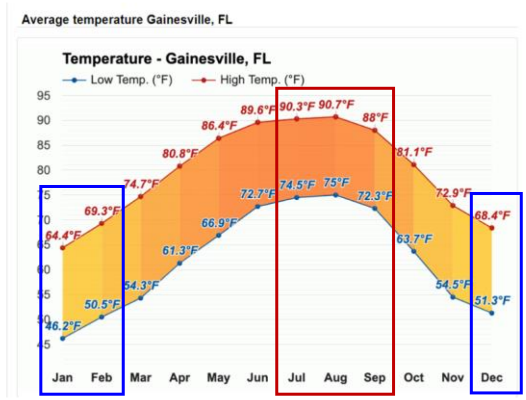
34

Design and Management

- **34 multiparous lactating Holstein cows**
- **2 Treatments:**

Hot Season:
HS; July, August and September; n=19

Cool Season
CS; December, January and February; n=15



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Design and Management

- **Study Period:** measurements were recorded for each cow during the first 9 weeks of lactation during the hot and cool seasons.
- **Temperature and Humidity Index,** was assessed during the entire study period.

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Design and Management

- Sand bedded free stalls
- Fans over stalls
- Soakers over feedline
- Fans on at 70º F (21.1ºC)
- Soakers on 1 min every 5 min at 72º F
- Lights were on for 14h/day

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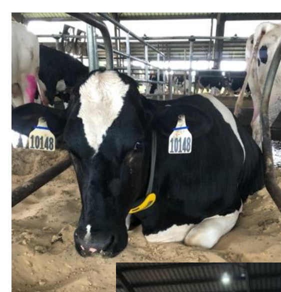
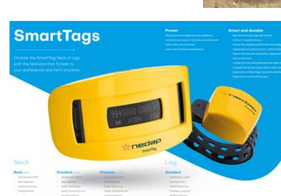
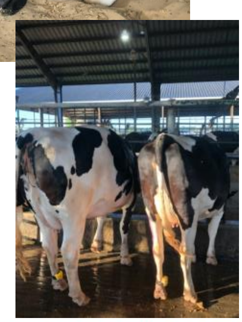
Design and Management



- **Leg Tag:**
  Measure lying time, standing time, walking and standing events
- **Neck Tag:**
  Measure eating time and rumination time
- **Acclimation Period**





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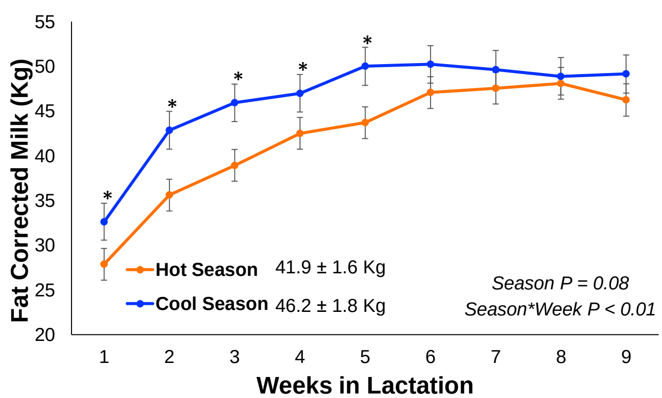
Seasonal Changes Affect Milk Production of Lactating Dairy Cows

- THI Cool Season: 54.4
- THI Hot Season: 78.2



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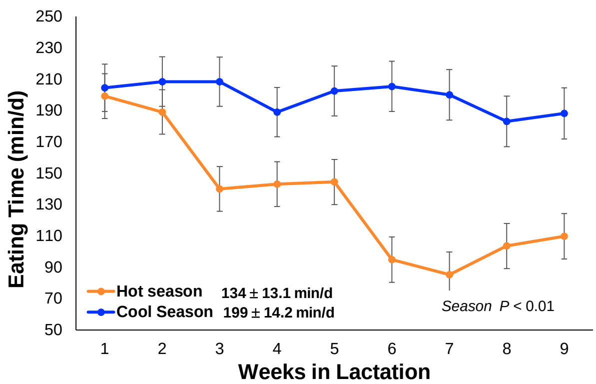
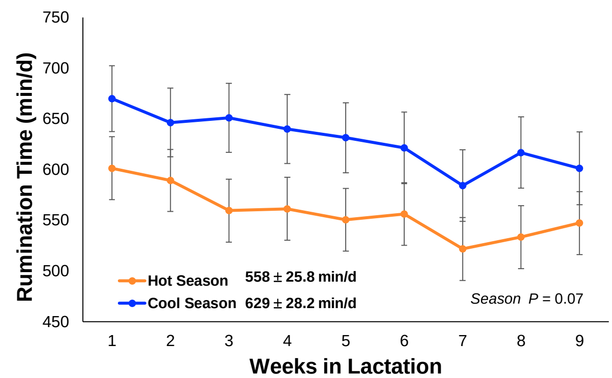
Eating and Rumination During the Cool and Hot Seasons





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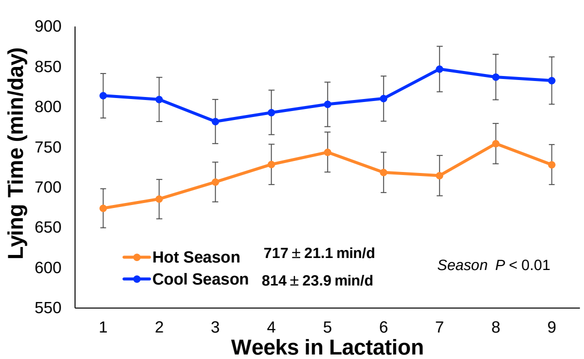
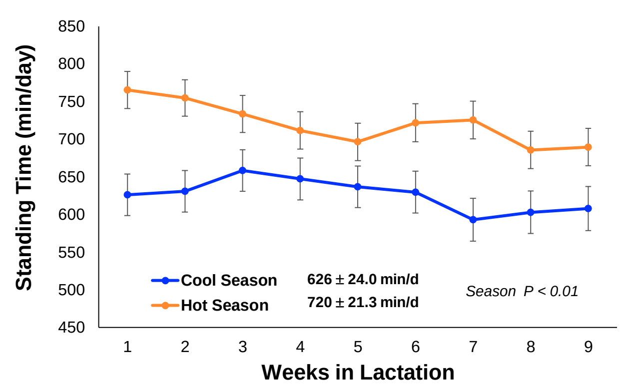
Lying Time and Standing Time During the Cool and Hot Seasons





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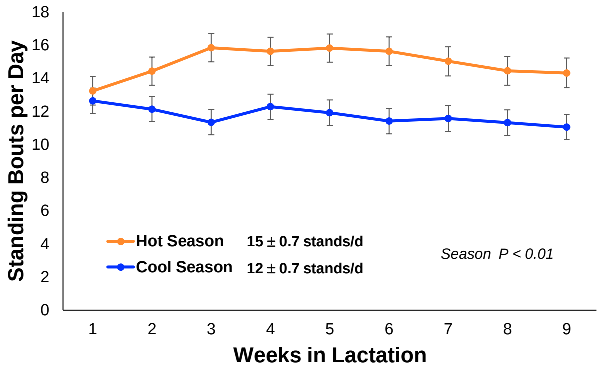
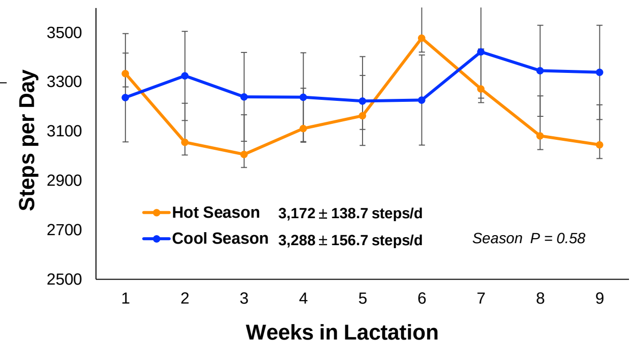
Standing Bouts and Standing Time per Day During the Cool and Hot Seasons





43

Summary

- Seasonal changes affect milk production of multiparous dairy cows.
- Exposure to heat during lactation seems to negatively affect the behavior and the daily time budget of lactating Holstein cows even in free-stall facilities with active cooling.
- A better understanding on how different seasons affect the daily time budget of lactating dairy cows may contribute to the development of more effective management strategies to decrease the negative effects of heat exposure.

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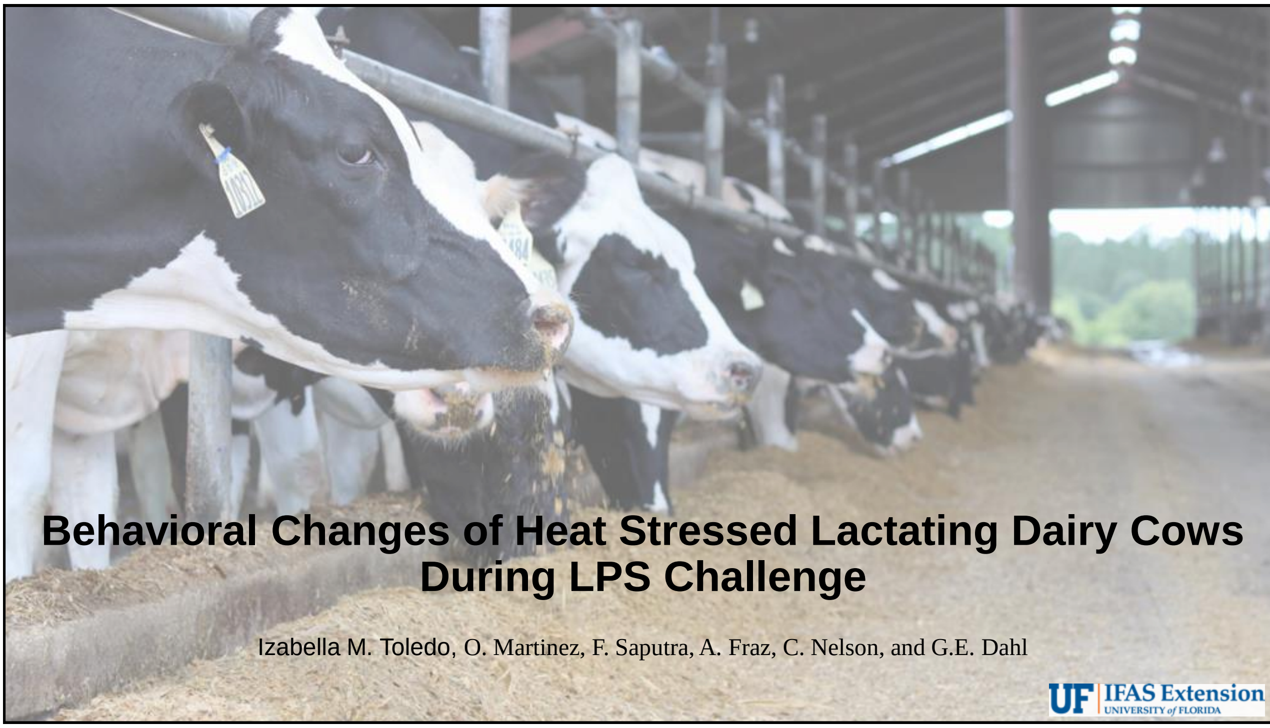

Behavioral Changes of Heat Stressed Lactating Dairy Cows During LPS Challenge

Izabella M. Toledo, O. Martinez, F. Saputra, A. Fraz, C. Nelson, and G.E. Dahl

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Hypothesis Heat stress will affect the behavior of multiparous lactating dairy cows challenged with LPS.

46

Objective

To have a better understanding of how the development of intramammary infections affect the behavior of lactating dairy cows in heat stress conditions .

47

Design and Management

- 12 multiparous lactating Holstein cows
- Sand bedded free stalls
- **Temperature and Humidity Index,** was assessed during the entire study period

Cool Treatment (n=6)

Heat Stress Treatment (n=6)

Shade

Fans over stalls
Fans on at 70º F (21.1ºC)

Soakers over feedline
Soakers on for 1 min every 5 min at 72º F (22.2ºC)

Shade

48

Design and Management

LPS Challenge

Left Front Quarter
(10mL of LPS 5mg/mL +
sterile saline solution)

Heat Stress Treatment

Cool Treatment

4 Weeks

Day -2 **Day -1** **Day 0** **Day 1** **Day 2**

Behavior Data Collection

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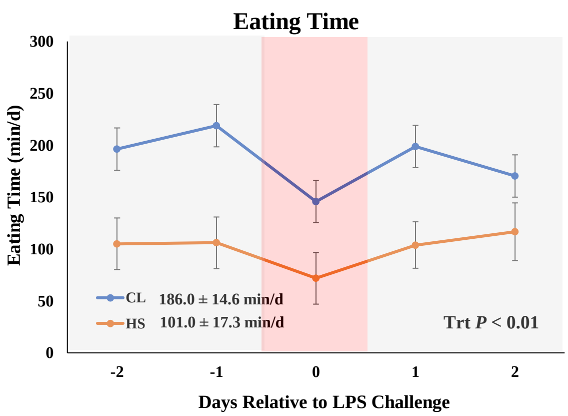
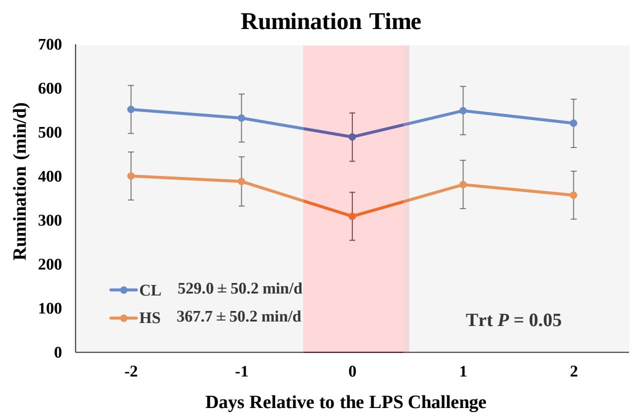
Heat Stress Affects Eating and Rumination Pre, During and Post LPS Challenge





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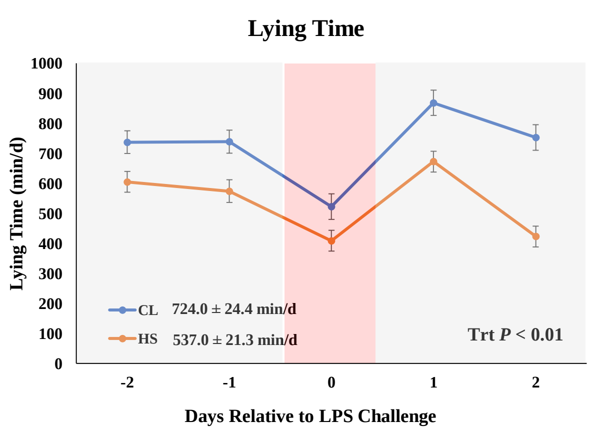
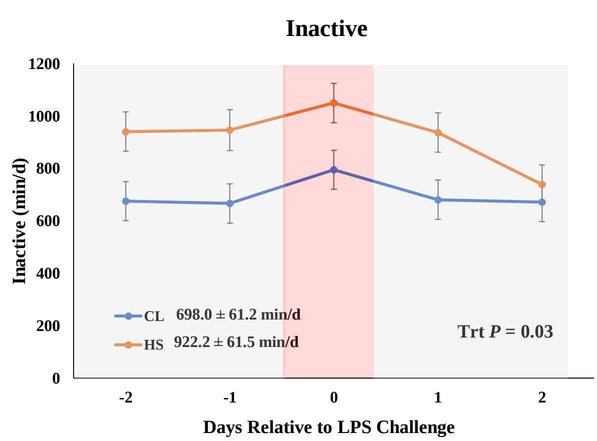
Heat Stress Affects Lying and Inactivity Pre, During and Post LPS Challenge





52

Heat Stress Does Not Affect Standing Bouts and Steps per Day

Behavior Activity	Cooled Cows	Heat Stressed Cows	*P*-value
Standing Bouts	13.5 ± 0.77	13 ± 0.65	0.61
Steps per Day	2,716 ± 142	2,524 ± 123	0.33

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Summary

- Exposure to heat affects the behavior of lactating dairy cows.
- Heat stress affects behavior of lactating dairy cows independently of the development of intramammary infections.
- Heat stress effects on behavior is not a good parameter to be used to monitor the development of intramammary infections.

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Take Home Message

- Exposure to heat stress affects the behavior of dairy cows at different stages of the lactation cycle
- Exposure to heat during lactation negatively affect the behavior and the daily time budget of lactating Holstein cows even in free-stall facilities with active cooling.
- Insights onto heat stress effects in the daily time budget of dairy cows during different seasons and stages of the lactation cycle may contribute to the development of more effective management strategies to decrease the possible negative effects of heat exposure.

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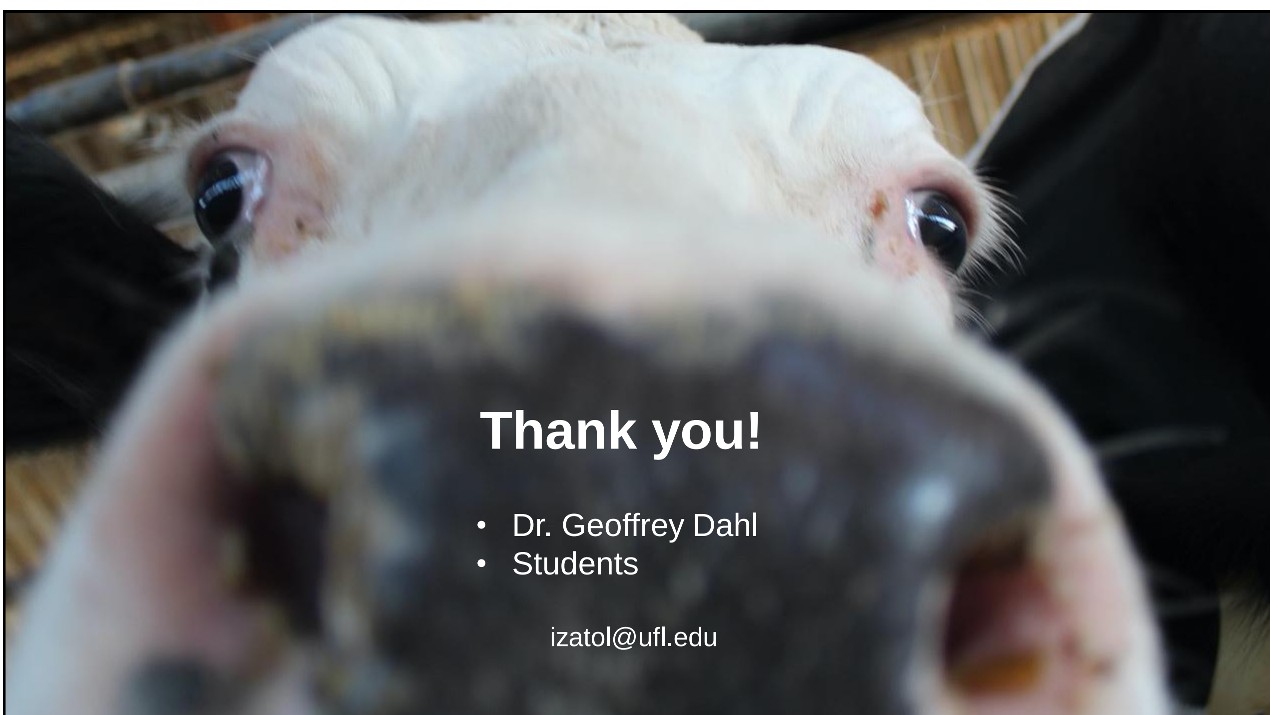

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Florida Ruminant Nutrition Symposium
February 27th, 2024

What a multibreed herd taught us about the influence of *B. indicus* genetics on dam reproduction and calf weaning weight

Cecilia Constantino Rocha, DVM, Msc.
Thiago Martins, DVM, PhD. University of Missouri
Mario Binelli, PhD. University of Florida

University of Florida Brahman Cattle

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Florida Cattlemen's Association

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1

Journal of Animal Science, 2022, **100**, 1–11
https://doi.org/10.1093/jas/skac366
Advance access publication 4 November 2022
Reproduction

OXFORD

AMERICAN SOCIETY OF ANIMAL SCIENCE

What a 31-yr multibreed herd taught us about the influence of *B. indicus* genetics on reproductive performance of cows

Thiago Martins[†,‡,1], Cecilia C. Rocha[†,1], Joseph Danny Driver[†], Owen Rae[§], Mauricio A. Elzo[†,2], Raluca G. Mateescu[†], Jose Eduardo P. Santos[†], Mario Binelli[†,3]

[†]Department of Animal Sciences and D.H. Barron Reproductive and Perinatal Biology Research Program, University of Florida, Gainesville, Florida, USA
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[§]Department of Large Animal Clinical Sciences, University of Florida, Gainesville, Florida, USA
[1]These authors contributed equally to this study.
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[3]Corresponding author: mario.binelli@ufl.edu

Intermediate proportion of *B. indicus* genetics favors the productivity of crossbred beef cows reared in subtropical conditions

Thiago Martins[a], Cecília Constantino Rocha[b], Joseph Danny Driver[b], Owen Rae[c], Mauricio Aguirre Elzo[b,*], Raluca G. Mateescu[b], José Eduardo Portela Santos[b], Mario Binelli[b,**]

Under review, Translational Animal Science

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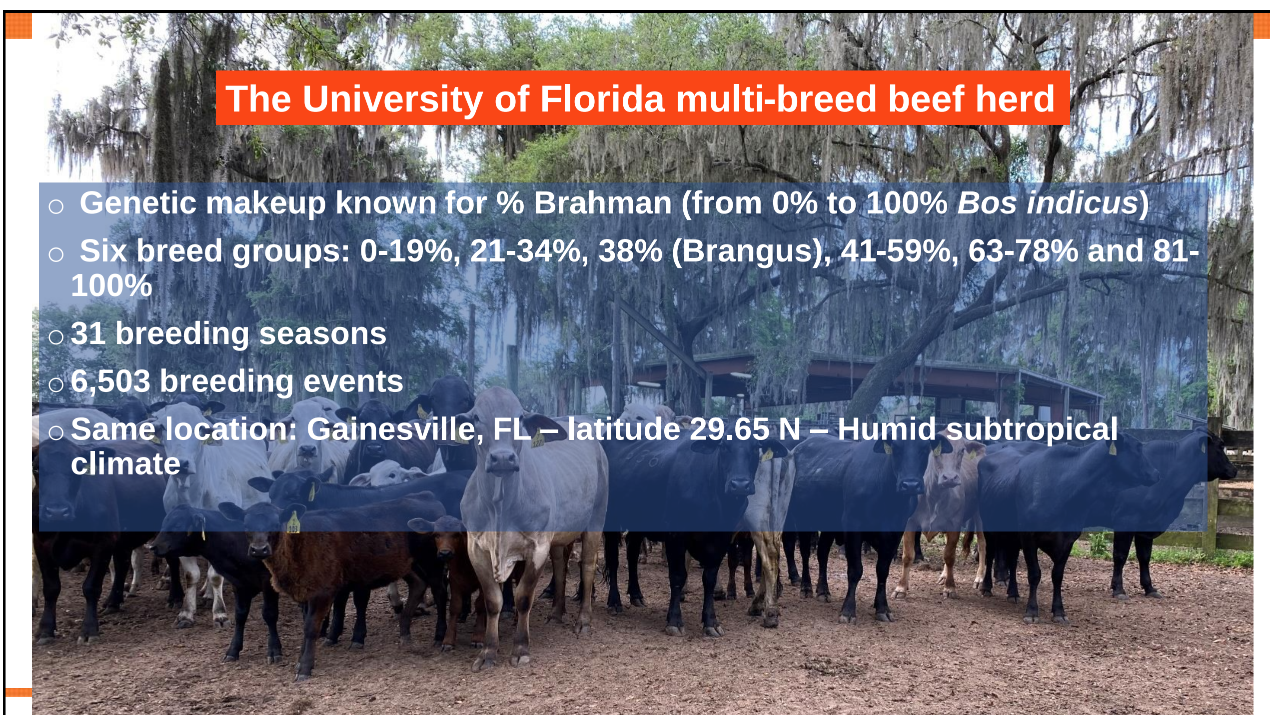
The University of Florida multi-breed beef herd

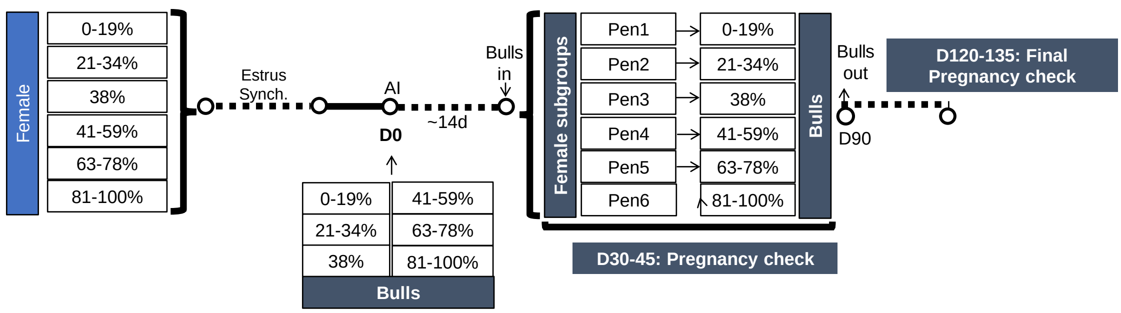
3


The University of Florida multi-breed beef herd
○ Genetic makeup known for % Brahman (from 0% to 100% *Bos indicus*)
○ Six breed groups: 0-19%, 21-34%, 38% (Brangus), 41-59%, 63-78% and 81-100%
○ 31 breeding seasons
○ 6,503 breeding events
○ Same location: Gainesville, FL – latitude 29.65 N – Humid subtropical climate

4

Reproductive management

- Diallel crossbreeding scheme



5

Productivity of a cow-calf operation

$$Productivity = \frac{Pounds\ of\ calf\ weaned}{Number\ of\ cows\ exposed}$$

6

Calendar of activities in a cow-calf operation system

Breeding season

Cows and Heifers

Month 1 Month 2 Month 3

Breeding season → 5 months → Calving season (Month 1 Month 2 Month 3 Month 4) → 8 months → Weaning (Day)


Early


Late

Stocker- Feedlot

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7

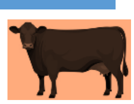
Performance in the breeding season

Cows and Heifers

Month 1 Month 2 Month 3

Breeding season


Early


Late

- Response to estrous synchronization protocol
- Pregnancy by artificial insemination
- Pregnancy at the end of the breeding season

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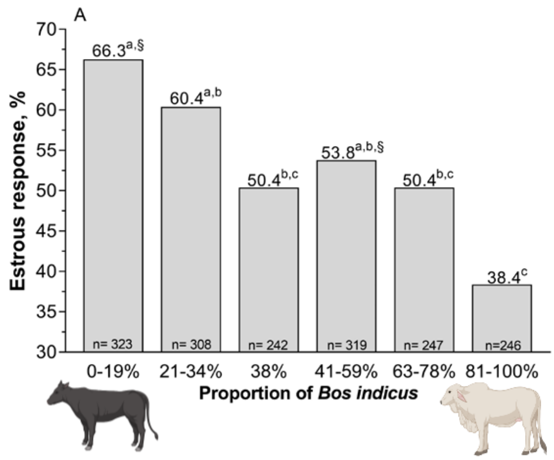
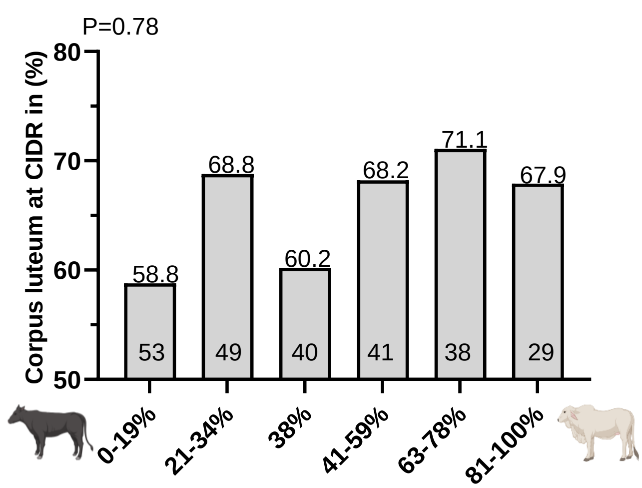
8

Probability of estrus response to synchronization protocol decreases as the *Bos indicus* proportion increases



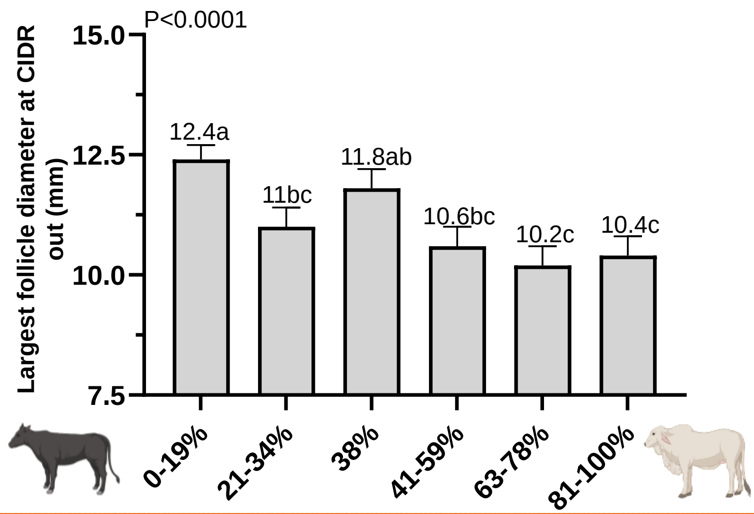
9

Cyclicity at the beginning of the synchronization protocol was similar across *Bos indicus* proportions



10

The diameter of the largest follicle at CIDR removal decreases when the *Bos indicus* proportion increases



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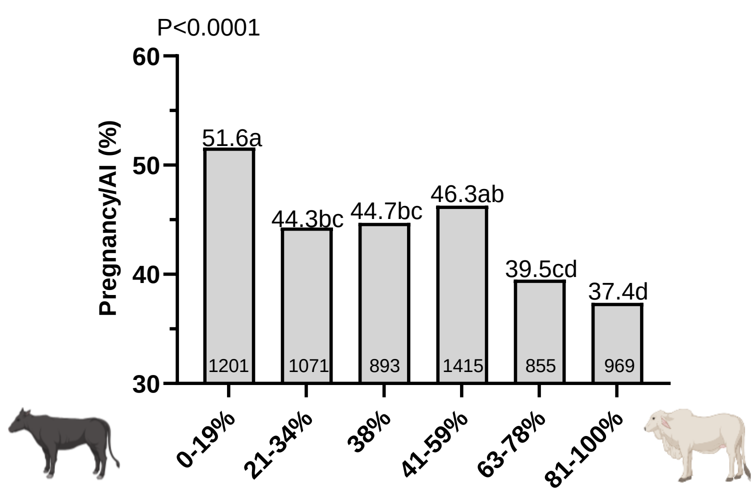
11

Pregnancy by AI is negatively associated with the proportion of *Bos indicus*



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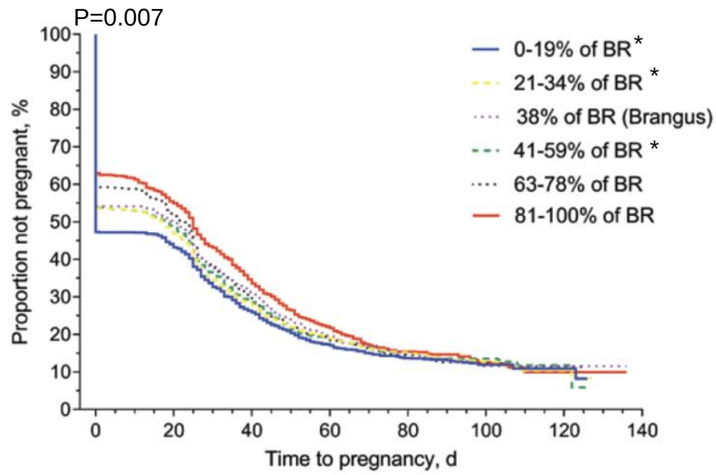
12

Cows with greater proportion of *Bos indicus* take longer to get pregnant in the breeding season



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13

Performance in the calving season

- Average days to calving in the calving season
- Gestation length

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14

The average days to calving in the calving season was longer in cows with greater proportion of *Bos indicus*

Table 1. Association between the proportion of *Bos indicus* genetics of cows and rate of calving in the calving season.

Item	Proportion of *B. indicus* genetics (groups)						*P*-value
	0-19%	21-34%	38% (Brangus)	41-59%	63-78%	81-100%	
Females, no.	1,180	1,039	876	1,395	848	974	.
Rate of calving[1]							.
AHR (95% CI)[2]	1.69* (1.54-1.86)	1.49* (1.35-1.64)	1.44* (1.30-1.59)	1.48* (1.35-1.62)	1.39* (1.26-1.54)	1.0 (reference)	< 0.0001
Days to calving							
Mean ± SEM	52.3 ± 1.2	59.0 ± 1.4	57.6 ± 1.4	57.3 ± 1.1	60.3 ± 1.4	78.0 ± 1.6	.
Median (95% CI)	38 (36-41)	47 (42-50)	48 (44-51)	47 (45-49)	50 (47-53)	68 (64-71)	.

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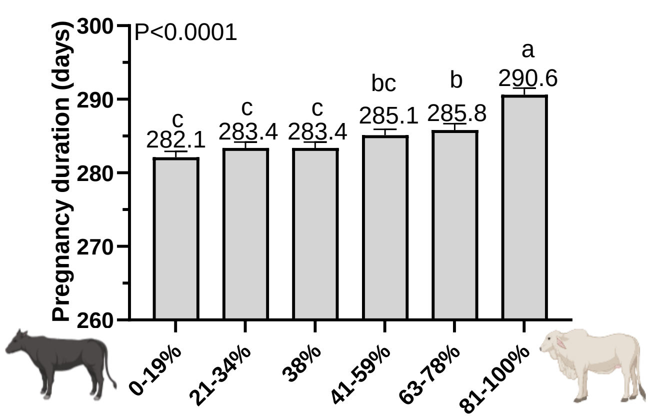
The average pregnancy duration is longer in cows with greater proportion of *Bos indicus*



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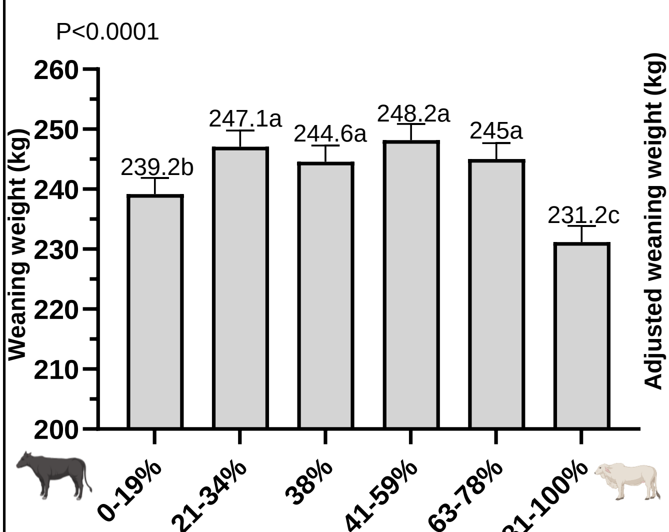
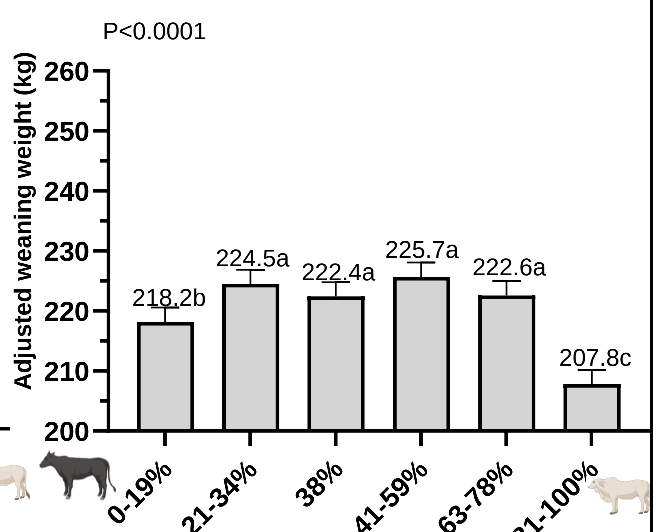
16

Performance at weaning

17

Weaning weight is lighter when the proportion of *Bos indicus* increases

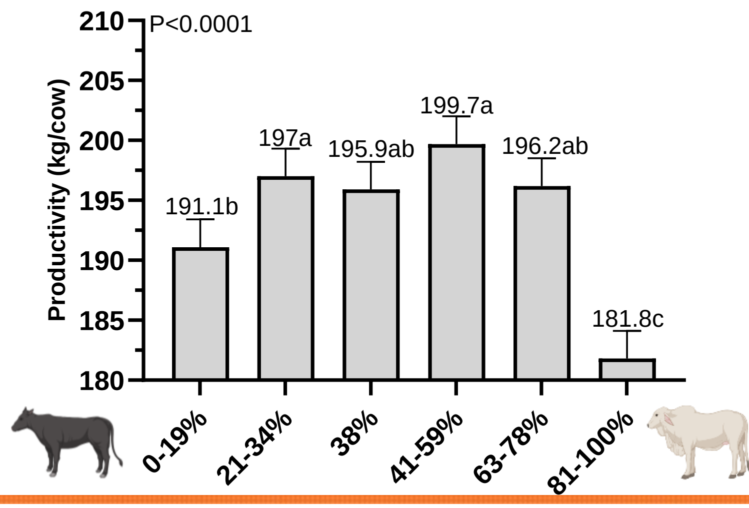




18

Productivity of a cow-calf operation

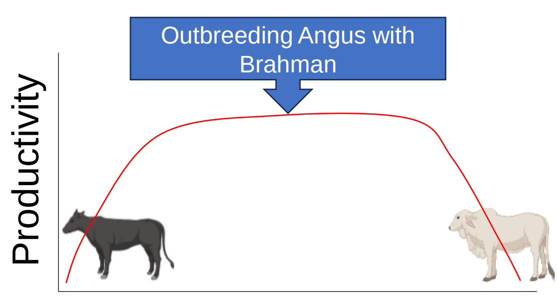
$$Productivity = \frac{Pounds\ of\ calf\ weaned}{Number\ of\ cows\ exposed}$$



19

Conclusions

- Greater Brahman (*Bos indicus*) genetics = less estrus to protocol = lower P/AI + longer gestation = longer days to calving.



20

Acknowledgements

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  - Mackenzie Mazziota
  - Andrey Cordeiro
  - Mariangela Maldonado
  - Abdul Waheed
  - Jessica Marsh
  - Ashley Bloomfield
  - Fernando Mesquita
  - Gabriela Lomba
  - Gabriella Marinho

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- Ana Montevecchio
- Luana Factor
- Philip Peixoto
- Tomas Gonzalez
- Alejandro Ojeda

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  - Tatiane Maia
  - Lane Haimon
  - Masroor Sagheer
  - Quinn Hoorn
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  - Gabriel Zayas
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  - Jesse Savell
  - Audy Spell
  - Brian
- Agronomy

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- Dr. Ky Pohler (TAMU)
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- Dr. Owen Rae

21

Feed Saved, a Novel Trait for Selection in Dairy Cattle

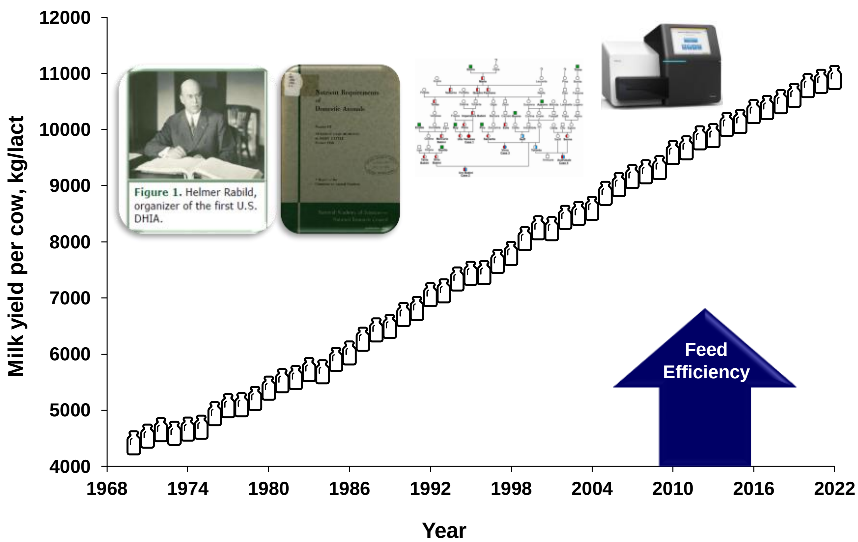
Mariana Nehme Marinho

University of Florida

Advisor: Dr. José E.P. Santos

1

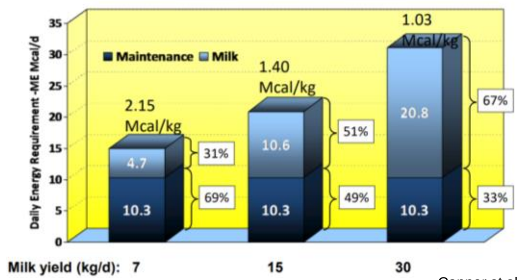
Milk Production Over the Years



USDA-ERS, 2023

2

Feed Efficiency Over the Years



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

Born 1967 **9,800 lb/lactation**

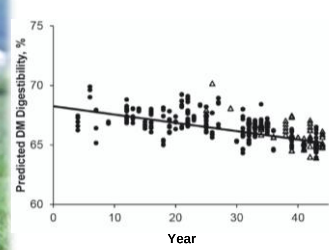
Larger

Greater intake

24,000 lb/lactation **Born 2018**

3

Greater Productivity, Larger Cows, Increased Intake…



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

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

4

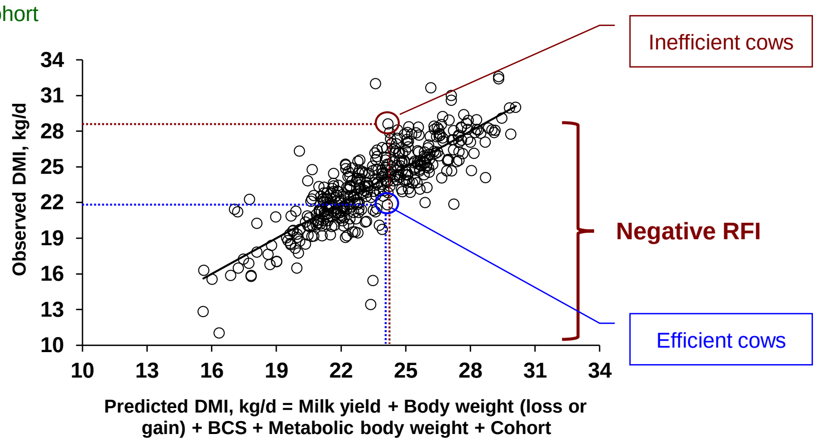
How Can we Improve Feed Efficiency?

- ✓ 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

5

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

6

Why Selection for RFI is Promising?

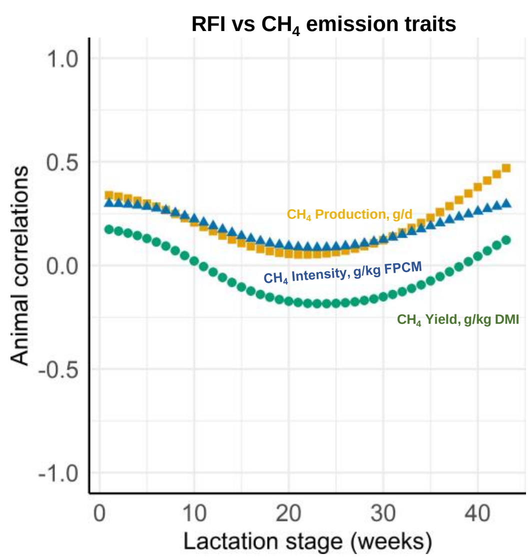
Feed represents more than 50% of total costs in a dairy farm (USDA, 2023)

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

7

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

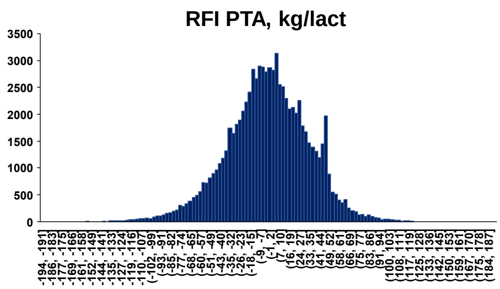


Fresco et al. (2024) *Animal:* 101110

8

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**

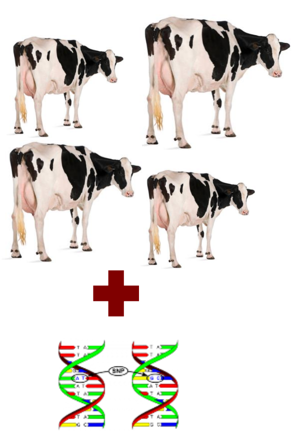
Trait	Heritability
Milk	0.20
Fat	0.20
Productive life	0.08
SCS	0.12
Udder composite	0.27
BW composite	0.40
Cow conception rate	0.02
Daughter pregnancy rate	0.04
Mastitis	0.031

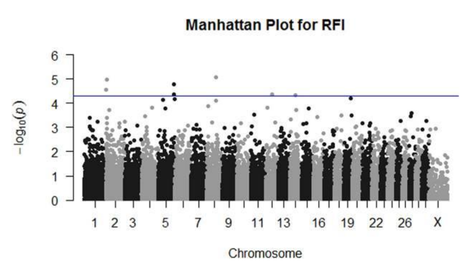
VanRaden et al. (2021); USDA AIPL report

Problem: Low Reliability

9

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

10

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:**
- ✓$\boldsymbol{PTA\ FS} = -1(PTA\ RFI) - 151.8\ (PTA\ \mathrm{BWC})$
  - ✓**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

11

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.

Ecofeed cow | A2A2 | Ultra Fertility | PROVEN

04/2023	CDCB SUMMARY GENOMIC				NM$ +1046
Milk	+1919	99%R	Cheese Merit $		+1053
Fat	+64	-0.03%	FM$ +991	GM$	+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		

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

☆

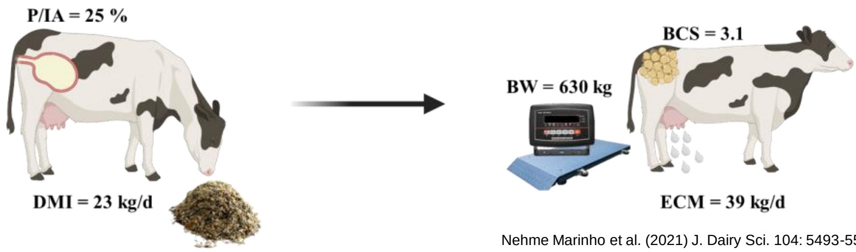
Sire: Mr Detour High Noon-ET TL TV TD
Dam: Ms Delicious Jedi 35127-ET

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

12

Is it Safe to Select for Negative RFI?

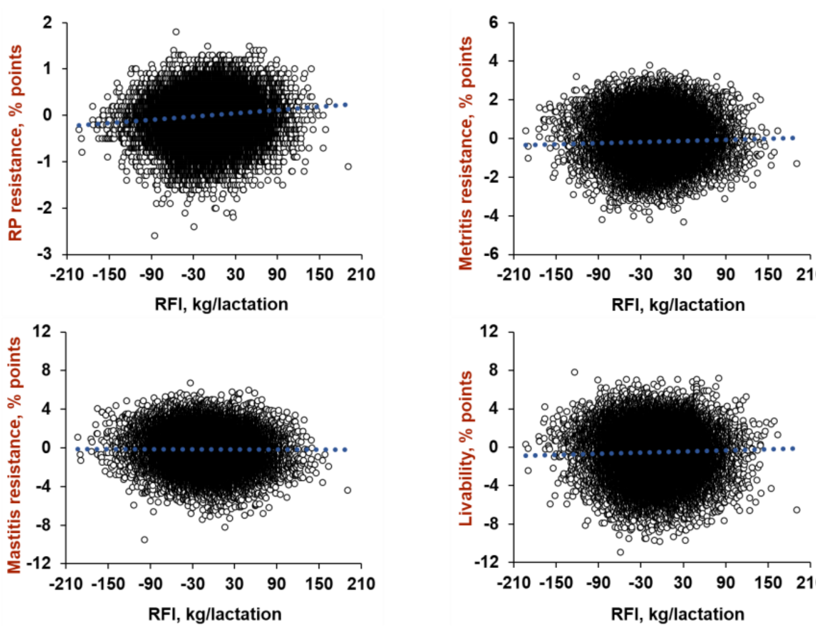
✓ More efficient Holstein cows had reduced dry matter intake with no associated detrimental impacts on health, production and reproduction



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

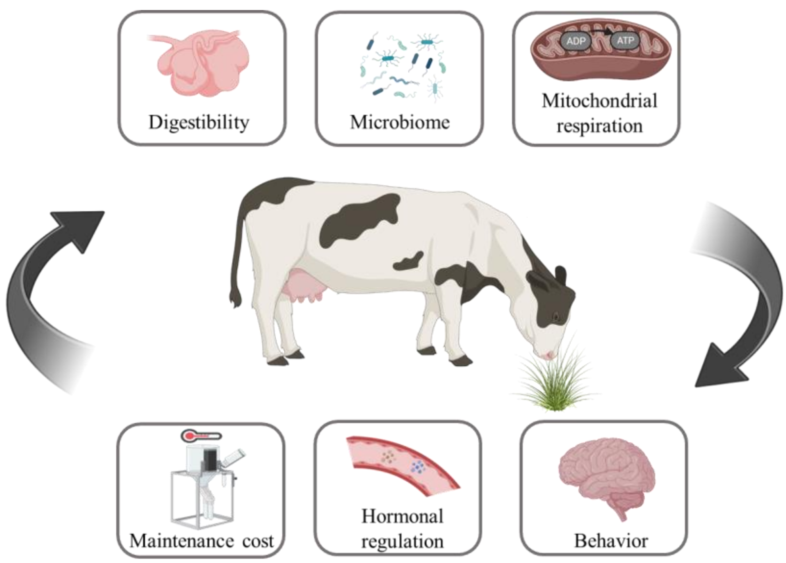
13

Is it Safe to Select for Negative RFI?



14

What Makes a Cow More Efficient?



Nehme Marinho et al. (2024) in preparation

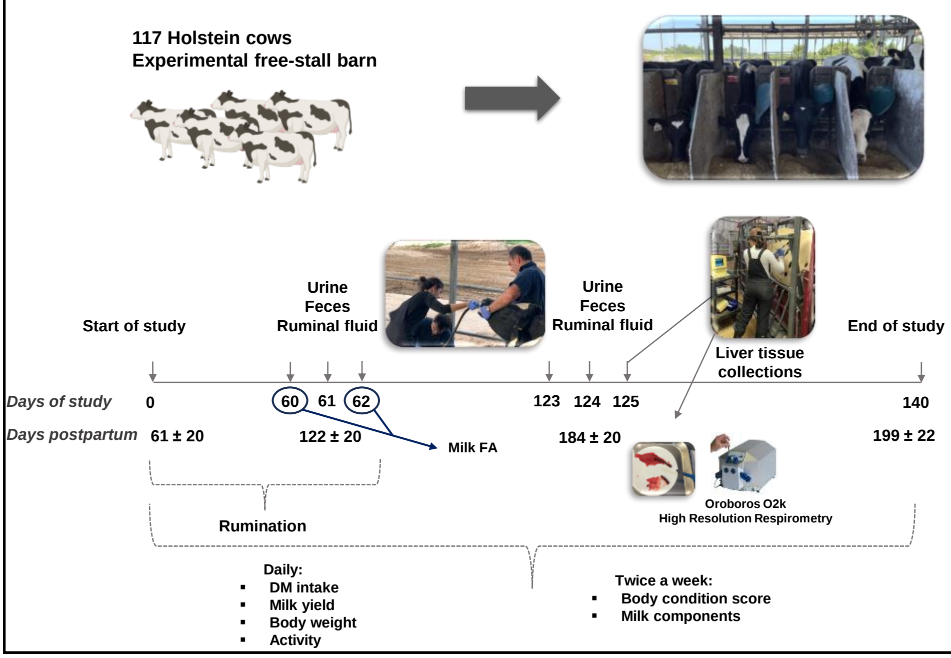
15

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

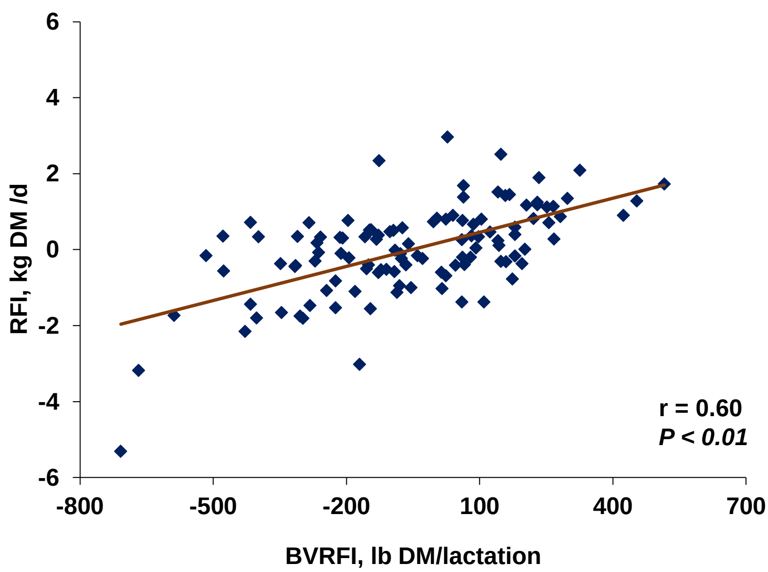
16

Methods



17

Phenotypic and Genomic RFI Correlation



Nehme Marinho et al. (2024) in preparation

18

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

Nehme Marinho et al. (2024) in preparation

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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

Nehme Marinho et al. (2024) in preparation

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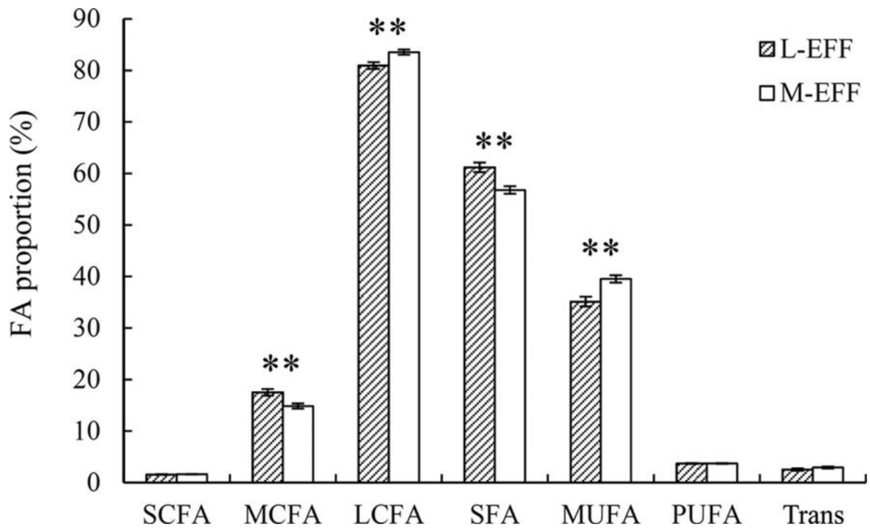
Milk Fatty Acids Profile Changed According to RFI



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

21

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

22

Relationship between RFI and Behavior Traits

	Feed Efficiency					
Item	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

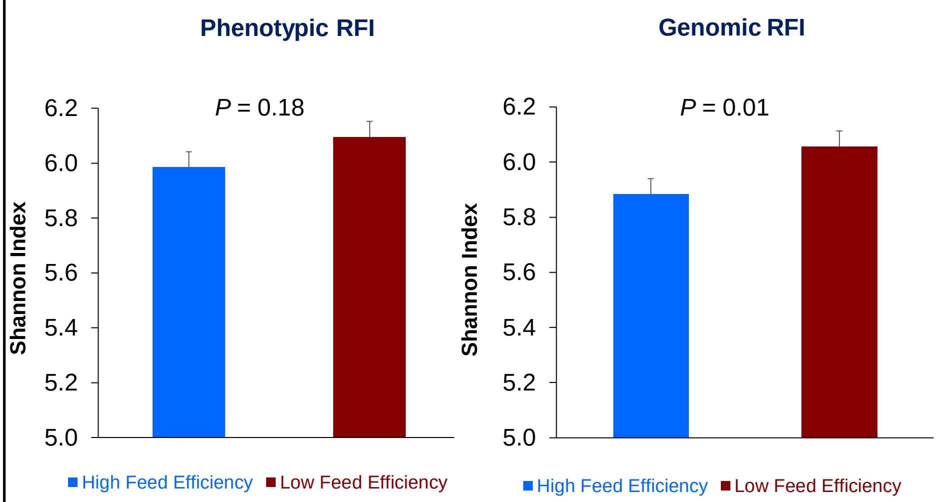
	Feed Efficiency					
Item	Q1	Q2	Q3	Q4	SEM	P-value
pH	6.2	6.2	6.4	6.3	0.1	0.06¶
Acetate, *mmol/L*	71.1	70.3	71.1	70.1	1.0	0.83
Propionate, *mmol/L*	26.1	26.1	26.8	25.6	0.7	0.58
Butyrate, *mmol/L*	16.0	15.0	15.5	15.3	0.4	0.25
Total VFA, *mmol/L*	118.6	116.5	118.8	116.2	1.4	0.49
Ammonia N, mg/dL	10.0	9.3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

§ Linear Effect
¶ Cubic Effect

Nehme Marinho et al. (2024) in preparation

24

Relationship Between RFI and Rumen Microbiome



Nehme Marinho et al. (2024) in preparation

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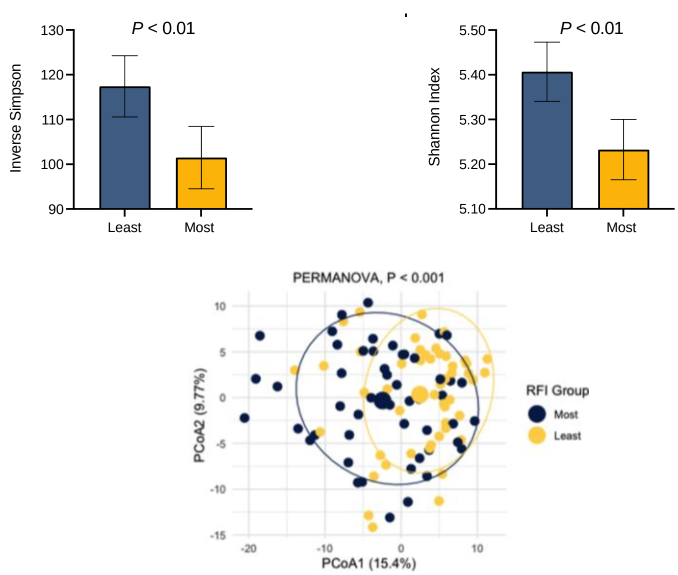
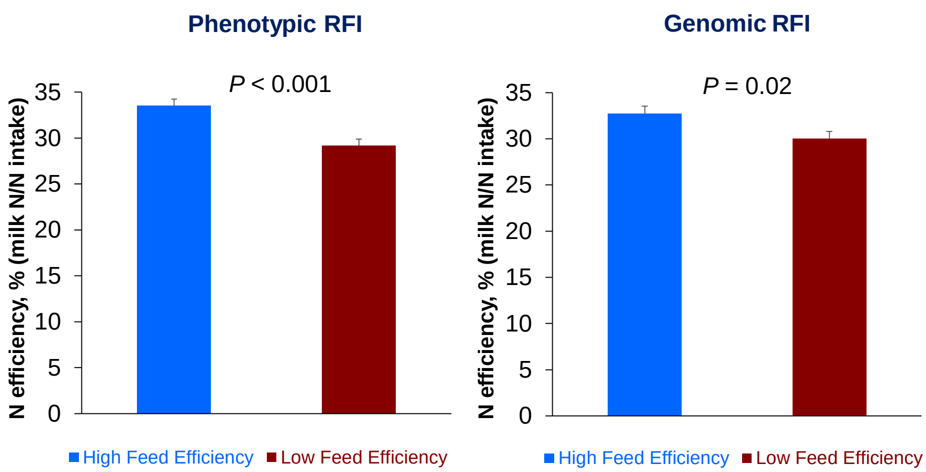
Relationship Between RFI and Rumen Microbiome



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

26

Relationship Between RFI and N Efficiency



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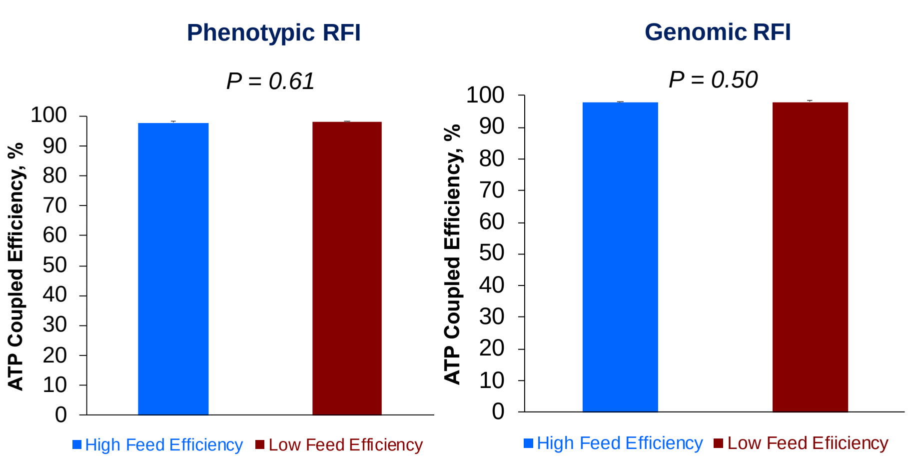
Relationship Between RFI and Hepatic Mitochondrial Respiration



Nehme Marinho et al. (2024) in preparation

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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

29

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- ✓Bruna S. Simões
- ✓Jessica Prim

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DAIRY SCIENCE RESEARCH

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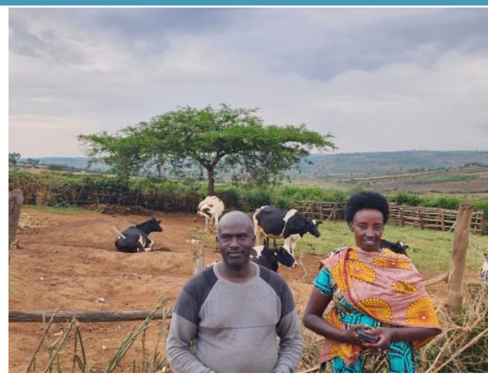

Importance of Animal Products In The Human Diet:

The experience of working in developing communities to improve livestock production

Gbola Adesogan
Department of Animal Sciences | Global Food Systems Institute |
Feed the Future Innovation Lab for Livestock Systems, University of Florida

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1

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OUTLINE

- Importance of livestock in developing countries
- Potential of ASF to address hidden hunger
- Effects of ASF on nutritional status, growth, and cognitive development
- Barriers to ASF consumption
- Conclusions

2

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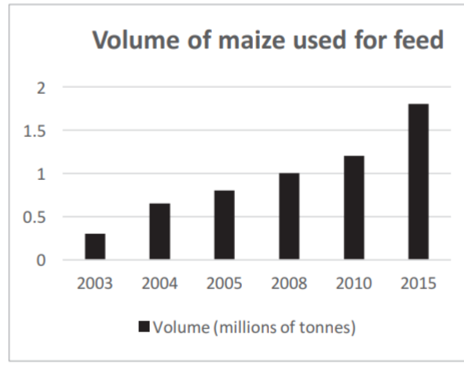
LIVESTOCK FOR LIFE IN LMICS

- Livestock support livelihoods of over 1 billion people
- Up to 80% of the population in some LMIC (1/3 of Africans) depend on livestock for livelihoods
- Livestock account for 40% of agricultural GDP on average
- As populations and incomes grow, demand for ASF grows

e.g., 600% poultry feed sector growth in Nigeria in 10 years due to growth in poultry production

Nigerian livestock sector



(GFC-UCDavis- FAO; AU-IBER, 2016; Liverpool-Tassie et al., 2016; LD4D, 2018; FAO, 2021; Berhanu, 2021)

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SOCIOCULTURAL SIGNIFICANCE

- Status symbol
- Religious veneration
- Ceremonial gifts
- Conflicts/wars

(Swanepoel et al., 2010)

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LIVESTOCK MANURE, A VERSATILE RESOURCE IN LMICS

- Manure is used as a fertilizer, cooking fuel and a building material in many parts of Asia and Africa
- Manure building blocks are being tested in The Netherlands; may reduce emissions by >30%.

(Christiaensen and Heltberg, 2012)

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NUTRIENT UPCYCLING AND CROP PRODUCTIVITY

- Crop residues/ marginal pastures dominate ruminant diets in LMIC
- Livestock upcycle poor quality forage into nutrient-dense products and manure
- Rwanda **GIRINKA** Project
  - More than 130,000 cows distributed
  - Increased household income
  - Crop yields increased (by up to 100%)
  - Contributed to a decrease in stunting (44% in 2012 to 32% today)

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DRAFT ANIMAL POWER

- Provided **traction for ~ 50%** of the world's farmers in 2009 (World Bank)
- Accounted for 25% of the total energy requirement for farming
- May foster less GHG emissions and non-renewable energy use vs. machinery
- Ideal for marginal lands particularly in rural areas

(Mota Rojas et al., 2021; FAO 1982; Sims and O'Neil, 2003)

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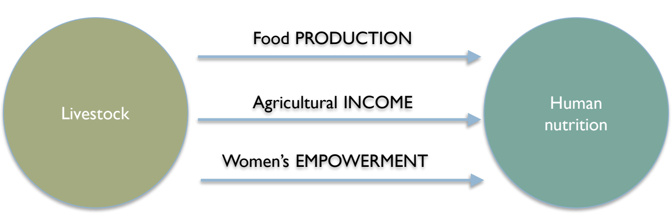
EMPOWERMENT OF WOMEN/YOUTH

- Are the only assets owned by many women in LMIC
- Determine if nourishing diets are fed
- Opportunity for youth employment



In Nepal: Distance learning increased community health worker training completion rate from by 80%

(Mullally et al., 2020)

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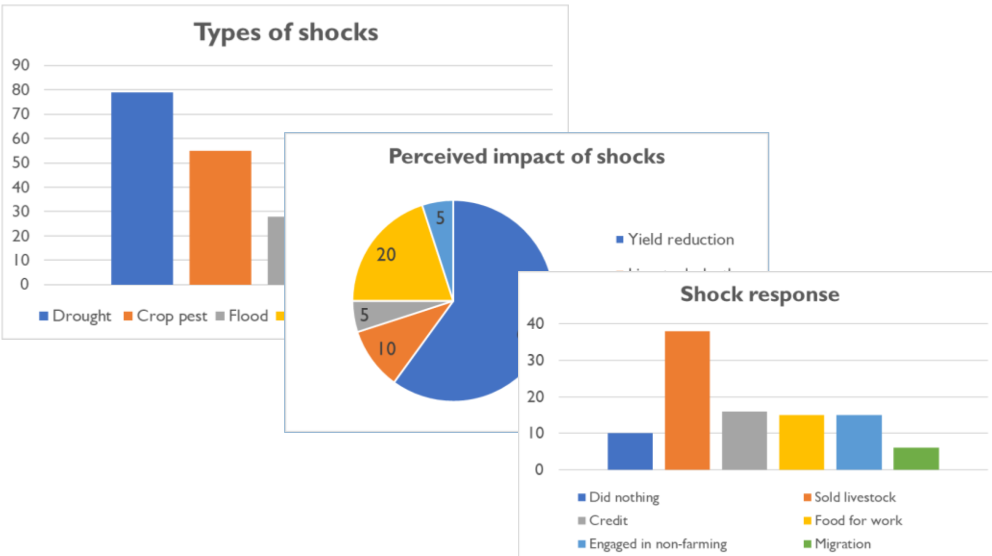
IMPROVING RESILIENCE (HARARGE ZONE, ETHIOPIA)



(Zeleke et al., 2021)

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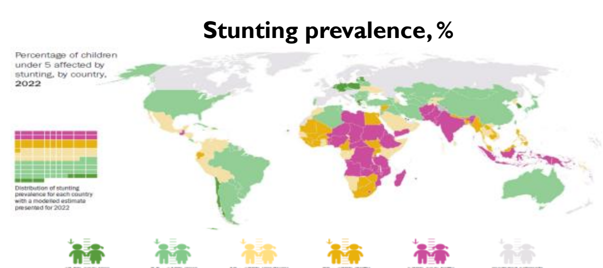
GLOBAL PREVALENCE OF UNDERNUTRITION

- Over 3 billion people cannot afford a healthy diet;
- 800 million are regularly hungry.
- 144 million children under 5 have stunted growth and cognition;
- 39 million are overweight.
- 45 million suffer from wasting, the deadliest form of malnutrition.



UNICEF/WHO/World Bank Group, 2023

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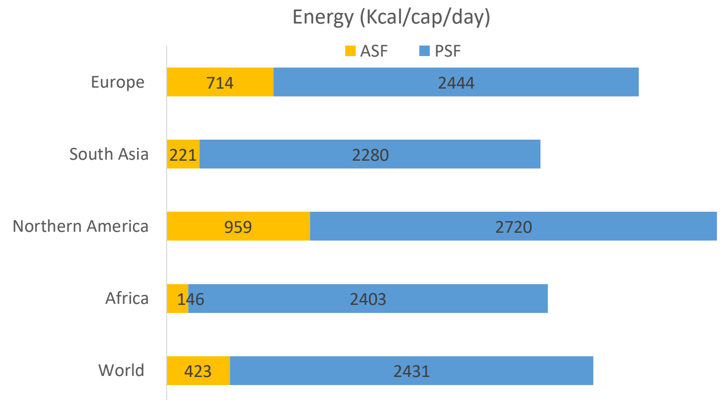
GLOBAL PLANT (PSF) VS. ANIMAL (ASF)-SOURCED FOOD CONSUMPTION



Hidden hunger is prevalent in the developing world, where most people are vegetarian (not by choice)

(FAO, 2021)

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FOOD TYPES AVAILABLE FOR GLOBAL CONSUMPTION

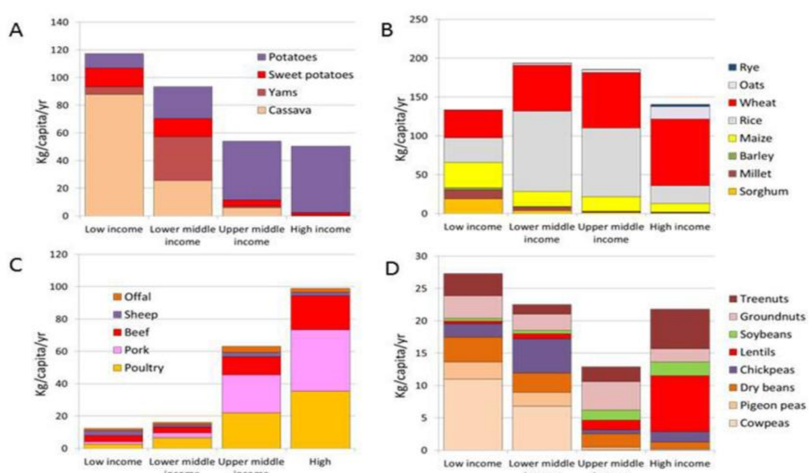

FIGURE 1. Roots and tubers (A), cereals (B), meats (C), and beans, pulses, legumes, and nuts (D) in kg/capita/year available for global human consumption. Data are FAOSTAT 2019–2020 by World Bank country categories by gross domestic product (GDP).

(Drewnoski, 2024; FAOSTAT, 2020, World bank)

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STARK DIFFERENCES IN GLOBAL MILK CONSUMPTION BY REGION/ COUNTRY (kg per person /year)

1	<30	30 to 150	>150	>300
DR Congo	Most of sub-Saharan Africa & East & Southeast Asia	India, Iran, Japan, Kenya, Mexico, Mongolia, New Zealand, North and Southern Africa, most of the Near East, Latin America and the Caribbean	Argentina, Armenia, Australia, Costa Rica, Europe, Israel, Kyrgyzstan, North America, and Pakistan	Sweden Finland

(Adapted from FAO, 2019)

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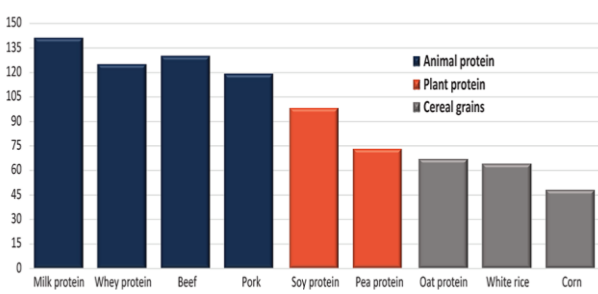
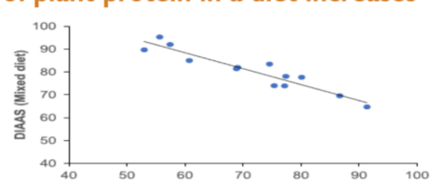
DIGESTIBLE AMINO ACID SCORE OF DIFFERENT FOOD ITEMS



DIASS decreases as the proportion of plant protein in a diet increases



(Bailey and Stein, 2019; Moughan 2021)

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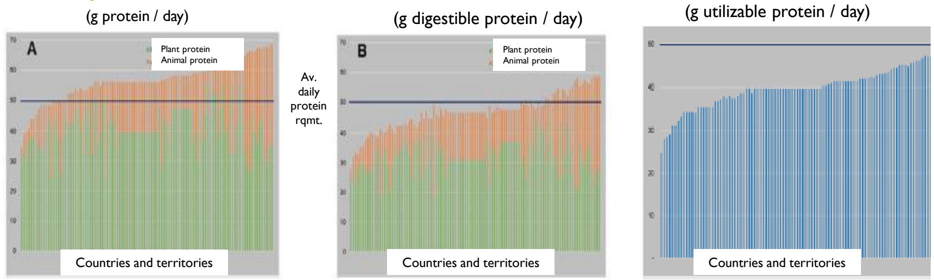
DEFFICIENCY OF QUALITY PROTEIN IN DIETS IN LMICS

Average per capita protein consumption in 103 LMICs
(g protein / day)

Corrected for protein digestibility
(g digestible protein / day)

Corrected for protein utilizability
(g utilizable protein / day)



Moughan (2021)

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Animal-Source Foods: Bioavailable Nutrient Cluster and Undernutrition Solution

- Superior-quality (ideal) protein
- Higher energy density
- Higher nutrient density and bioavailability

Nutrient	Advantage vs. plant-source food
Protein	Higher quality/complete
Iron	Only dietary source of bioavailable haem
Zinc	More bioavailable
Calcium	More bioavailable
Vitamin B12	Only dietary source
Vitamin A	Only preformed source (retinol); more bioavailable
Vitamin D3	Only dietary source; more active and bioavailable than D2
Choline	Main dietary source
EPA and DHA	Main dietary source
Thiamin, riboflavin, Vitamin B6	

Allen et al., 2019; Beal et al., 2020

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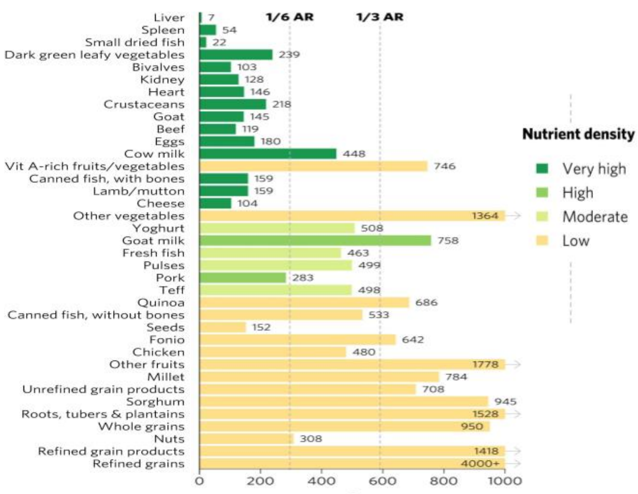
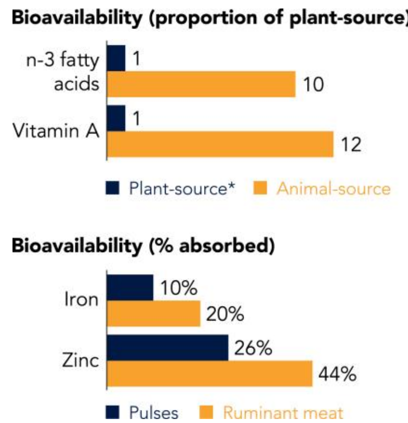
FOOD AMOUNTS THAT GIVE 1/3 OF RECOMMENDED INTAKES (AR) OF KEY MICRONUTRIENTS IN WOMEN OF REPRODUCTIVE AGE

(Vit. A, folate, vit. B12, Ca, Fe, Zn)





(Beal T. and Ortenzi F. 2022)

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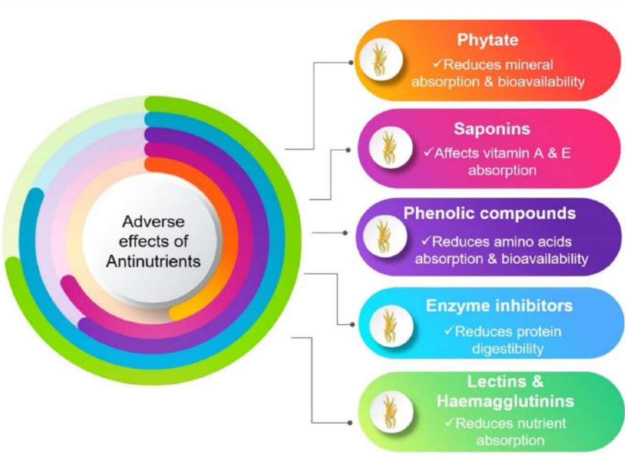
PLANT ANTINUTRIENTS



Legumes, nuts, seeds

Vegetables, legumes, nuts

Fruits, vegetables grains, legumes, nuts

Legumes, nuts

Grains, legumes, nuts

(Tharifkhan et al., 2021; Commerford et al., 2021)

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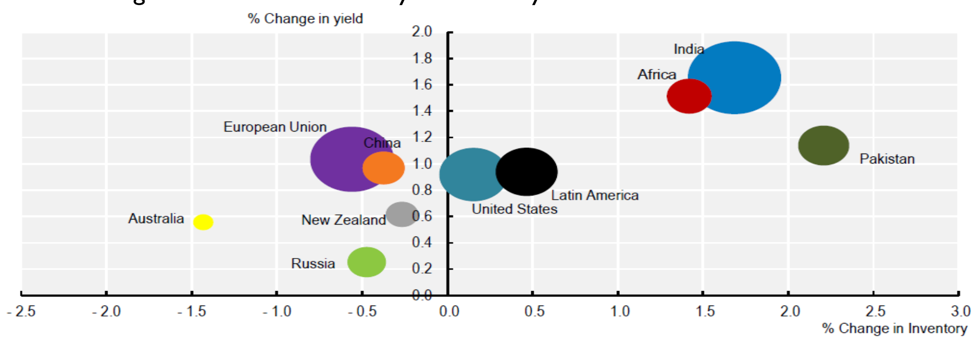
GLOBAL MILK PRODUCTION GROWTH BY REGION

Annual changes in inventories of dairy herds and yields between 2021 and 2031



Bubble size indicates yield in the base period 2019-21.

(Wyrzykowski et al., 2018)

(OECD/FAO, 2022)

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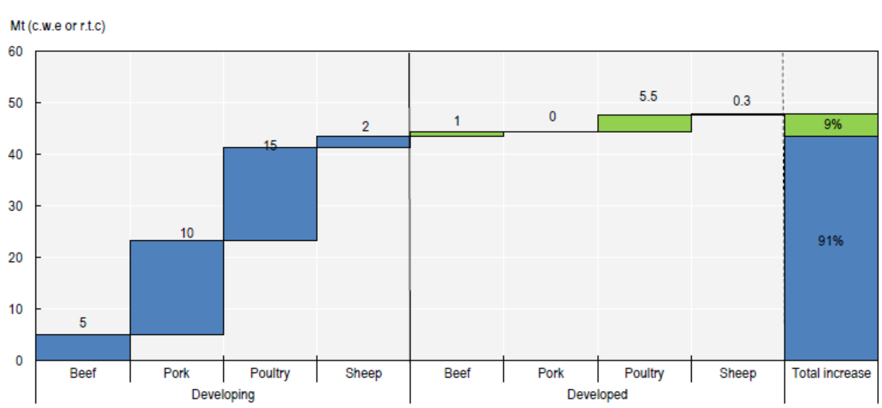
GROWTH OF MEAT PRODUCTION BY REGION AND TYPE

2031 vs 2019-21



Note: c.w.e. is carcass weight equivalent, r.t.c. is ready to cook equivalent.

(OECD/FAO, 2022)

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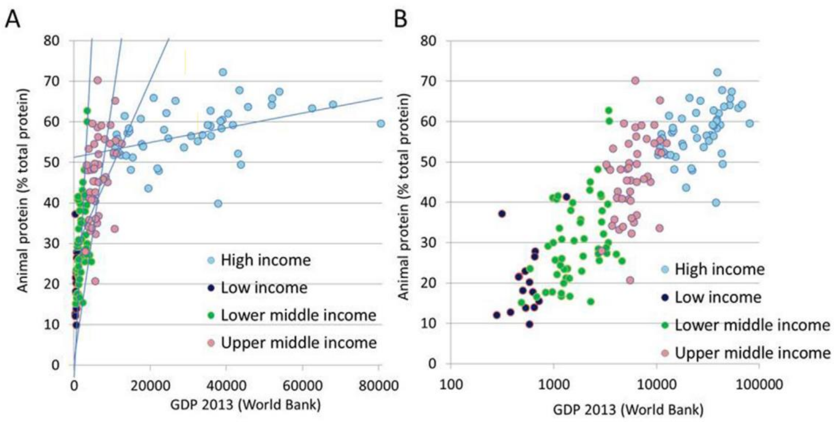
ANIMAL PROTEIN CONSUMPTION RELATIVE TO GDP ACROSS COUNTRY INCOME LEVELS



(Drewnoski, 2024; FAOSTAT, 2013, World bank)

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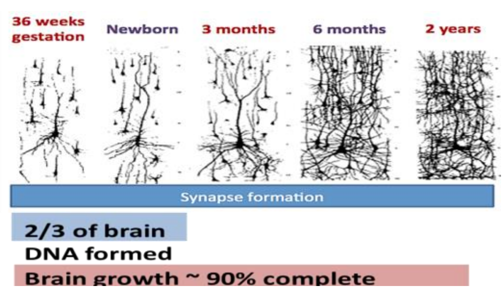
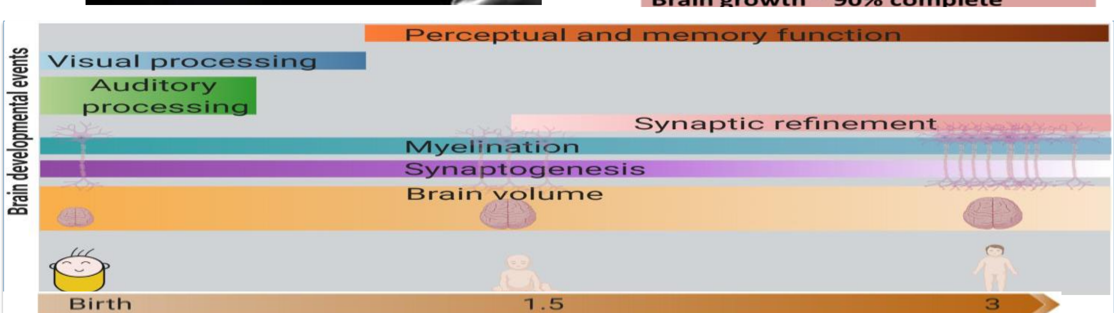
BRAIN DEVELOPMENT EVENTS





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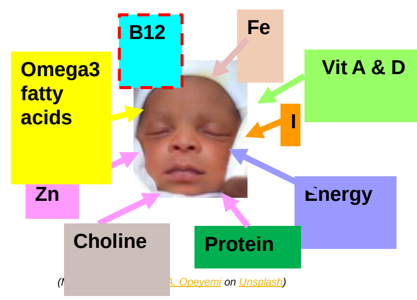
NUTRIENTS AFFECTING BRAIN DEVELOPMENT

Macro
Protein
Glucose
Fats (Long chain PUFA)

Micro
Iron
Iodine
Zinc
Copper

Vitamins/Cofactors
B vitamins (B6, B12)
Vitamin A
Vitamin K
Choline

If I, Zn and Fe deficiencies are eliminated, global IQ will increase by 10 points



Animal-source foods (ASF) are the best source of high-quality, nutrient-rich foods for children aged between 6 and 23 months (WHO, 2017).

Nutrient deficiency impacts
- Reduced brain size
- Impaired neuronal growth
- Altered synapses
- Cognitive delays
- Reduced neurotransmitter production
- Altered myelination
- Growth failure
- Chronic illness
- Lower IQ

(Georgieff, 2022)

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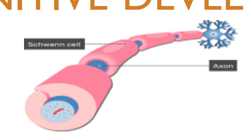
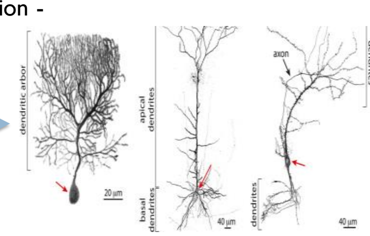
HOW ASF ENHANCES COGNITIVE DEVELOPMENT

ASF

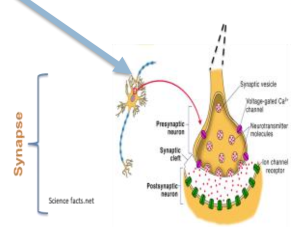
Bioavailable micronutrients: Iron, zinc, iodine, and B vitamins (B12, B6, folate, and riboflavin)



Enhanced myelination -



Dendritic arborization



Synaptic connectivity

(Lövblad et al., 1997; Lanouie et al. 2019; Sheffield, 2022).

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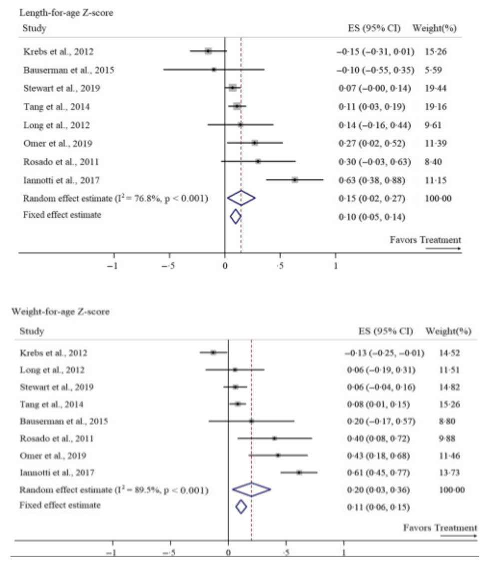
ASF IMPROVED NUTRITION AND PHYSICAL GROWTH

- Meta analysis of 8 studies (Randomized controlled trials)
- Studies had 42 to 1471, 5 to 24 month-old children from rural parts of Africa and Asia
- Background diets contained little or no ASF
- ASF supplementation resulted in lower stunting and wasting

(Asare et al., 2022)



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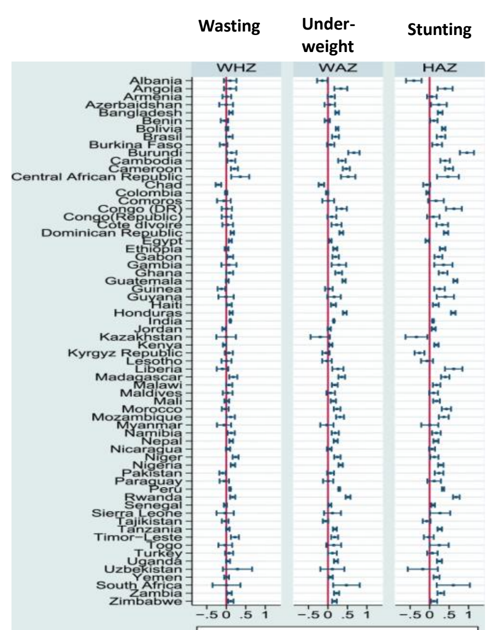
MILK CONSUMPTION REDUCES UNDERNUTRITION

- Monitored milk consumption based on 24 h recall by mothers from 67 LMIC
- Measured child stunting (HAZ), underweight (WAZ) and wasting (HAZ)
- Approx. 668,000 children aged 6 to 59 months per measure
- Milk consumption was associated with reduced stunting (HAZ) and underweight (WAZ)

(Herber et al., 2020)



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LULUN EGG PROJECT, ECUADOR

- Giving one egg per day to 6–9-month-olds in Ecuador for six months
- Reduced stunting (low height or length for age) by **47%**
- Reduced wasting (low weight for age) by **74%**

lulun project

(Ianotti et al, 2017)

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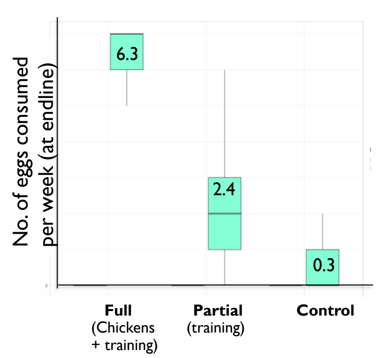
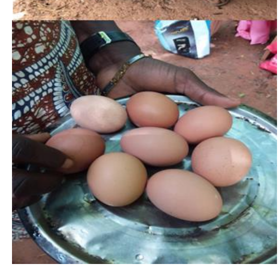
ONE EGG PROJECT, BURKINA FASO

Our culturally tailored behavior change intervention

- Increased egg intake in children with and without gifting chickens
- Reduced wasting and underweight
- Increased women's decision-making power



Baseline egg consumption was zero.



(McKune et al., 2020)

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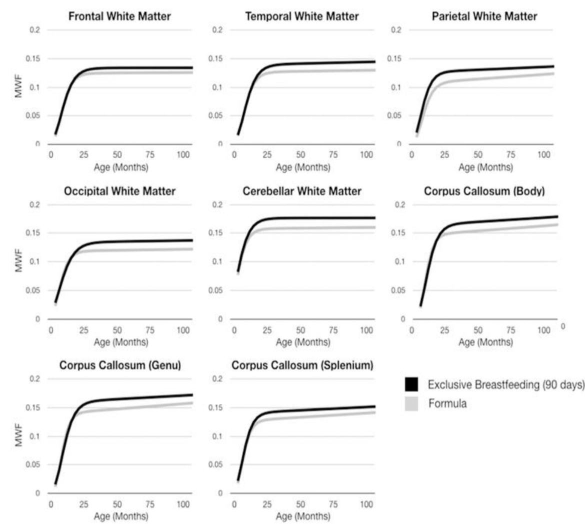
GROWTH OF BRAIN REGIONS IN BREAST VS. FORMULA-FED INFANTS

Breastfed children had:

- improved overall myelination
- increased general, verbal, and non-verbal cognitive abilities
- long-chain PUFA, iron, choline, sphingomyelin and folic acid are significantly associated with early myelination



(Deoni et al., 2018)

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ASF INCREASED CHILDREN'S COGNITION IN KENYA

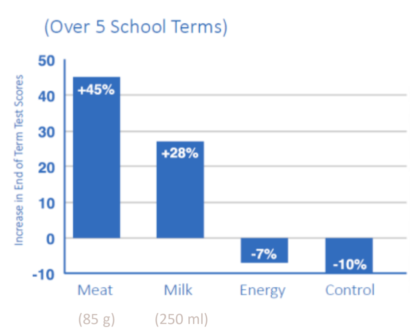
Embu Kenya, 2 years; 7–10-year-olds; n=554

Meat improved:

- Cognitive performance (Raven's score, math)
- School test scores
- Physical activity, initiative and leadership
- Arm muscle mass, B12 status

Milk improved:

- Linear growth if stunted
- B12 status



(Neumann et al., 2007; Hullet et al., 2014)

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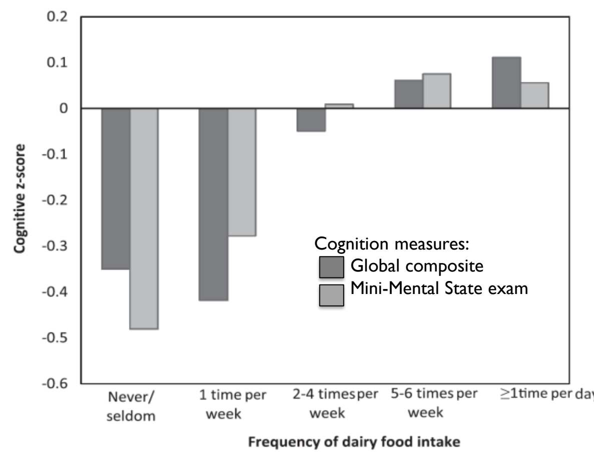
DAIRY INTAKE ASSOCIATED WITH INCREASED COGNITION IN ADULTS

- Cross-sectional analyses
- 399 males and 573 females, aged 23–98 years
- Monitored self-reported frequency of dairy consumption
- Measured cognition in different ways.
- Increased dairy consumption frequency was associated with increased cognition



(Crichton et al. 2016)

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ASSOCIATION BETWEEN MEAT CONSUMPTION AND HEIGHT OR COGNITION

(20,086 Chinese men and women that were >50)

	CHILDHOOD MEAT EATING[a]				
	Yearly/Never	**About once a month**	**About once a week**	**Almost daily**	**Trend *P value***
Height (cm)[b]	–	0.24*	0.54***	0.76***	< 0.001
Cognition (delayed 10 word recall)		0.12**	0.32***	0.57***	< 0.001
Cognition (Immediate 10 word recall)		0.72***	1.47***	1.77***	< 0.001

[a] Adjusted for age and sex; *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$

(Heys et al., 2010)

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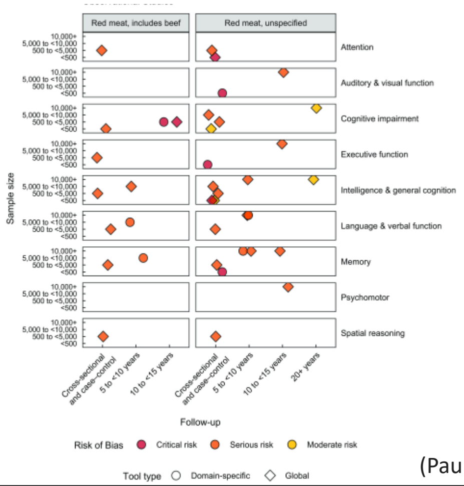
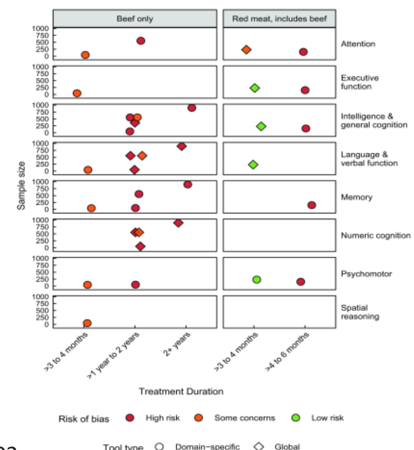
FACTORS DIFFERING AMONG STUDIES ON MEAT CONSUMPTION AND COGNITION

Observational studies (n=13)



Intervention studies (n=9)



(Paul and Fleming, 2023)

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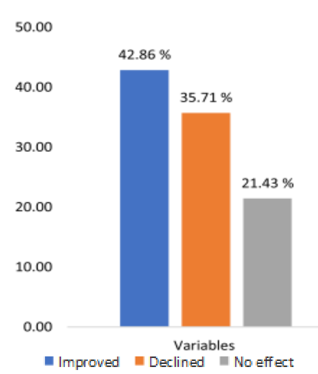
MEAT CONSUMPTION ASSOCIATED WITH IMPROVED COGNITION

- Types of studies: 9 studies (5 interventional and 4 observational)
- Subjects: 10617 children (age range 3 months to 14 years)
- Countries: China, Estonia, Finaland, Kenya, UK
- Variables studied: 28 Variables / measures of cognitive function
- Results: 12 cognitive function variables (from 5 studies) improved as a result of meat supplementation or were positively associated with meat consumption, 10 other variables (from 3 studies) were negatively affected by meat supplementation, 8 of which were on subjects under mitigatory conditions. 6 variables (from 2 studies) did not show significant relationship with meat consumption.



[1] If the 8 studies with confounding HIV effects are removed, **meat consumption increased cognition in 71% of variables**

(Balehegn et al., 2022)

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BARRIERS TO ASF CONSUMPTION

- Sociocultural factors
  - Gender
  - Caste
  - Religion
  - Cultural taboos
  - Fads
- Biases (crops, fortificants)
- Availability (low livestock productivity)
- Affordability
- Accessibility

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TAKE HOME MESSAGES

- Livestock play a vital role in social status, conflict, religion, equity, incomes, educations and livelihoods in the developing world
- Stunting affects 144 million children under five, constraining their growth, health, education, and future productivity
- ASF are at superior for preventing stunting and enhances cognitive development and growth
- ASF are inadequately consumed in LMIC due to socio-cultural factors, biases and lack of affordability, accessibility and availability.
- Multisectoral approaches are needed to improve supply of and demand for ASF in developing countries.

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Disclaimer

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39

Effects of Trace Mineral Supplementation on Fiber Digestion and Cow-Calf Production

Terry Engle
Colorado State University
Department of Animal Science

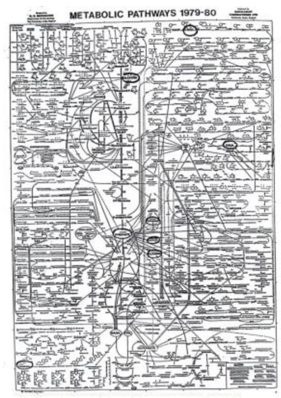
1

- **Outline**
  - **Trace minerals (Cu and Zn)**
    - ✓ **Function**
    - ✓ **Mineral requirements**
    - ✓ **Rumen fermentation**
      - **Microbial function**
      - **Solubility**
      - **Fiber digestion**
      - **Redox potential**
  - **Current and future experiments**
    - ✓ **Rumen: mineral solubility, fermentation characteristic, and binding strength to rumen digesta.**
    - ✓ **Long-term cow-calf production experiment**

2

General Functions of Minerals:

- Structural (bone, cytoskeleton, connective tissue)
- Maintenance of homeostasis
  - acid base balance (RBC and kidney)
- Enzyme activity
  - metalloenzymes
  - metal activated enzymes
- Components or regulators of hormones - Iodine
- Lipid metabolism
- Gene expression
- Hormone (production, storage, and secretion)
- Vitamin metabolism
- Component of Vitamin B_{12} (prop. → succ.-CoA; methyltransferase)
- Reproduction
- Membrane stability
- Immunity



http://mcb.berkeley.edu/courses/mcb100fall/past/2003/assets/metabolic_pathways.jpg

3

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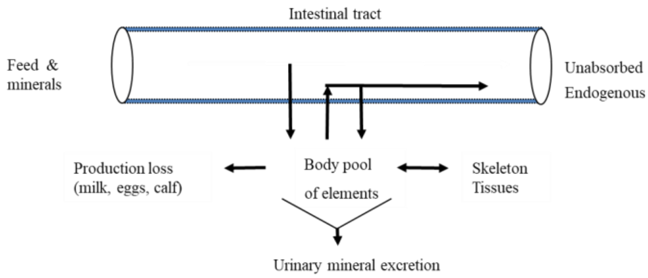
However, if you think you may have a mineral deficiency:

CHECK THE ENERGY AND PROTEIN CONTENT OF THE DIET <u>FIRST</u>

4

Determining Mineral Requirements

- Factorial estimates – determining gross mineral requirement: Sum of the components of net requirements for maintenance and production and divide the total by the coefficient of absorption



  - **Advantages** -Requirements of a specific mineral can be estimated for a wide range of production levels and physiological stages. Works well for Ca and P measurements – high degree of accuracy.
  - **Disadvantages:** Difficult to accurately measure and experiments are limited.
    - Absorption coefficients are potentially a major source of error (can be impacted by dietary components as well as physiological status of the animal).
    - Absorption coefficients for certain trace minerals are more accurately measured when dietary concentrations are at or below the animal's requirements. Elevated concentrations activate homeostatic control mechanisms that can reduce absorption.

5

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Determining Mineral Requirements:

Dietary experimentation estimates (most common)

- **Basic approach** – supplement a diet deficient or suspected of being deficient in a mineral with one or more concentrations of a specific mineral of interest.
- **Response variables are then measured** (e.g., growth, reproduction, bone strength, etc.)
  - **Advantages**
    - Supplementation experiments can arrive at an estimate of the requirement in the whole animal.
  - **Disadvantages**
    - Supplementation experiments rarely give precise estimates of requirements.
    - It is difficult and costly to estimate requirements using experiments for cattle of different ages and varying physiological states (growth, maintenance, reproduction, lactation, etc.).
    - Dependent on response variables measured.

6

DATA COMPARISON

- **BR-CORTE** (2016)
- **ARC:** Agricultural Research Council: The Nutrient Requirements for Ruminant Livestock
- **AFRC** – Agriculture and Food Research Council (Report 6)
- **NASEM/NRC** (2016) – National Research Council Nutrient Requirements for Beef/Dairy Cattle
- **CSIRO** – Commonwealth Scientific and Industrial Research Organization
- **Costa e Silva** (2016) Macrominerals and Trace Element Requirements for Beef Cattle
- **BR CORTE** (2010) – Nutrient requirements for Zebu beef cattle. Valadares Filho et al., (2010).

Costa e Silva et al. (2015)

7

Dietary Requirements

	mg/kg dry matter intake					
Item	Cu	Fe	Mn	Se	Zn	Co
NRC	10.0	50	20	0.10	30	0.15
CSIRO (2007)	---	---	---	0.05	11.6	---
Costa e Silva et al. (2015)	9.53	218	9.5	0.57	61	2.78
BR-CORTE (2016)	7.91	207.3	23.1	0.56	56.8	0.78

Costa e Silva et al. (2015); Absorption coefficients, where reported, are highly variable: Cu 6-84%; Mn 1-75%; Se 30-50%; Zn 5-80%.

Costa e Silva et al. (2015)

8

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Why the variation in ruminant data (Cu, Mn, Zn, dose and source)?

– The duration and concentration of mineral supplementation
– The duration of deficiency
– Environmental factors
– The absence or presence of dietary trace mineral antagonists
– Breed differences in mineral metabolism and immune response.
– Stress

9

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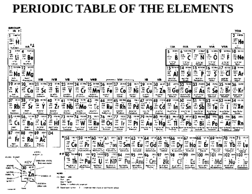
Factors Affecting Trace Mineral Requirements

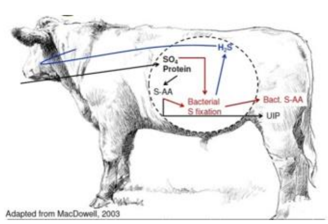
- **Interactions with other elements**
  - **Cu-Mo-S** (thiomolybdates; mono, di, tri, tetra)
    - High concentrations of Mo (10 mg Mo/kg DM) may not affect Cu status of cattle any more than moderate concentrations of Mo (5 mg Mo/kg DM).
    - **Mo in water** – does not appear to have the same influence on Cu metabolism relative to Mo in the feed/diet. (Kincaid, 1980 calves; Kistner et al., 2017 feedlot steers: Thorndyke, et. al., 2020, 2021, 2023 Cows, calves, and steers)
  - **Fe and Cu**
    - Synergistic (Enzymes)
    - Antagonistic (Gut)
  - **High Zn can decrease Cu absorption**
    - Molecular adaptation of the intestinal cells.

Puls, 1994

PERIODIC TABLE OF THE ELEMENTS



Adapted form Sargent-Welch Scientific Company



Adapted from MacDowell, 2003

10

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Rumen Fermentation

- The role that Cu and Zn play in rumen microbial fermentation is not well understood.
- The majority of research determining microbial trace mineral requirements has been conducted *in vitro*.
- Early *in vitro* rumen simulated experiments indicate that low concentrations of Cu and Zn in artificial rumen fluid were adequate to optimize fiber digestion (Cheng et al, 1955; Hubbert et al, 1958; Durand and Kawashima, 1980).
- Requirements of the host ruminant for zinc and copper are much higher than those needed by rumen microorganisms (≈0.1 mg Cu/l; Zn 0.2 mg/l).

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Ruminal disappearance of copper and zinc from forages from dacron bags incubated for 0 or 72 hours in the rumen of cattle

	Copper		Zinc	
Forage	0[a]	72 h	0[a]	72 h
	------------ % of total -------------			
Alfalfa	88.9	92.9	25.8	79.4
Rhizoma peanut	50.6	89.6	18.1	80.5
Dwarf elephantgrass	84.4	94.3	7.3	75.5
Bermudagrass	69.9	75.8	43.1	62.1
Bahiagrass	63.1	81.7	33.8	53.0
Limpograss	70.0	69.5	26.6	67.2

[a]Amount disappearing following washing with water.

Emanuele and Staples (1990)

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Rumen Microorganisms

- Bacteria metal homeostasis
- Regulated by metal sensor proteins that regulate:
  - Metal uptake
  - Metal efflux
  - Metal binding proteins
- Data would indicate that practical diets fed to ruminants without Cu and Zn supplementation are able to meet the microbial Cu and Zn requirements (Emmanuel and Staples, 1990).
- Numerous factors can impact rumen solubility of minerals such as the pH of the rumen, the concentration of dietary antagonists (Mo, Fe, S, fiber, etc.), diet type, and mineral source.
- Microenvironments and soluble minerals?

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Trace mineral source

- Copper from Cu hydroxychloride was relatively insoluble (0.6%) in water (pH 7.0) and highly soluble (81.4%) at a low pH (2.2), whereas Cu from $CuSO_4$ was almost completely soluble in both water and at a low pH (Spears 2004).
- Zinc hydroxychloride has also been reported to have low solubility in water (Cao et al. 2000) and was less soluble in the rumen of cattle when compared to Zn from $ZnSO_4$ (Shaeffer, 2006).

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Effect of trace mineral source on fiber digestion in lactating dairy cows[a]

Item	Sulfate[a]	Hydroxy[a]
NDF digestion, %[b]		
Forage diet[c]	43.0	45.9
By-product diet[d]	49.8	51.2

[a]Copper, zinc, and manganese were supplemented at 10, 32, and 30 mg/kg, respectively.
[b]Trace mineral source effect ($P < 0.02$).
[c]44% corn silage, 20% alfalfa silage.
[d]11% corn gluten feed, 15% beet pulp, 14.1% soy hulls.

Faulkner and Weiss (2017)

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Beef Cattle

- 8 crossbred steers fitted with ruminal cannulas
- Steers were fed a TMR (corn silage, steam-flaked corn-based diet) that contained appropriate trace mineral treatments.
- Treatments: 10 mg Cu/kg DM; 20 mg Mn/kg DM; 30 mg Zn/kg DM
  - 1) Sulfate
  - 2) Hydroxy
- Steer were acclimated to individual metabolism stalls for 5 d followed by a 5-d fecal and urine collection.

Caldera et al. (2019)

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Influence of trace mineral source on DM and NDF digestibility[a]

	Treatment			
Item	Sulfate[1]	Hydroxy[2]	SEM	P <
DM intake, kg/d	9.92	9.89	0.96	0.98
DM digestibility, %	65.6	70.7	2.4	0.18
NDF digestibility, %	37.8	41.2	1.7	0.09

[a]Zinc, copper, and manganese were supplemented at 30, 10, and 20 mg/kg DM, respectively.

Caldera et al. (2019)

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Rumen solubility of trace minerals

- To determine the impact of Cu and Zn source (SO_4 vs HTM) on rumen characteristics in steers fed a low-quality forage-based diet:
    - Dry matter and fiber digestibility.
    - Rumen soluble concentrations of Cu and Zn.
    - Rumen fermentation characteristics.
    - Binding strength of Cu and Zn to rumen solid digesta.

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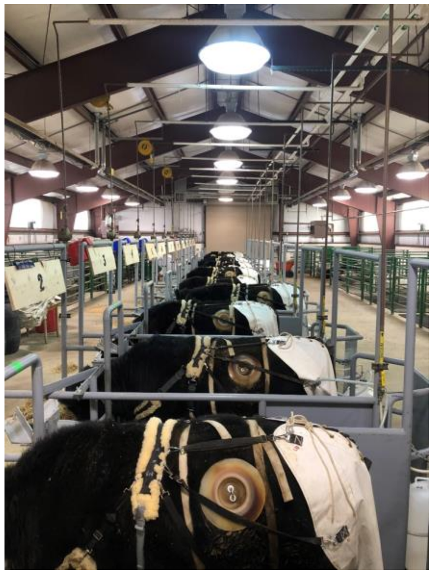
Experimental Design

- 12 crossbred steers fitted with ruminal cannulas.
- Group fed a low-quality grass hay-based diet for 60 days.
- Treatments:
  20 mg Cu/kg DM
  40 mg Mn/kg DM
  60 mg Zn/kg DM
  - 1) Sulfate
  - 2) Hydroxy

Ingredient	%DM
Grass hay	90.0
Protein/mineral supplement	10.0
Analyzed composition	
Dry matter, %	89.1
Crude Protein, %	12.4
Acid detergent fiber, %	37.2
Neutral detergent fiber, %	60.4
Copper, mg/kg DM	6.6
Manganese, mg/kg DM	58.4
Zinc, mg/kg DM	27.4



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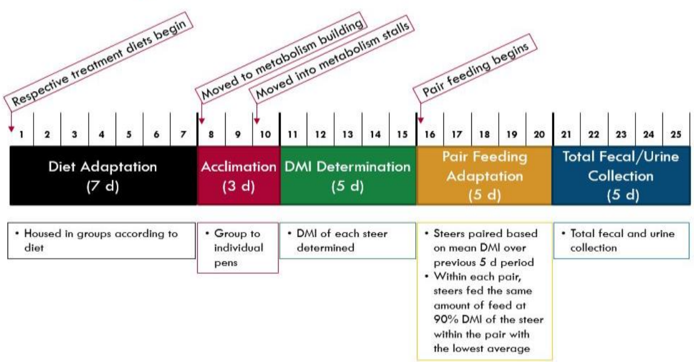
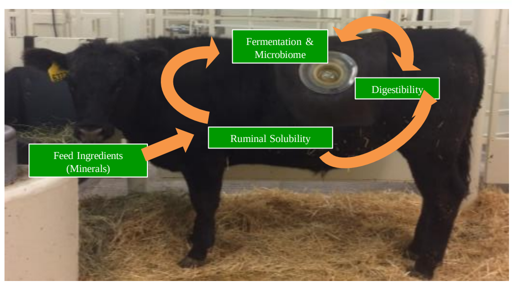
Trial Design





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Effect of trace mineral source on digestibility in steers fed a low-quality hay supplemented with protein[a]

	Sulfate	Hydroxy	P<
DMI, kg/d	7.4	7.4	-------
DM digestibility, %	51.9	53.4	0.07
NDF digestibility, %	40.4	42.7	0.04
ADF digestibility, %	32.4	34.1	0.05
CP digestibility, %	51.2	54.3	0.06

[a]Copper, manganese, and zinc were supplemented at 20, 40, and 60 mg/kg, respectively.

Guimaraes et al. (2019)

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Day 6

Influence of trace mineral source on short chain fatty acid production at 0, 2, and 4 hours post feeding.

	Treatment[a]				
Item	STM[b]	HTM[c]	Trt	Time	Trt*Time
pH	6.59	6.68	0.47	0.01	0.57
Butyric acid, mM/100mM	16.3	14.9	0.02	0.001	0.93
Total SCFA, mM	59.8	72.3	0.05	0.85	0.86

[a]Treatments: 20 mg Cu/kg DM; 40 mg Mn/kg DM; 60 mg Zn/kg DM from hydroxy or sulfate trace mineral sources.
[b]Sulfate trace minerals.
[c]Hydroxy trace minerals.
[d]Short chain fatty acids.

Guimaraes et al. (2019)

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Bolus dose experiment

- Following the SCFA collection all steers were fed the basal diet without supplemental Cu, Mn, or Zn was fed for 14 days.
- Followed by a bolus dose in 0.23 kg of ground corn of Cu, Mn, and Zn at 2 x NASEM (2016) requirements for Cu, Mn, and Zn (20, 40, and 60 mg/kg of Cu, Mn, and Zn, respectively).
- Rumen grab samples were collected at 2-hour intervals beginning at -4 hours through 24 hours post dosing.

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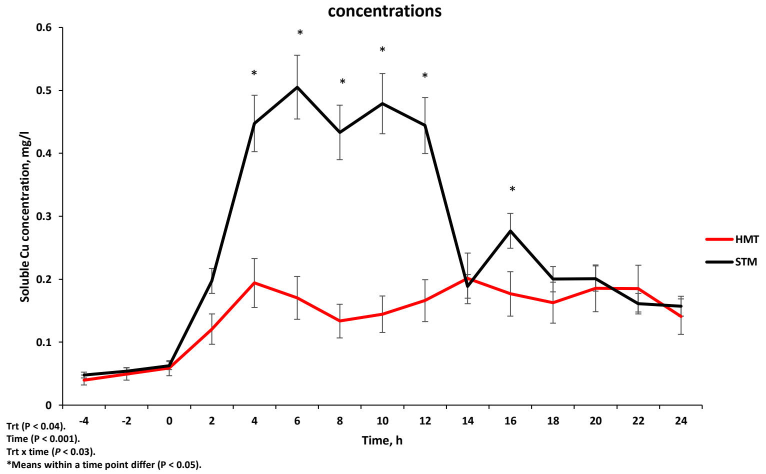
Figure 1a. Influence of trace mineral source on rumen soluble Cu concentrations



Guimaraes et al. (2019)

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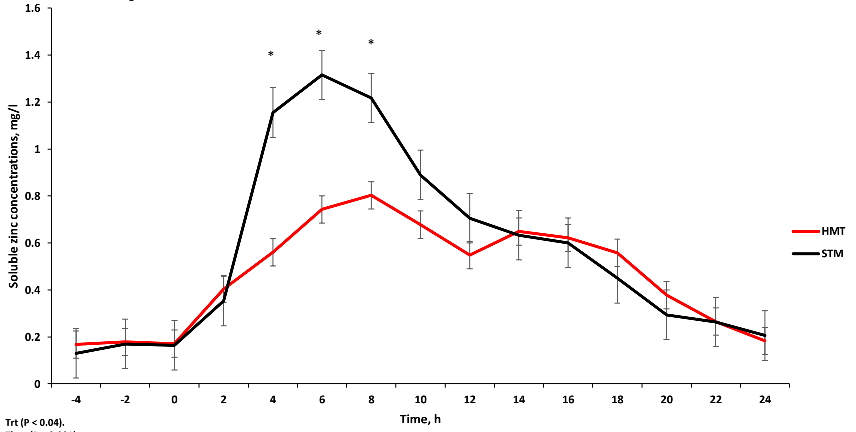
Figure 1b. Influence of trace mineral source on rumen soluble Zn concentrations



Trt (P < 0.04).
Time (P < 0.001).
Trt x time (P < 0.02)
*Means within a time point differ (P < 0.05)

Guimaraes et al. (2019)

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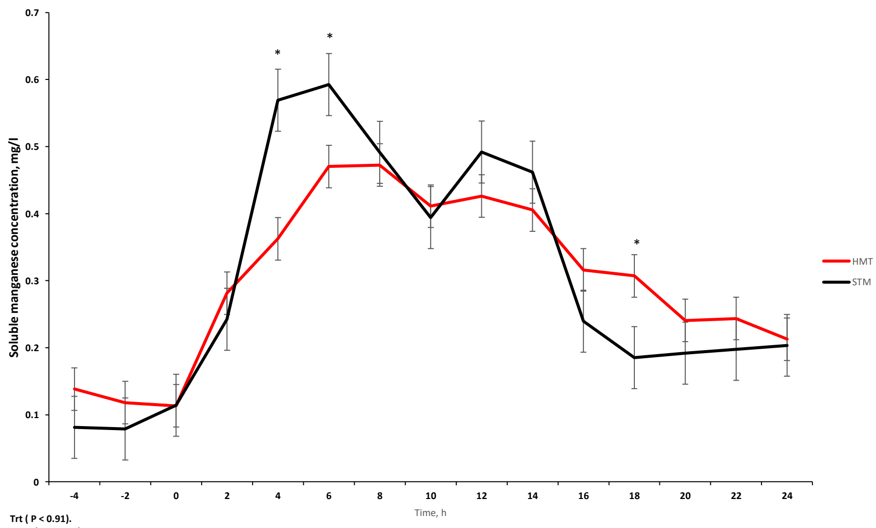
Figure 1c. Influence of trace mineral source on rumen soluble Mn concentrations



Trt (P < 0.91).
Time (P < 0.001).
Trt x Time (P < 0.03).
*Means within a time point differ (P < 0.05).

Guimaraes et al. (2019)

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Binding strength of copper, manganese, and zinc to rumen solid digesta

- Estimated using release of copper, manganese, and zinc from solid digesta by dialysis against 0.05M Tris-EDTA.

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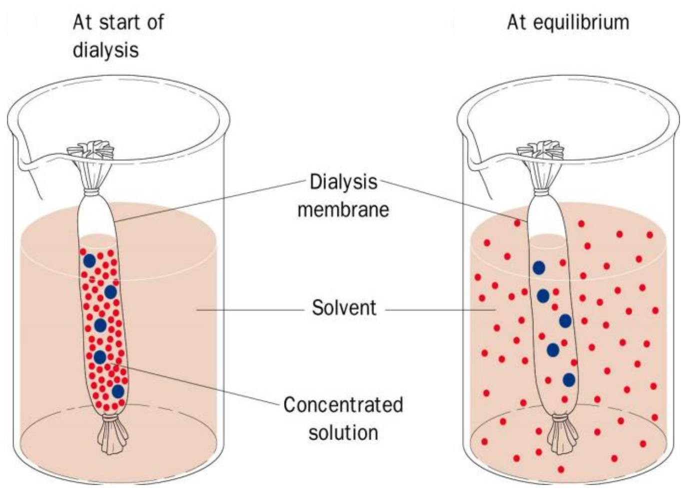

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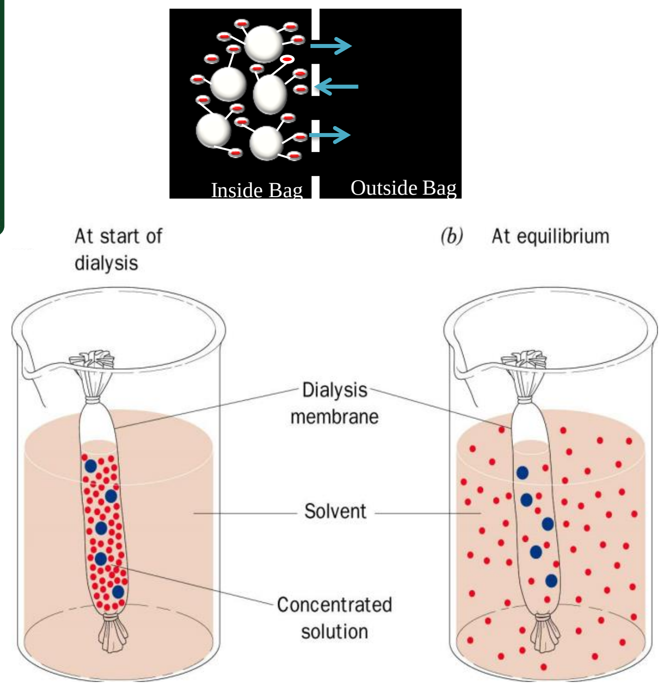

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Effect of trace mineral source on release of copper and zinc from rumen digesta at 12 hours after a pulse dose of 20 mg Cu, 40 mg Mn, and 60 mg Zn/kg DM

	Hydroxy	Sulfate	*P*<
Initial concentration in digesta, mg/kg DM			
Copper	31.6	8.1	0.001
Manganese	38.2	35.3	0.030
Zinc	129.6	37.3	0.001
Released by Tris-EDTA, %			
12h			
Copper	59.2	26.5	0.01
Manganese	63.7	77.2	0.01
Zinc	87.8	34.3	0.01

Guimaraes et al. (2019)

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Experiment 2 – Dairy diet[a]

Ingredients,%	Inclusion, % DM	
Corn Silage	64.5	
Alfalfa Hay	10.2	
Supplement	25.5	
Soybean meal		64.0
Dry distillers grain		16.2
Cracked corn		9.4
Limestone		7.5
Salt		1.9
Magnesium oxide		0.64
Trace mineral premix		0.35

[a]Formulated to provide 45.5 kg milk/day.
Treatments: Sulfate, Organic, and HTM (Cu, Zn, and Mn).

Experiment 3 –Feedlot diet[a]

Ingredients,%	Inclusion, % DM	
Steam-flaked corn	66.9	
Corn Silage	10.0	
Alfalfa hay	10.0	
Dry distillers grain	10.0	
Supplement	3.1	
Limestone		48.4
Urea		35.5
Salt		9.6
VTM premix		6.5

[a]Formulated to target 1.6 kg ADG.
Treatments: Sulfate and HTM (Cu, Zn, and Mn).
.

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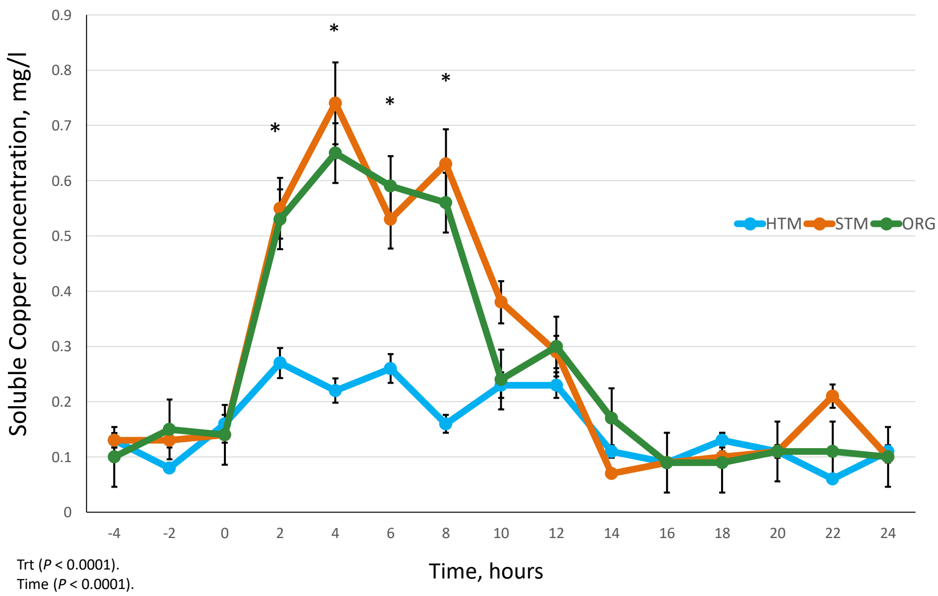
Influence of trace mineral source on rumen soluble Copper concentrations



Trt ($P < 0.0001$).
Time ($P < 0.0001$).
Trt x Time ($P < 0.0002$).
*means within a time point differ ($P < 0.05$).

Guimaraes et al. (2022)

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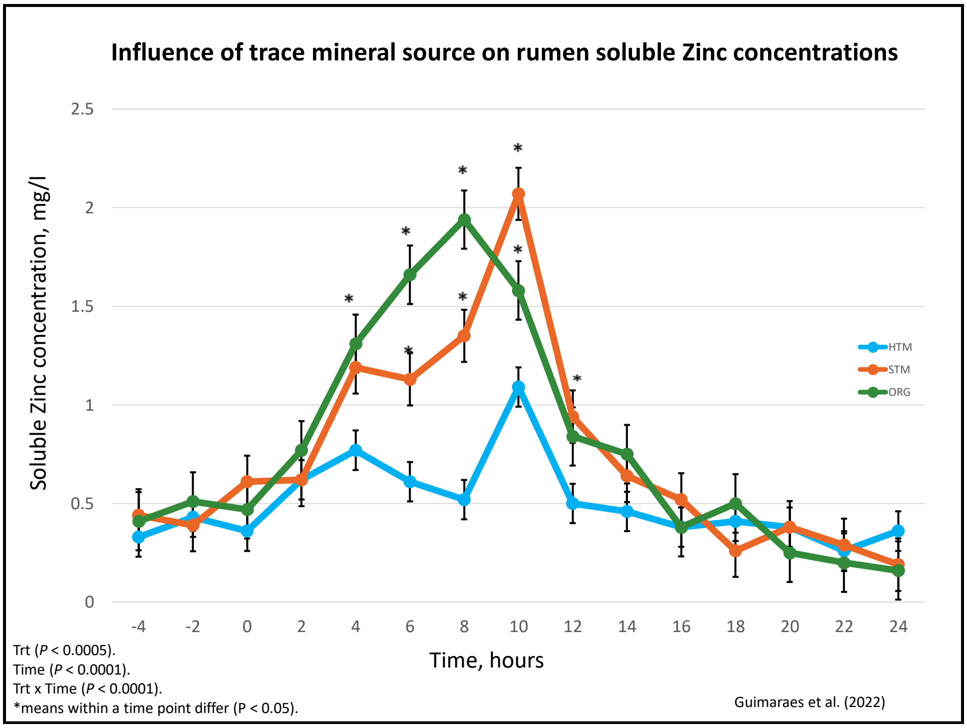
Influence of trace mineral source on rumen soluble Zinc concentrations
Soluble Zinc concentration, mg/l
Time, hours
HTM
STM
ORG
Trt (P < 0.0005).
Time (P < 0.0001).
Trt x Time (P < 0.0001).
*means within a time point differ (P < 0.05).
Guimaraes et al. (2022)

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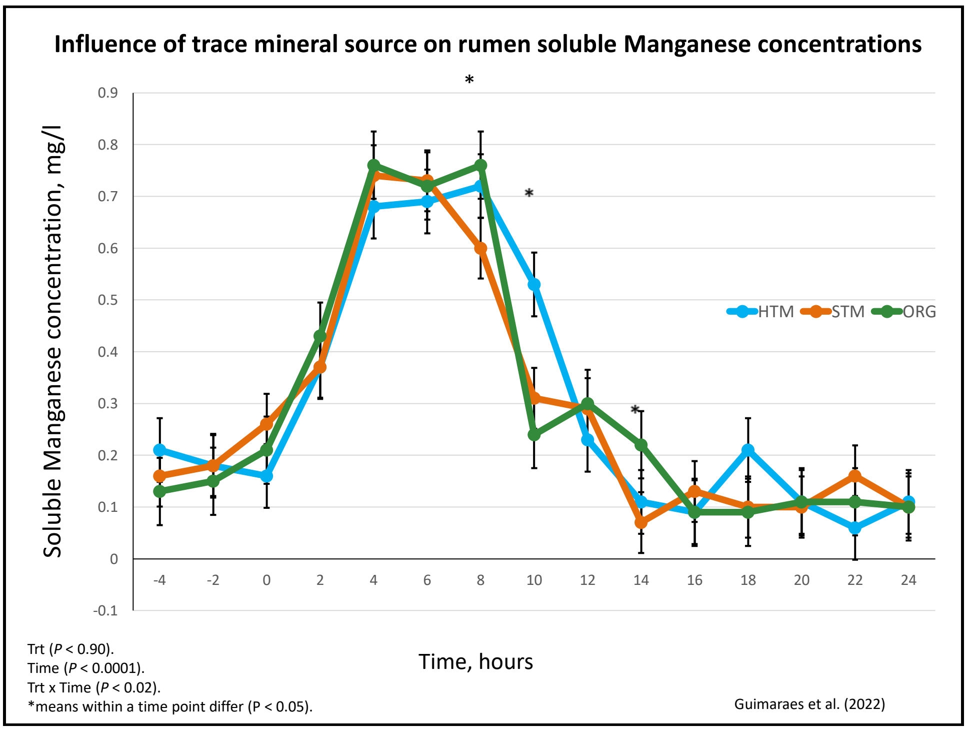
Influence of trace mineral source on rumen soluble Manganese concentrations
Soluble Manganese concentration, mg/l
Time, hours
HTM
STM
ORG
Trt (P < 0.90).
Time (P < 0.0001).
Trt x Time (P < 0.02).
*means within a time point differ (P < 0.05).
Guimaraes et al. (2022)

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Influence of trace mineral source on dry matter and neutral detergent fiber digestibility (dairy diet).

ITEM	Treatment STM	ORG	HTM	SEM	P<
DMI, kg/day	8.2	8.2	8.2	---	---
DM dig., %	64.6	65.7	66.5	0.57	0.11
NDF dig., %	43.0[a]	47.0[b]	47.6[b]	1.2	0.05
ADF dig., %	29.8.0[a]	31.6[b]	32.4[b]	0.49	0.05
CP dig., %	63.5	63.7	64.3	0.31	0.20

[a,b] Means within a row with different superscripts differ ($P < 0.04$).

Guimaraes et al. (2022)

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Influence of trace mineral source on short chain fatty acid (SCFA) production post feeding (dairy diet).

ITEM	Treatment ZTM	ORG	HTM	SEM	*P* value Trt	Time	Trt x Time
Rumen pH	6.38	6.42	6.59	0.09	0.26	0.01	0.17
Total VFA, mM	73.3	78.0	77.4	0.8	0.01	0.01	0.05

Guimaraes et al. (2022)

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Conclusion

- Results indicate that ruminal solubility of copper and zinc differs between sulfate, organic, and hydroxy sources.
- It appears that rumen copper and zinc solubility from sulfate forms may impact rumen fermentation of cattle fed high forage and dairy-type diets. Metal ion release in the rumen may influence fiber digestibility (sulfate compared to ORG and HTM).
- Future analysis
  - Completed additional experiments with a feedlot type diet. Microbiome analysis. Directly measure the free ion load in the rumen and rumen redox potential.

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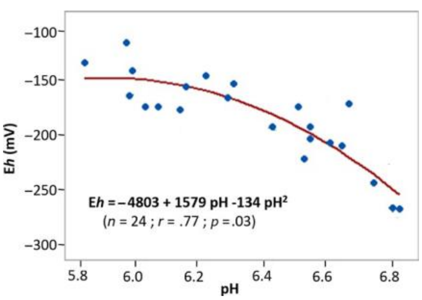
Rumen Redox (oxidation-reduction) Potential



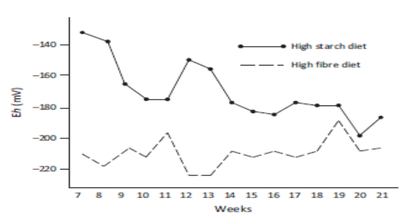
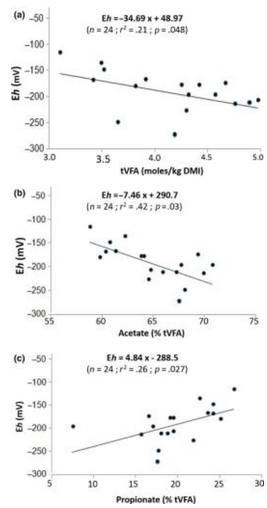


FIGURE 2 Changes in ruminal Eh in heifers fed high starch-diet or fed high fibre diet (from Monteils et al., 2009). Eh, redox potential



Huang et al. (2017)

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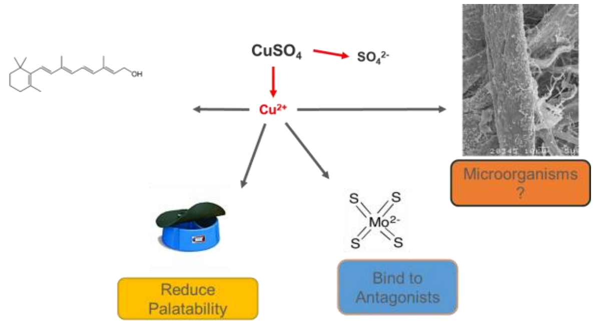
Question: Can soluble ions of trace elements impact rumen redox potential?

- DCAD/EB and Redox potential in soil can influence mineral availability.
- What can free metal ions do? Alter redox potential?



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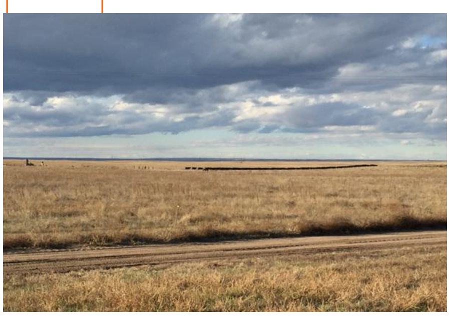
Influence of supplemental copper, manganese, and zinc source on reproduction, mineral status, and performance in a grazing beef cow-calf herd over a four-year period.



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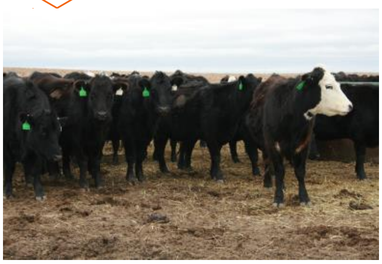
Materials and Methods

- 180 Angus x Hereford cows (3 years old)
- 9 pastures with 20 cow per pasture (rotated monthly across 18 pastures).
- Replicates: 3 pasture replicates per treatment
- 3 free-choice trace mineral treatments.



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Materials and Methods (Cont.)

- Free-choice trace mineral treatments

Free-choice mineral supplement ingredient composition on a DM basis.

	Free-choice mineral supplement treatment		
Item, %*	Sulfate[1]	Hydroxy 1X[2]	Hydroxy 0.5X[3]
Monocalcium Phosphate 21%	28.45	28.43	28.47
Salt, NaCl[4]	25.55	25.55	25.45
Calcium Carbonate $CaCO_3$	20.75	21.45	22.00
Elemental sulfur, S	11.65	11.65	11.65
Corn Distillers Dried Grains	4.90	4.90	5.00
Magnesium Oxide, MgO	3.07	3.07	3.07
Selenium 0.16%, Se	1.88	1.88	1.88
Soybean Oil	1.00	1.00	1.00
Copper Sulfate (25%, Cu)	0.40	-	-
Zinc Sulfate (36%, Zn)	0.83	-	-
Manganese (32%, Mn)	0.63	-	-
Intellibond Cu	-	0.18	0.09
Intellibond Mn	-	0.46	0.23
Intellibond Zn	-	0.55	0.27
Cobalt Carbonate 2%, $CoCO_3$	0.08	0.08	0.08
Calcium Iodate 8%, CaI	0.06	0.06	0.06
Vitamin A		0.62	0.62
Vitamin D_3	0.05	0.05	0.05
Vitamin E	0.11	0.11	0.11

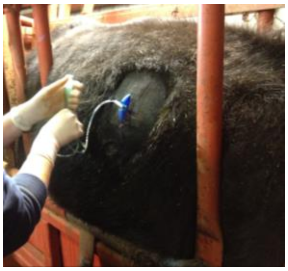
[1] Sulfate= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Sulfate source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn.
[2]Hydroxy 1X= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN) .
[3]Hydroxy 0.5X= 0.5 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 500, 1,000, and 1,500 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN).
[4]On month 10 of the experiment, an additional 16.6% salt was added to each free-choice mineral feeder at the time of mineral delivery and thoroughly mixed by hand.

Ahola et al., 2004. 82-2375-2383. Negative control; ING; ORG – No supplemental Cu, Mn, and Zn for greater than 2 years decreased pregnancy rates,

42

Materials and Methods (Cont.)

- BW, BCS, weaning weights.
- Monthly forage and water samples.
- Blood and liver biopsies were collected at the end of each year.
- Weaning weights, reproductive performance, offspring feedlot performance and carcass characteristics.
- Monitored monthly free-choice mineral intake.



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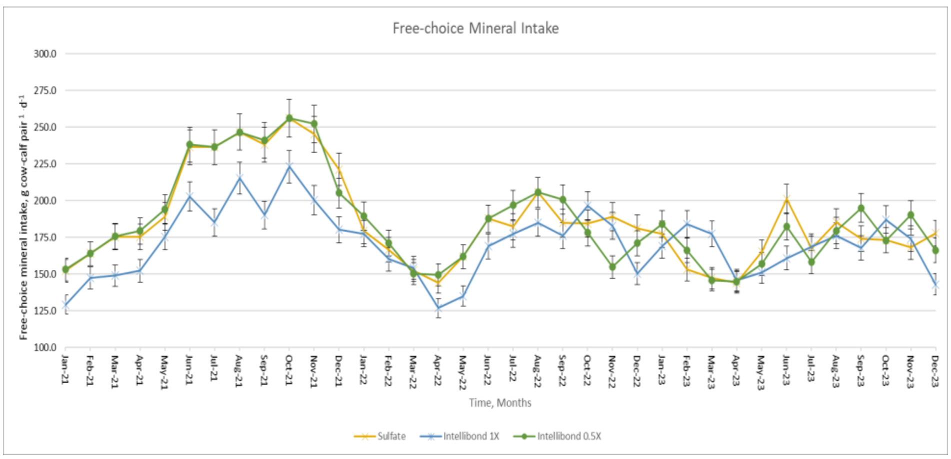
Free-choice trace mineral intakes



Calving: Feb/Mar
Breeding: July
Weaning: October

Unpublished data

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Effects of trace mineral supplement on cow BW, BCS, reproductive performance, and actual and 205 day adjusted weaning weights (Year 1, 2, and 3; Preliminary Data).

Item	Treatment			SEM	Contrast	
	Sulfate[1]	Intellibond 1x[2]	Intellibond 0.5x[3]		Sulfate vs. Intellibond 1x	Intellibond 1x vs. Intellibond 0.5x
BW, kg						
d 0	562.6	568.0	569.2	14.2	0.94	0.87
d 314, yr. 1	607.5	616.0	613.1	17.8	0.89	0.94
d 659, yr. 2	618.9	621.3	622.4	18.0	0.90	0.91
d 984, yr. 3	622.3	624.1	625.3	19.7	0.84	0.92
BCS[4]						
d 0	5.9	5.9	5.9	0.08	0.88	0.91
d 314, yr. 1	5.7	5.8	5.8	0.04	0.91	0.92
d 659, yr. 2	5.4	5.5	5.5	0.06	0.94	0.94
d 984, yr. 3	5.1	5.4	5.3	0.05	0.91	0.94

[1] Sulfate= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Sulfate source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn.
[2]Hydroxy 1X= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN) .
[3]Hydroxy 0.5X= 0.5 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 500, 1,000, and 1,500 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN).
[4]1=emaciated, 9= obese; Richards eat al., 1986.
[5]Artificial insemination.
[6]Adjusted for sex.

Unpublished data

45

Effects of trace mineral supplement on cow BW, BCS, reproductive performance, and actual and 205 day adjusted weaning weights (Year 1, 2, and 3; Preliminary Data).

Item	Treatment			SEM	Contrast	
	Sulfate[1]	Intellibond 1x[2]	Intellibond 0.5x[3]		Sulfate vs. Intellibond 1x	Intellibond 1x vs. Intellibond 0.5x
Pregnancy rate to AI[5], %						
Year 1	55.0	63.3	56.7	5.1	0.64	0.63
Year 2	30.0	57.5	51.7	6.2	0.05	0.41
Year 3	40.4	60.9	57.3	5.3	0.07	0.40
Overall Pregnancy Rate, %						
Year 1	91.7	93.3	93.1	2.3	0.86	0.92
Year 2	95.0	95.0	96.7	5.9	0.98	0.87
Year 3	94.8	95.0	96.1	6.3	0.97	0.83
WW, kg						
Year 1	236.4	240.1	235.9	6.1	0.87	0.91
Year 2	242.2	249.9	244.2	3.8	0.10	0.29
Year 3	242.1	248.3	250.3	4.9	0.07	0.17

[1] Sulfate= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Sulfate source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn.
[2]Hydroxy 1X= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN) .
[3]Hydroxy 0.5X= 0.5 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 500, 1,000, and 1,500 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN).
[4]1=emaciated, 9= obese; Richards eat al., 1986.
[5]Artificial insemination.

Unpublished data

46

Effects of pasture trace mineral supplement on offspring feedlot performance and carcass characteristics (Year 1, and 2; Preliminary Data).

Item	Treatment			SEM	Contrast	
	Sulfate[1]	Intellibond 1x[2]	Intellibond 0.5x[3]		Sulfate vs. Intellibond 1x	Intellibond 1x vs. Intellibond 0.5x
Year 1 (2022)						
Feedlot initial BW, kg	240.1	243.3	241.9	5.3	0.86	0.86
Feedlot Final BW, kg	634.2	637.1	638.9	7.9	0.60	0.79
Feedlot ADG, $kg \cdot animal^{-1} \cdot d^{-1}$	1.76	1.77	1.78	0.07	0.91	0.94
Hot carcass weight, kg	384.2	385.3	385.2	6.4	0.87	0.88
Dressing percentage[4]	63.1	63.0	62.8	0.24	0.74	0.78
Marbling score[5]	634.2	648.3	644.8	9.3	0.36	0.37
Fat thickness, cm.	1.38	1.30	1.19	0.54	0.76	0.84
Ribeye area, cm.^{2}	83.2	84.1	82.9	1.97	0.91	0.87
USDA YG	2.78	2.69	2.81	0.07	0.62	0.55
Year 2 (2023)						
Feedlot initial BW, kg	240.4	244.7	243.9	5.9	0.74	0.81
Feedlot Final BW, kg	637.2	648.3	647.1	6.7	0.21	0.73
Feedlot ADG, $kg \cdot animal^{-1} \cdot d^{-1}$	1.73	1.75	1.76	0.08	0.92	0.94
Hot carcass weight, kg	387.2	391.2	395.6	5.2	0.64	0.88
Dressing percentage[4]	63.3	62.9	63.6	0.31	0.42	0.38
Marbling score[5]	638.7	654.1	632.1	10.3	0.67	0.58
Fat thickness, cm.	1.41	1.30	1.29	0.11	0.47	0.38
Ribeye area, cm.^{2}	84.1	85.2	82.9	0.94	0.85	0.19
USDA YG	2.89	2.58	2.84	0.09	0.05	0.04

[1] Sulfate= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Sulfate source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn.

[2]Hydroxy 1X= 1 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 1,000, 2,000, and 3,000 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN).

[3]Hydroxy 0.5X= 0.5 times NASEM (2016) requirements for Cu, Zn, and Mn – Hydroxychloride source mineral containing 500, 1,000, and 1,500 mg/kg of Cu, Mn, and Zn (Intellibond C, Z, M, Micronutrients USA LLC (Indianapolis, IN).

[4]Final live body weight pencil-shrunk by 4% prior to dressing percentage calculation.

[5]Slightly Abundant=800, Moderate=700, Modest=600, Small=500, Slight=400.

[a,b]Means in a row with different superscripts differ $P < 0.05$.

Unpublished data

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Future Challenges/Opportunities:

- Mineral availability from basal feed ingredients.
- Mineral solubility throughout the gastrointestinal tract.
- Rumen pH, reducing potential, and abomasal retention time.
- Minerals and growth (Zn, Cr, Cu, etc.).
- Cow production efficiency.
- Bacterial and protozoal uptake and metabolism of trace minerals.

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Thank You!

49

Obtaining value from a feed/forage lab engagement

Florida Ruminant Nutrition Symposium
February 27, 2024

Ralph Ward
Cumberland Valley Analytical Services

1

Role of the feed lab

- Execute defined peer reviewed assays
  - AOAC, AOCS, AACC, ASTM, NFTA
  - Journal published assays
  - Lab results should be able to be associated with specific assays
  - Assay definitions should be published and easily located
- Ensure quality control in execution of assays
  - What are the quality control systems in the laboratory?
  - Is there a quality control officer?
  - How are samples controlled?
  - How are samples ground / processed?

2

Role of the feed lab

- Execute quality control (proficiency) programs
  - NFTA
  - AAFCO
  - AOCS
  - AACC
  - BIPEA
- Execute under ISO 17025 or other quality assurance program (?).
- Manage internal data in a well-developed LIMS (laboratory information management system).
- Execute and report results in an agreed upon time-frame.
- Communicate and manage client data effectively.
- Effective communications between lab and the client.

3

Potential roles of the feed lab

- Assist in interpretation of data
- Nutritional support
- Research support
- Method development research
- Provision of data libraries
- Sample collection and transit (“drop box” system)
- Farm sampling services
- Improved time in transit execution

4

U.S. forage lab industry engagement

- Unique to global ruminant industry
- Many small labs in the 1980's that engaged the new technology of NIR
- Initially, questionable NIR results but set the stage for rapid low-cost analysis
- Services available as the role of forage quality became recognized and ration modeling started in earnest.
- Low cost, rapidly available lab services underwrote the development of the ruminant nutritional services industry in the U.S.
- Lack of external lab quality regulation allowed for labs to keep costs low.
- Routine testing has implemented the concept of process control and mitigation of variation in feed sources.
- Significant value contribution.

5

U.S. feed lab evolution

- Formerly many small chemistry labs served the U.S. feed industry.
- Small lab ownership was not carried forward, labs closed or were bought out in successive lab aggregations.
- Technology has allowed large feed manufacturers to internalize QC.
- In the U.S. only a few large providers of feed analysis services.
- Forage lab analysis for ruminant purposes now resides with 4 primary labs in the U.S.

6

Quality control systems vs sample cost

- Extensive quality control system engagement by labs is a requirement in many industries.
  - Example: EPA certifications for environmental work.
- In EU in many cases feed lab service provision requires ISO or similar certification.
- These quality control systems drive up costs but don't always bring functional value, especially in forage testing where needs are different.
- Forage and feed lab quality control systems will evolve over time.

As a lab client, becoming familiar with forage and feed lab processes will allow for improved value in the absence of these programs and will assist in keeping costs low and routine analysis affordable.

7

Chemistry versus NIR utilization

- In the U.S., >90% of routine analysis for forage and ingredient quality is by NIR.

8

NIR History

- Described in literature as early as 1939
- Dr. Karl Norris and coworkers first applied the concept to agricultural products in 1968 with instrumentation at a USDA research lab.
- Dr. John Shenk, a plant scientist at Penn State pushed Dr. Norris to consider the use of NIR for evaluating forage quality (published communication) and in 1976 it was demonstrated that absorption at specific wavelengths was correlated with chemical analysis of forages.

9

NIR History

- In 1978 a portable unit was designed for use in a van on farm and at hay auctions. This developed into a university extension program using mobile NIR vans in PA, MN, WI, and IL.
- By the early 1980's, several companies were manufacturing commercial units.
- At Penn State, John Shenk and his associate Mark Westerhouse became the world's leading authority on the development and use of NIR for agricultural applications.

10

What makes a good NIR equation?

- Just because a lab generates a nutrient value on an NIR report does not mean that the number has value!
  - "Good" calibration statistics do not guarantee a good equation.
  - Large numbers of samples do not guarantee a good equation.
  - Having samples "over many seasons" does not necessarily make for a good equation.
  - Having good calibration statistics is not a guarantee of a good prediction.
  - Is the reported nutrient a NIR prediction, a calculation, or a value based on an NIR calibration.

So, what makes for a good NIR equation?

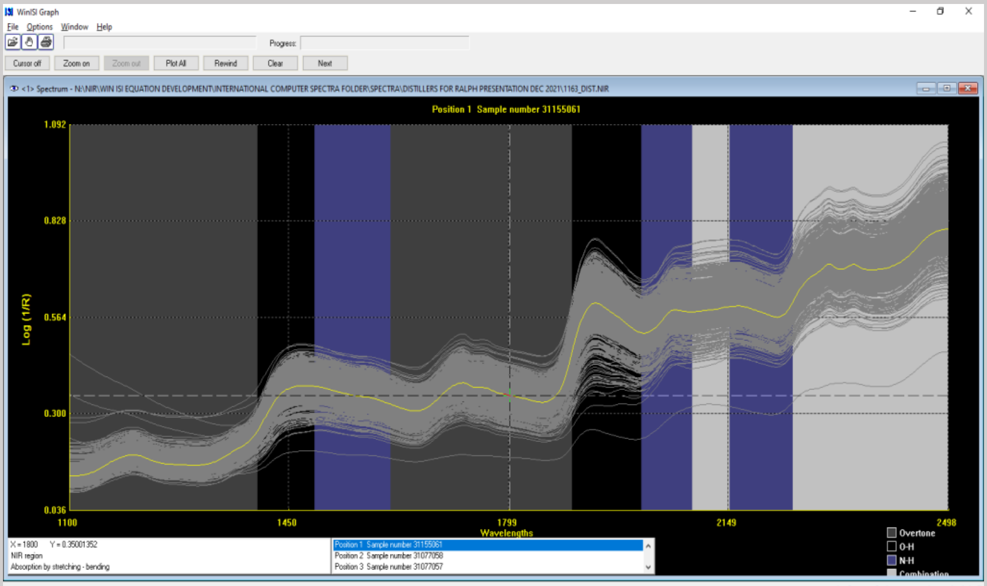
11

What makes a good NIR equation?

- Applying NIR to an organic constituent that has C-H, O-H, N-H, or S-H bonding
- A broad range of like characteristic spectra
  - From a defined feed type such as "hay" or "corn stover"
- A set of spectra that **uniformly** covers the spectral range of a defined feed material
  - This can be the hard part, obtaining a representative set of materials
- Accurate chemistry information for the nutrient being calibrated!
  - Chemistry analysis is difficult to do on a large set of samples and costly
- Equation statistics that provide a high R2 and low Standard Error of the Calibration (SEC)
- Validation of the equation against a broad range of routine samples
- Validation of the of the calibration samples against the general population
- Does the predicted nutrient have ***prediction value***?

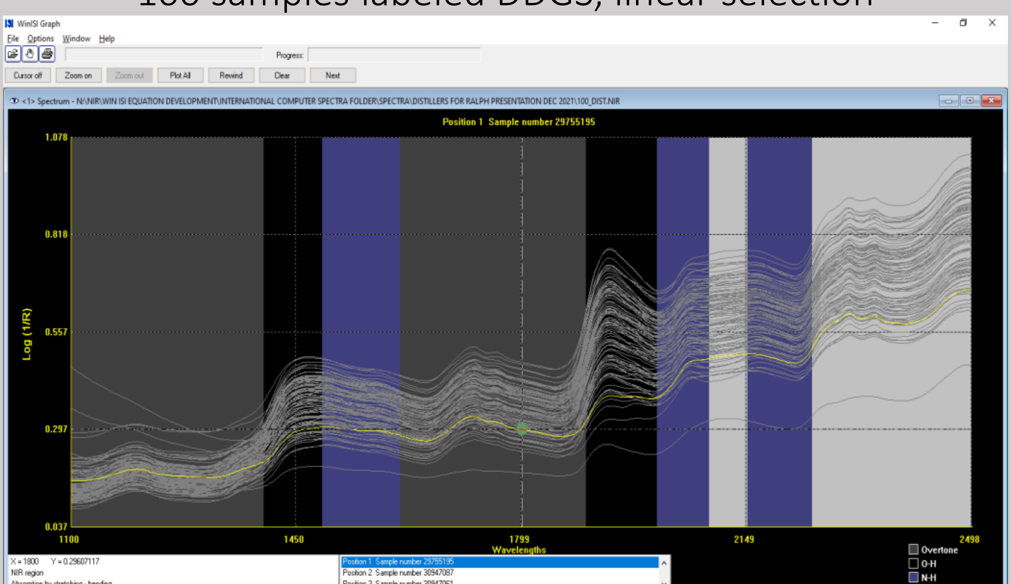
12

1163 samples labeled DDGS



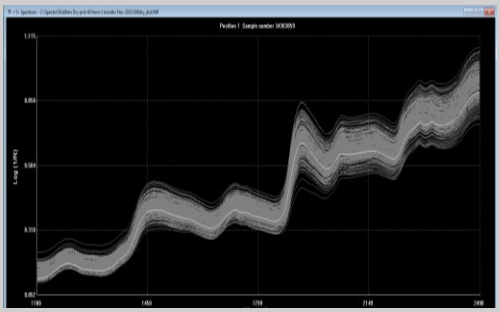
13

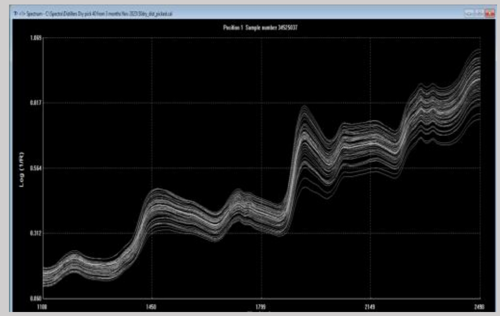
100 samples labeled DDGS, linear selection



14

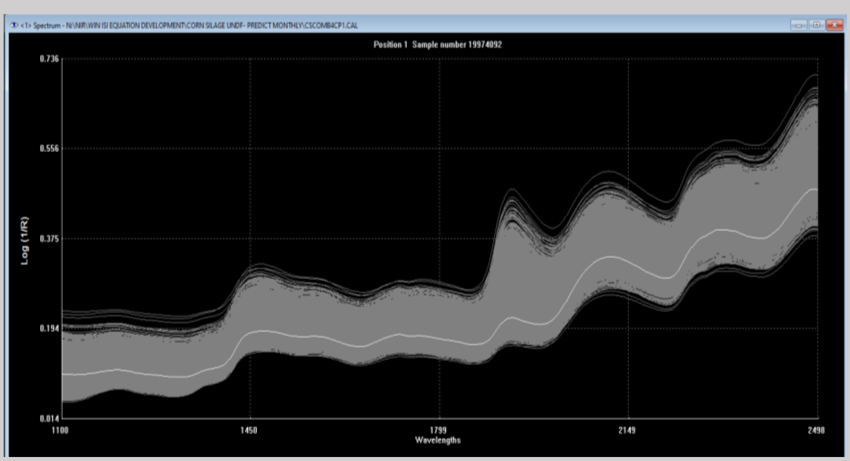
Large set of calibration spectra versus a selected set





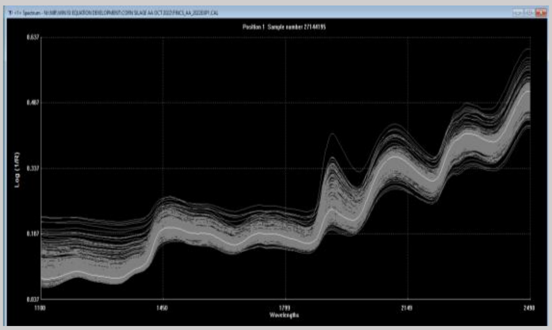
15

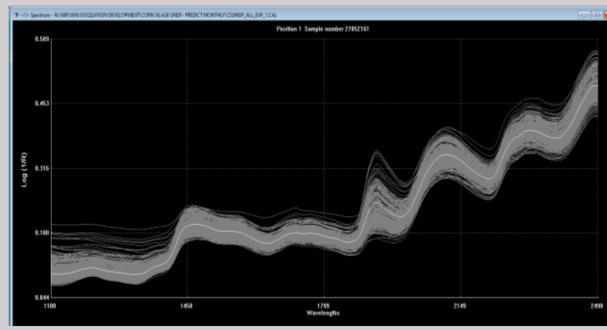
7900 corn silage spectra for selection process



16

Selected corn silage spectra
Amino acid calibration, uNDF calibration





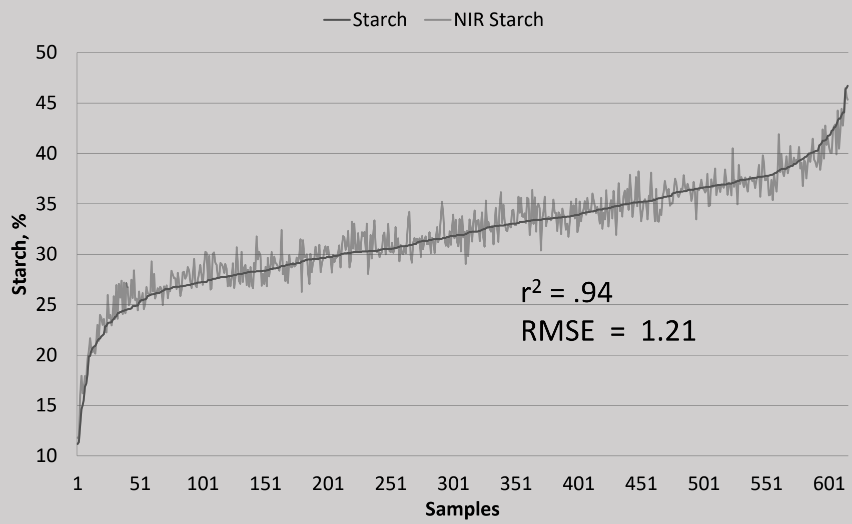
17

Starch Evaluation by NIR
CVAS Calibration Statistics

	N	Mean	RSQ	SEC
Corn Silage	1677	28.1 %	.98	1.01
Corn Grain	1302	71.2 %	.99	.45

18

Comparison of Starch by Chemistry and NIR



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New Report Reference Information

- Nutrient Z Score
  How far is the value from the mean
- Nutrient Global "H"
  How far is the spectra from neighbors in the population
- Nutrient RPD value
  What is the prediction value for the nutrient

This information will assist the user in knowing if the reported information has decision value.

20

What is a "Z score?"

- A Z score is the number of standard deviations that a value is above or below the mean value.
- The Z score is a single value that provides understanding of how far a nutrient value falls from the mean. It is a more descriptive way of understanding how a value relates to a population.

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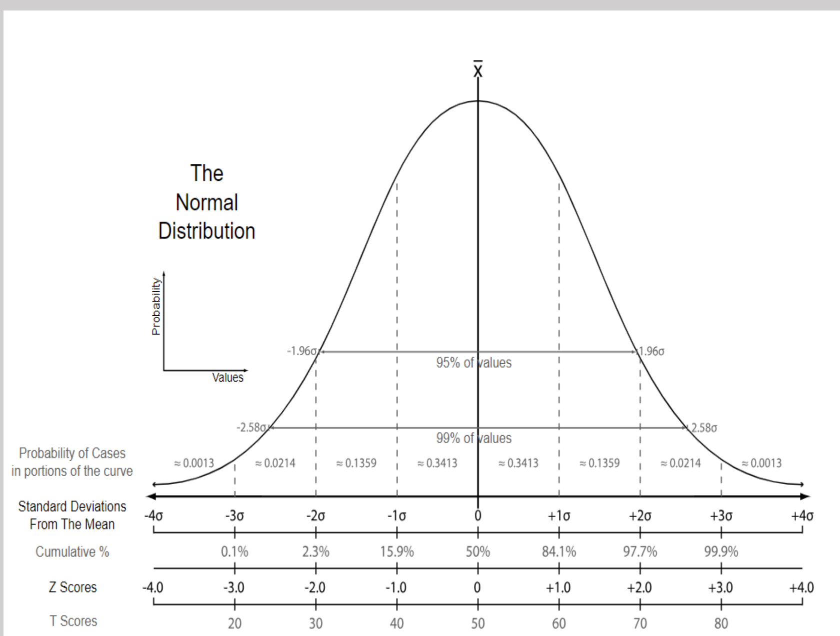


22

What is the sample definition for a population for comparing a sample?

- We often compare samples to “range values”, perhaps a mean and plus/minus 1 SD.
- To obtain value from comparisons define objectives and use the appropriate summarized population!
  - Corn distillers
  - Low fat distillers
  - High protein distillers
  - Wheat distillers
- Large population averages do no change significantly over time
  - U.S. corn silage analysis averages do not vary much from year to year.

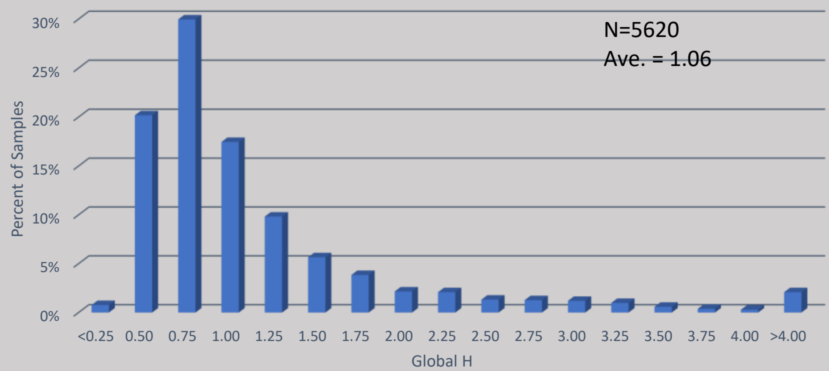
23

What is a Global H value?

- Statistical Term
- The “H” refers to the “Hat” or “^”
- The value is the squared distance between a sample spectrum and the average spectrum sample in a population
- A low H, or distance, means that the sample belongs to the population (<3)
- A very high H means that the sample probably does not belong to the population (>7?) while an intermediate value (3 to 5) means that the calibration may benefit by adding the sample to the calibration set.
- The Neighborhood H value is the distance of the between a spectra and its nearest neighbor spectra and should be <.6.

24

Distribution of NIR GH Values for uNDF Calibration of Haylage



25

GH evaluation across 15,000 samples, 3 corn silage calibrations

Three calibrations were evaluated by applying them each to a set of 15,000 sample spectra. The GH values generated for each sample were summarized by calibration.

- Random spectra selection for general nutrients (developed from 1154 samples)
  - GH Average = 1.16, SD = .50
- Linear spectra selection for amino acids (255 samples)
  - GH Average = .82, SD = .48
- Linear spectra selection for uNDF calibrations (305 samples)
  - GH Average = .58, SD = .32

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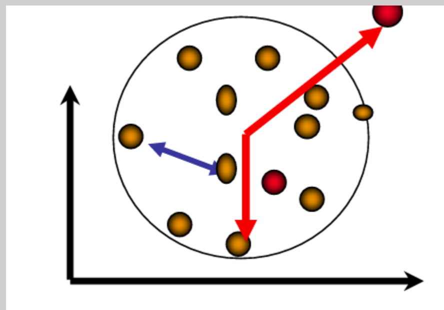
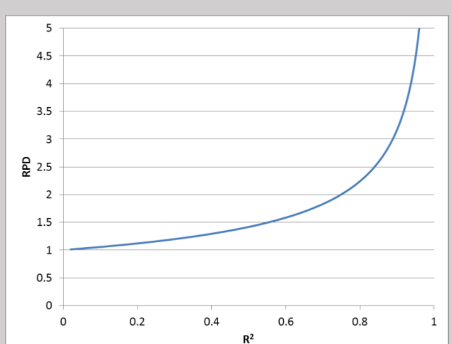
Illustration of the Global H and Neighborhood H Values



27

What is RPD?

- RPD is the "ratio of performance to deviation".
- A mathematical definition would be RPD = $(1\text{-}R^2)^{-0.5}$.
- Practical definition is the "Standard Error / Nutrient Standard Deviation"



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CVAS NIR Calibration Statistics for uNDF in Corn Silage

Constituent	N	Mean	SD	Est. Min	Est. Max	SEC	RSQ	SECV	SD/SECV
NDFom	205	39.311	6.748	19.069	59.554	1.004	0.978	1.181	5.714
uNDFom4HR_DM	305	37.407	6.454	18.045	56.768	1.256	0.962	1.344	4.802
uNDFom8HR_DM	310	31.765	5.629	14.879	48.652	1.364	0.941	1.479	3.807
uNDFom12HR_DM	306	24.999	4.560	11.318	38.680	1.329	0.915	1.454	3.137
uNDFom16HR_DM	307	22.186	4.058	10.011	34.360	1.180	0.916	1.380	2.940
uNDFom20HR_DM	101	19.020	3.101	9.718	28.322	1.029	0.890	1.181	2.625
uNDFom24HR_DM	98	17.314	3.204	7.703	26.925	0.784	0.940	1.088	2.943
uNDFom30HR_DM	296	16.052	3.914	4.309	27.794	1.072	0.925	1.221	3.206
uNDFom36HR_DM	95	13.142	2.988	4.179	22.105	0.574	0.963	0.854	3.497
uNDFom48HR_DM	300	12.880	3.332	2.884	22.875	0.924	0.923	1.111	3.000
uNDFom72HR_DM	302	12.030	3.123	2.660	21.400	0.865	0.923	1.009	3.095
uNDFom96HR_DM	97	10.998	2.809	2.573	19.424	0.449	0.974	0.641	4.382
uNDFom120HR_DM	302	10.930	3.011	1.898	19.962	0.955	0.899	1.060	2.840
uNDFom240HR_DM	306	10.307	2.905	1.593	19.020	0.905	0.903	1.040	2.792

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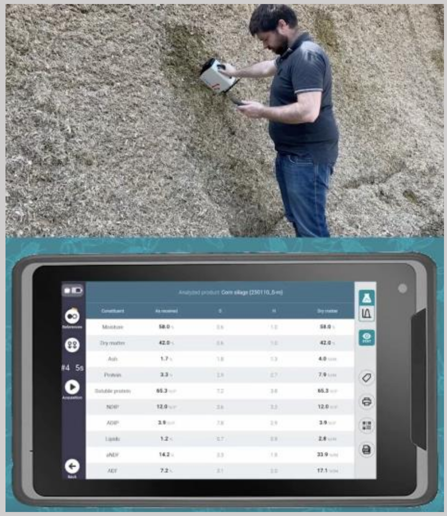
The NIR Team

Representing over 50 years of experience!

30

NIR Technology Application



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Handheld NIR Opportunities

- Several models of handheld NIR available in the market.
  - NeoSpectra
  - Trinamix
- Easily portable, few moving parts, advanced spectrophotometric capabilities.
- Good operating apps to work from phone for scanning and basic data management.
- Calibration statistics on dried ground material can be quite good.
- Affordable pricing.

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Handheld NIR Limitations

- Sample presentation to the NIR unit is a challenge for obtaining precise and repeatable results.
- Sample homogeneity is a key requirement for precision NIR analysis.
- As-received samples that are coarse and/or have high moisture may not provide reliable results.
- Predictions on ingredients can be acceptable if the material is ground.
- Matching of instruments can create problems in deployment of calibrations.

33

Sci-Ware CVAS Corn Silage Model

Parameter	N	Mean	SD	Min	Max	SEC	R2 CV	SECV	SD/SECV
DM	192	35.30	3.77	26.90	42.90	1.26	0.83	1.42	2.70
CP	192	7.84	0.79	6.10	12.10	0.47	0.50	0.54	1.50
NDF	191	37.91	3.56	30.00	60.00	1.98	0.62	2.31	1.50
LIGNIN	192	3.02	0.39	2.00	4.30	0.26	0.45	0.30	1.30
STARCH	185	34.63	5.16	16.50	44.10	2.71	0.62	3.20	1.60
FAT	180	3.26	0.32	2.20	4.10	0.21	0.38	0.25	1.30
ASH	189	3.26	0.32	1.80	7.80	0.24	0.30	0.27	1.20
LACTIC	196	3.42	1.06	1.00	9.00	0.75	0.30	0.90	1.20
ACETIC	195	5.09	1.41	0.30	8.50	0.81	0.50	0.98	1.40
PH	193	3.81	0.15	3.45	4.35	0.09	0.40	0.11	1.40

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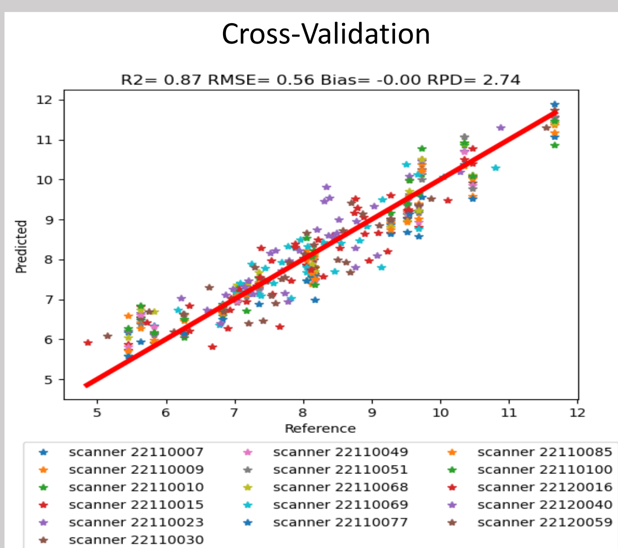
Dried ground corn silage model performance

Parameter	N	Mean	SD	Min	Max	SEC	r2 - CV	SECV	SD/SECV
ACETIC	153	2.01	1.34	-0.78	6.60	0.86	0.56	0.89	1.51
ADF	150	25.43	4.81	12.44	42.77	1.13	0.93	1.23	3.90
AMMONIA	152	0.89	0.30	0.21	1.73	0.14	0.76	0.15	2.03
ASH	151	4.57	1.50	-0.77	9.03	0.74	0.72	0.79	1.90
CP	152	8.12	1.55	4.85	11.67	0.54	0.87	0.57	2.74
FAT	152	3.01	0.44	1.49	4.44	0.23	0.70	0.24	1.81
LACTIC	153	4.45	1.98	0.61	9.33	0.83	0.81	0.86	2.30
LIGNIN	152	3.26	0.66	1.44	5.69	0.30	0.76	0.32	2.06
NDF	153	41.39	7.45	23.38	66.82	2.00	0.92	2.09	3.56
PH	152	3.93	0.18	3.50	4.39	0.09	0.71	0.10	1.84
STARCH	153	29.28	11.49	0.75	51.09	2.93	0.93	2.97	3.87
TFA	152	2.47	0.50	1.05	3.54	0.24	0.75	0.25	2.00
uNDFom240HR_DM	152	11.50	2.52	5.07	21.83	1.29	0.72	1.34	1.89
uNDFom30HR_DM	151	16.90	2.98	8.91	29.31	1.40	0.75	1.49	1.99

35

CP model



36

Handheld NIR Opportunities

- Match the technology to the optimal use.
- Speed of access to information is only of value as that information allows for time-sensitive decisions to be made.
- Does the technology bring value or require time, capital, administrative, and technical resources?

37

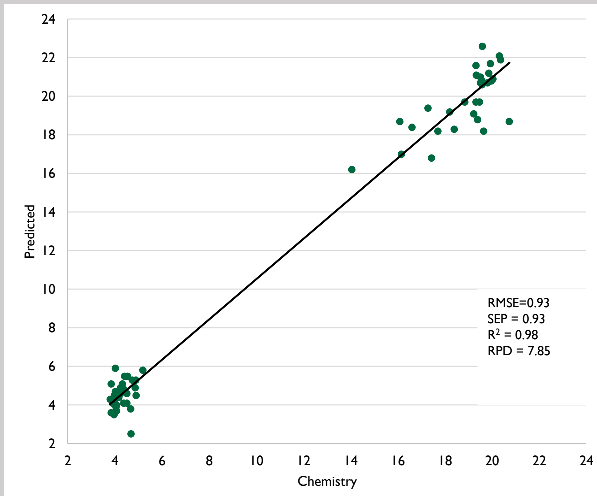
Use case: Receiving soybeans at the mill

- High oleic soybean genetics are coming into the marketplace.
- Mills receiving these soybeans need to know in real time if the beans being delivered are high oleic.
- The NeoSpectra NIR unit will allow the mill to effectively determine whether soybeans are high oleic or traditional genetics.

38

NIR Predicted Oleic Acid vs Chemistry, High Oleic versus Traditional Genetics

(% of DM)



39

Future Opportunities

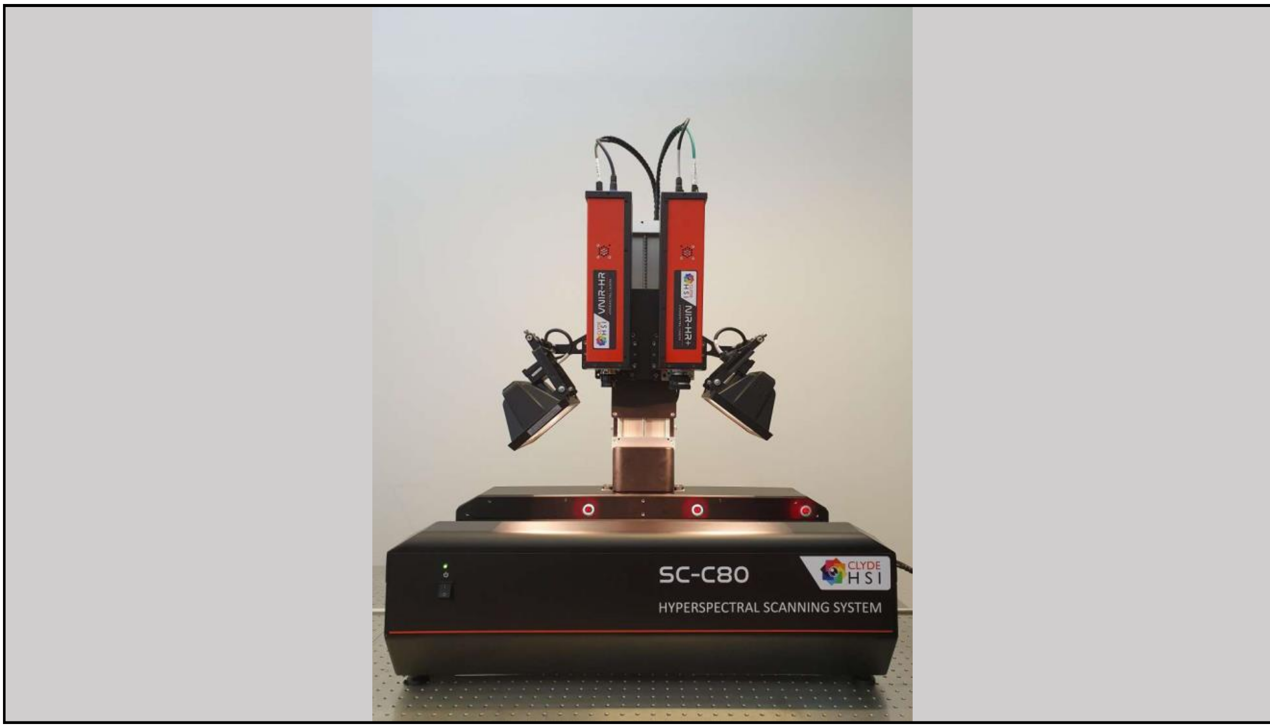
- VNIR Hyperspectral imaging

A technology that uses sensors to collect a broad range of spectral data in the NIR and visible regions on a pixel basis evaluating a material multidimensionally using advanced computing to derive relationships.

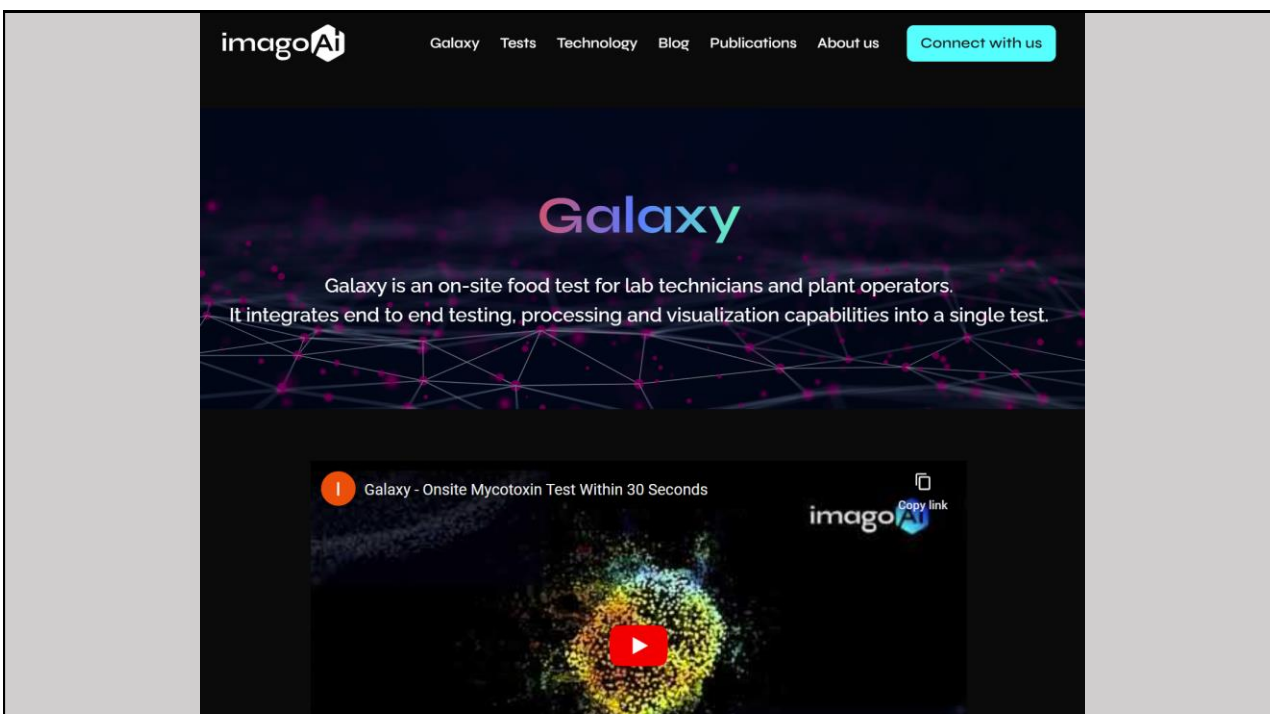
Used in a variety of quality evaluations such as food quality control

There is significant research to apply this in various quality control realms.

40


VNIR-HR
NIR-HR+
SC-C80
CLYDE
HSI
HYPERSPECTRAL SCANNING SYSTEM

41


imagoAi
Galaxy
Tests
Technology
Blog
Publications
About us
Connect with us
Galaxy
Galaxy is an on-site food test for lab technicians and plant operators.
It integrates end to end testing, processing and visualization capabilities into a single test.
Galaxy - Onsite Mycotoxin Test Within 30 Seconds
Copy link
imagoAi

42

Future Opportunities

- Reducing analytical error through replication:

$$SE = \frac{\sigma}{\sqrt{n}}$$

Standard deviation

Number of samples

43

Future Opportunities

- Improved quality of calibrations.
- Expanded calibrations or new calibrations built around specific materials or forage species.
- Expert systems to develop information from sample comparison to the population or recognizing change over time.
- Increased understanding of what data is important in recognizing quality and variation over time.

44

Obtaining value from a feed/forage lab engagement

Florida Ruminant Nutrition Symposium
February 27, 2024

Ralph Ward
Cumberland Valley Analytical Services

45

Control of milk protein synthesis by amino acids in dairy cows

Sebastian I Arriola Apelo

Arriola Apelo Lab

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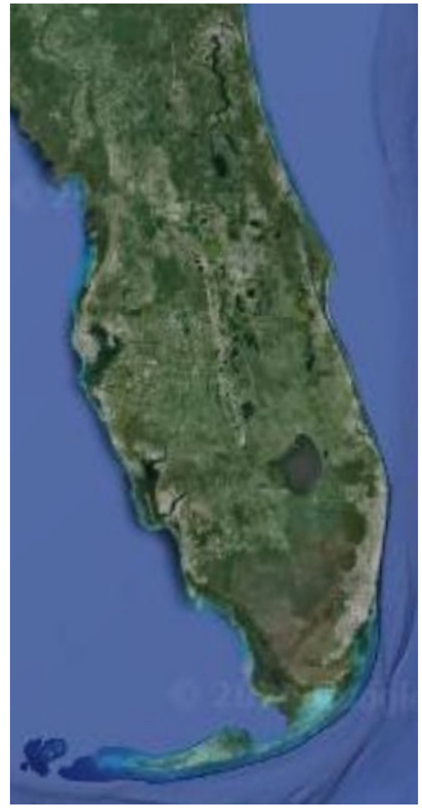
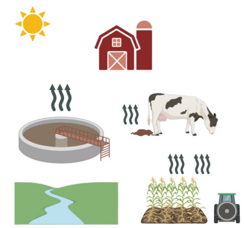
❖ @arriolaapelolab
❖ arriolaapelolab.andysci.wisc.edu

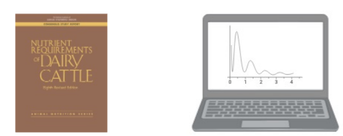


Google earth

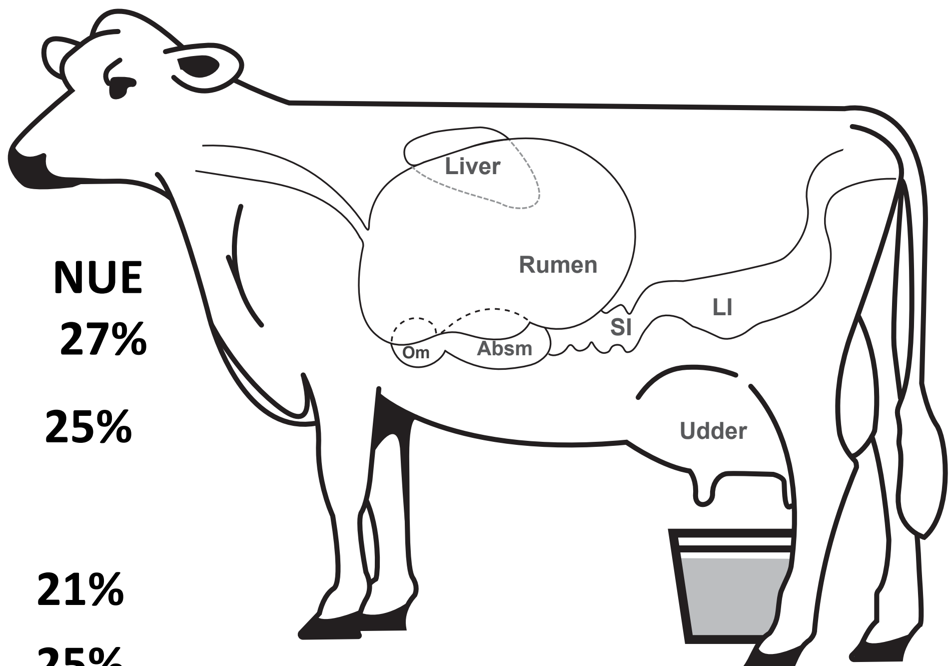
OUTLINE



- ➢ Nitrogen (N) efficiency and emissions
- ➢ Limiting amino acids (AA)
- ➢ Regulation of milk protein synthesis, . . . *and beyond*
  - ➢ Transcription
  - ➢ Translation
  - ➢ Insulin role
  - ➢ Energy sources
- ➢ Model performance

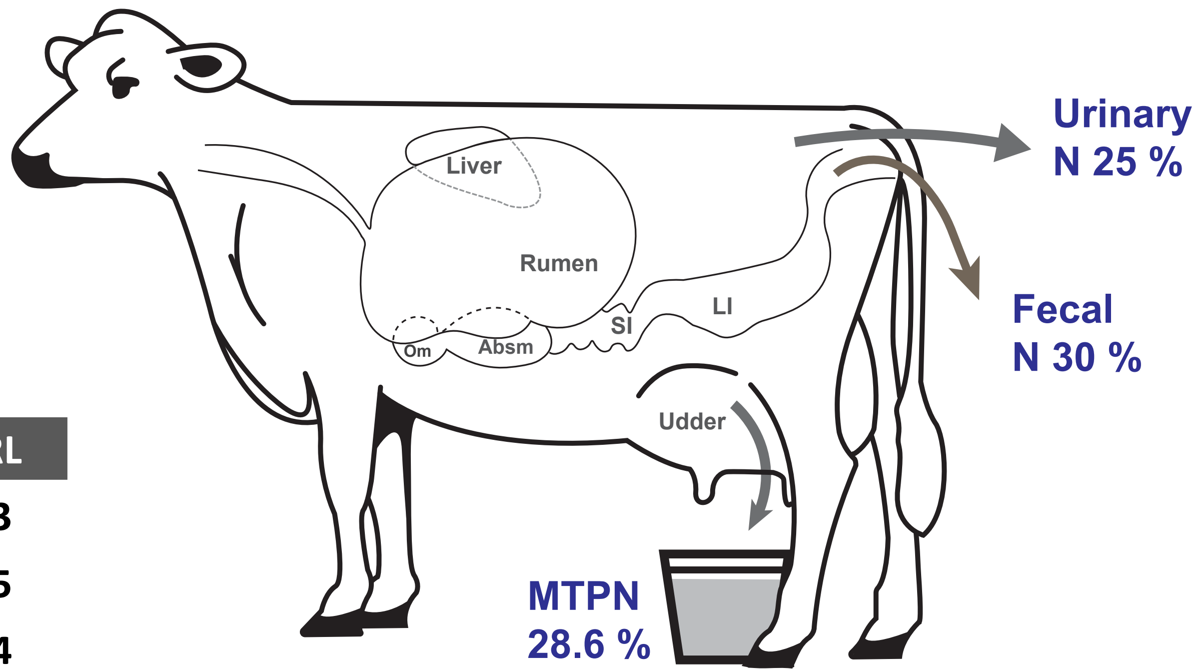


How much N does a lactating cow waste?



	NUE
Spek et al., 2013	**27%**
Arriola Apelo et al., 2014	**25%**
Brito & Silva, 2020	
Jersey - Organic	**21%**
Jersey - Conventional	**25%**
Non-Jersey - Organic	**27%**

Where is the N going?

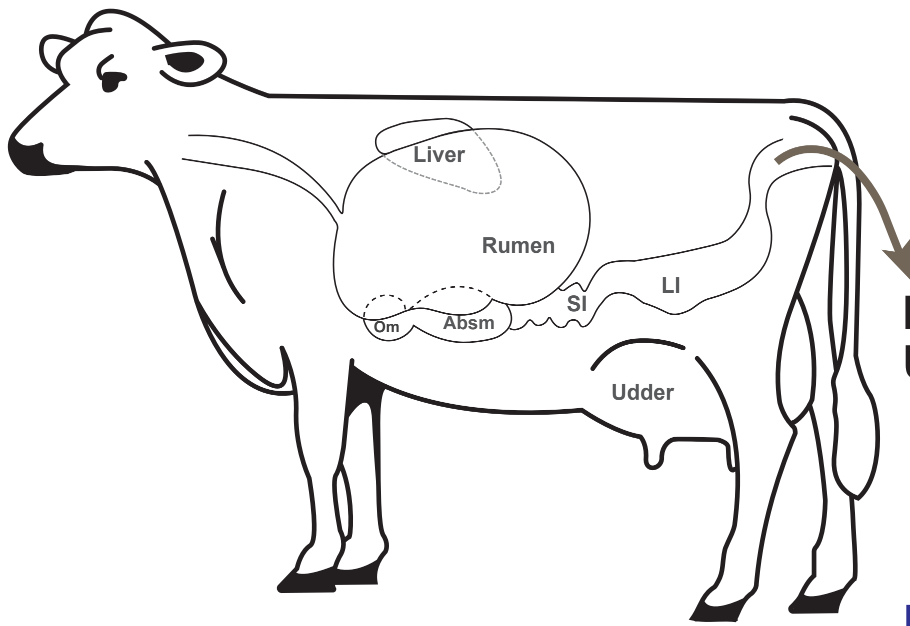


	CTRL
CP %	17.3
DMI, lb/d	48.5
Milk lb/d	83.4
Protein %	2.99
MUN mg/dL	11.9

Adapted from Chowdhury et al. JDS 2024

Is all the N excreted the same?

Risk of negative environmental impact of N emissions



Fecal N

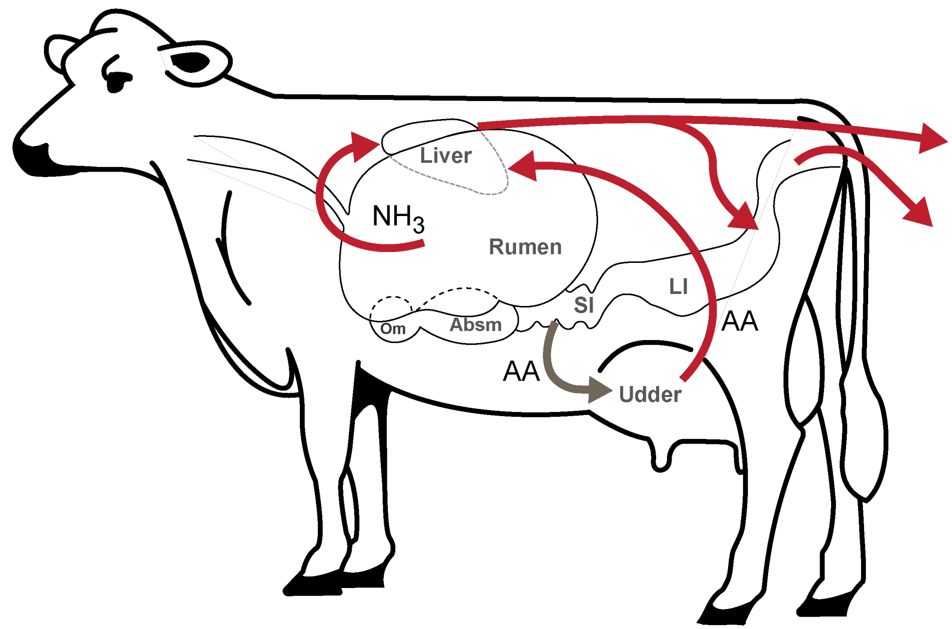
Undigested proteins

- ADIN
- Maillard
- MiCP
- Endogenous

Low risk

Is all the N excreted the same?

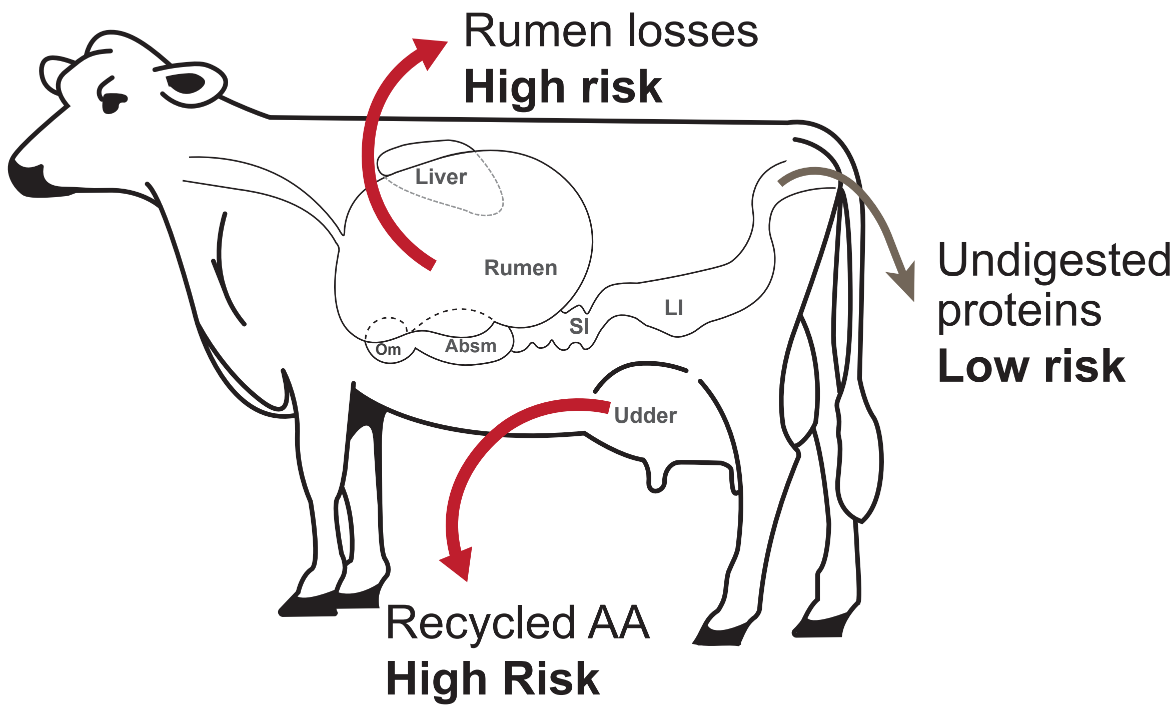
Risk of negative environmental impact of N emissions



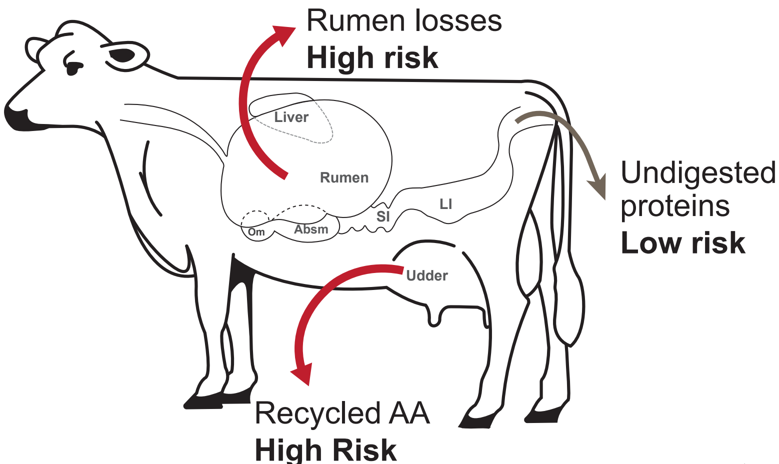
Hepatic ureagenesis
- Rumen ammonia
- AA catabolism

High risk

Risk of negative environmental impact of N emissions



Prediction of N partitioning by NASEM



N losses, % intake	CTL	BAA
[1]Rumen	21.6	18.7
[2]Intestinal	24.9	29.2
[3]Catabolic	13.0	17.6

[1]Rumen = $\frac{\text{RDP\_Bal\_g}}{6.25 \times \text{NIn\_g}}$

[2]Intestinal = $\frac{(\text{RUPIn\_g} + \text{MiCP\_g} - \text{An\_MPIn\_g})}{6.25 \times \text{NIn\_g}}$

[3]Catabolic = $\frac{(\text{MPIn\_g} - \text{Mlk\_NP\_g} - \text{Scrf\_NP\_g} - \text{Fe\_NPEnd\_g} - \text{UrNPEnd\_g})}{6.25 \times \text{NIn\_g}}$

Ruh, . . ., Arriola Apelo, Unpublished data

Effect of protein level on N use efficiency

	CTRL	L-CP	*P (n=14)*
CP %	17.3	15.1	
DMI, lb/d	48.5	46.4	0.37
Milk lb/d	83.4	79.9	0.17
Protein %	2.99	3.01	0.4
MUN mg/dL	9.44	6.91	<0.01
NUE %	**28.6**	**33.9**	**<0.01**

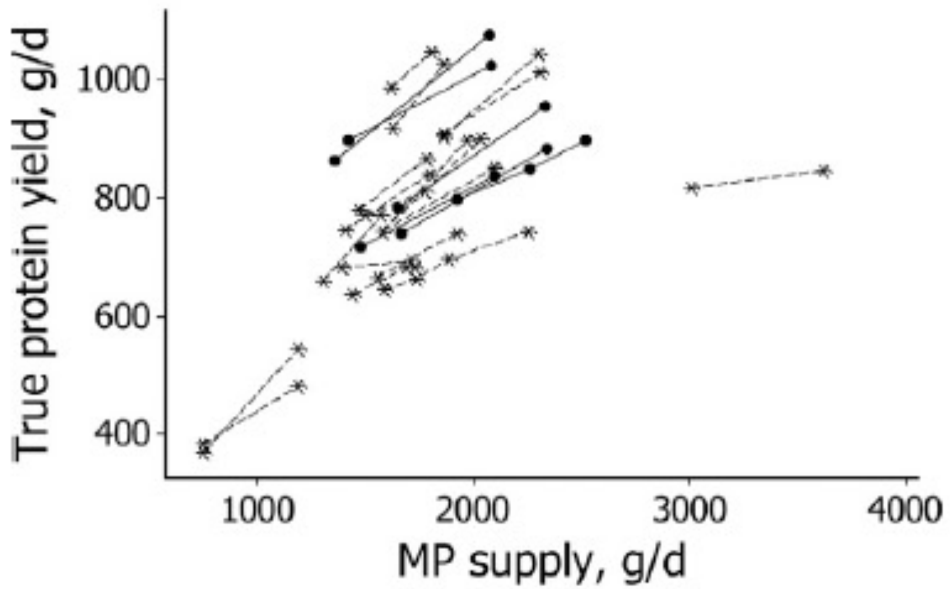
– 25% increase in N efficiency

– Relative increase in more stable fecal N

– Absolute and relative decrease in urea-N losses

Adapted from Chowdhury et al. JDS 2024

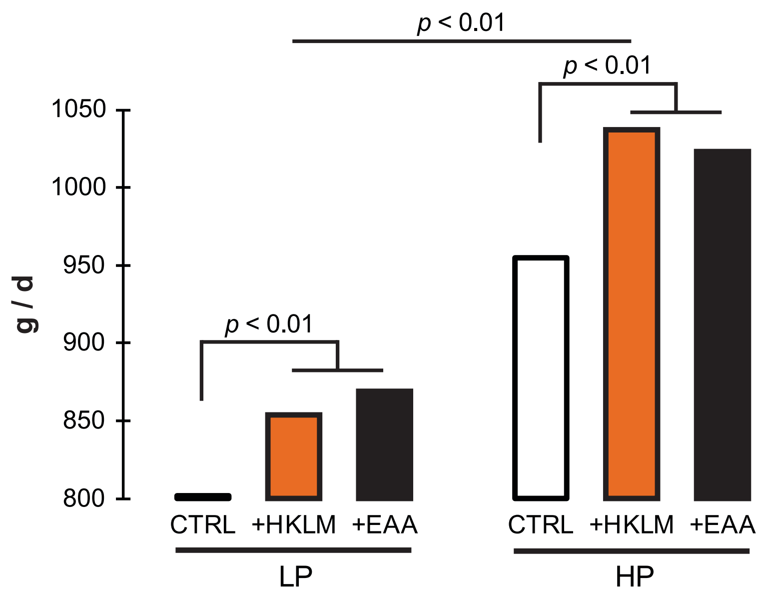
MP effect on MTP yield



POSSITIVE **DIMINISHING** RESPONSE

Lapierre et al. JAS 2012

Balancing for His, Lys, Leu, and Met or all the EAA



Milk protein yield

Haque et al., JDS 2012

Limiting AA theory

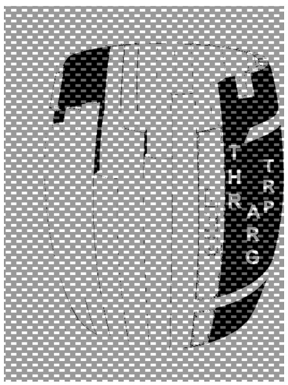
The **first limiting AA** (e.g. Met) limits responses to other AA

Substrate based approach, but . . .

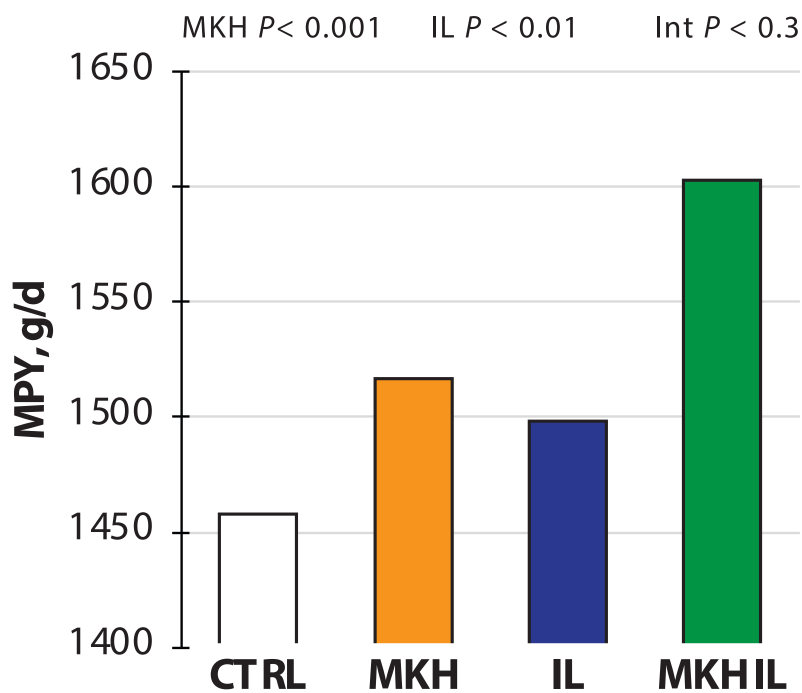
Does the cow runs out of AA?

What about fat responses?

Independent AA effects – MPY response to jugular infusion of 5 essential AA



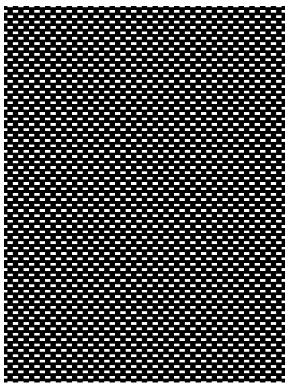
Independent, additive responses to different AA contradicts the idea of a first limiting AA



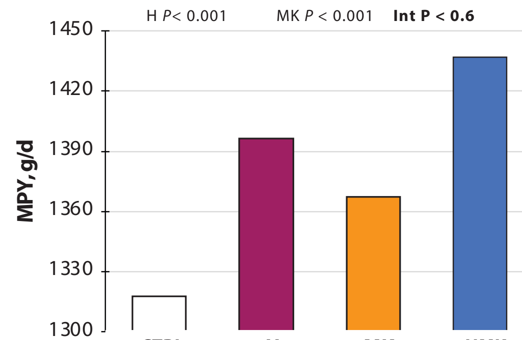
<u>Met, Lys, His, Ile, and Leu</u> became the 5 NASEM AA with independent, additive effects on MPY

Adapted from Yoder et al. JDS 2020

Independent AA effects – diet approach



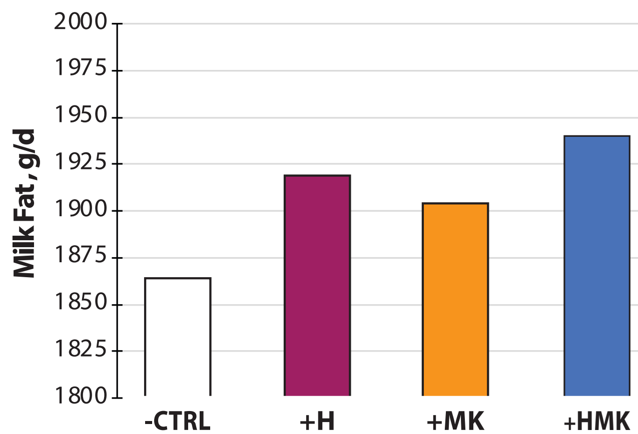
Independent, additive responses using dietary approaches



	-CTRL	+H	+MK	+HMK
His	–	21	3	24
Lys	–	6	42	44
Met	–	-1	14	13
Ile	–	-8	5	-4
Leu	–	15	21	32
EAA	–	81	108	184
MP	–	100	191	272

Killerby, . . . Arriola Apelo, unpublished

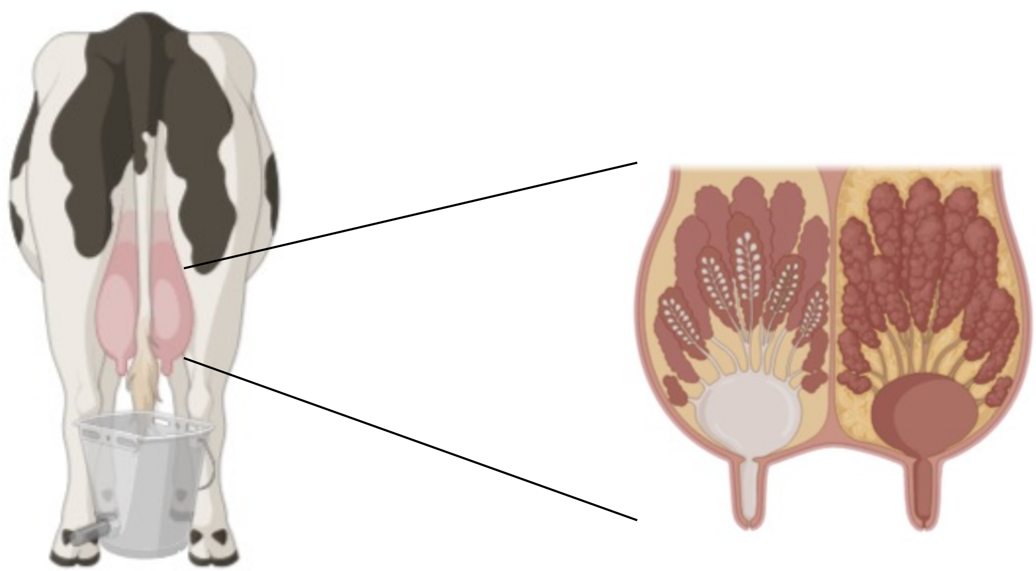
AA effects on milk fat production

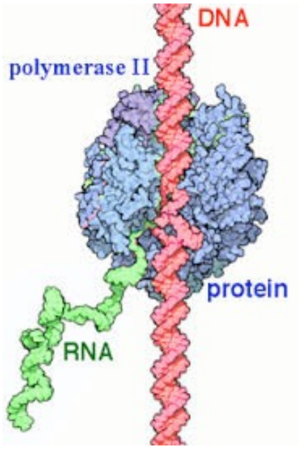


Independent AA effects on milk fat synthesis

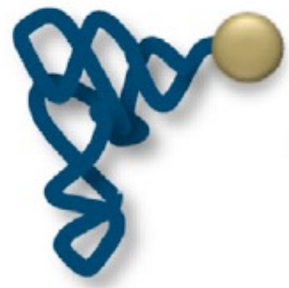
Killerby, . . . Arriola Apelo, unpublished

Regulation of milk protein synthesis in the mammary glands





DNA



tRNA

Ribosome

Transcription

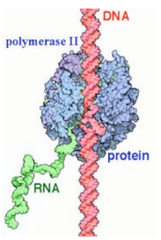
Translation

Jak
STAT

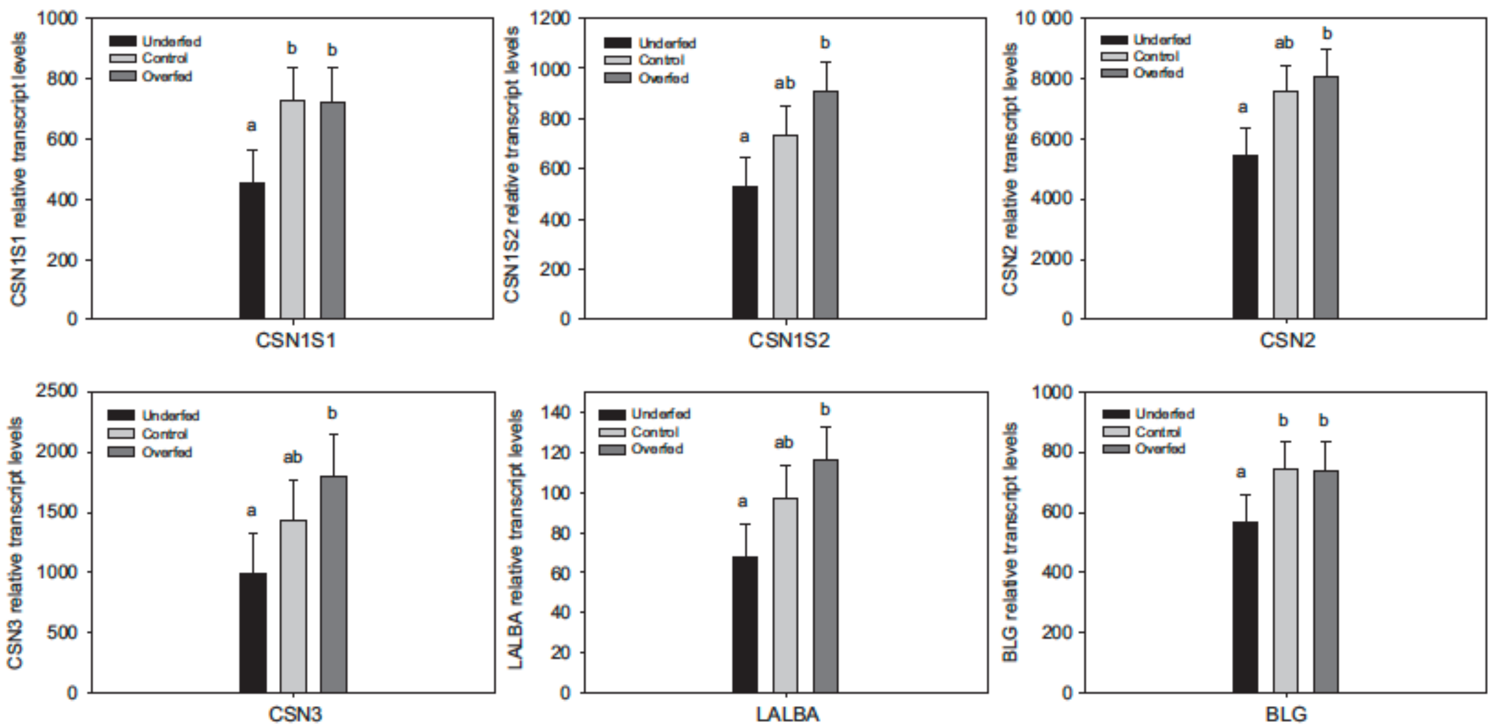
Integrated
Stress
Response

mechanistic
Target **o**f
Rapamycin
Complex 1

Regulation of milk protein's gene transcription



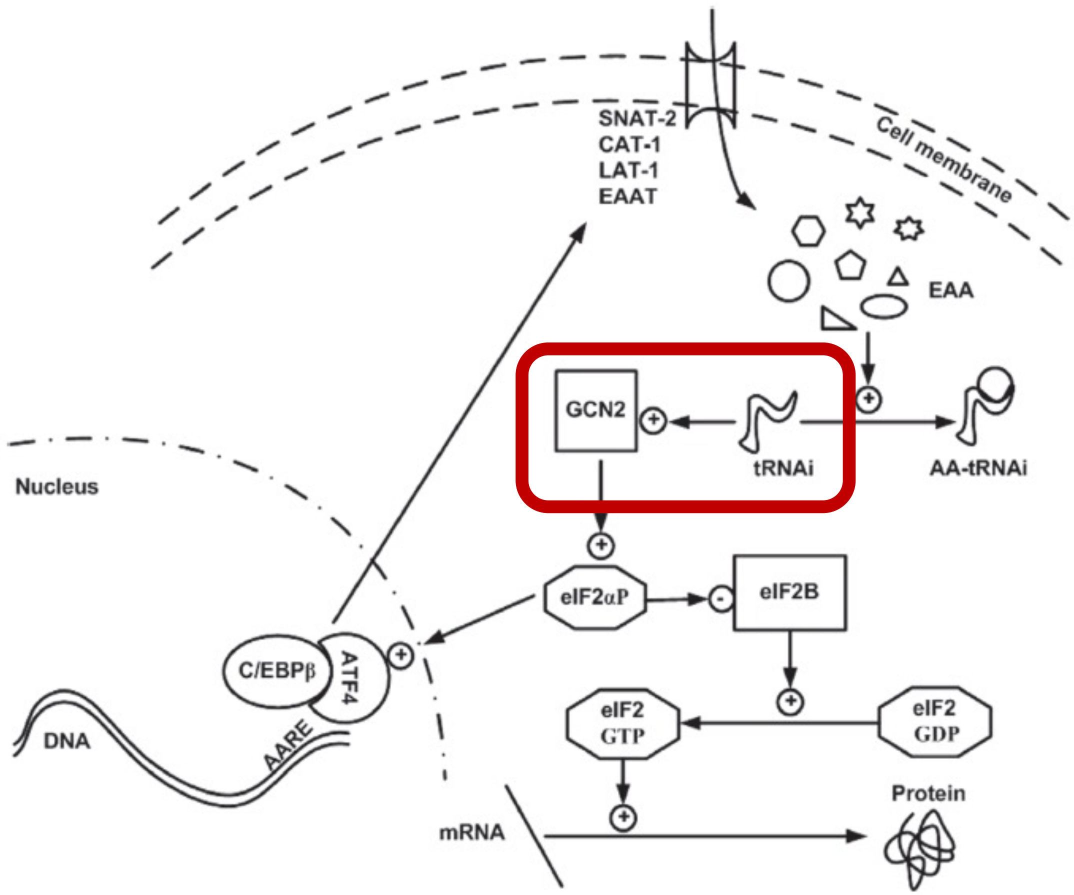
Transcription



Tsiplakou et al., JAPAN, 2015

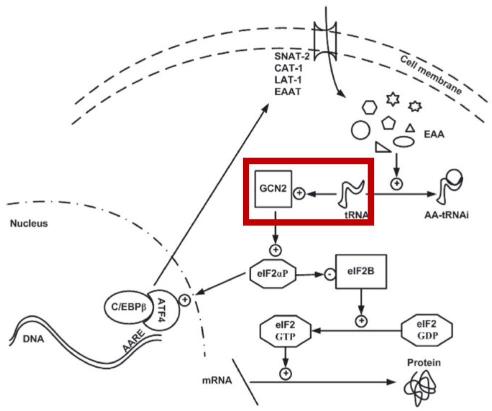
Regulation of milk protein translation - ISR

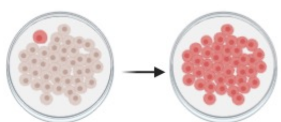
tRNA

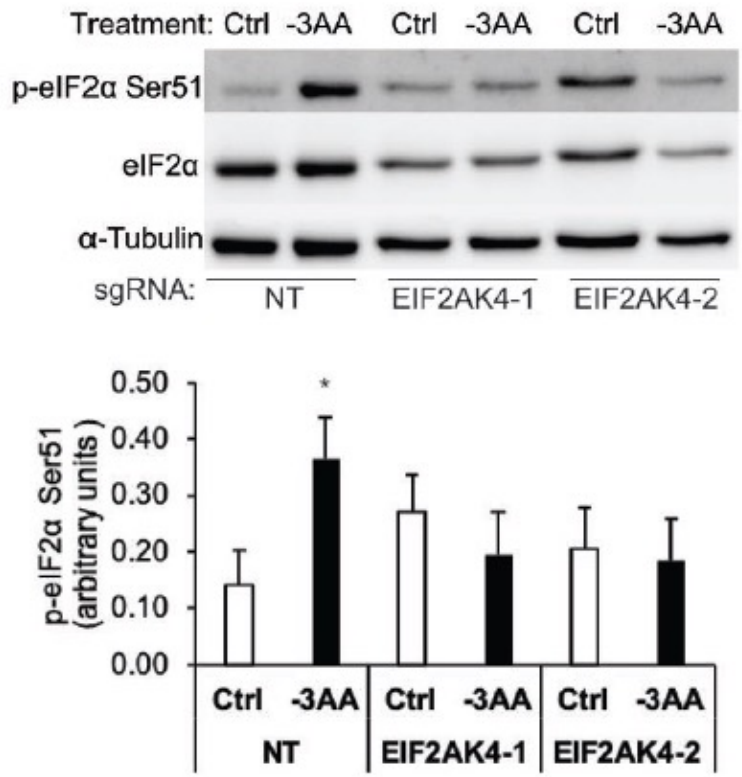


Arriola Apelo et al., JDS 2014

GCN2 sensing of AA in BMEC

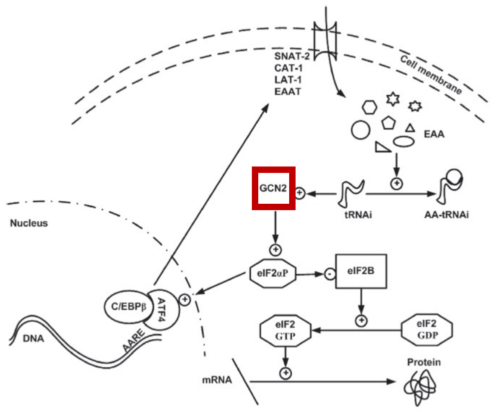




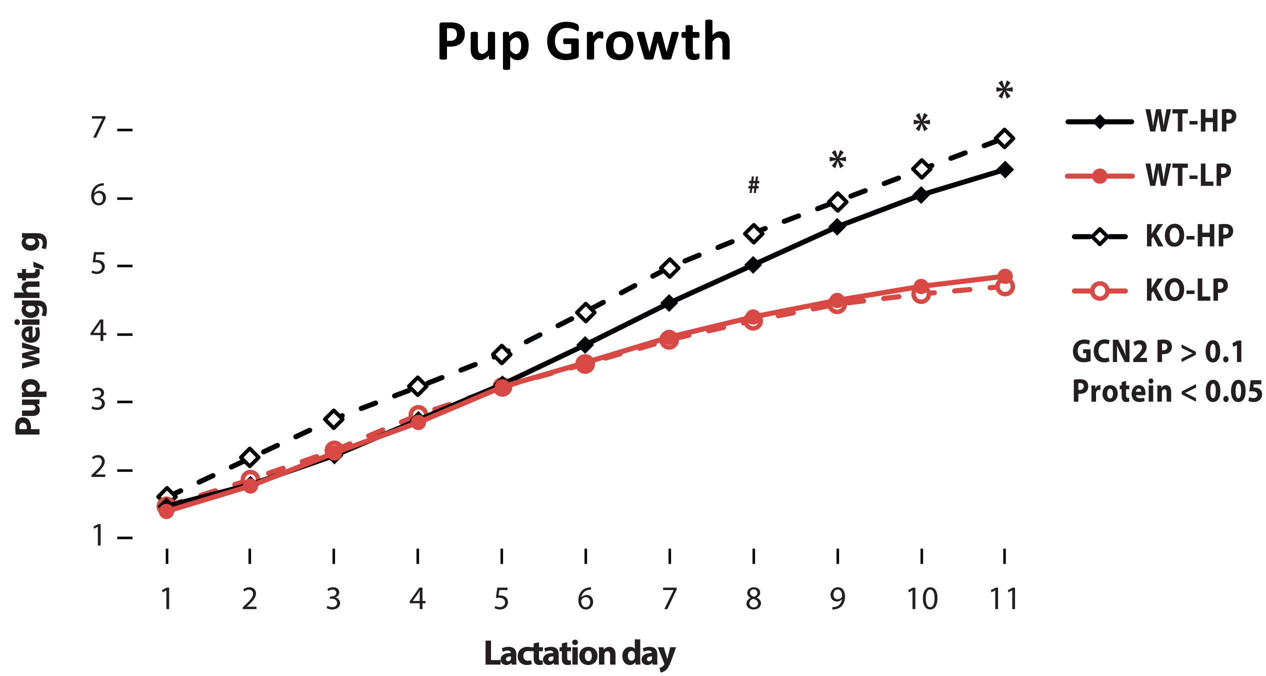


Edick et al., JDS 2021

GCN2 regulation of lactation

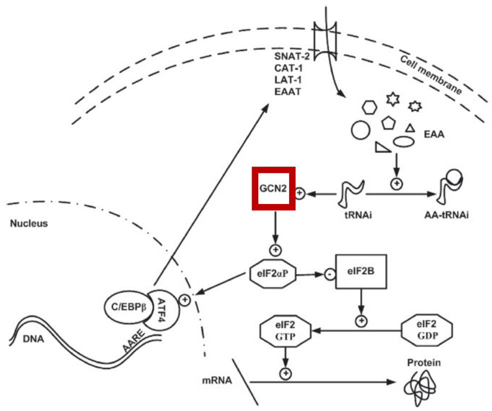


WAP-cre GCN2

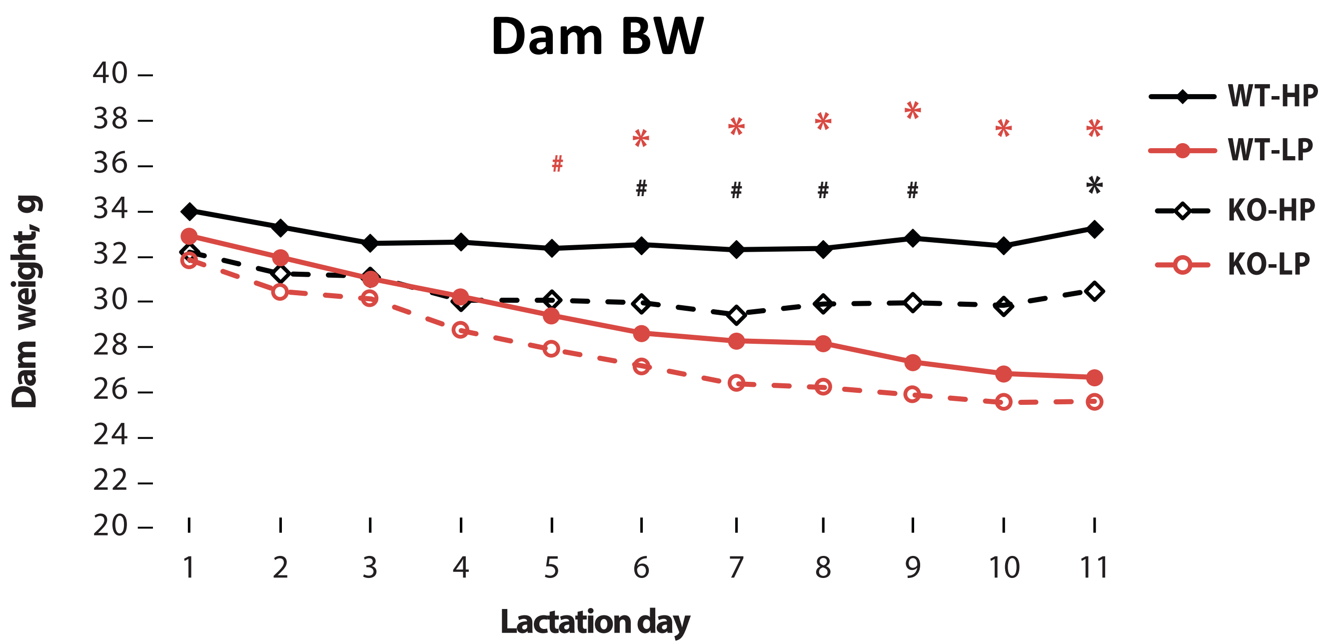


Arriola Apelo, unpublished

GCN2 regulation of lactation

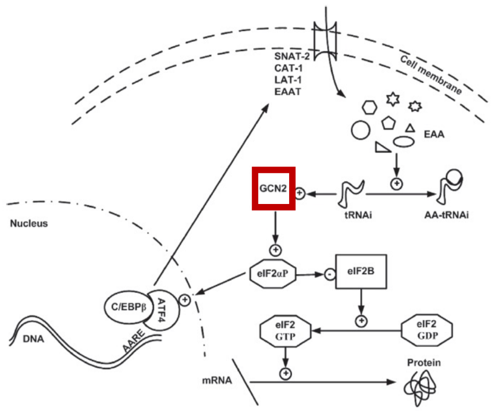


WAP-cre GCN2

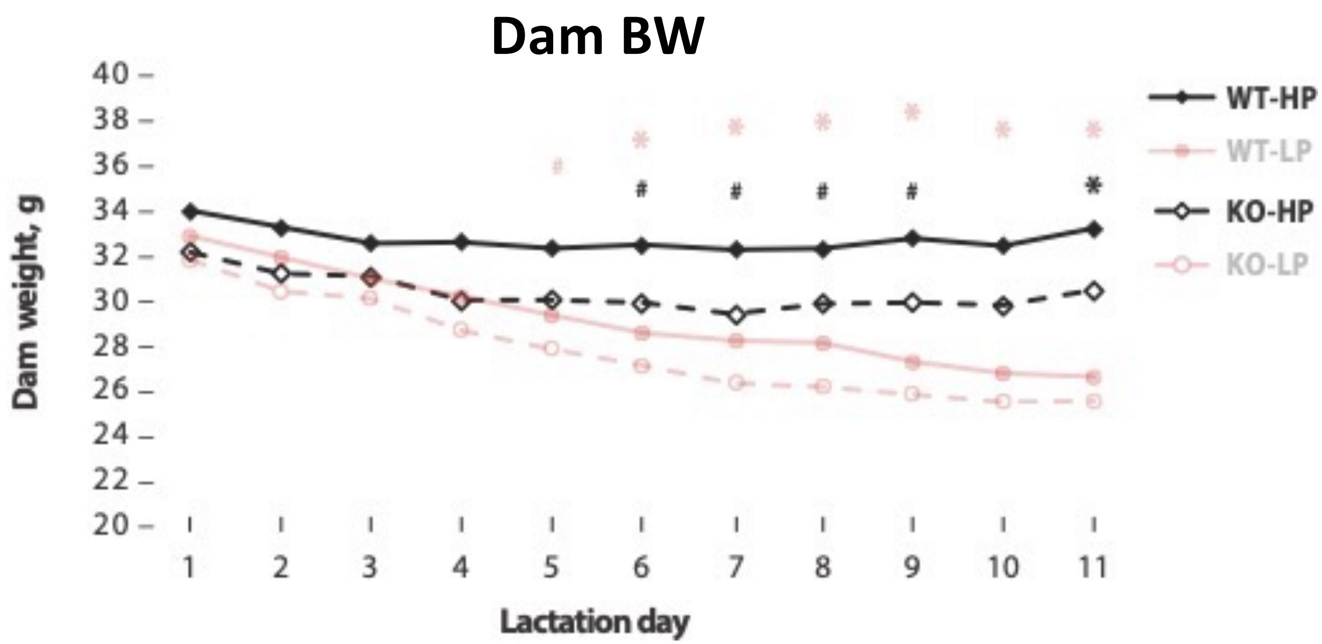


Arriola Apelo, unpublished

GCN2 regulation of lactation

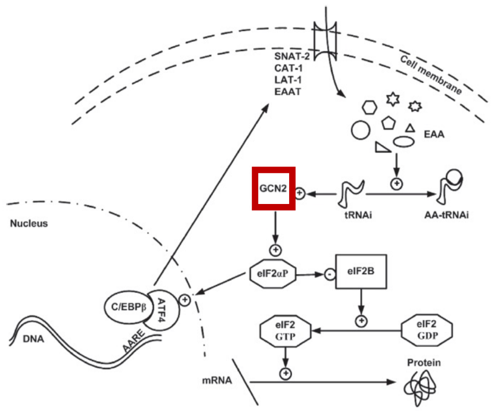


WAP-cre GCN2

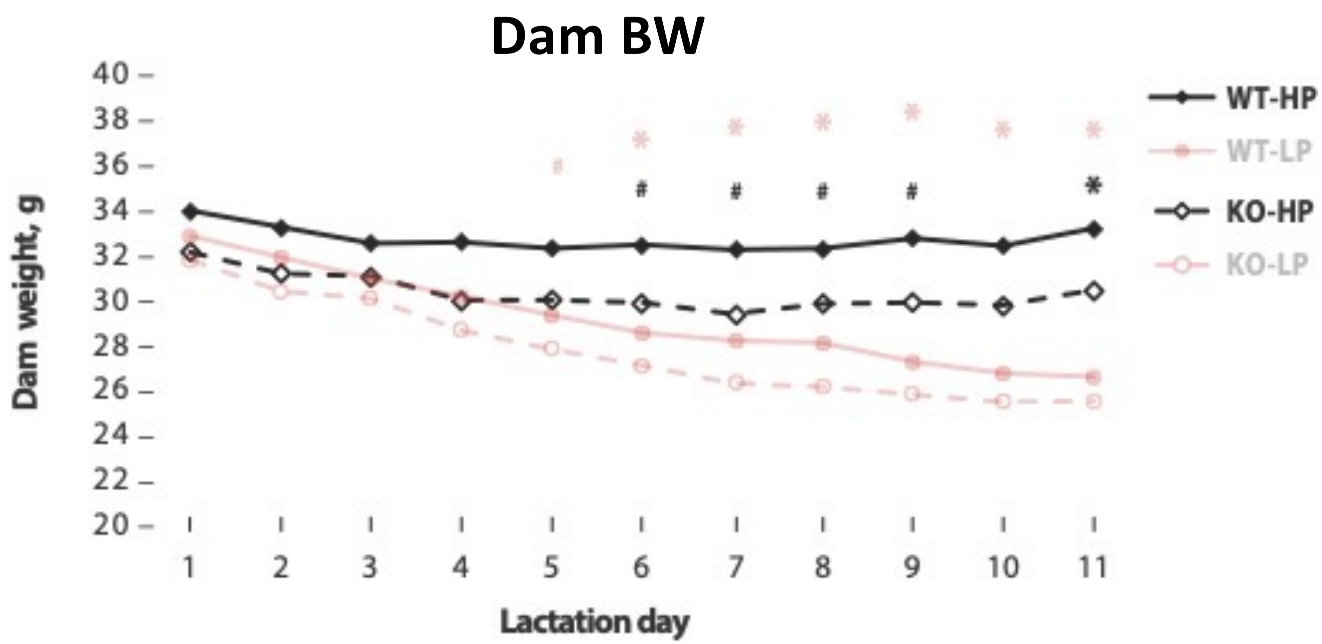


Arriola Apelo, unpublished

GCN2 regulation of lactation



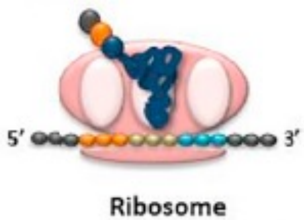
WAP-cre GCN2

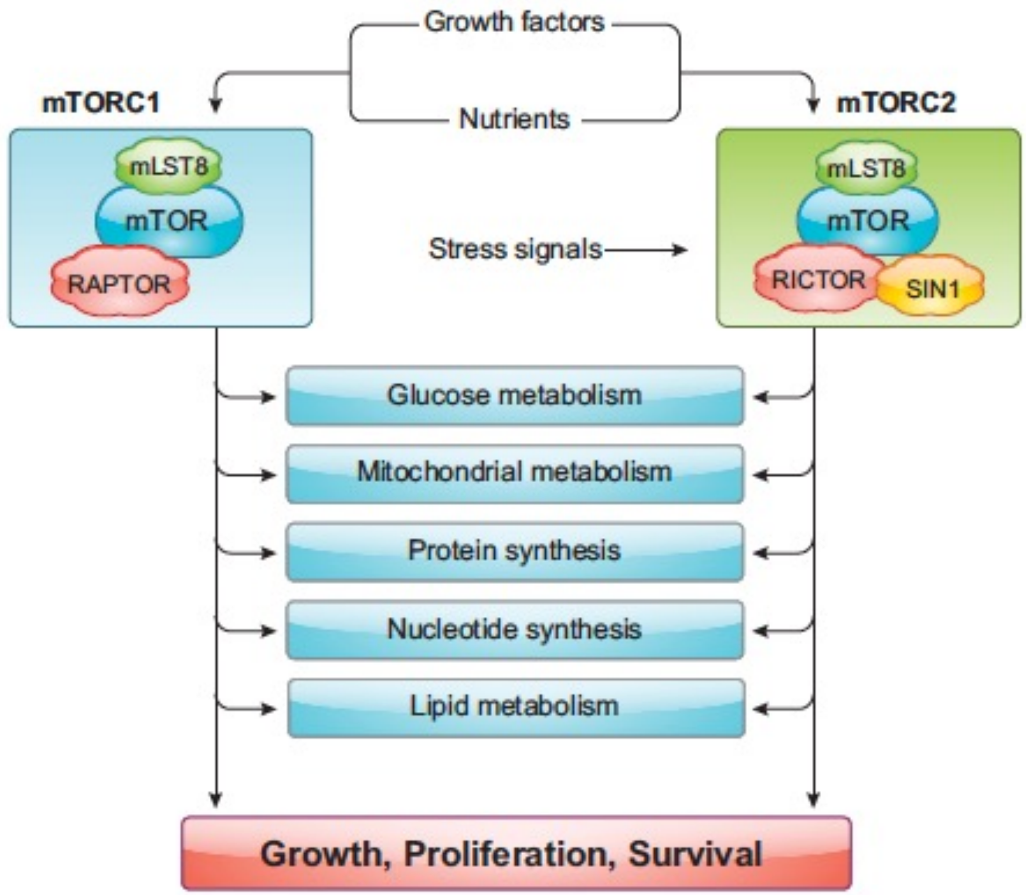


- Limited evidence in vitro and other species
- Probably more relevant under strong AA imbalance

Arriola Apelo, unpublished

mTORC1 regulation of translation, . . . *and beyond*





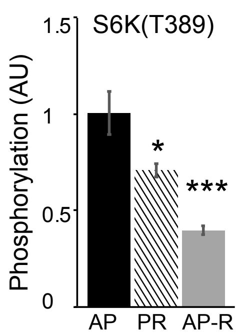
Swed et al., PR 2021

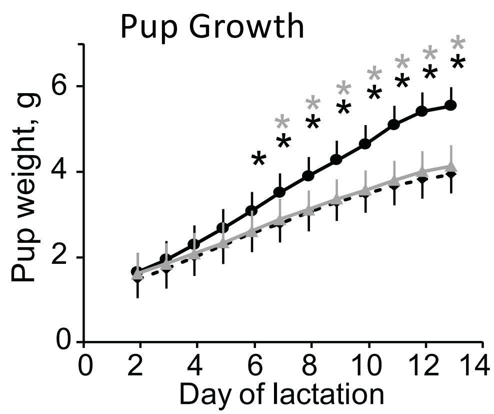
Review

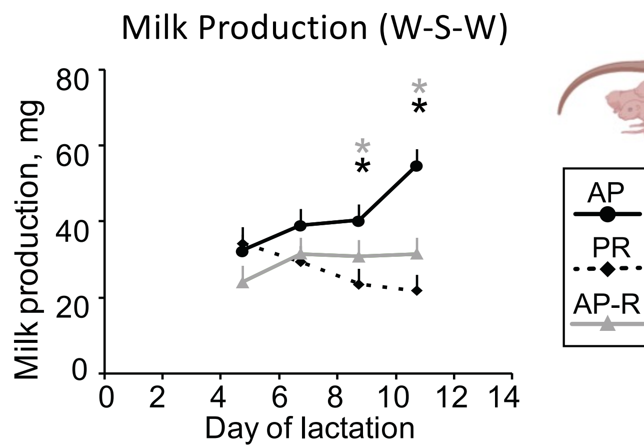
Rapamycin: An InhibiTOR of Aging Emerges From the Soil of Easter Island

Sebastian I. Arriola Apelo and Dudley W. Lamming

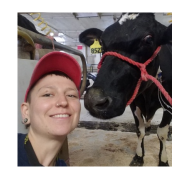
Department of Medicine, University of Wisconsin–Madison and William S. Middleton Memorial Veterans Hospital, Madison, Wisconsin.







- mTORC1 mediates AA effect in murine lactation

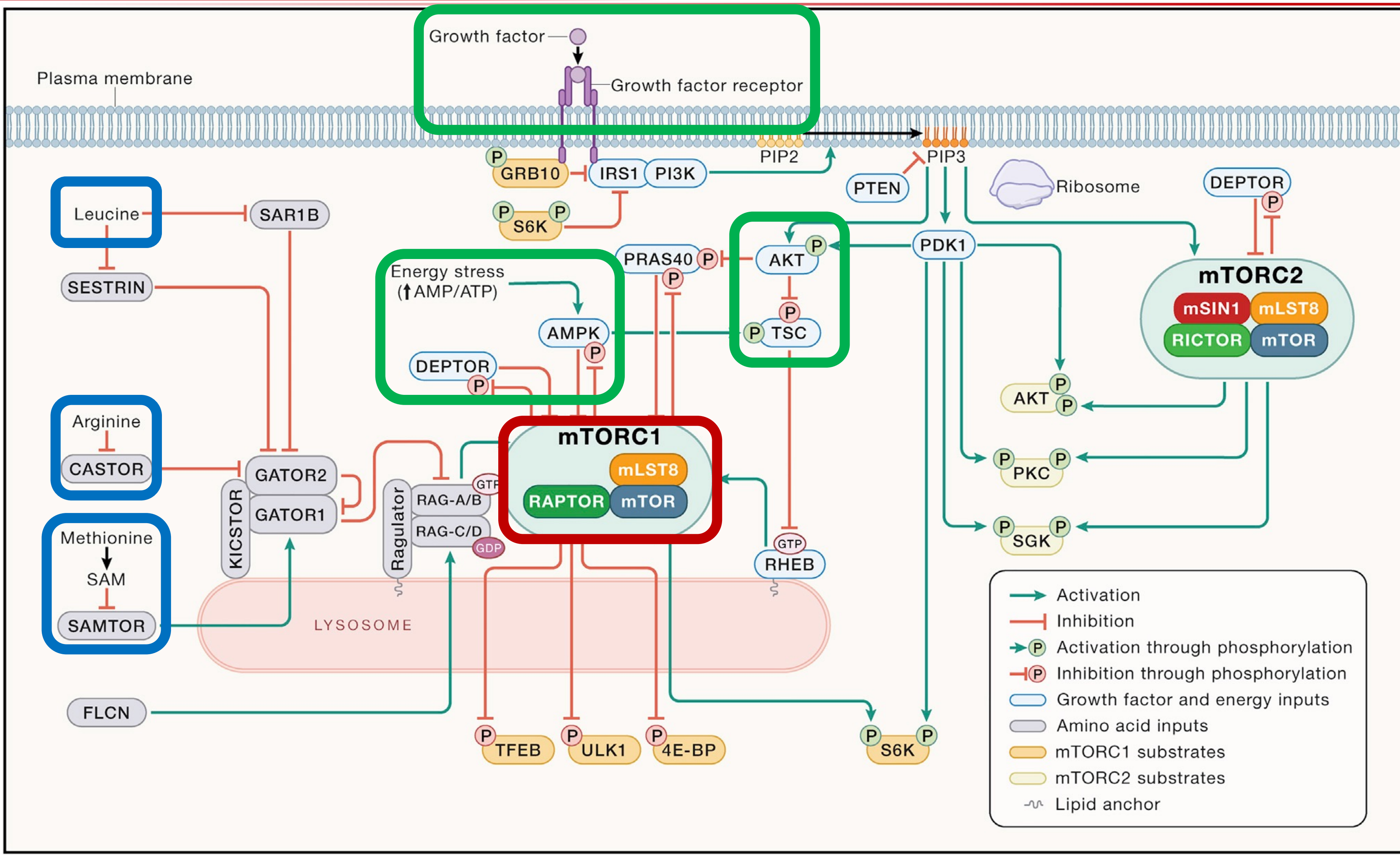


Pszczolkowski et al., JASB 2020

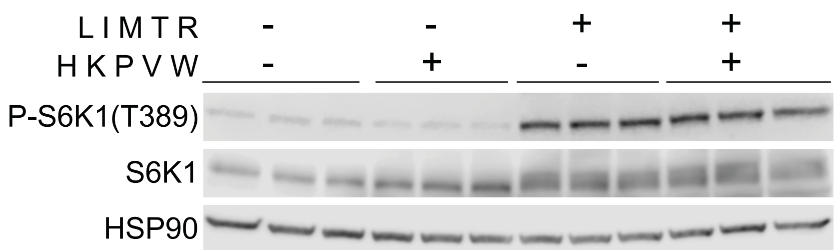
REGULATORY MECHANISMS

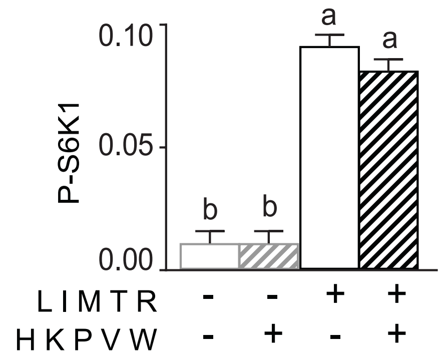
Arriola Apelo Lab

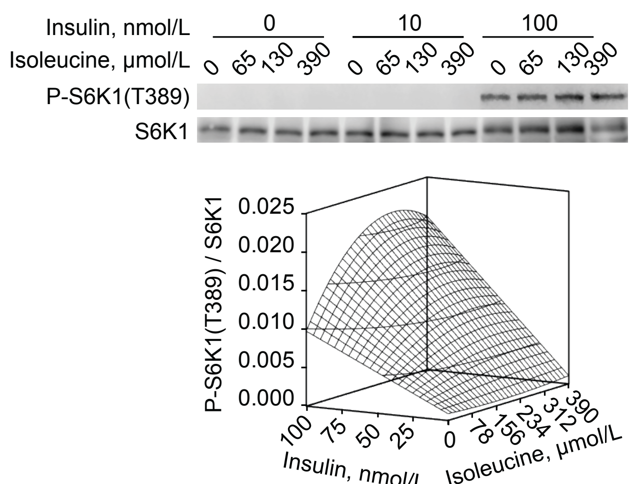
ANIMAL & DAIRY SCIENCES
University of Wisconsin-Madison

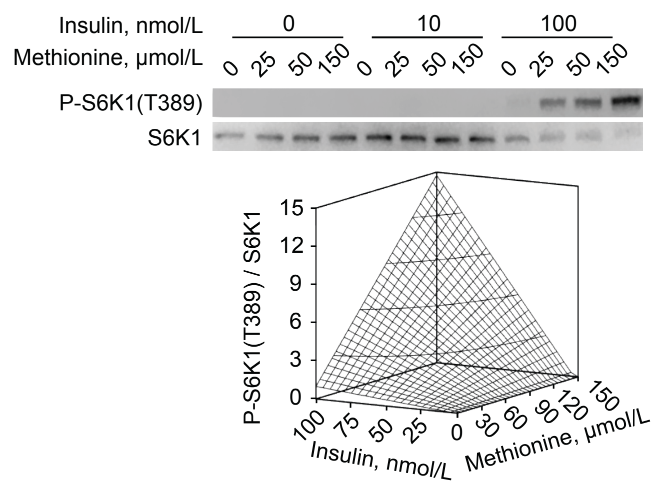


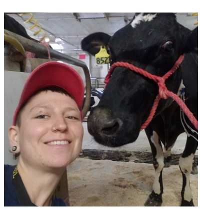
Specific AA regulation of mTORC1





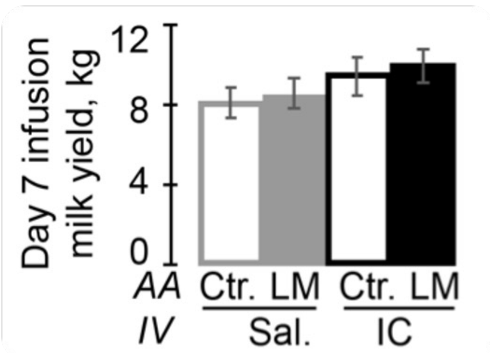


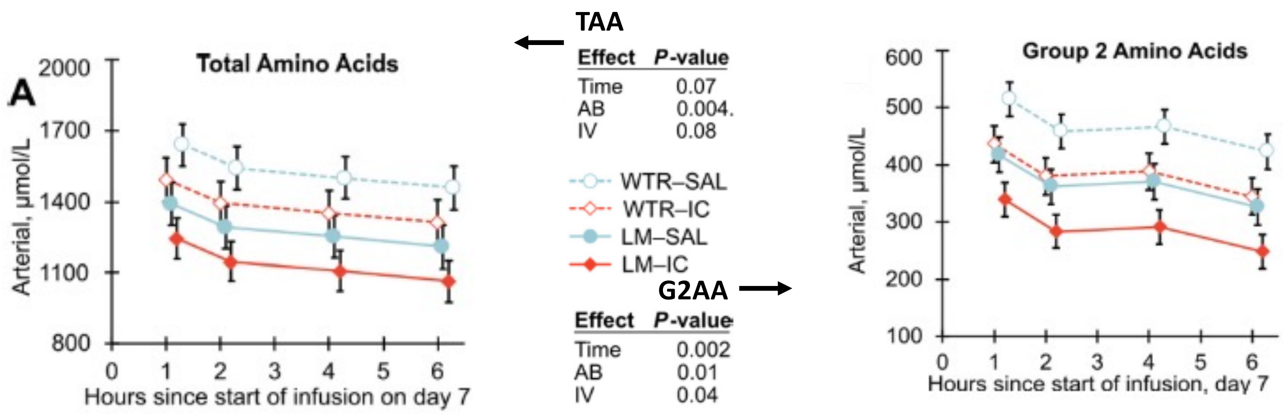


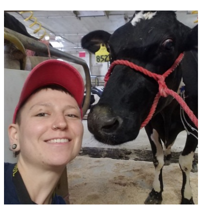


Pszczolkowski, Zhang et al., 2020

Insulin role in AA regulation of milk production







Pszczolkowski et al., DAE 2022

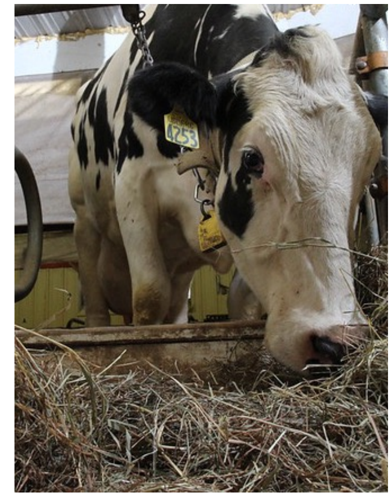
Mammary gland extraction of AA at h 6 of clamp

	WTR		LM			p-value	
%	SAL	IC	SAL	IC	SEM	AB	IV
Total AA	22.9	24.2	23.2	24.5	5.07	0.95	0.79
EAA	39.5	37.8	38.8	37.1	6.12	0.34	0.69
Group 1 AA	34.5	36.7	31.0	33.2	6.30	0.43	0.64
Group 2 AA	38.9	35.5	46.6	43.2	5.30	0.05	0.39
NEAA	14.2	16.5	11.8	14.1	6.05	0.68	0.70

Starch role in milk production

Item	Diets (NDF : starch ratios)			
	T1	T2	T3	T4
Ingredient, % DM				
Alfalfa	15.0	15.0	15.0	15.0
Corn silage	20.0	25.0	30.0	35.0
Oat hay	0.0	5.0	10.0	15.0
Corn	35.0	25.0	15.0	5.0
CP	17.5	17.6	17.6	17.6
NDF	29.8	34.0	37.7	41.2
ADF	18.1	20.5	25.0	27.7
Starch	34.4	28.8	23.2	17.6
NEL†, Mcal/kg	1.81	1.73	1.65	1.57
DMI, kg/day	23.2^{a}	21.7^{a}	20.1^{b}	18.3^{c}
MP¶, g/day	3,029^{a}	2,831^{ab}	2,614^{bc}	2,462^{c}
Milk yield, kg/day	33.2^{a}	33.0^{a}	31.4^{b}	28.3^{c}
FCM†, kg/day	32.2^{a}	32.5^{a}	32.0^{a}	29.2^{c}
ECM‡, kg/day	34.2^{a}	34.1^{a}	33.4^{b}	30.2^{c}
Protein, kg/day	1.06^{a}	1.02^{b}	0.96^{c}	0.85

Adapted from Zhao et al. ASJ 2016



Substituting starch decreases:

- Dietary energy density
- Dry matter intake
- VFA production
- MiCP & MP supply
- Lactose, protein, and fat yield

Isocaloric substitution of starch with non-pNDF (+fat) in AA balanced diets

Ingredient, % DM	HS-DAA	HS-BAA	LS-DAA	LS-BAA
Corn silage	37.8	37.8	38.0	38.0
Haylage	33.5	33.5	33.6	33.6
Corn grain	14.7	14.3	8.0	7.6
Soybean hulls	10.7	8.1	14.8	12.2
80:10 C16C18:1	0.0	0.0	1.5	1.5
Soybean meal	0.8	0.8	1.6	1.6
SE-SBM	0.4	0.8	0.4	0.8
Corn gluten meal	0.0	2.4	0.0	2.4
RP-Met/Lys	0.0	0.2	0.0	0.2

Isocaloric substitution of starch with non-pNDF (+fat)

Ingredient, % DM	HS-DAA	HS-BAA	LS-DAA	LS-BAA
Corn silage	37.8	37.8	38.0	38.0
Haylage	33.5	33.5	33.6	33.6
Corn grain	14.7	14.3	8.0	7.6
Soybean hulls	10.7	8.1	14.8	12.2
80:10 C16C18:1	0.0	0.0	1.5	1.5
Soybean meal	0.8	0.8	1.6	1.6
SE-SBM	0.4	0.8	0.4	0.8
Corn gluten meal	0.0	2.4	0.0	2.4
RP-Met/Lys	0.0	0.2	0.0	0.2
RDP	9.0	9.0	9.0	9.0
MP	7.5	8.8	7.8	9.0
NDF	34.5	31	39.6	36.0
Starch	28.0	28.2	20.5	20.7
FA-H	3.4	3.4	5.7	5.6

=MP

Isocaloric substitution of starch with non-pNDF (+fat) in AA balanced diets

	HS		LS		*P* - values		
Item	DAA	BAA	DAA	BAA	ES	AA	ES x AA
DMI, kg/d	31.38	33.97	31.32	33.91	0.86	< 0.001	1.00
Milk kg/d	41.7	45.2	44.0	46.7	< 0.001	< 0.001	0.36
ECM, kg/d	42.4	46.0	46.4	49.4	< 0.001	< 0.001	0.61
Fat, g/d	1567	1674	1794	1878	< 0.001	< 0.001	0.67
Protein, g/d	1188	1356	1235	1380	0.03	< 0.001	0.47
Fat, %	3.85	3.80	4.10	4.05	< 0.001	0.39	0.97
Protein, %	2.87	3.05	2.87	2.95	0.12	< 0.001	0.11

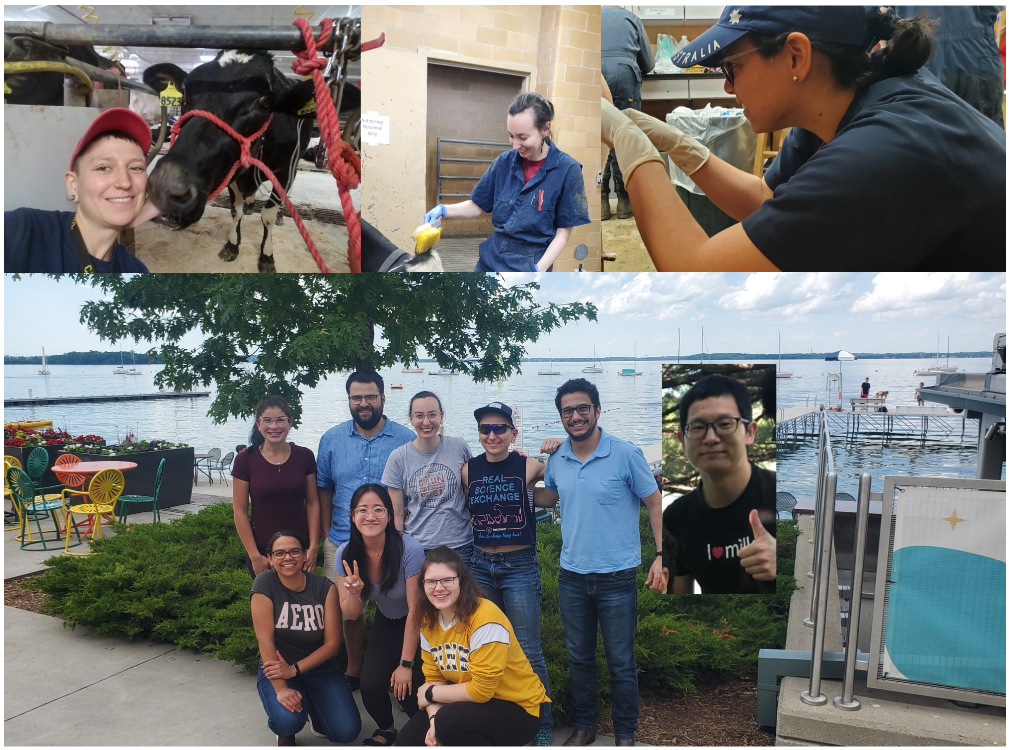
Isocaloric substitution of starch with non-pNDF (+fat) in AA balanced diets

Item	HS		LS		*P* - values		
	DAA	BAA	DAA	BAA	ES	AA	ES x AA
Allantoin, mmol/d	445	440	493	465	0.19	0.56	0.68
MiCP, g/d	2164	2610	2251	2638	0.005	< 0.001	0.14
Urine N, g/d	149	195	174	237	< 0.001	< 0.001	0.048
Fecal N, g/d	274	310	262	318	0.81	< 0.001	0.24
PUN, mg/dL	8.4	11.3	10.8	14.1	< 0.001	< 0.001	0.44
MUN, mg/dL	8.3	11.0	9.8	13.3	< 0.001	< 0.001	< 0.01

Conclusions

- There is room to reduce N emission by dairy cows, specifically at **rumen** and post-absorptive levels
- Balancing for specific AA improves milk protein and **milk fat responses**, and . . .
- The mechanisms for the regulation of milk components synthesis have been largely elucidated
- Energy plays a critical role in milk protein synthesis regulation
- However, the mammary has the plasticity to use different energy sources
- Peripheral roles of insulin, post peak-lactation could shadow the effect of glucogenic energy sources

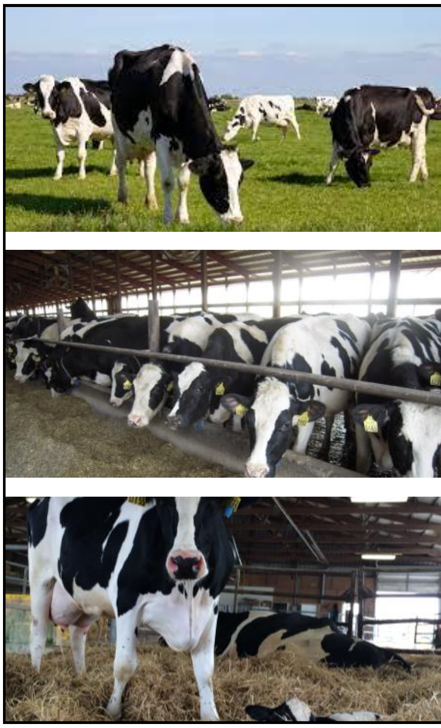
AKNOWLEDGEMENTS



Collaborators

- Wenli Li
- Jimena Laporta
- Laura Hernandez
- Joao Dorea

Hatch
NIFA AFRI
NIFA Predoctoral

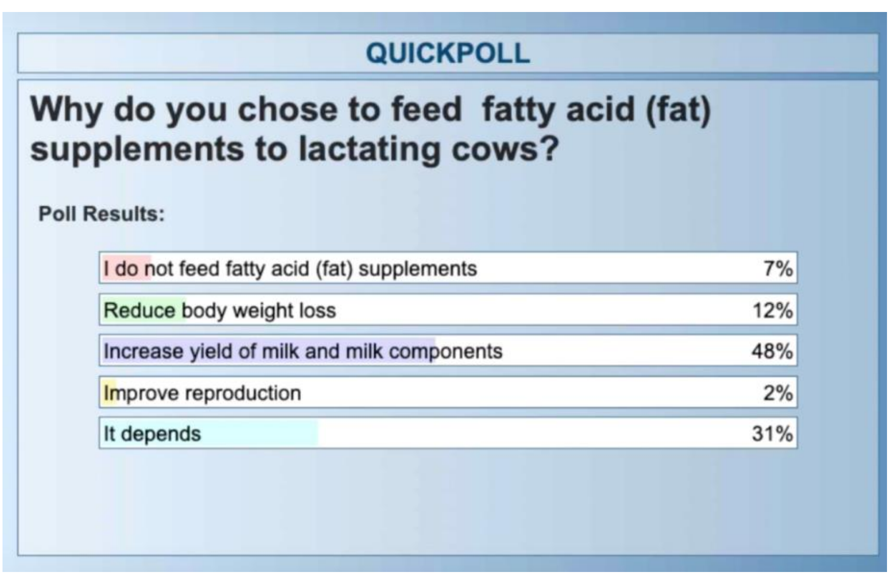


Impact of Supplementing Fatty Acids on Performance and Digestibility in Dairy Cows

Jonas de Souza, PhD
Director of Tech Services and R&D
Perdue Animal Nutrition

1

Why do We Feed Fatty Acids to Dairy Cows?



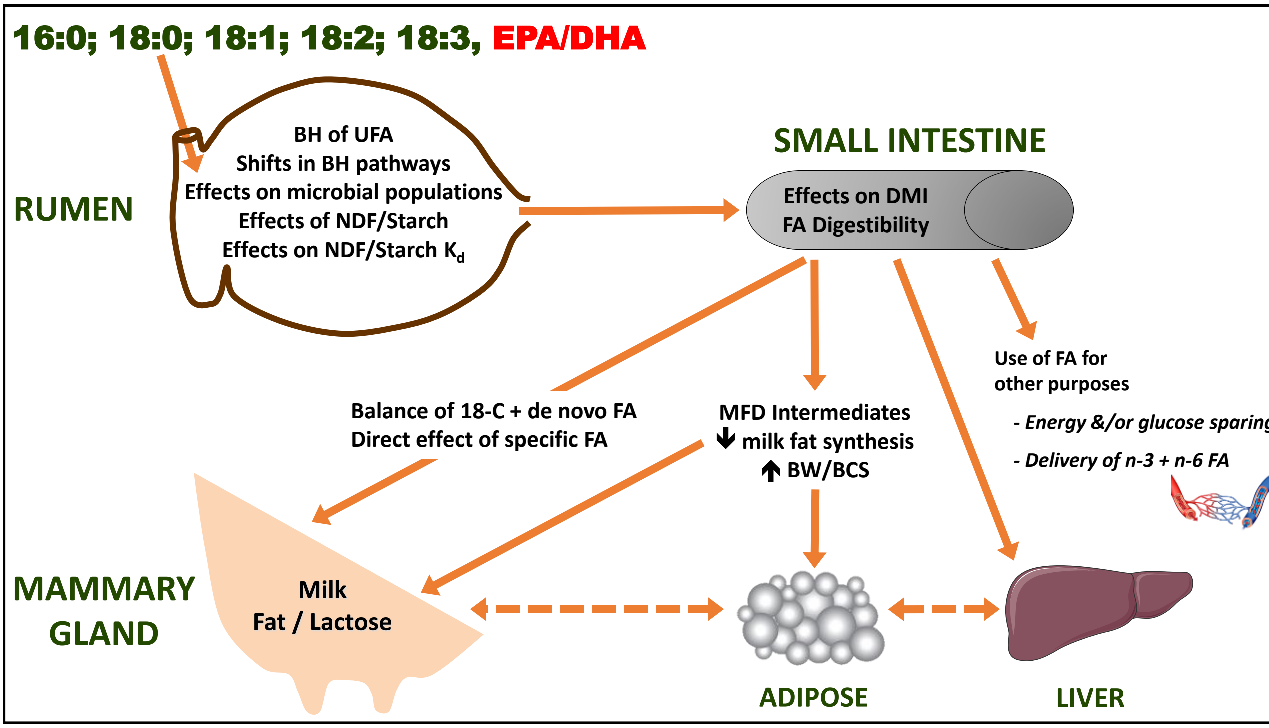
QUICKPOLL

Why do you chose to feed fatty acid (fat) supplements to lactating cows?

Poll Results:

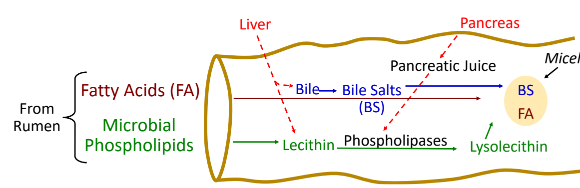
I do not feed fatty acid (fat) supplements	7%
Reduce body weight loss	12%
Increase yield of milk and milk components	48%
Improve reproduction	2%
It depends	31%

2

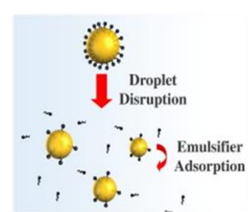


3

What Limits/Impacts FA Digestibility?



- Profile of FA reaching the duodenum
- Emulsification capacity
- Total FA flow to the duodenum
- Degree of esterification/physical form

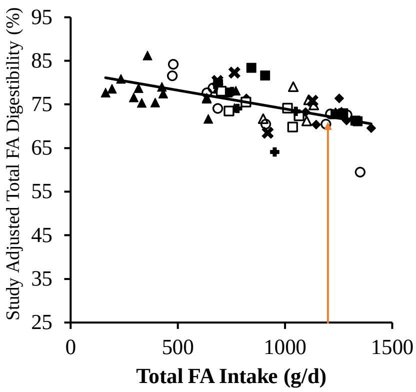


➢ The ability of ruminants to absorb SFA is much higher than that of non-ruminants
  - In most feeding situations, C18:0 is the predominant FA available for absorption
  - **The greatest opportunity will be to improve C18:0 absorption and/or limit its effects on the absorption of other FA**

4

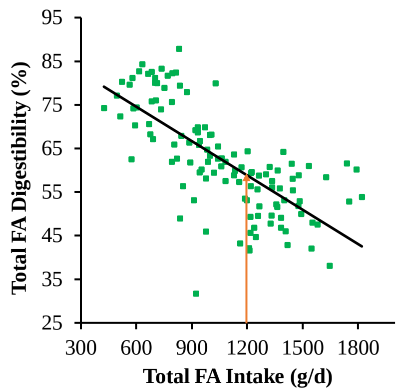
Apparent Intestinal Digestibility of Fatty Acids

Intestinal Digestibility
Meta Analysis



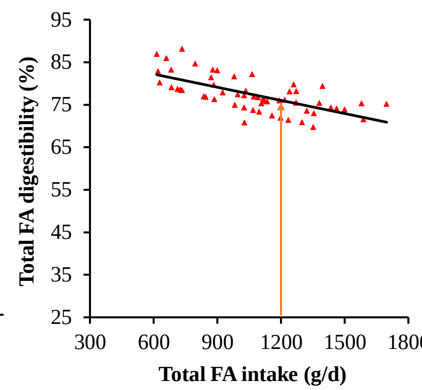
Boerman et al. 2015.
J. Dairy Sci. 98:8889–8903

Dose Response C18:0
Supplementation Study



Boerman et al. 2017.
J. Dairy Sci. 100:1-10

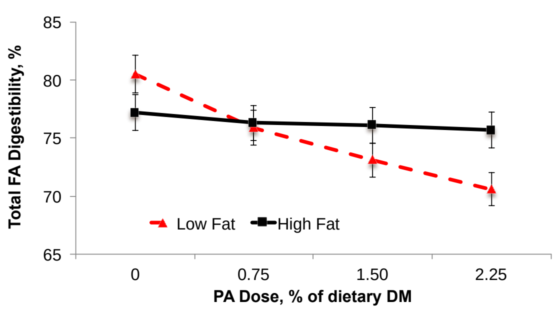
Dose Response C16:0
Supplementation Study



Rico et al. 2017.
J. Animal Sci. 95:436-446

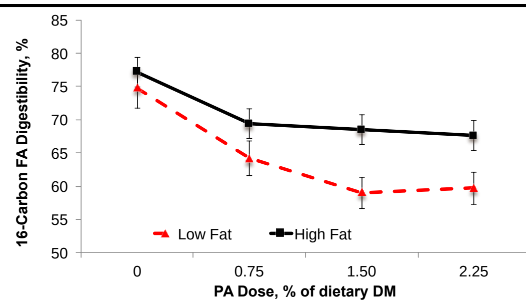
5

Effect of C16:0 Intake and Basal diet on FA Digestibility



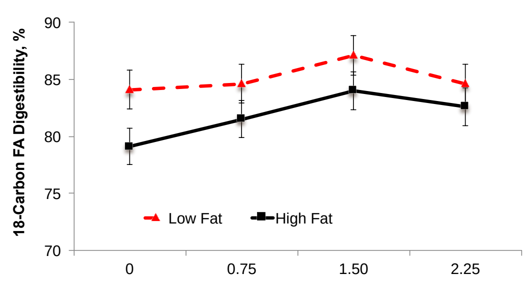
P value
Dose = 0.01, Basal = 0.09
Basal x Dose = 0.05

Linear PA dose effect: P = 0.01



P value
Dose < 0.01, Basal = 0.01
Basal x Dose = 0.038

Quadratic PA dose effect: P= 0.01



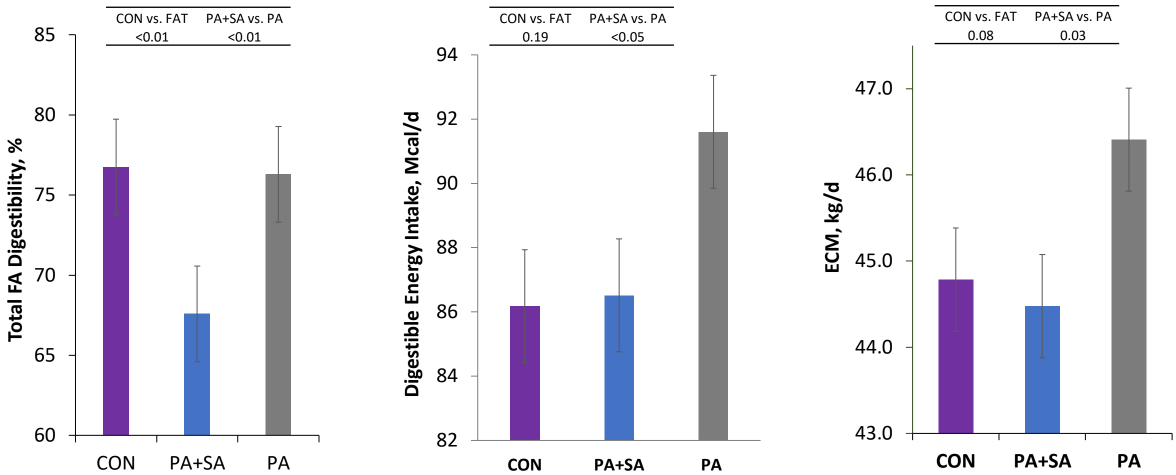
P value
Dose = 0.05, Basal = 0.07
Basal x Dose = 0.35

Quadratic PA dose effect: P = 0.01

Rico et al. 2017. J. Animal Sci. 95:436-446

6

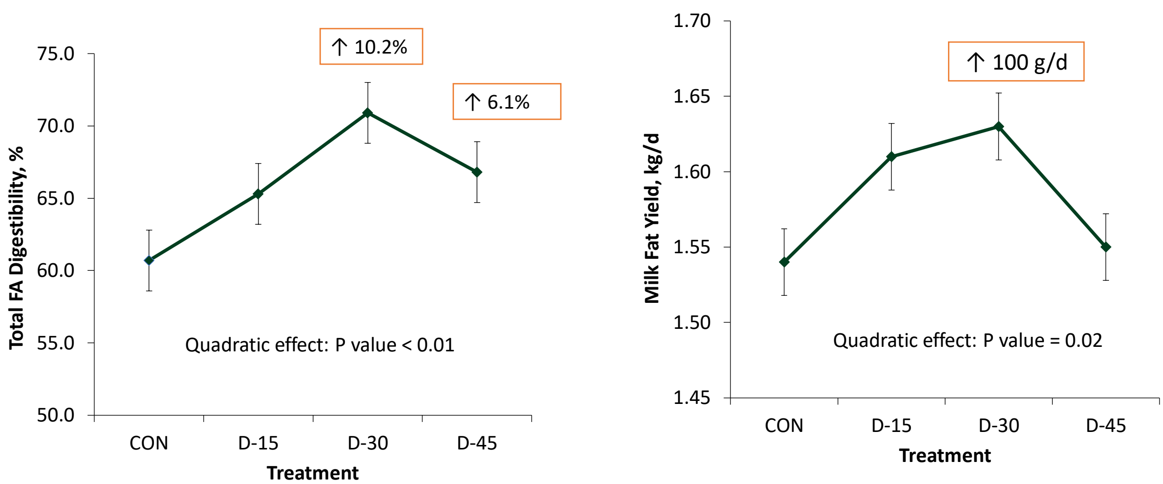
Effect of Altering the FA Profile of the Supplement on FA Digestibility and Performance



Western et al. 2020. J. Dairy Sci. 103: 5131–5142

7

Abomasal Infusion of an Exogenous Emulsifier



de Souza et al. 2020 J. Dairy Sci. 103:6167–6177

8

Association of Feeding Lysophospholipids and FA Supplements

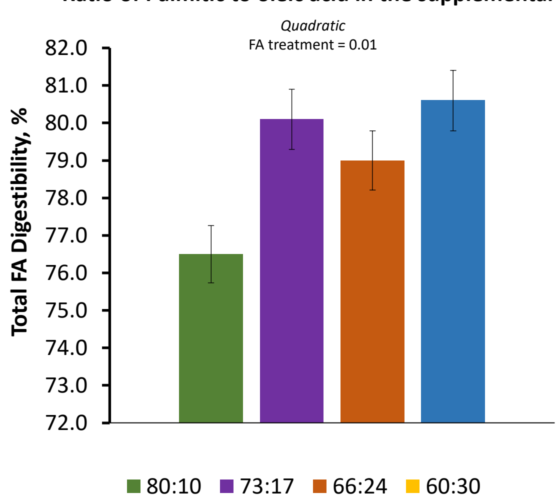
	PA	PA+SA	No	LPL	SEM	FA	LPL	Int
DMI, kg/d	27.3	27.5	27.6	27.5	0.81	0.84	0.84	0.21
Milk yield, kg/d	40.4	38.7	39.8	39.3	2.65	0.21	0.70	0.42
ECM, kg/d	39.7	36.8	38.1	38.4	1.03	0.02	0.81	0.34
ECM/DMI, kg/kg	1.44	1.35	1.38	1.40	0.027	<0.01	0.54	0.75
Fat, kg/d	1.60	1.42	1.50	1.52	0.05	<0.01	0.82	0.32
Protein, kg/d	1.30	1.26	1.28	1.28	0.058	0.38	0.91	0.54
Lactose, kg/d	1.96	1.91	1.96	1.92	0.147	0.48	0.60	0.47
Fat, %	4.00	3.74	3.83	3.91	0.277	0.12	0.64	0.68
Protein, %	3.24	3.30	3.24	3.30	0.08	0.42	0.39	0.84
Lactose, %	4.84	4.93	4.90	4.87	0.042	0.03	0.49	0.79
BW initial, kg	691	686	696	681	22.2	0.72	0.35	0.63
BW final, kg	703	701	709	694	18.8	0.91	0.33	0.99

Porter et al. 2024 J. Dairy Sci. In Press

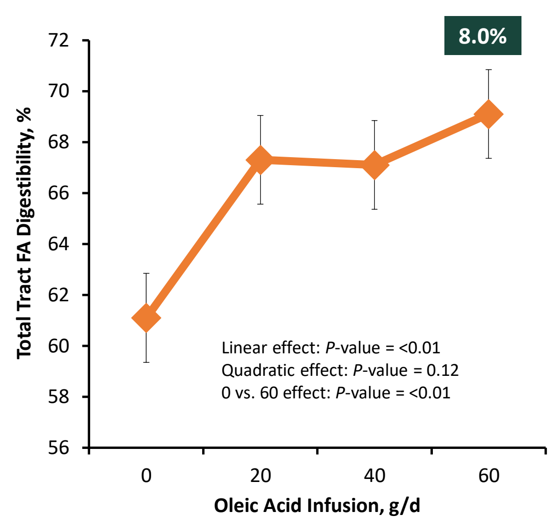
9

Oleic Acid Improves Total Tract FA Digestibility

Ratio of Palmitic to oleic acid in the supplemental fat



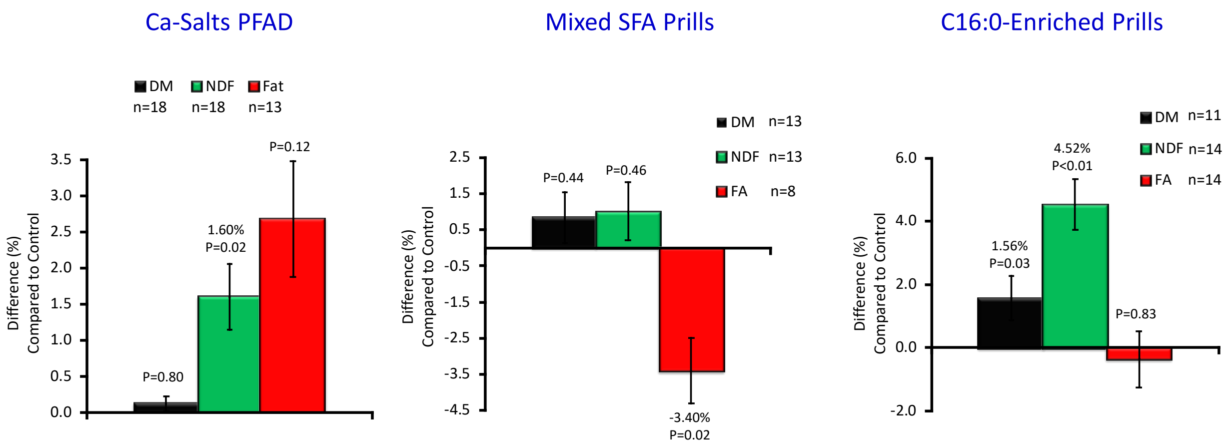
de Souza et al. 2019. J. Dairy Sci. 102:9842–9856



Prom et al. 2021. J. Dairy Sci. 104:12616-12627

10

Effect of FA Supplements on Nutrient Digestibility

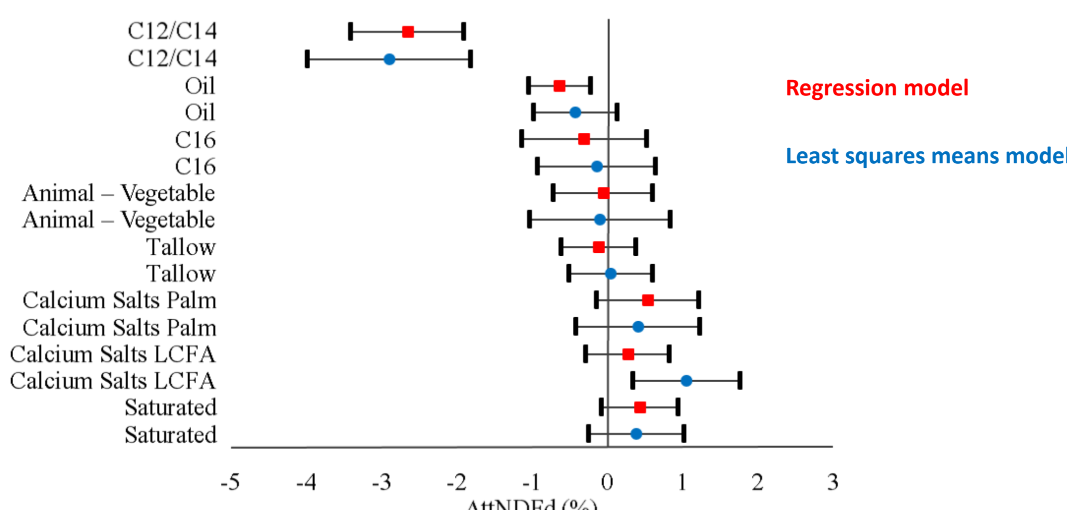


Neto et al. 2021. J. Dairy Sci. 104:9752-9768
Neto et al. 2021. J. Dairy Sci. 104:12628-12646

11

Effect of Fat Supplementation on Fiber Digestibility

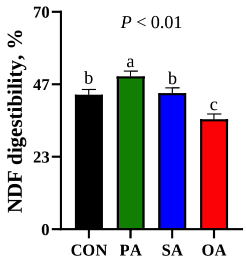
Slide courtesy of Lou Armentano, University of Wisconsin



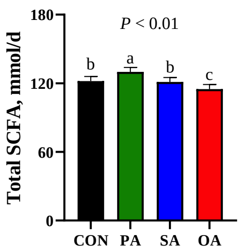
Weld and Armentano. 2017 J. Dairy Sci. 100:1766–1779

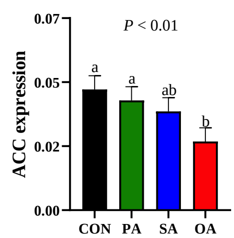
12

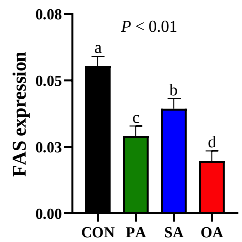
Effect of Individual FA on Fiber Digestibility



	CON	PA	SA	OA	P
Prevotella	18.3^{B}	22.7^{A}	17.4^{B}	18.0^{B}	<0.01
Megasphaera	1.76^{B}	2.06^{B}	2.22^{B}	3.10^{A}	0.05
Fibrobacter	0.71^{AB}	1.07^{A}	0.70^{AB}	0.28^{B}	0.01
Acidaminococcus	0.30^{AB}	0.36^{AB}	0.57^{A}	0.17^{B}	0.02
Pseudobutyrivibrio	0.33^{B}	0.44^{B}	0.35^{B}	0.62^{A}	0.02
Anaerovibrio	0.07^{B}	0.07^{B}	0.07^{B}	0.17^{A}	0.02
Ruminococcus	1.29	1.16	1.42	1.36	0.53
Butyrivibrio	1.09	0.96	0.77	0.90	0.34

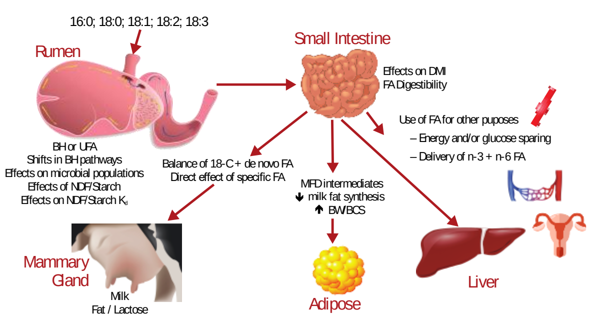


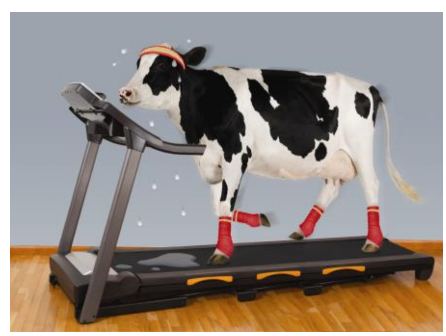




Sears et al., 2024. JDS. 107:902-916

13



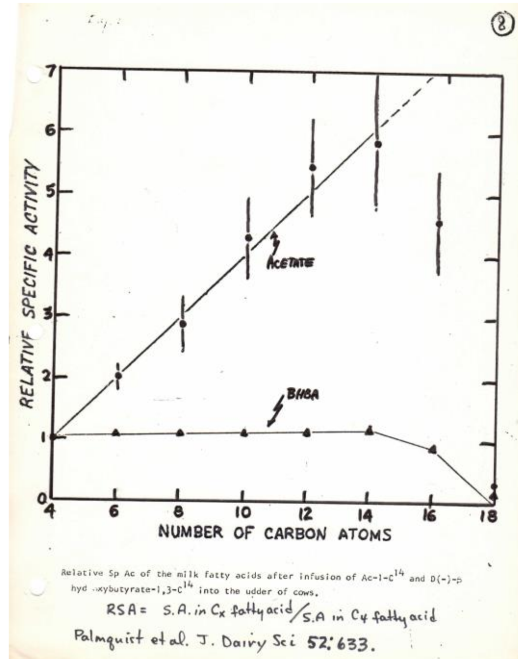


Effect of Dietary FA on Performance

14

Source of Milk Fatty Acids

- **De novo synthesis**
  - **C4 to C14**
  - **Part of C16**
    - ➢ Acetate
    - ➢ B-hydroxybutyrate
- **Uptake of preformed fatty acids**
  - **Part of C16**
  - **All long chain**
    - ➢ Absorbed from digestive tract
    - ➢ Mobilized from body fat



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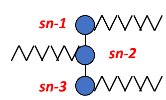
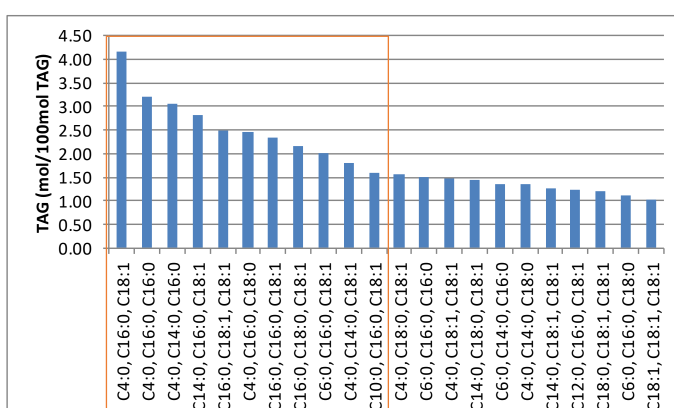
Milk Triglycerides



mol/100mol fatty acid[1]

	C4:0	C6:0	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1
sn-1	1.6	3.1	10.3	15.2	23.7	27.3	44.1	54.0	37.3
sn-2	0.3	3.9	55.2	56.6	62.9	65.6	45.4	16.2	21.2
sn-3	98.1	93.0	34.5	28.2	13.4	7.1	10.5	29.8	41.5

Major TAG in bovine milk fat[2]
Only TAG > 1% are shown
Position of individual FA on glycerol backbone may vary

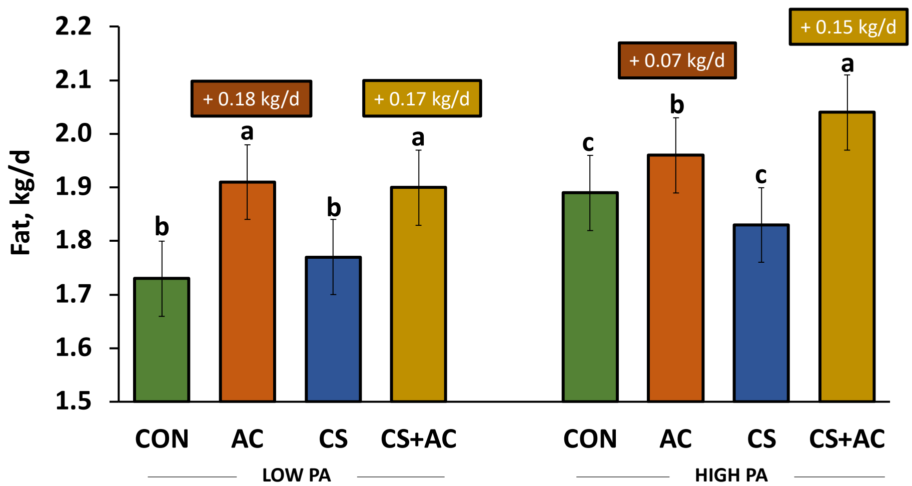


Lipid synthesis is highly coordinated in order to produce a fluid milk fat

1. Calculated by Jensen (2002) J. Dairy Sci. 85: 295-350 from Australian butter reported by Parodi (1979) J. Dairy Res. 46:75-81
2. Gresti et al. (1993) J. Dairy Sci. 76: 1850-1869. Normandy summer milk

16

Altering the Dietary Supply of De Novo and Preformed Fatty Acids



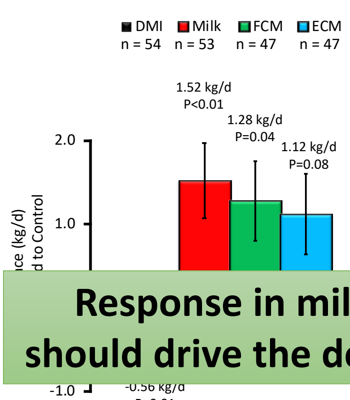
Base *P* = 0.27
CS *P* = 0.42 | AC *P* < 0.01
CS*AC *P* = 0.19
Base*CS*AC *P* < 0.01

Benoit et al. (ADSA Abstract 2023)

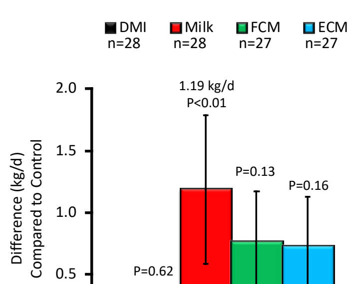
17

Effect of FA Supplements on DMI and Milk Yields

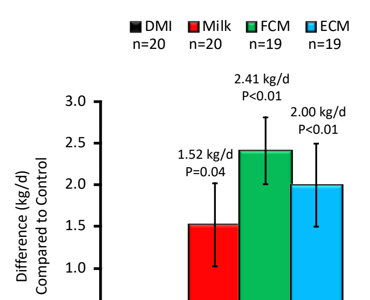
Ca-Salts PFAD



Mixed FA Prills



C16:0-Enriched Prills

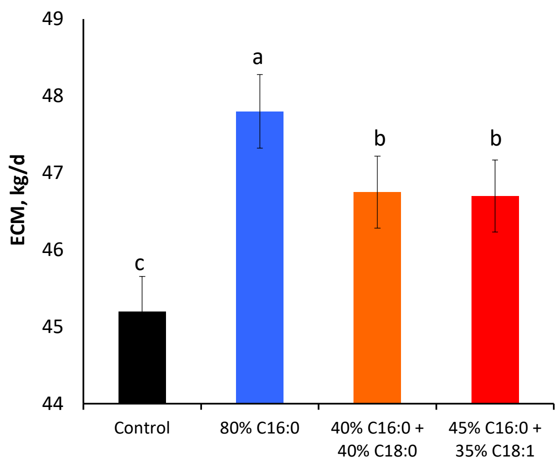


Response in milk, milk components, health and reproduction should drive the decision and be continually evaluated/considered

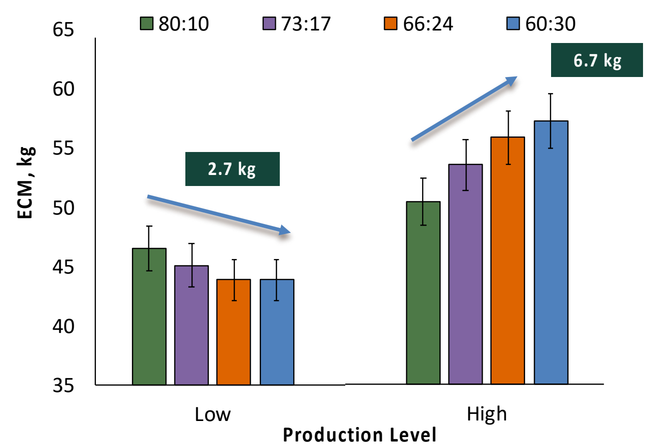
Neto et al. 2021. J. Dairy Sci. 104:9752-9768
Neto et al. 2021. J. Dairy Sci. 104:12628-12646

18

Effect of Palmitic, Stearic, and Oleic Acids in Post-Peak Cows



de Souza et al. 2018. J. Dairy Sci. 101:172–185



de Souza et al. 2019. J. Dairy Sci. 102:9842–9856

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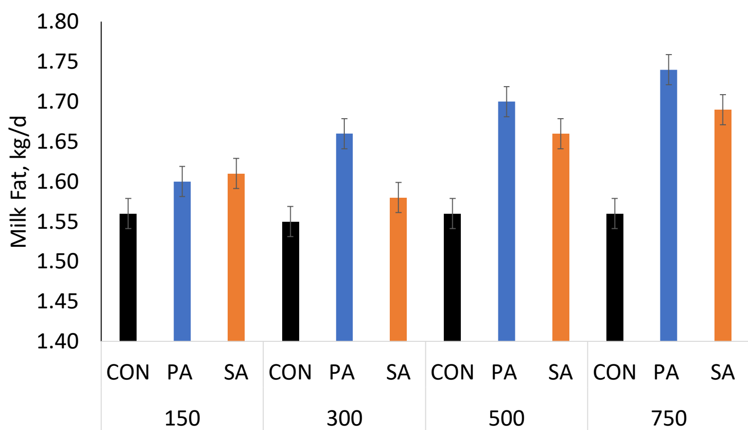
Milk Fat Responses to Level and Profile

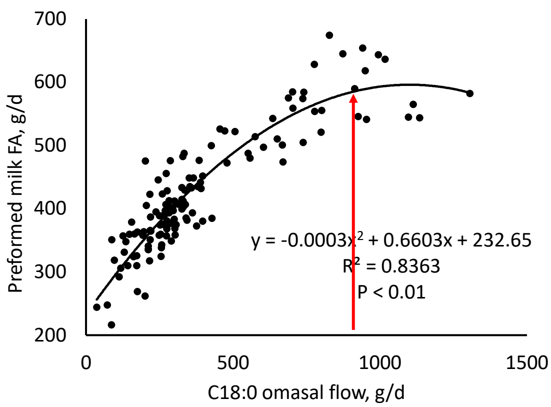


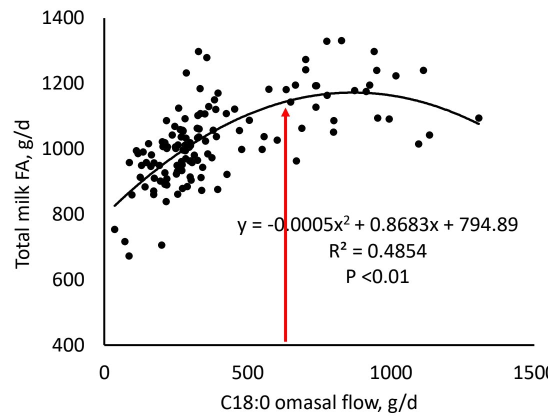
	Transfer, %	
	PA	**SA**
150	**0.27**	**0.33**
300	**0.39**	**0.10**
500	**0.28**	**0.20**
750	**0.24**	**0.17**

Staffin et al., 2023 (ADSA Abstract)

20

Relationship Between C18:0 Omasal Flow on Preformed and Total milk FA



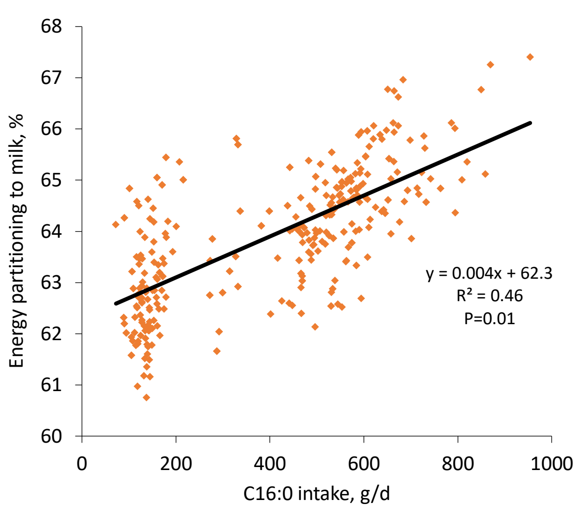


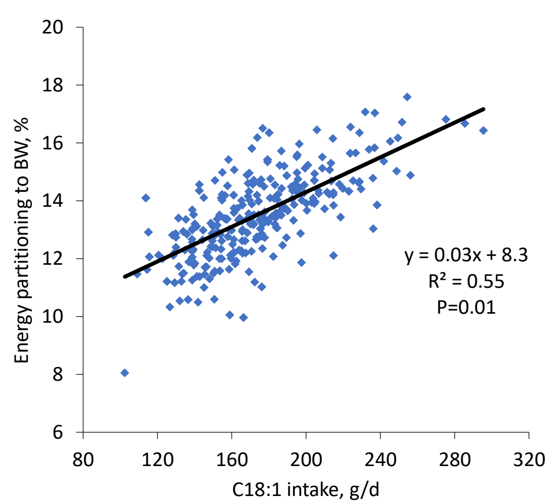
De Souza et al., 2018 (ADSA Abstract)

21

Palmitic and Oleic Effects on Energy Partitioning

(Post Peak Cows)

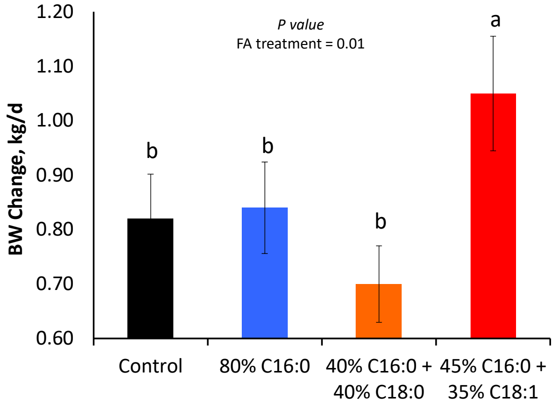


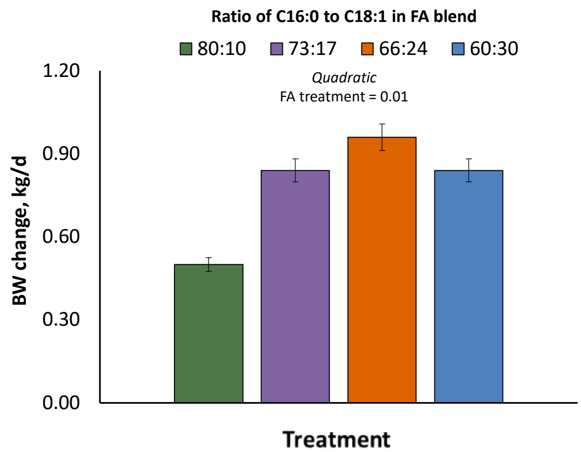


de Souza & Lock (Unpublished)

22

Effect of Palmitic, Stearic, and Oleic Acids in Post-Peak Cows



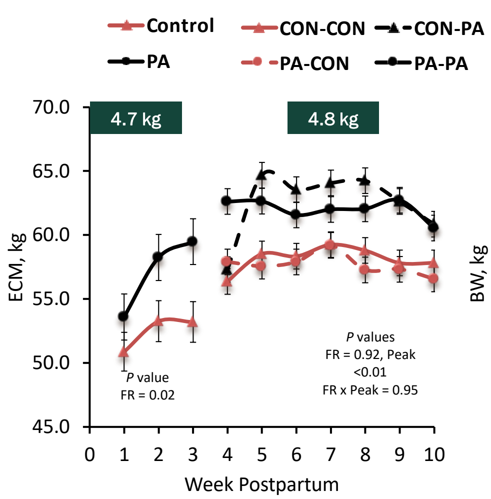


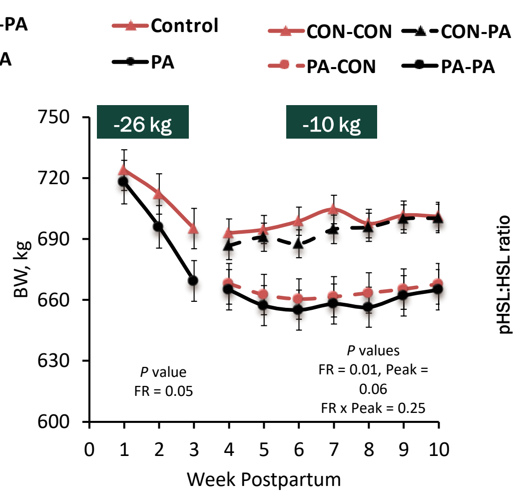
de Souza et al. 2018. J. Dairy Sci. 101:172–185

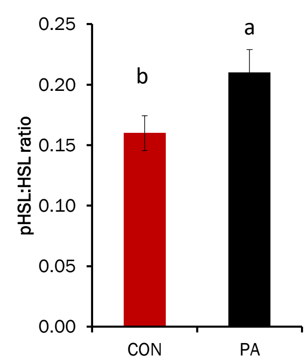
de Souza et al. 2019. J. Dairy Sci. 102:9842–9856

23

Effect of Palmitic Supplementation – Early Lactation



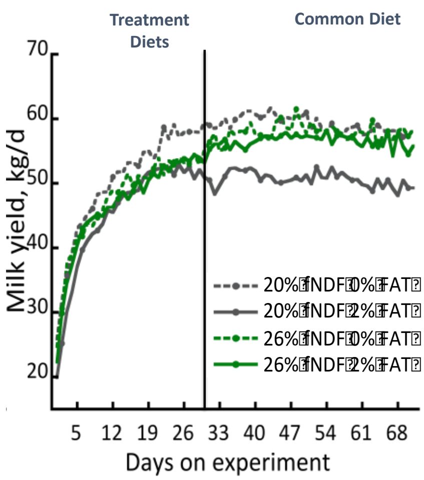


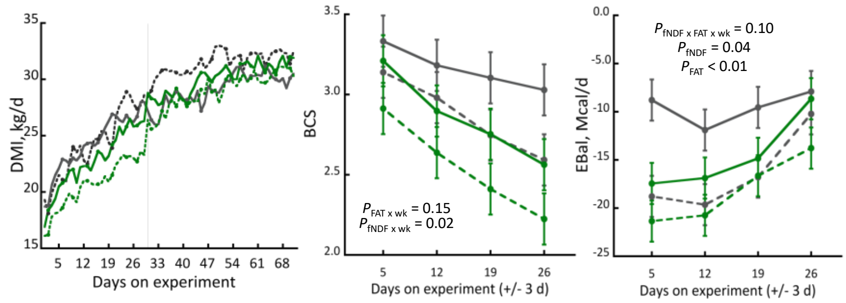


de Souza & Lock. 2019. J. Dairy Sci. 102:260-273
de Souza et al. 2019. J. Dairy Sci. 102:274-287

24

Effect of a C16:0 + C18:0 FA Supplement in Early Lactation



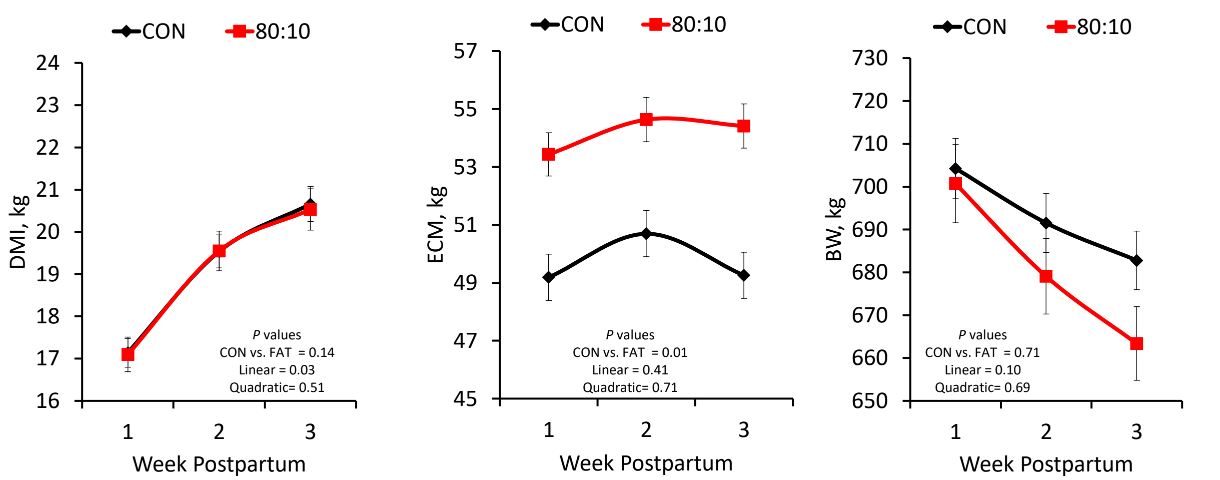


- During PP:
  - Increased DMI and tended to decrease milk yield, increasing BCS
- During carryover:
  - Decreased milk yield and cumulative milk yield, but did not affect DMI, increasing BCS

Piantoni et al. 2015. J Dairy Sci. 98:3309–3322; Piantoni et al. 2015. J Dairy Sci. 98:3323–3334

25

Effect of Altering the Palmitic to Oleic Ratio of Supplemental Fats to Fresh Cows

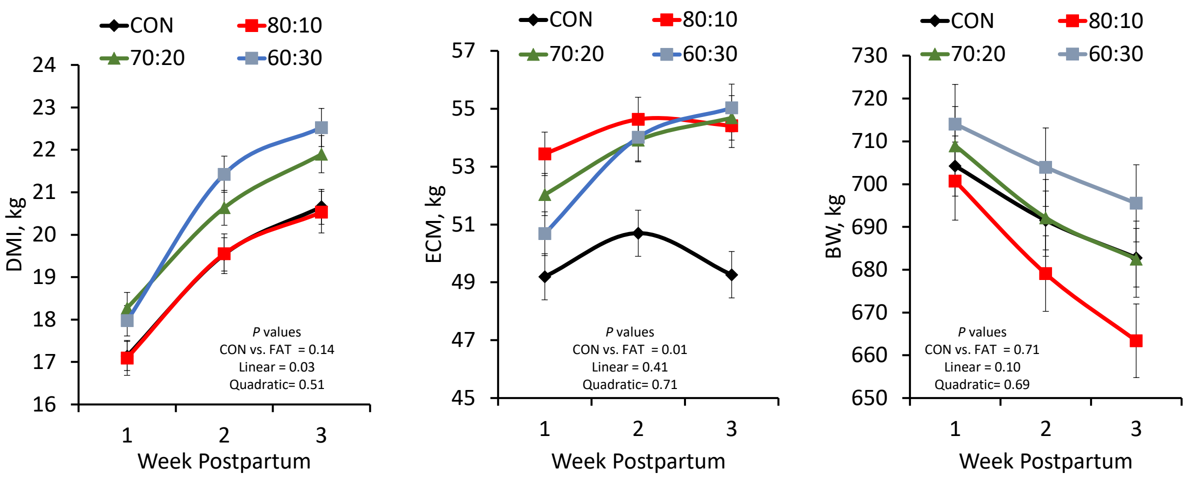


- CON: Control diet (no supplemental fat)
- FA supplement blends fed at 1.5% DM
- Supplemental fat blends fed from calving for first 3 wk of lactation

de Souza et al., 2021. JDS 104:2896

26

Effect of Altering the Palmitic to Oleic Ratio of Supplemental Fats to Fresh Cows

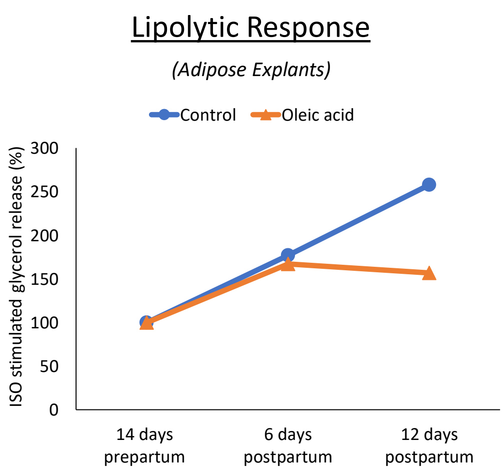


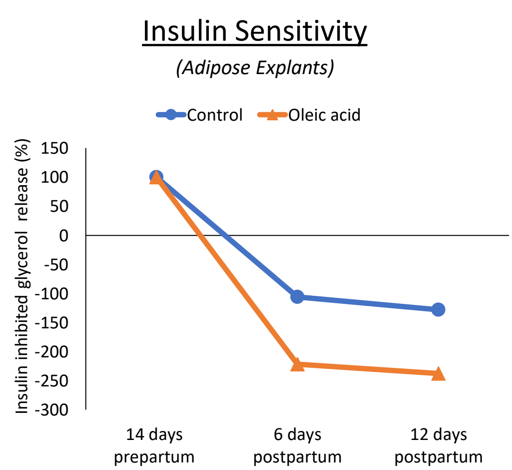
- CON: Control diet (no supplemental fat)
- FA supplement blends fed at 1.5% DM
- Supplemental fat blends fed from calving for first 3 wk of lactation

de Souza et al., 2021. JDS 104:2896

27

Abomasal Infusion of Oleic Acid in Fresh Cows





- Results suggest that oleic acid supplementation immediately postpartum may reduce lipolytic responses and improves insulin sensitivity of AT in early lactation dairy cows

Abou-Rjeileh et al. 2023. J. Dairy Sci 106:4306–4323

28

Fatty Acids and Repro

SYMPOSIUM: OPTIMIZING ENERGY NUTRITION FOR REPRODUCING DAIRY COWS

Influence of Supplemental Fats on Reproductive Tissues and Performance of Lactating Cows[1]

C. R. STAPLES,[2] J. M. BURKE, and W. W. THATCHER
Department of Dairy and Poultry Sciences,
University of Florida, Gainesville 32611

Item	RR or SMD (95% CI)	I^2	P-value
Proportion pregnant to service[2]			
Overall	1.20 (1.04 to 1.38)	19.9	0.19
	1.27 (1.09 to1.45) (Knapp-Hartung)		
Oilseed	1.14 (0.91 to 1.43)	0.0	0.51
CSFA	1.05 (0.78 to 1.42)	31.8	0.16
Tallow	1.09 (0.53 to 2.24)	63.3	0.07
CLA	1.29 (0.89 to 1.88)	0.0	0.84

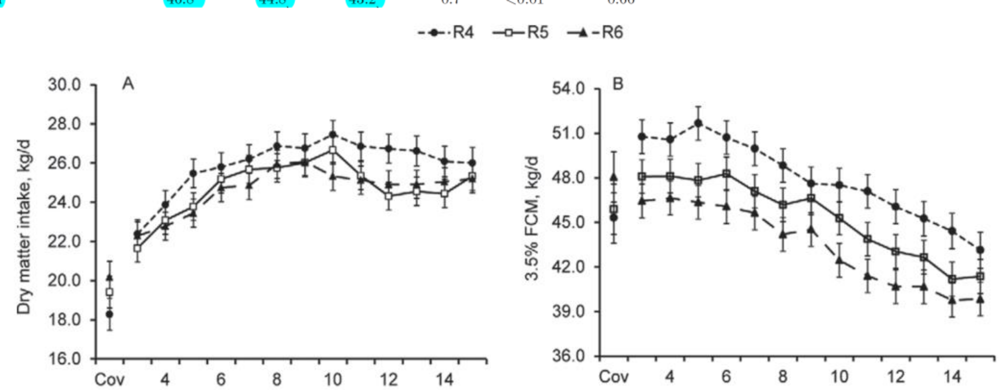
Rodney et al. 2015. J. Dairy Sci 98:5601–5620

29

Altering n-6 to n-3 Fatty Acids in Early Lactation

	Treatment[1]				P-value[2]	
Item	R4	R5	R6	SEM	Trt	Trt × Wk
DMI, kg/d	26.1[a]	24.6[b]	24.7[b]	0.5	0.07	0.46
FA intake,[3] g/d	931.5	952.9	975.0	24.1	0.45	0.46
Linoleic	298.1[c]	329.5[b]	369.4[a]	8.6	<0.001	0.50
EPA + DHA	21.3[a]	14.9[b]	10.0[c]	0.3	<0.001	0.44
Total n-6	300.6[c]	332.0[b]	371.9[a]	8.6	<0.001	0.50
Total n-3	77.3[a]	67.3[b,x]	62.8[b,y]	1.7	<0.001	0.38
Milk, kg/d	46.8[a,x]	44.8[y]	43.2[b]	0.7	<0.01	0.66

- Treatment diets fed from 14 DIM

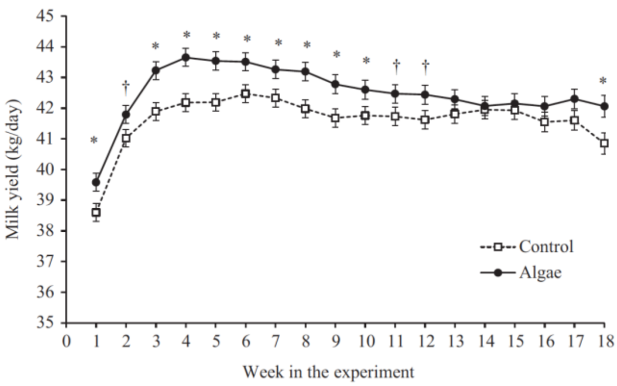


Greco et al. 2015. J Dairy Sci. 98:602–617.

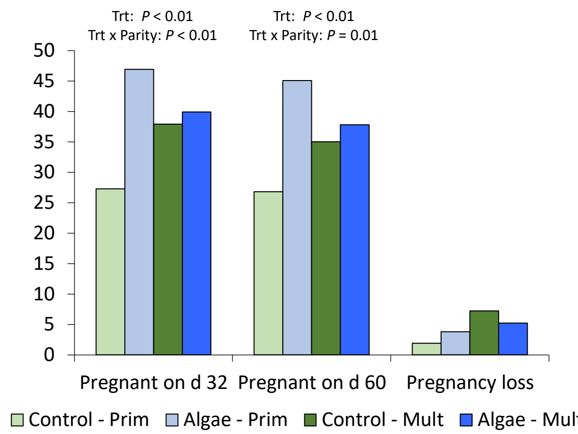
30

Feeding Algae Rich in DHA (C22:6 n-3)

Milk Yield



Pregnancy per AI



- Treatments started 27 ± 5 d postpartum and lasted 120 d
- Treatments supplied 10 g of DHA per cow per d

Sinedino et al. 2017. Reproduction. 153:707–723.

31

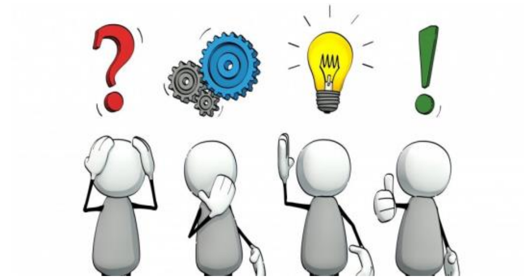
What Ingredients Should I use to Provide FA?

	First Source	Second Source
C16:0	Supplements	Oilseeds (Cottonseed)
C18:0	Basal diet (rumen BH)	Supplements
C18:1	Supplements	Oilseeds (HO soybeans)
C18:2	Basal diet	Oilseeds (Cottonseed)
C18:3	Basal diet	Supplements, oilseeds
Omega 3	Supplements	Oilseeds

32

Considerations for Supplemental Fat

- Fresh / Peak lactation
  - ECM milk response
  - Managing BCS and repro
  - ***Positive ROI***
- Post-peak lactation
  - Primarily milk fat response
  - Depending on production level of the herd
  - ***Likely positive***
- Late lactation cows
  - Consider energy content of diet
  - ***Likely negative ROI***



33

Thanks!

Jonas.deSouza@perdue.com

https://www.perdueanimalnutrition.com/

34

Reducing the carbon footprint of beef production: current alternatives to mitigate enteric methane emissions

Dr. Nicolas DiLorenzo

University of Florida-NFREC

February 28, 2024

1

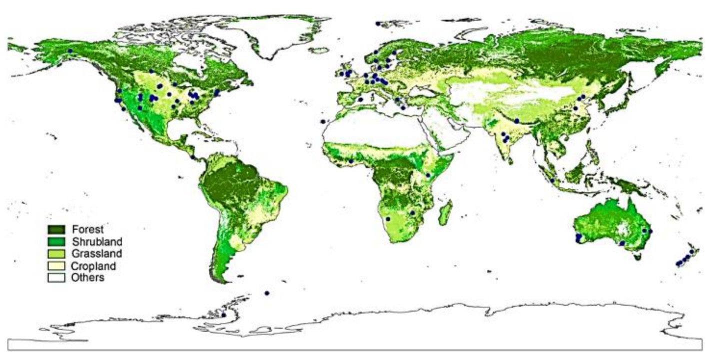
Fiber and forage-based livestock systems

- **Grasslands occupy ~40% of ice-free terrestrial surface**

  (Hewins et al., 2018)
- **Forage grass is the most consumed livestock feed in the world (48% of all biomass consumed)**

  (Peters et al., 2013)
- **Even in the U.S. conventional beef production systems, 80% of total feed consumption is forage, 10% grain, and 10% other sources**

  (NASEM, 2016)

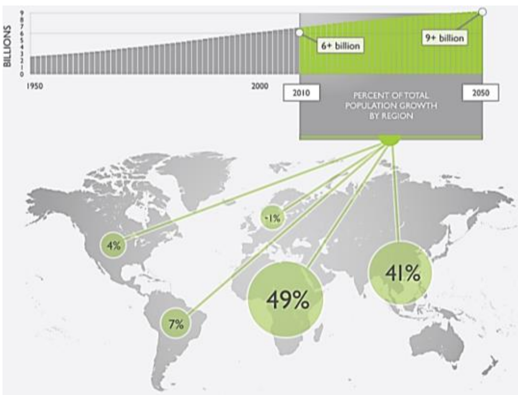


Qiao et al. (2019). Sci. Rep. 9:5621

2

Beef production and human population growth

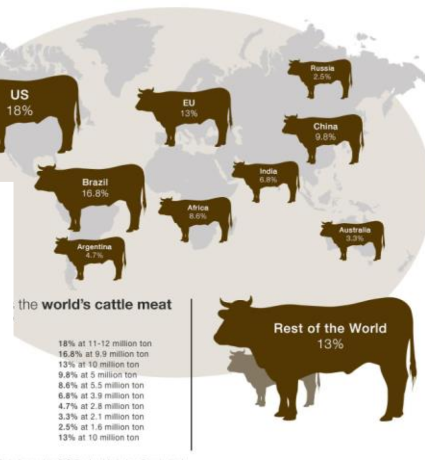
Global Population Growth and Percent of Growth by Region (2010 – 2050)



Silva 2018

Global beef production 2023

1)	USA	20%
2)	Brazil	18%
3)	China	12%
4)	EU	11%
5)	India	7%
6)	Argentina	5%
7)	Australia	4%
8)	Mexico	3%
9)	Rest of the World	20%



Capper 2012

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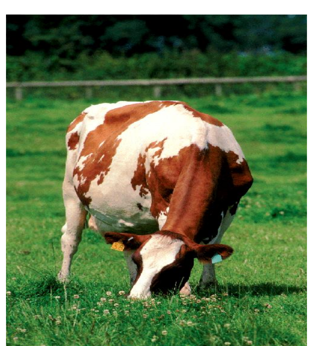
3

The importance of ruminants in food production systems

- Of the solar energy captured by the earth's biomass, only 5% potentially available for human food directly (Russell and Gahr, 2000)
- The rest…



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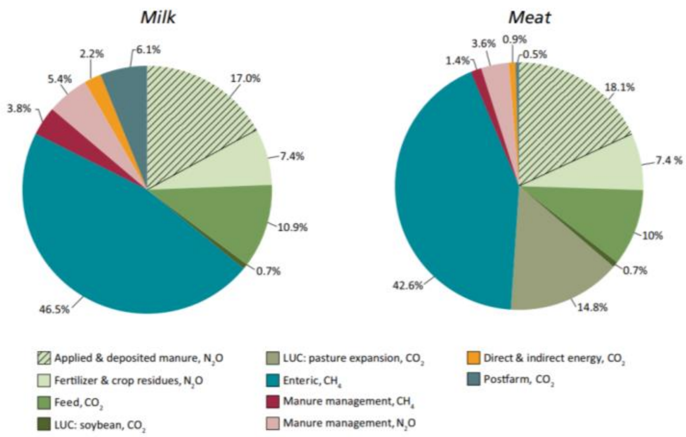
4

Global emissions of GHG from cattle destined to produce milk and meat: methane is the big one!



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Source: FAO, 2013

5

Emissions intensities are going down…

- In the last 50 years GHG emissions intensities (per kg of milk or meat produced) have improved
- Dairy farms are producing almost twice the milk with approx. 25% fewer cows
- Beef cattle operations are producing approx. 20% more meat with 12% fewer cattle

- More work to do in beef systems

Alan Rotz (2022). GGAA 2022

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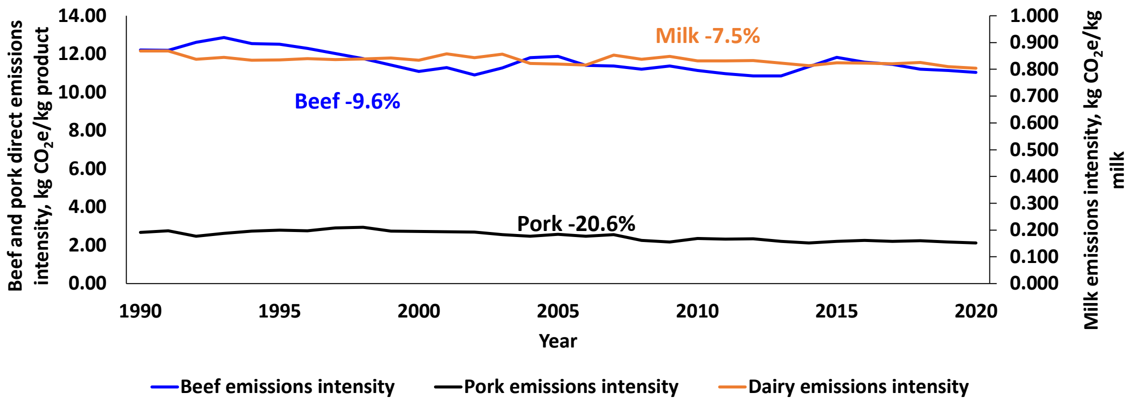
GHG emission intensity has declined in the US, but decoupling is not enough to halt absolute emissions growth



US EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020 and USDA NASS

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Improvements in beef cattle emissions intensity

(Rotz, 2022)

1970
Intensity = 24 kg CO2e/kg carcass
Total = 241 Tg CO_2e

2020
Intensity = 21 kg CO2e/kg carcass
Total = 255 Tg CO_2e

Source: https://www.cattlemax.com/

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8

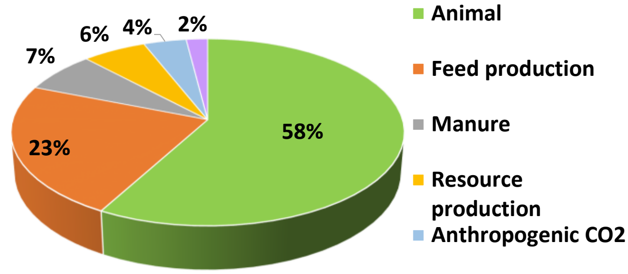
Beef Farm Gate Footprint in the U.S.

"The GHG emissions related to producing a kg of carcass weight is similar to that emitted by driving a car about 85 km"

A. Rotz, GGAA 2022, Orlando, FL

21 kg CO_2e/kg carcass weight

Ranges from:
17 to 27 across U.S. Regions
16 to 39 across Production systems

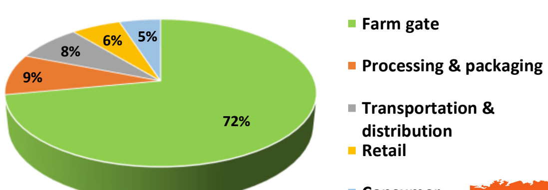


Alan Rotz (2022). GGAA 2022

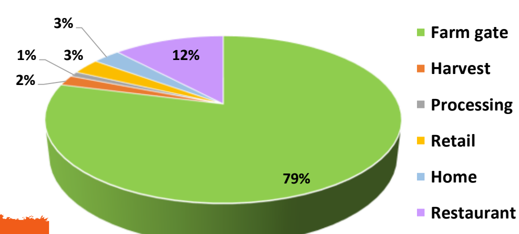
9

Full Life Cycle Emission

1.8 kg CO_2e/kg milk consumed



43 kg CO_2e/kg beef consumed

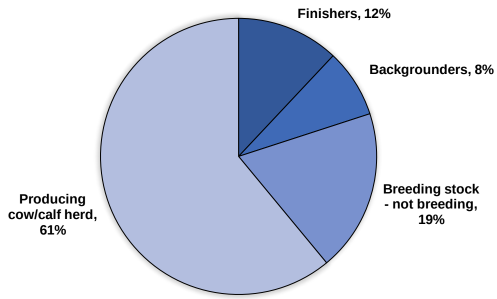


Adapted from Rotz (2022; GGAA conference)

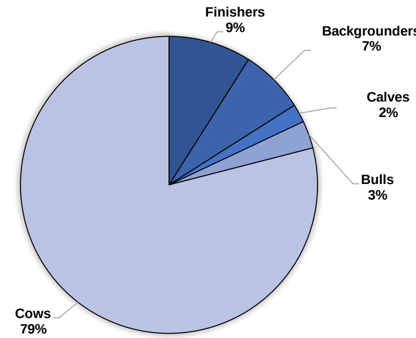
10

Beef cattle emissions: cow/calf is the low-hanging fruit!

Breakdown of total GHG emissions in CO_2e



Breakdown of enteric CH_4 emissions



Beauchemin et al. (2010). Agr Systems. 103:371-379

11

Where to focus mitigation efforts?

Cow/calf segment

- Grazing management (⇧C seq.)
- Reproduction
- Cow size
- Feed (forages) digestibility
- Reduced mortality/morbidity
- Implants

Carbon Footprint Reduction

Beef feedlot	
More efficient feeding	1-2%
Enteric methane inhibitor	8
Feeding of fat	4-5
Scraped feed lane	7-8
Anaerobic digester	18-20
No manure storage	18-25
Improved animal health	1-2
Solar collection	10-20
Combined system	50-60%

- Feedlot: improvements may impact overall C footprint by 3%
- Cow-calf: combination of techniques may lead to 8-10% potential reduction in C footprint

Alan Rotz (2022). GGAA 2022

12

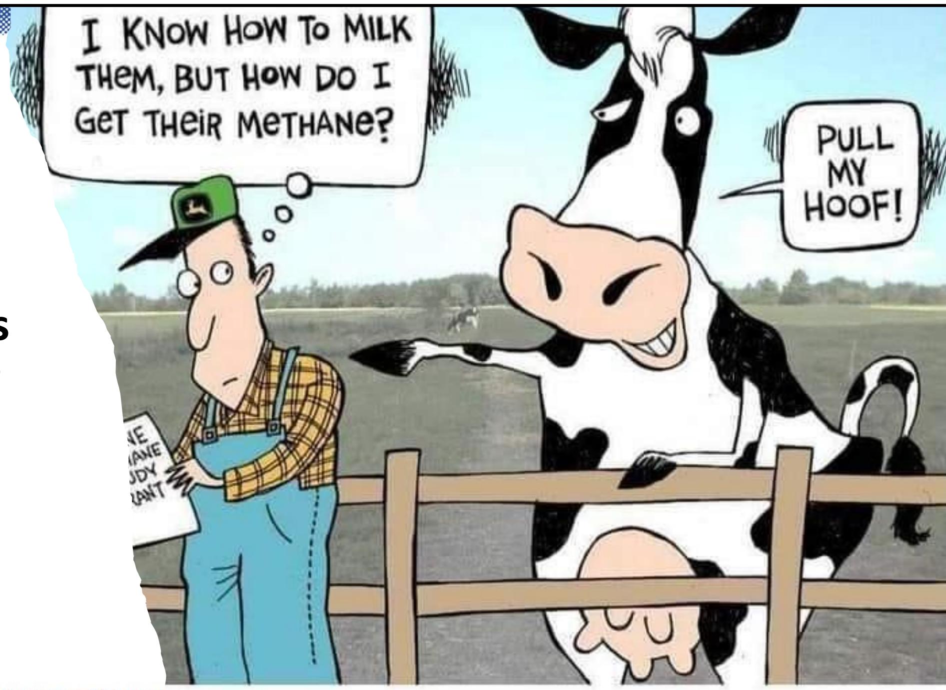
However, little work has been done on cow/calf systems in terms of GHG emissions

13

What is the "State of the Science" in terms of enteric methane mitigation?

14

Measuring CH_4 emissions in vivo under grazing conditions: a challenge



15

The SF_6 tracer technique

16

The challenges of measuring methane under grazing conditions

University of Florida

17

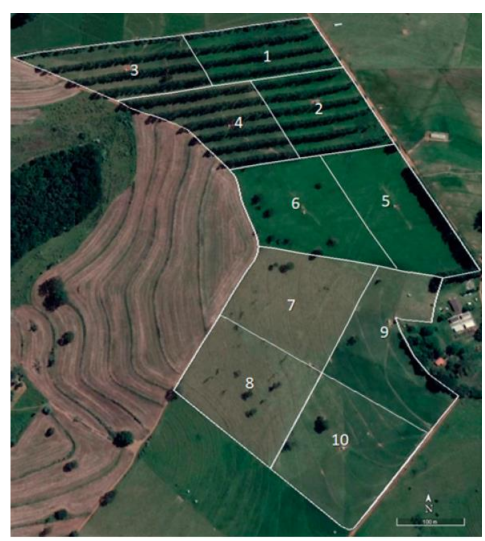
Can intensification of grazing management help?

agronomy

Article

Can Intensified Pasture Systems Reduce Enteric Methane Emissions from Beef Cattle in the Atlantic Forest Biome?

Paulo Meo-Filho [1,2,*,†], Alexandre Berndt [2], José R. M. Pezzopane [2], André F. Pedroso [2], Alberto C. C. Bernardi [2], Paulo H. M. Rodrigues [3], Ives C. S. Bueno [1], Rosana R. Corte [3] and Patrícia P. A. Oliveira [2]



Meo-Filho et al. (2022; Agronomy, doi.org/10.3390/agronomy12112738)

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Can intensification of grazing management help?

Variables	Systems *					
	n	EXT	INT	iCL	SEM	*p*-Value
ILW (kg)	60	253	267	256	8.39	0.5940
FLW (kg)	60	429^{b}	484^{a}	466^{a}	16.76	<0.0001
DMI (kg day^{-1})	60	9.8^{a}	8.7^{ab}	7.5^{b}	0.31	<0.0001
LWG (kg ha^{-1} $year^{-1}$)	60	290^{c}	615^{a}	487^{ab}	53.98	<0.0001
CH_4 (g day^{-1})	60	199.7	226.1	209.8	7.3	0.1606
CH_4 (g kg LW^{-1})	60	0.62	0.58	0.61	0.03	0.2047
CH_4 (kg $kgDMI^{-1}$)	60	0.028^{a}	0.028^{a}	0.029^{a}	0.001	<0.0001
gCH_4 $kgADG^{-1}$ LWG ha^{-1} $year^{-1}$	60	1.6^{a}	0.6^{c}	0.8^{bc}	0.09	0.0031
$kgCH_4$ kg Carcass $eq.^{-1}$	60	0.496^{a}	0.250^{b}	0.297^{b}	0.024	0.0047

- EXT = continuous stocking, low input
- INT = rotational grazing, lime and fertilizer applied
- iCL = integrated crop/livestock: corn harvested for silage in a rotation

- 3 year-study with 6 replicated pastures/trt

Meo-Filho et al. (2022; Agronomy, doi.org/10.3390/agronomy12112738)

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Intensification of grazing management and crop rotation

- **Can reduce GHG emissions intensity by 62%**
- **More studies like this needed**
- **Recovery of degraded pastures has great potential to increase C sequestration**
- **LCA is needed for systems approach (impact of fertilization, liming, additional fuel, etc.?)**

Meo-Filho et al. (2022; Agronomy, doi.org/10.3390/agronomy12112738)

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20

We need to tackle emissions in grazing systems…

Technologies available for this are still insufficient

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Tools available to mitigate enteric methane

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Additive	Efficacy: CH_4 reduction potential [1]	Efficacy: No. of academic papers [2]	Efficacy: Confidence in efficacy [3]	Potential animal welfare risks	Potential food safety risks
3-Nitrooxypropanol	Very High	> 20	5	None known	None known
Asparagopsis	Very High	< 10	1	Damage to rumen wall	Bromide & iodine residues in animal tissue/products
Nitrate	High	< 20	4	Toxicity in non-adapted animals	None known
Essential Oils	Low	< 20	2	None known	None known

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Fuente: Hegarty et al. (2021)

23

Additive	Efficacy: CH_4 reduction potential [1]	Efficacy: No. of academic papers [2]	Efficacy: Confidence in efficacy [3]	Potential animal welfare risks	Potential food safety risks
Saponin	Low	< 15	1	None known	None known
Tannins	Low	< 15	2	None known	None known
Monensin	Low	> 20	5	None known	None known
Microalgae	Low	< 5	1	None known	None known

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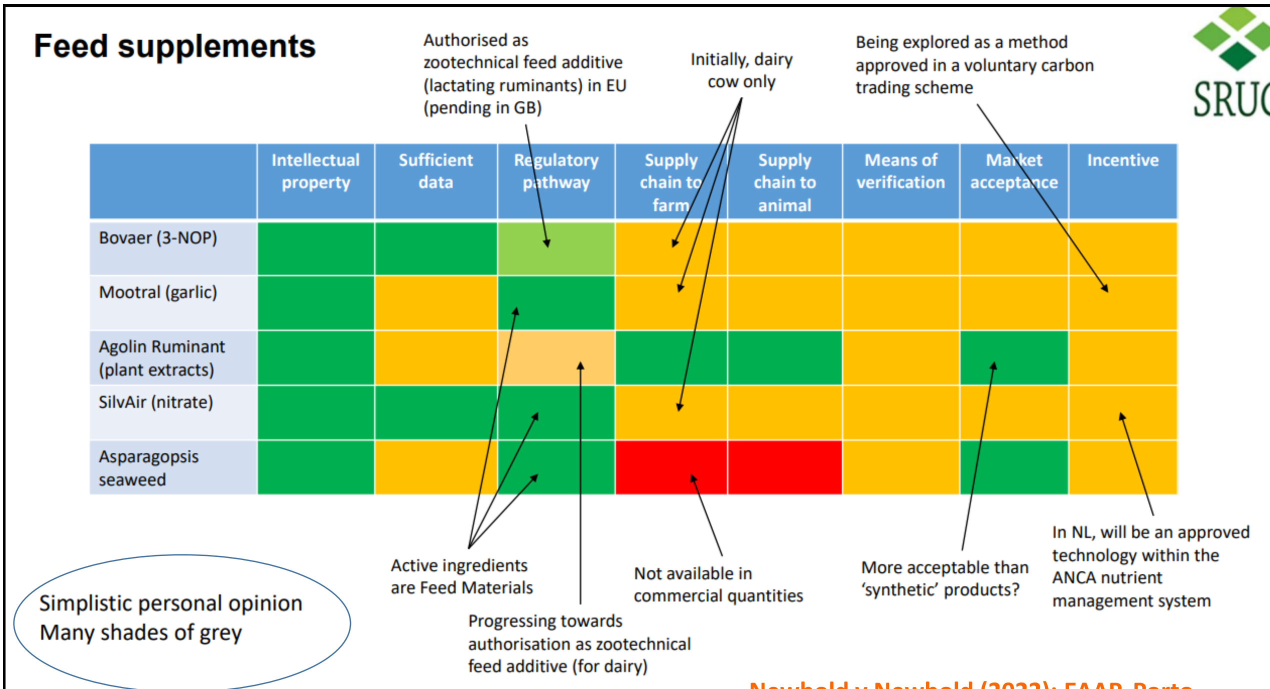
Fuente: Hegarty et al. (2021)

24

Feed supplements

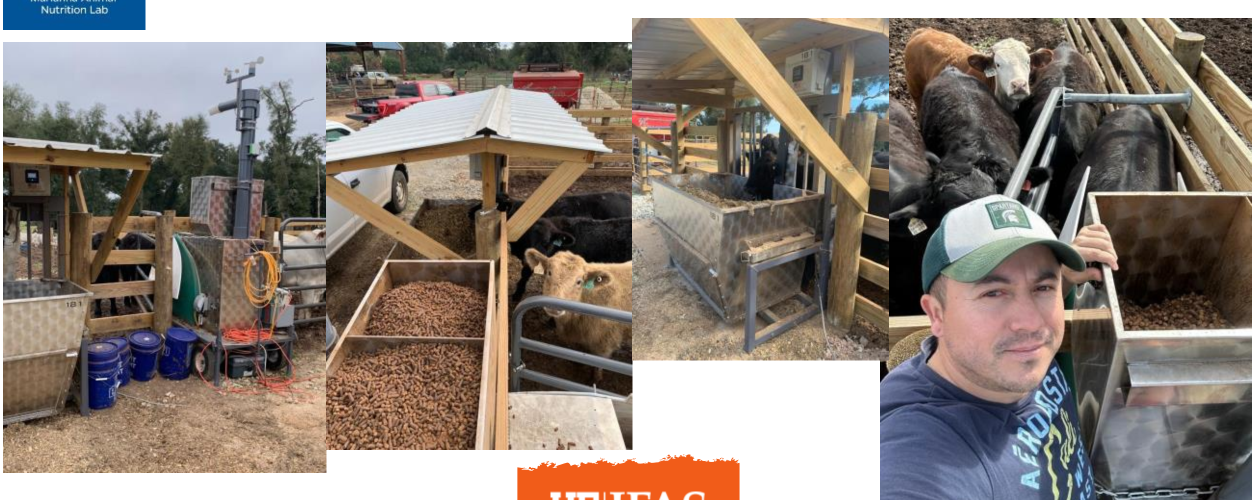


Newbold y Newbold (2022); EAAP, Porto

25

UF | IFAS NFREC Marianna Animal Nutrition Lab

UF studies addressing enteric methane



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26

Replacing urea with nitrates as a non-protein nitrogen source can decrease enteric methane by 11% (Henry et al., 2020; J. Anim. Sci.)

Meta-analysis of beef and dairy studies shows a mean reduction of 12.2% for beef (Feng et al., 2022; J. Dairy Sci.)

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USDA United States Department of Agriculture National Institute of Food and Agriculture

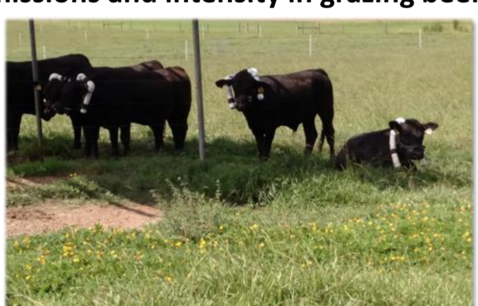
27

Inclusion of legumes in pastures

University of Florida

Hypothesis

The inclusion of legumes will decrease enteric methane emissions and intensity in grazing beef cattle



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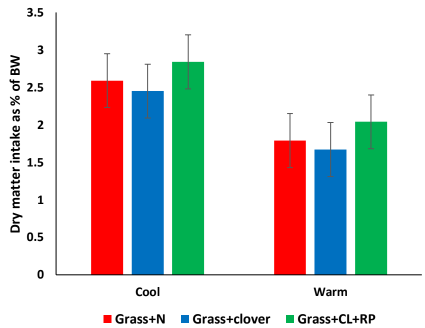
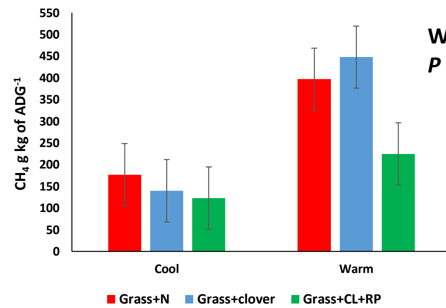
28

DMI as % of body weight and CH_4 emissions intensity in cool and warm season





Warm season, $P = 0.18$

Treatment × season, $P = 0.99$
Season effect, $P = 0.01$

Treatment × season, $P = 0.36$
Season effect, $P < 0.001$

Garcia et al. (2019)

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Feeding *Aspergillus oryzae* prebiotic (AOP)

	Treatment			
	AOP	CTL	SEM	*P*- value
Intake				
DM, kg/d	6.9	7.3	0.24	0.17
OM, kg/d	6.6	7.0	0.23	0.16
DM, as % of BW	2.62	2.67	0.070	0.58
Methane emissions				
g/d	262.8	237.8	19.03	0.26
g/kg DMI	39.1	32.8	2.73	0.09
g/kg OMI	40.7	34.1	2.85	0.09
g/kg DMD	58.2	50.2	4.15	0.14
g/kg OMD	59.1	51.0	4.20	0.15
g/kg MBW	4.0	3.5	0.28	0.16

Podversich et al. (unpublished)

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Most of the research conducted is in *Bos taurus*

- What is the impact of selection for feed efficiency on mature cow productivity and methane emissions on Brahman-influenced cattle
- The UF multibreed herd
- Collaboration with:
  - Drs. Mateescu, Rezende, Jeong, Nelson, Batistel, and Lourenço (UGA)

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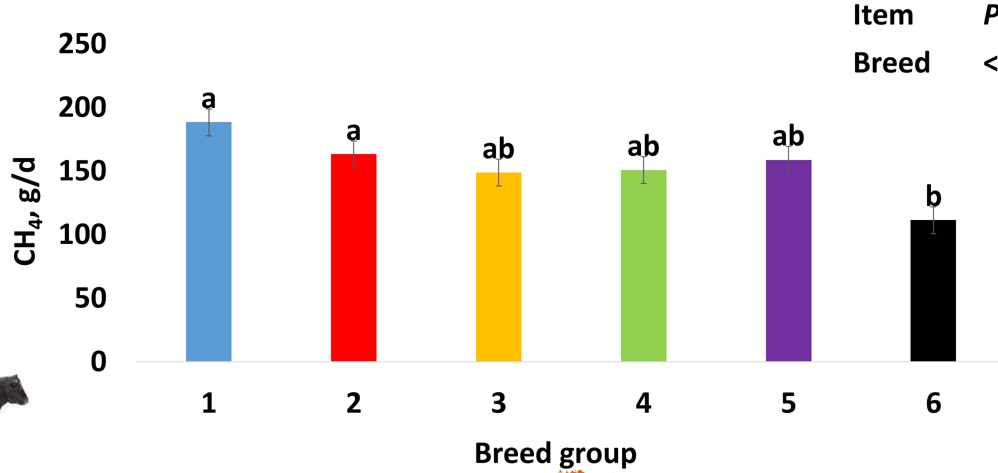
Effect of breed on methane emissions rate

Item	*P*-value
Breed	<0.01



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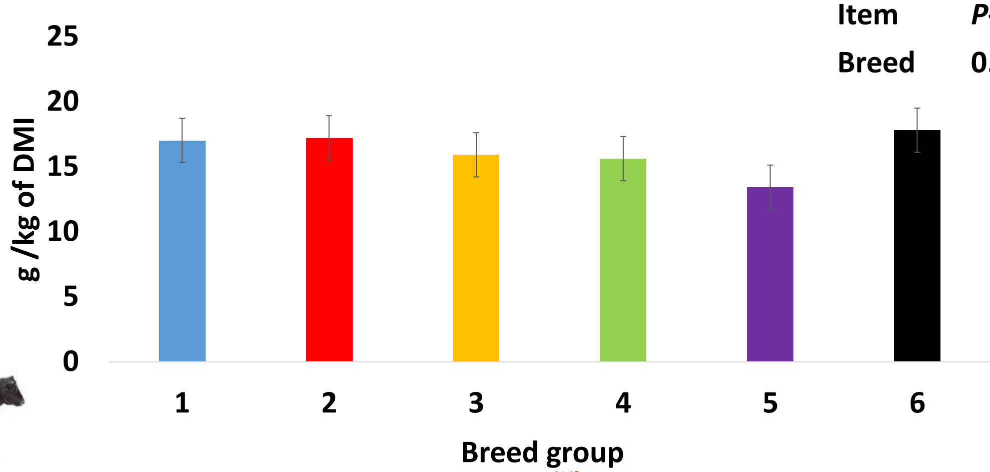
No breed differences on methane yield

Item	*P*-value
Breed	0.68



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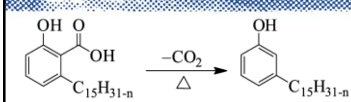

Anacardic acid Cardanol

Essential oils: CNSE
Anacardic acid and cardanol

SUPPLEMENT'S DELIVERING

CNSE // CON (pellet)
3 lb / d / steer
EU = Steer
Same feeder to each steer
(1, 2 Vs 3,4) throughout experiment

BASAL DIET (TMR)

08:00
Ad libitum
Finishing diet
(84:16% DM basis)

CO_2 and CH_4 emissions

1.5 Lb/d / Steer
Up to 30 drops/d (50g/drop)
5 visits/d (3 visits min)
Aim to ≥ 38 visits / period

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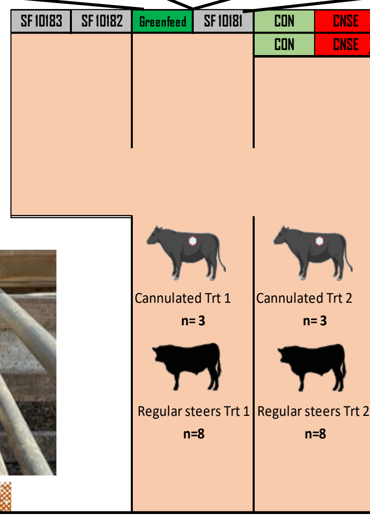
Experimental setup

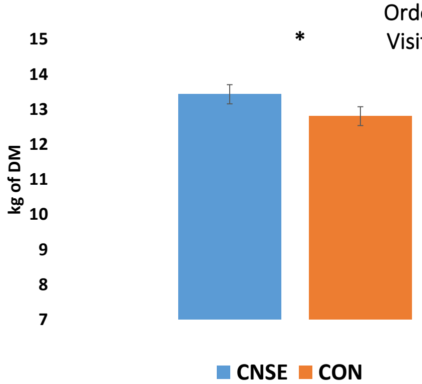


35

Cashew nutshell extract (CNSE) may decrease CH_4 in high-concentrate diets

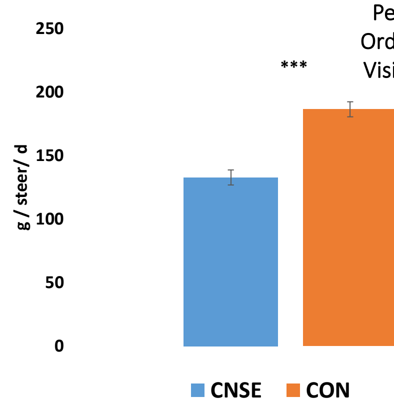
DMI

	P
Trt	0.04
Per	<0.001
Order	0.91
Visits	0.20



Methane emission rate

	P
Trt	<0.001
Per	0.06
Order	0.09
Visits	0.57



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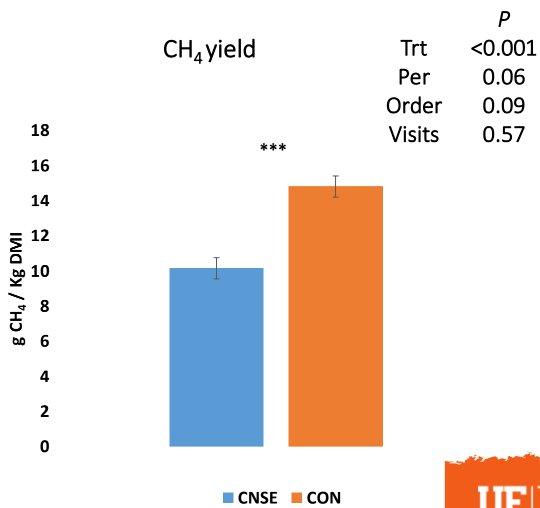
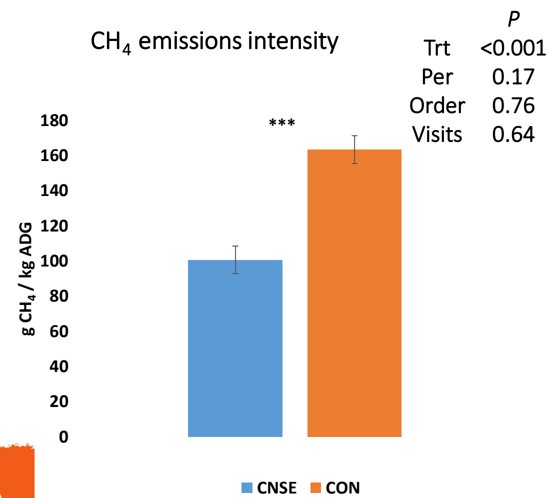
36

Cashew nutshell extract (CNSE) may decrease CH_4 yield and intensity





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Conclusions

- More focus on cow-calf and grazing systems is needed in order to make an impact on GHG emissions
- Legumes in pastures
  - ✓ With tannins: direct inhibition of methanogens (intensity?)
  - ✓ Without tannins: it needs to improve intensity
- Grazing management can help a lot
  - ✓ ⇧C sequestration and improve emissions intensity
- Tools for confinement: some additives show potential (3-NOP, algae, polyphenols?)
  - ✓ No production benefits associated so far
- 8-10% emissions improvement potential in cow-calf and stocker systems ➔ more focus on these!

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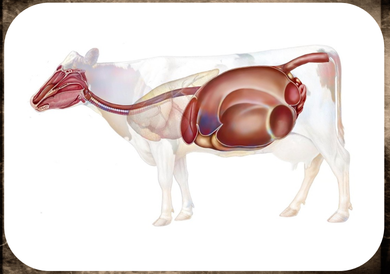
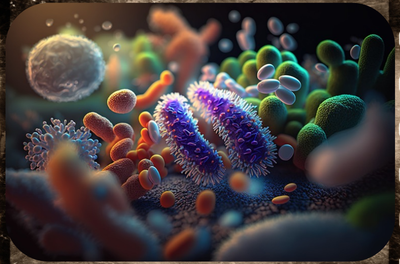
NFREC Marianna Animal Nutrition Lab

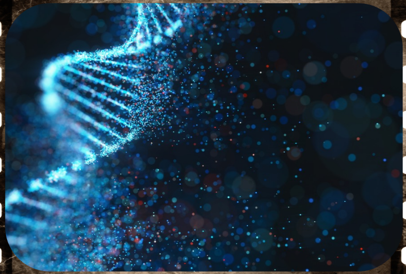
Thanks!

https://www.dilorenzonutritionlab.com/

39







THE RUMEN MICROBIOME AND LINKS WITH THE GENOME AND PRODUCTION IN DAIRY COWS

35th Annual Meeting

UF|IFAS UNIVERSITY of FLORIDA

UF | ANIMAL SCIENCES

02/28/24

Fabio Lima, DVM, MS, PhD, Diplomate ACT

Assist Prof of Livestock & Theriogenology

Department of Population Health & Reproduction

UCDAVIS VETERINARY MEDICINE

Lima Lab

75 YEARS UCDAVIS VETERINARY MEDICINE

TAKEAWAYS

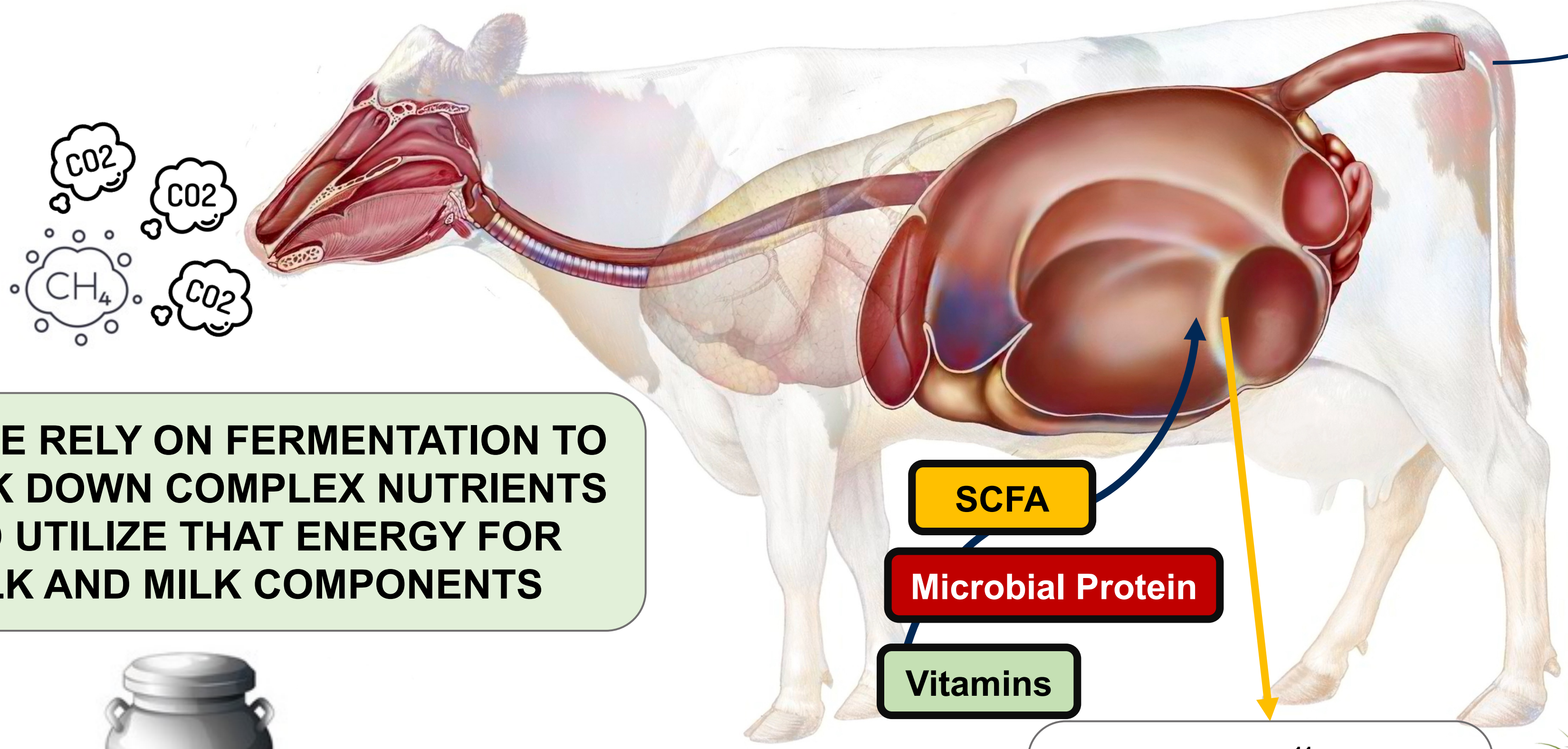
ASSOCIATIONS WITH PRODUCTION

ASSOCIATIONS WITH RFI

CONTRIBUTIONS TO PREDICTIONS OF PRODUCTIVE TRAITS

GENOME - MICROBIOME LINK TO RFI

ENTERIC FERMENTATION IN RUMINANTS



Lower Gut

Short-Chain Fatty Acids (SCFA)
70% of daily energy requirement

Microbial Protein
60% of daily protein requirement

Van Soest (1994)

CATTLE RELY ON FERMENTATION TO BREAK DOWN COMPLEX NUTRIENTS AND UTILIZE THAT ENERGY FOR MILK AND MILK COMPONENTS

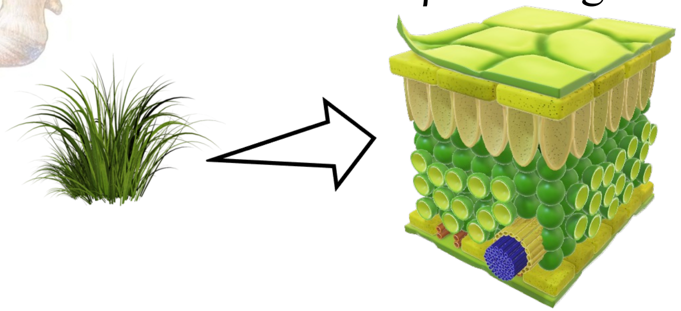
SCFA

Microbial Protein

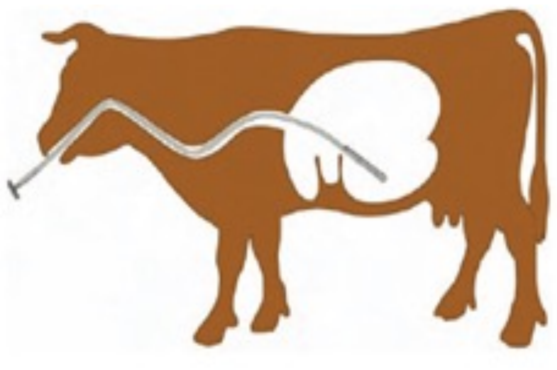
Vitamins

Bacteria (1 x 10^{11} cells/mL)
Archaea (1 x 10^{9})
Protozoa (1 x 10^{6})
Fungi (1 x 10^{5})
Viruses (1 x 10^{9})

β - linkages



EXPERIMENTAL DESIGN



CALVING

-7 Days prepartum 0 7 Days postpartum 150

-7 d

7 d

144 d

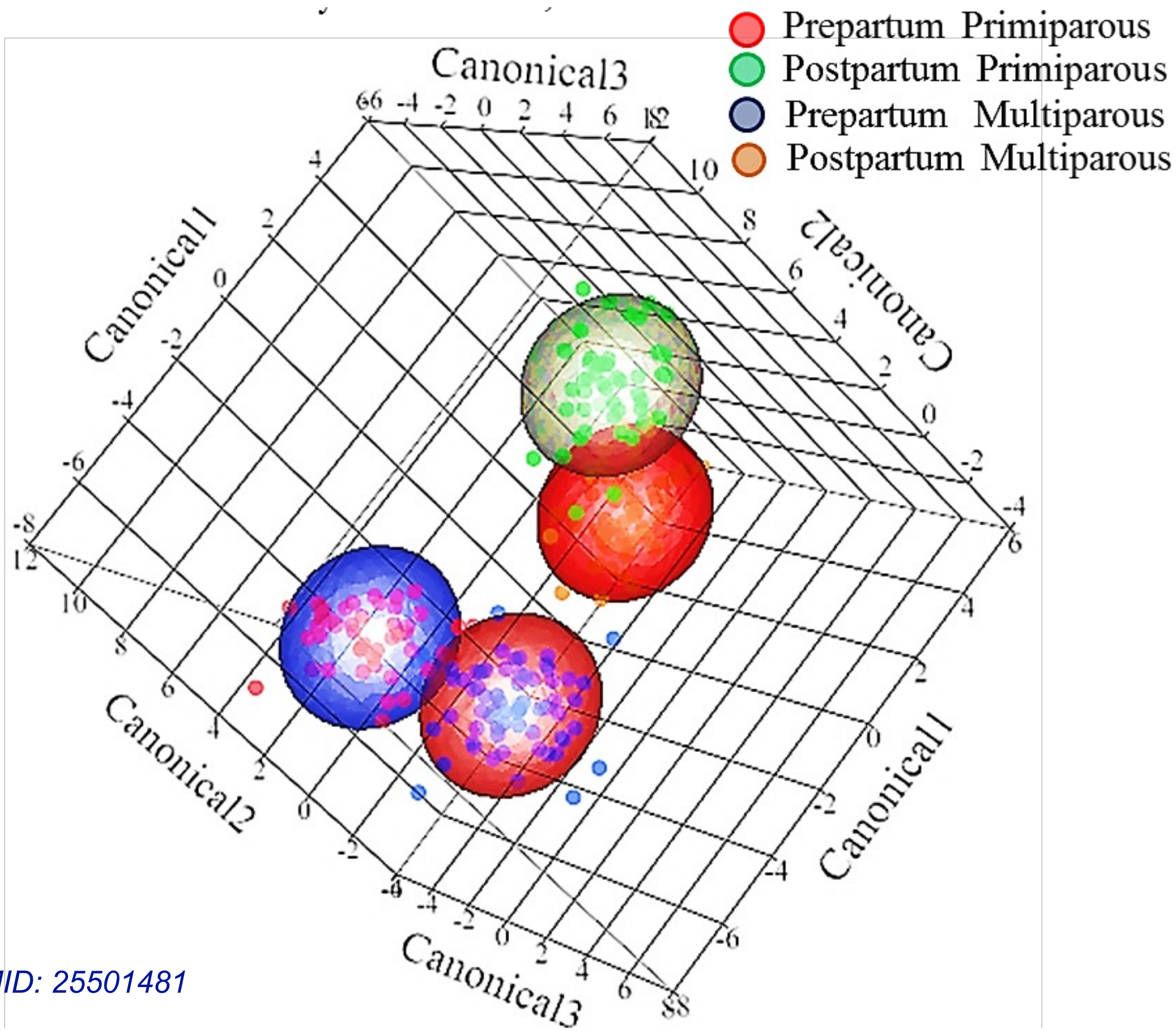
Rumen fluid samples
(n= 115)

Rumen fluid samples
(n=115)

Weekly evaluation of milk production and monthly evaluation milk fat and protein %

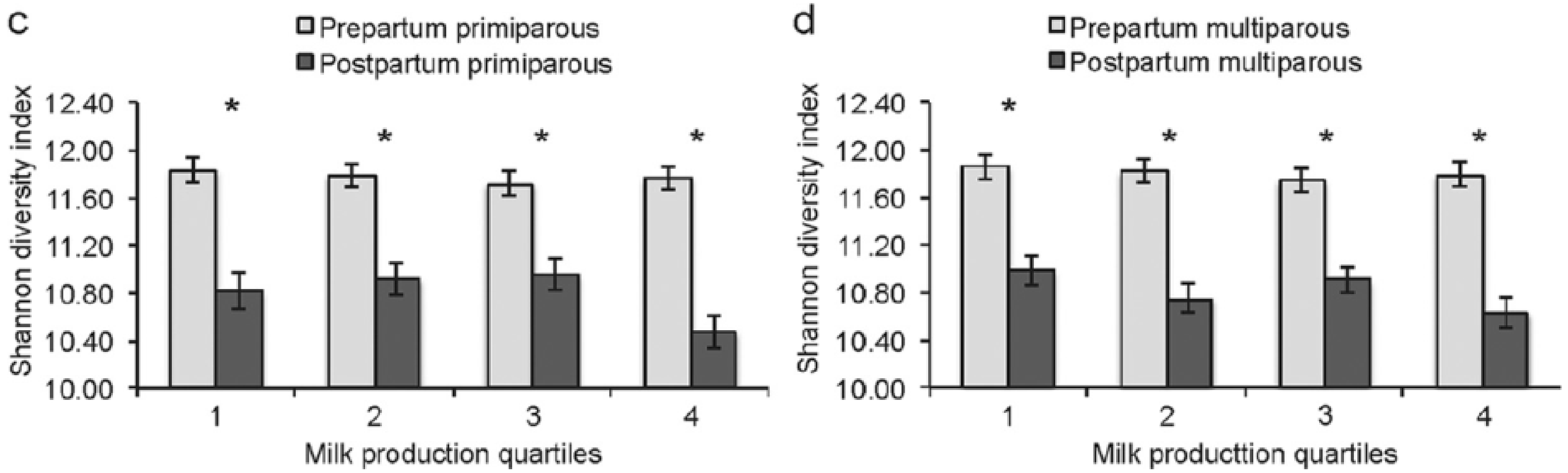
Lima et al., 2015. Appl Environ Microbiol. PMID: 25501481

PARITY AND TIME RELATIVE TO CALVING: ≠ RUMEN MICROBIOME



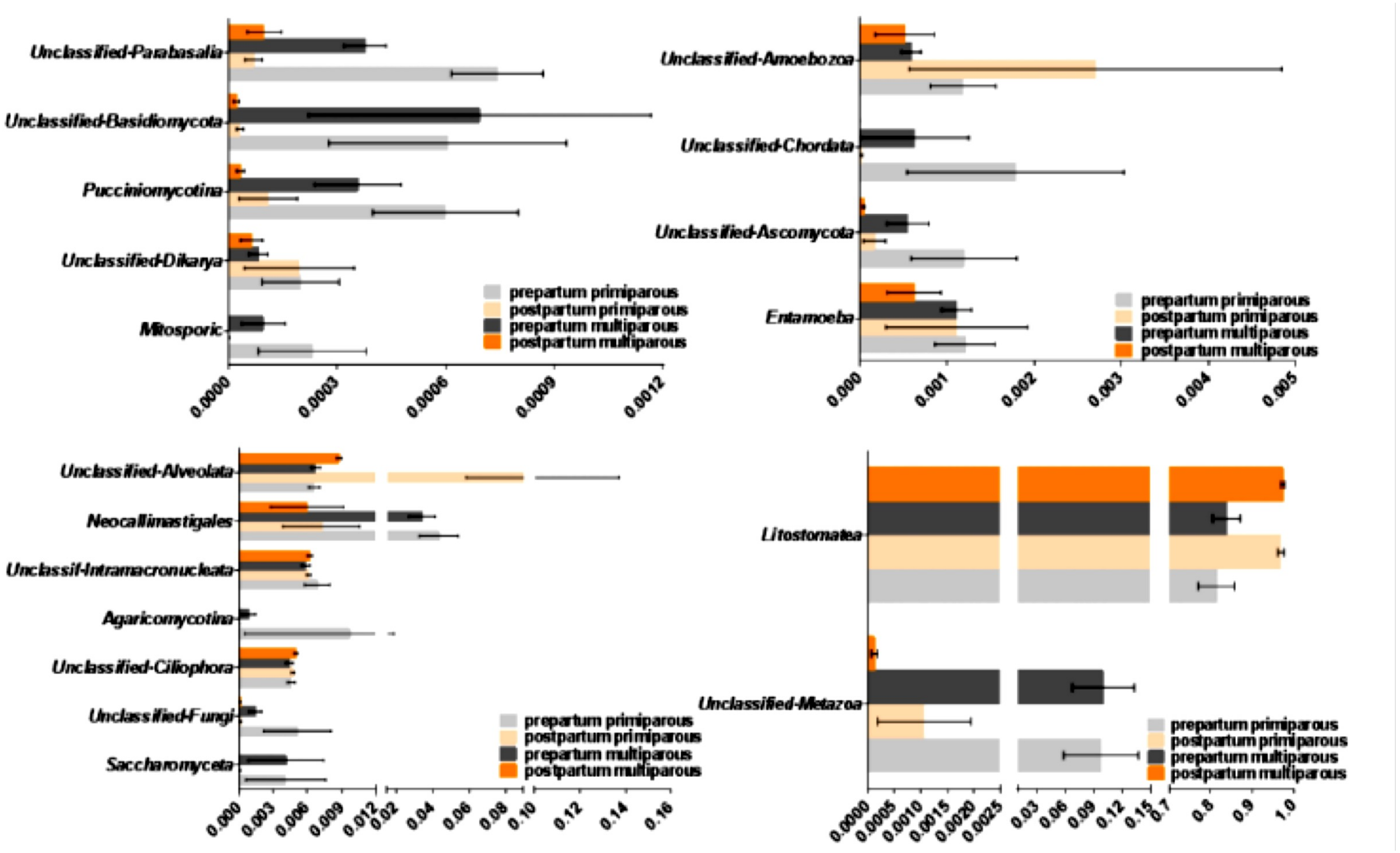
Lima et al., 2015. Appl Environ Microbiol. PMID: 25501481

PREPARTUM MICROBIOME – HIGHER DIVERSITY



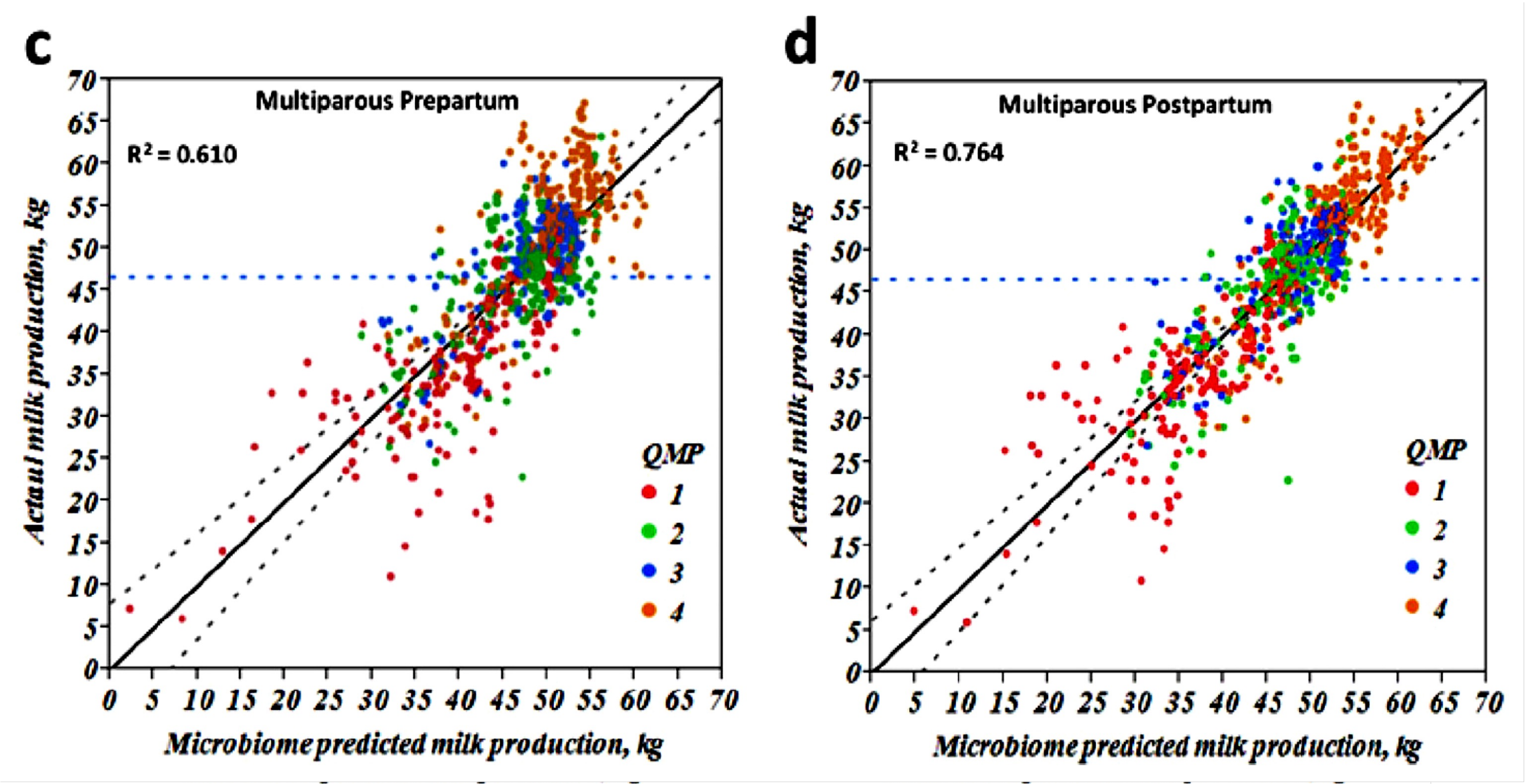
Lima et al., 2015. Appl Environ Microbiol. PMID: 25501481

FUNGI: ⬆ PREPARTUM   PROTOZOA: ⬆ POSTPARTUM



Lima et al., 2015. Appl Environ Microbiol. PMID: 25501481

MICROBIOME PREDICTED AND ACTUAL MILK PRODUCTION



Lima et al., 2015. Appl Environ Microbiol. PMID: 25501481

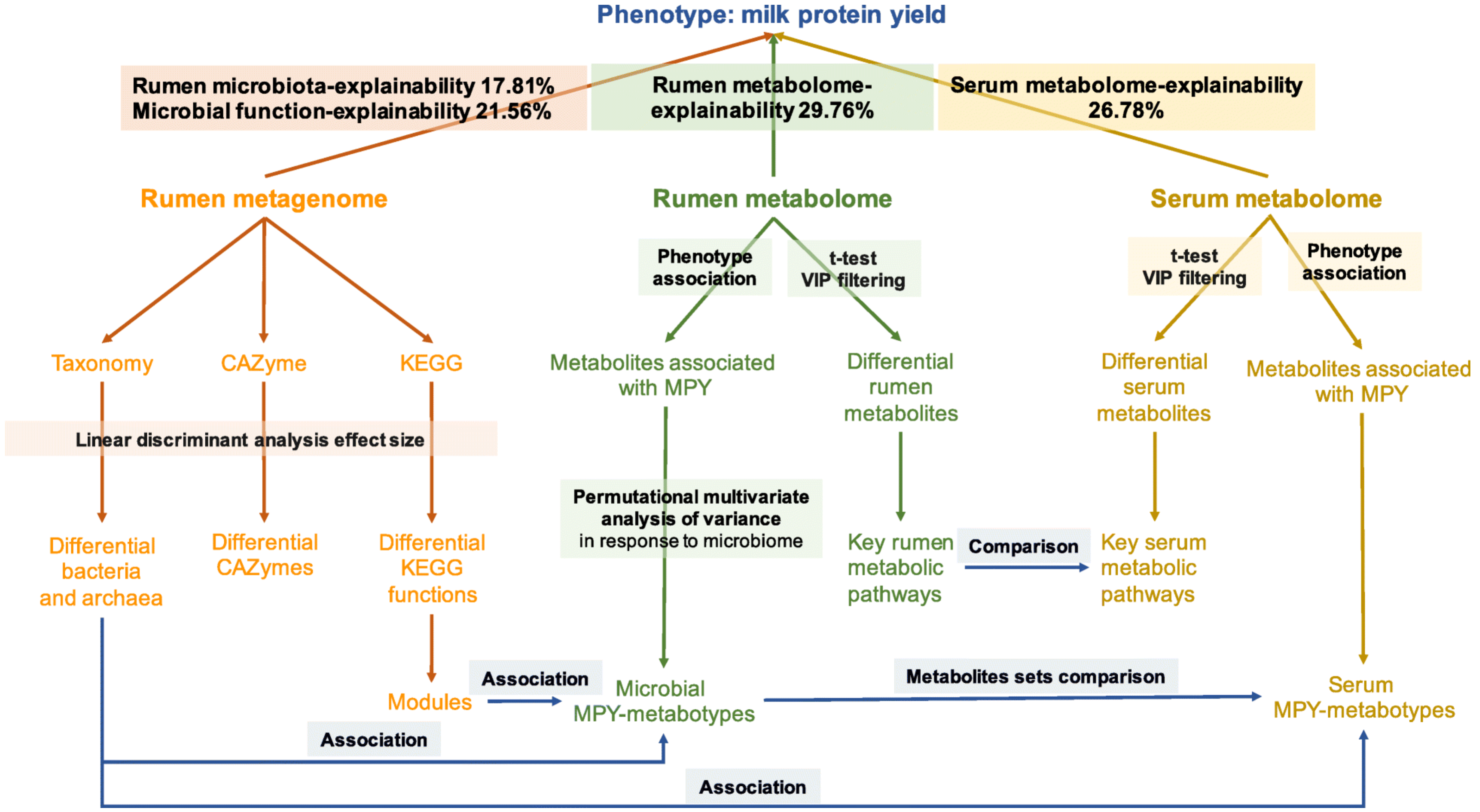
Deltaproteobacteria, Faecalibacterium and Virgibacillus Prevotellaceae, Micrococcaceae and Butyrivibrio

CONCLUDING REMARKS

- **Pre and postpartum microbiome: different prevalence of classic cellulolytic and amylolytic bacteria**
- **Prepartum = increased prevalence of fungi associated with cellulose digestion**
- **Postpartum = increased prevalence of protozoa associated with starch digestion**
- **Rumen microbiome model had a high goodness of fit of the regression models for milk production**

Lima et al., 2015. Appl Environ Microbiol. PMID: 25501481

HOW DOES THE MICROBIOME CONTRIBUTE TO MILK PRODUCTION EFFICIENCY?

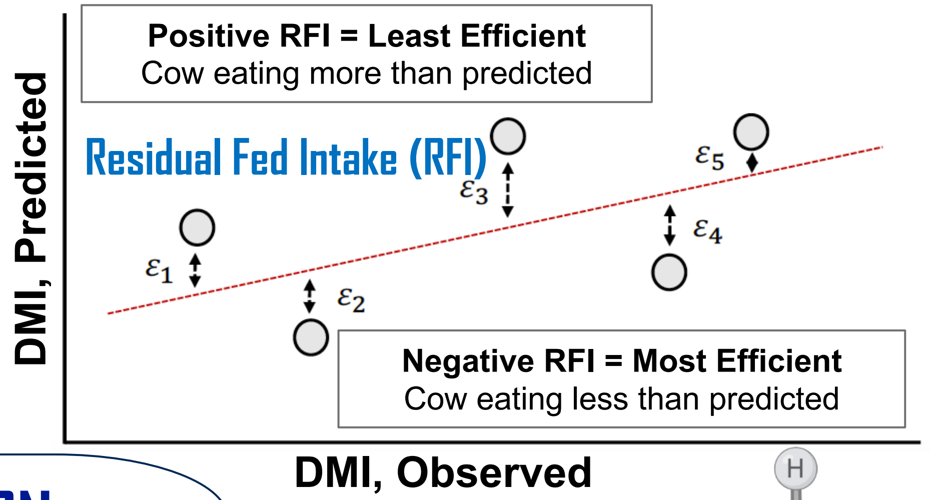


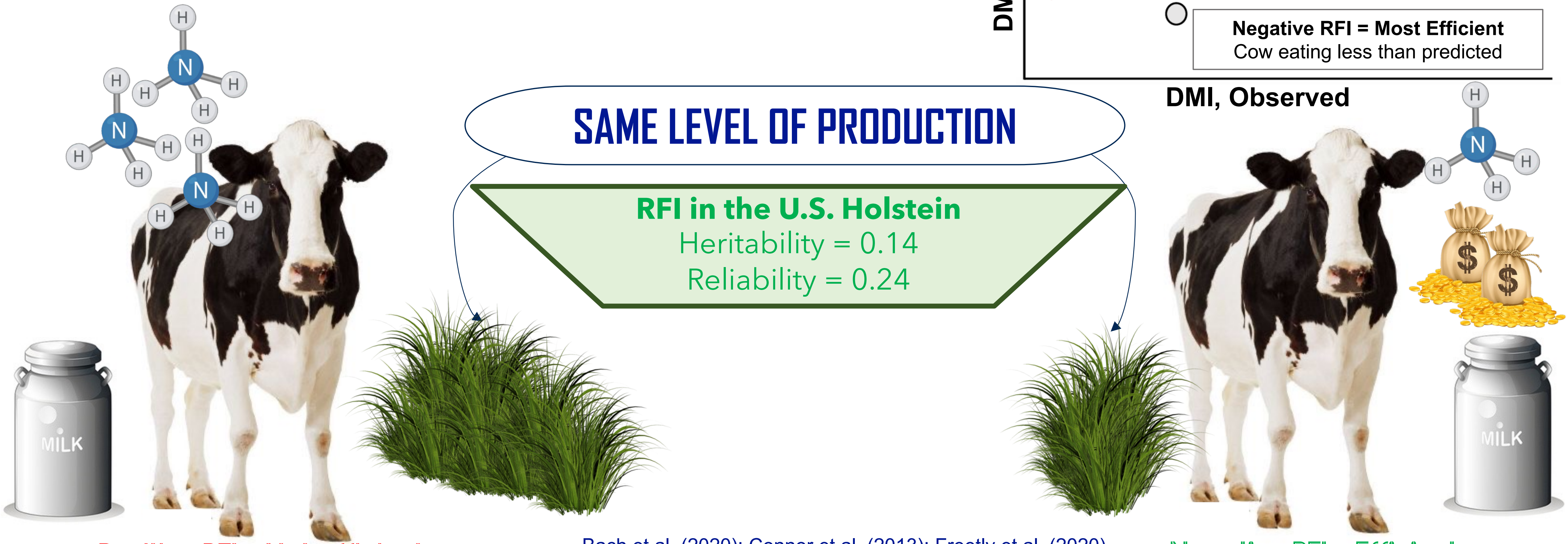
Xue et al., 2020. Microbiome. PMID: 32398126

TAKEAWAYS

- ASSOCIATIONS WITH PRODUCTION
- ASSOCIATIONS WITH RFI
- CONTRIBUTIONS TO PREDICTIONS OF PRODUCTIVE TRAITS
- GENOME - MICROBIOME LINK TO RFI

RUMEN MICROBIOME RESILIENCE AND ASSOCIATION WITH FEED EFFICIENCY



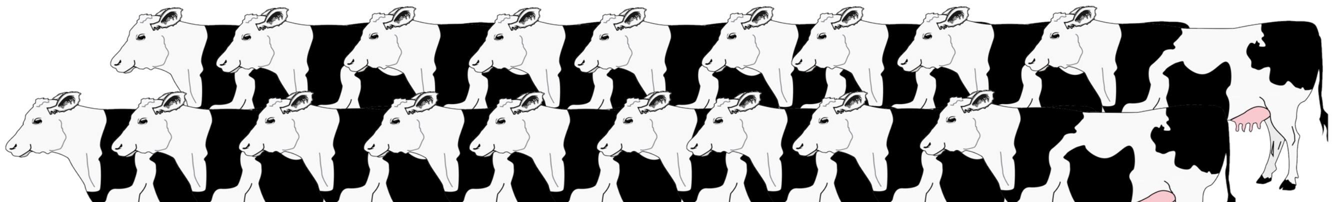


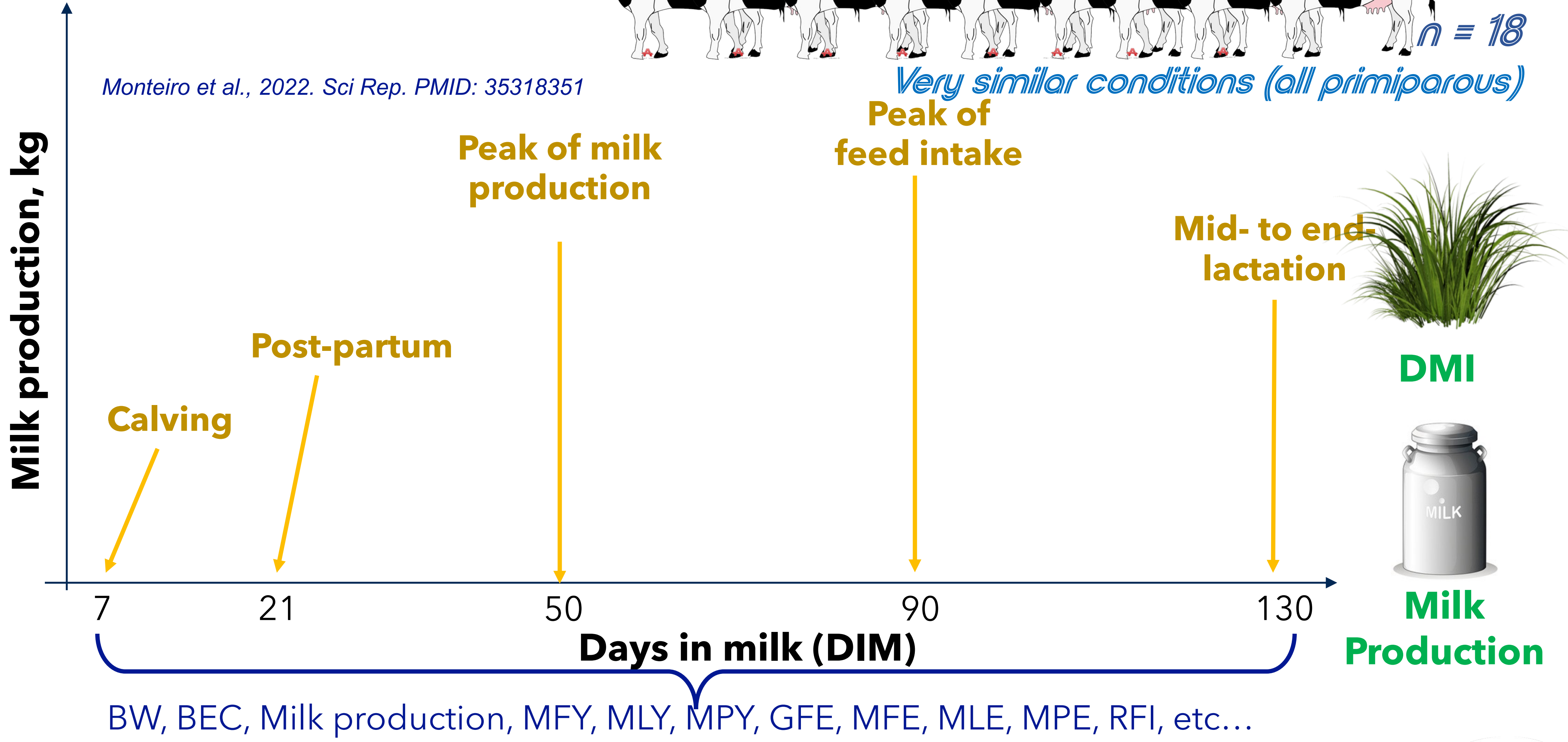
Positive RFI = Not efficient

Bach et al. (2020); Connor et al. (2013); Freetly et al. (2020)

Negative RFI = Efficient

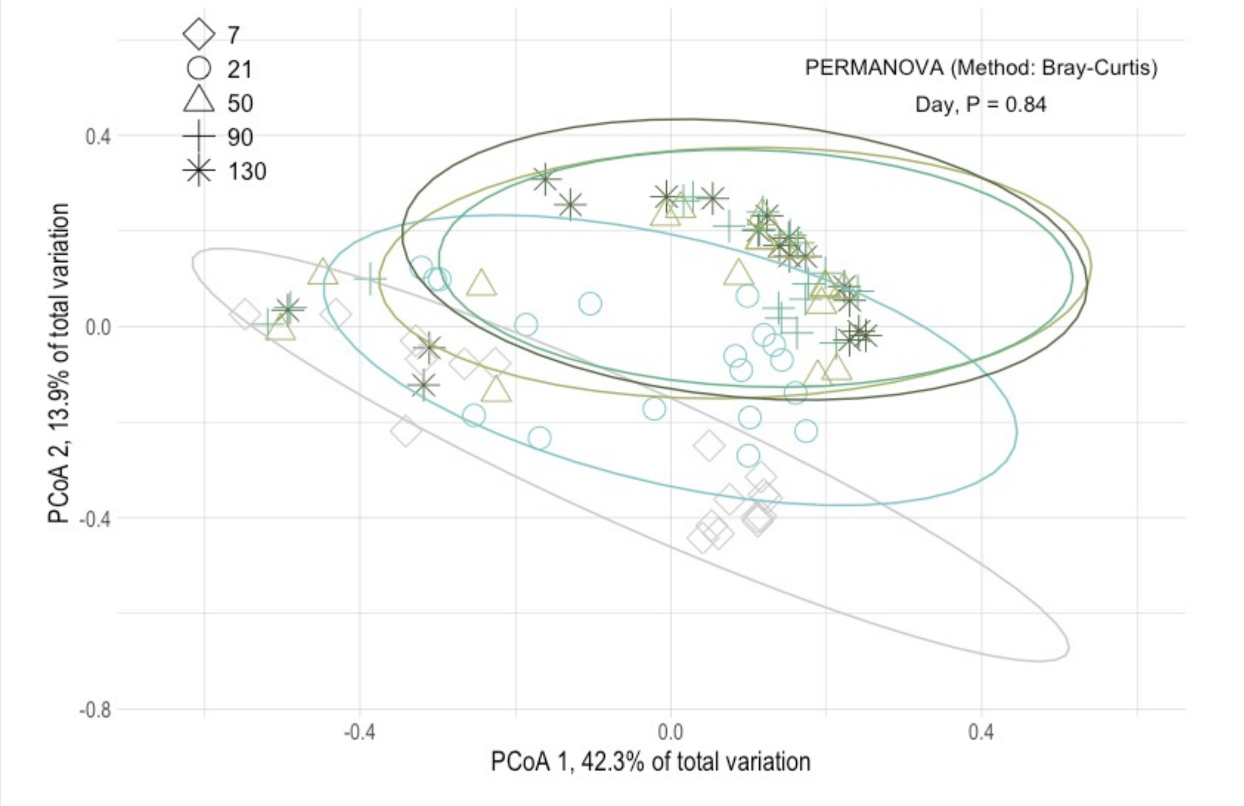
EXPERIMENTAL DESIGN



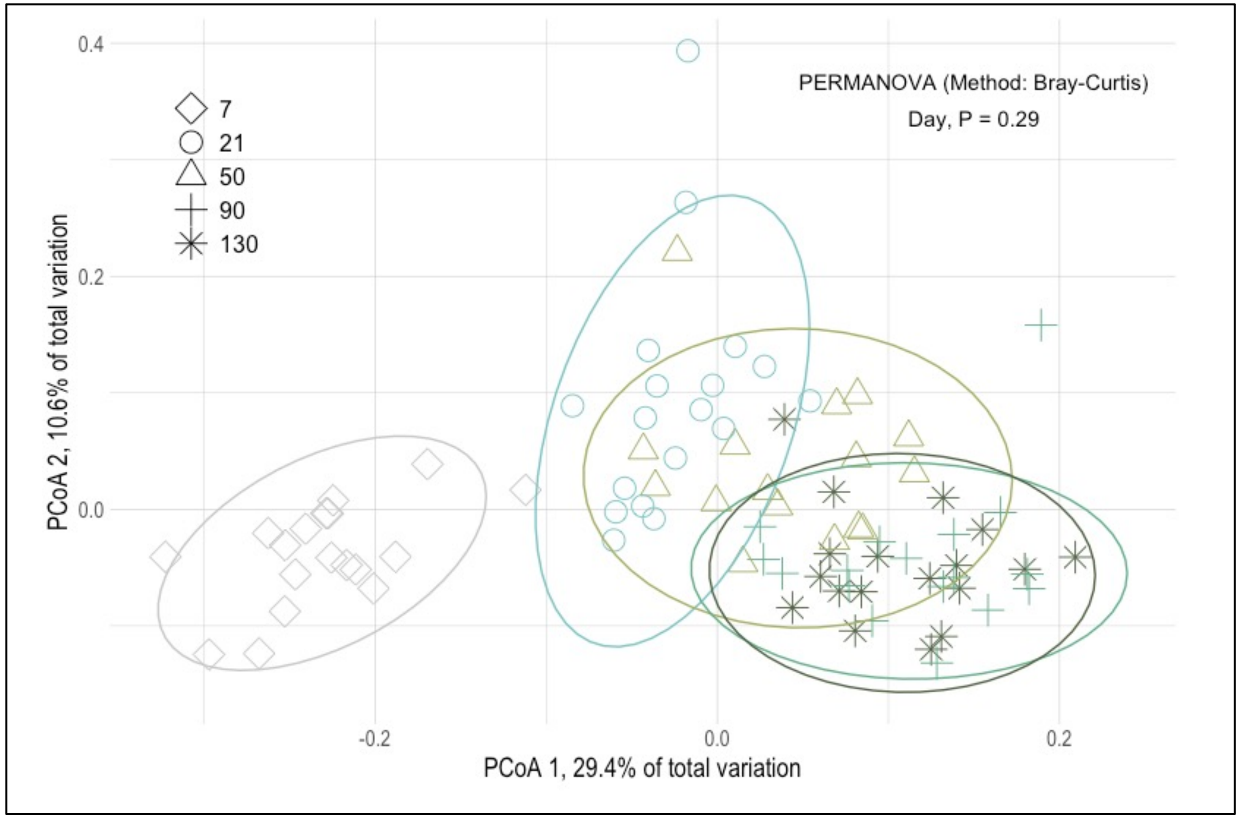


SAMPLING EFFECT

RUMEN MICROBIOME



LOWER GUT MICROBIOME



*No interaction with **DAY** was detected for the remaining variables

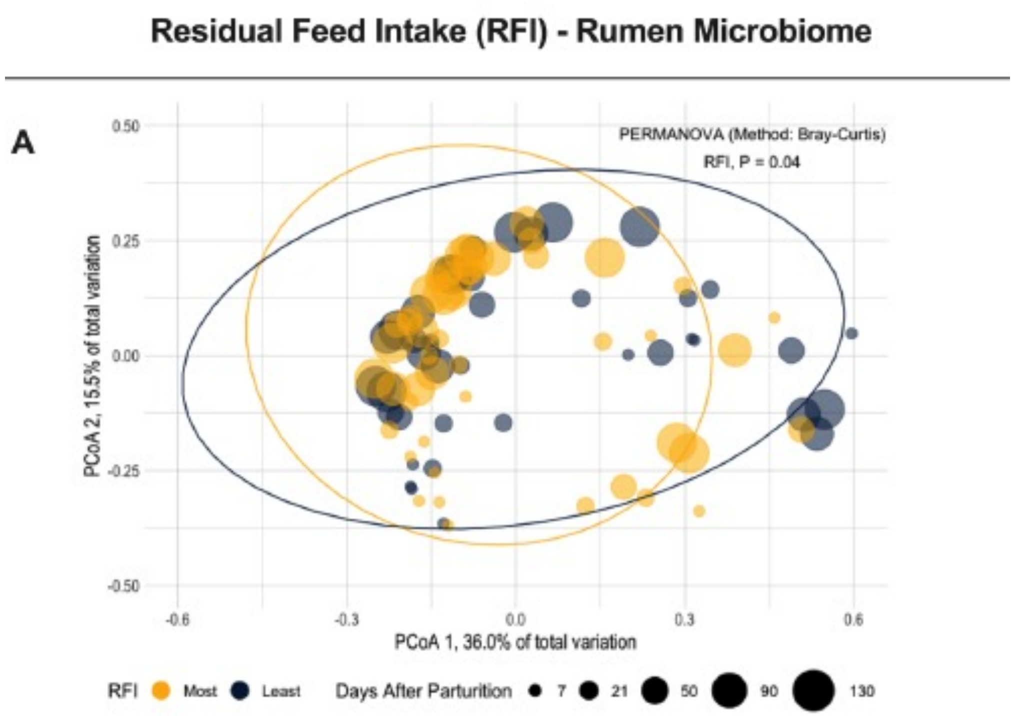
Monteiro et al., 2022. Sci Rep. PMID: 35318351

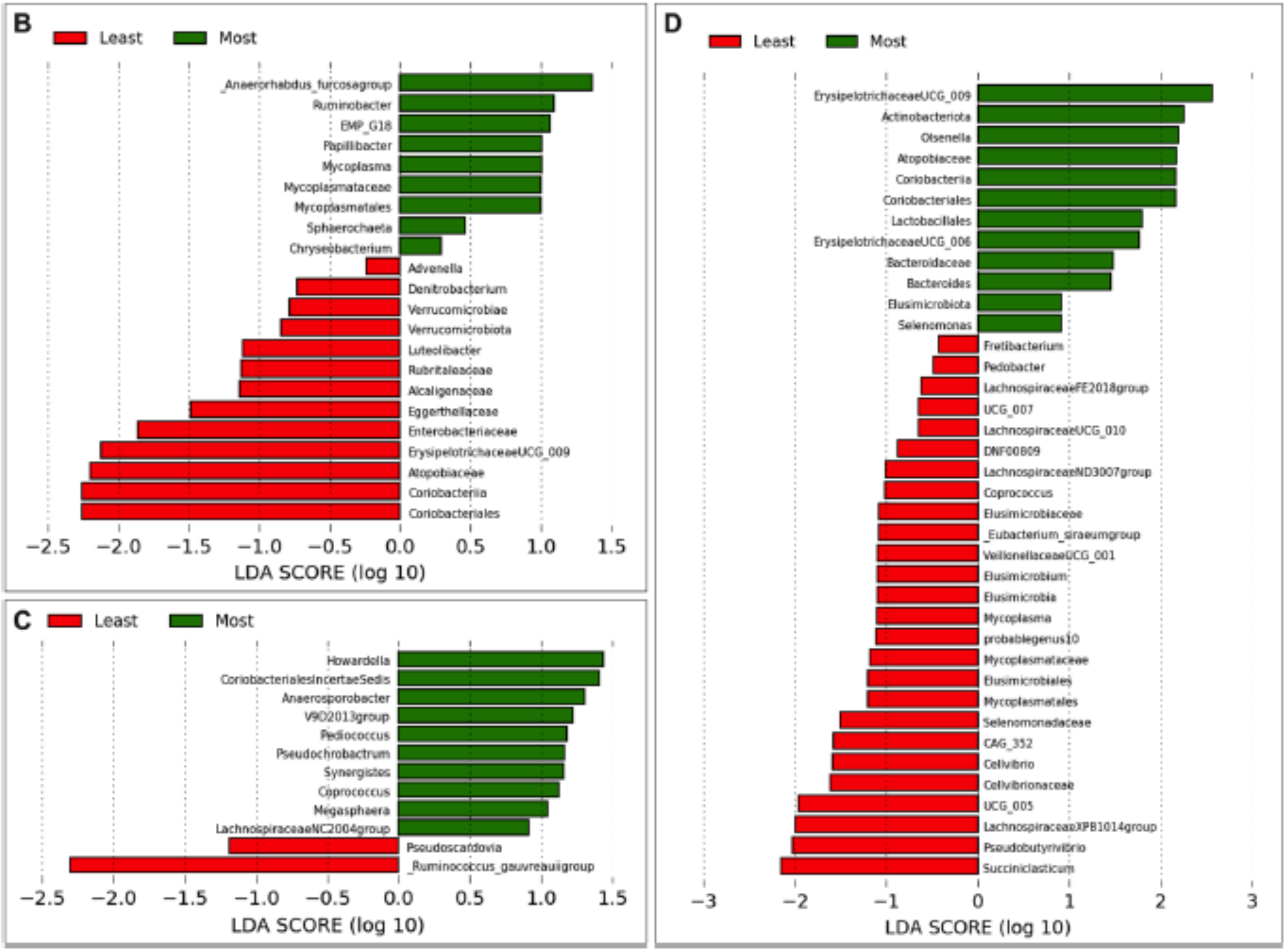
RESULTS – PERMANOVA CORRECTED FOR DMI

Item	*P*-Values	
	Rumen	Lower Gut
Day	0.84	0.29
DMI, kg/d	< 0.01	< 0.001
Milk production, kg/day		
ECM	< 0.01	< 0.001
Milk fat	< 0.001	< 0.01
Milk lactose	< 0.001	< 0.01
Milk protein	< 0.001	< 0.001
Feed efficiency		
Residual feed intake, RFI	0.04	0.04
RFI variables		
MBW, kg	< 0.001	< 0.001
BEC, Mcal/d	< 0.001	0.26
NESec, Mcal/d	< 0.01	< 0.001
RFI variables, unit/kg DMI		
MBW	0.01	0.19
BEC	0.03	0.01
NESec	< 0.001	< 0.001
Production efficiency, kg/kg DMI		
Energy-corrected milk, a.k.a. GFE	0.18	< 0.01
Milk fat	0.12	0.03
Milk lactose	0.30	0.19
Milk protein	0.49	< 0.01

Monteiro et al., 2022. Sci Rep. PMID: 35318351

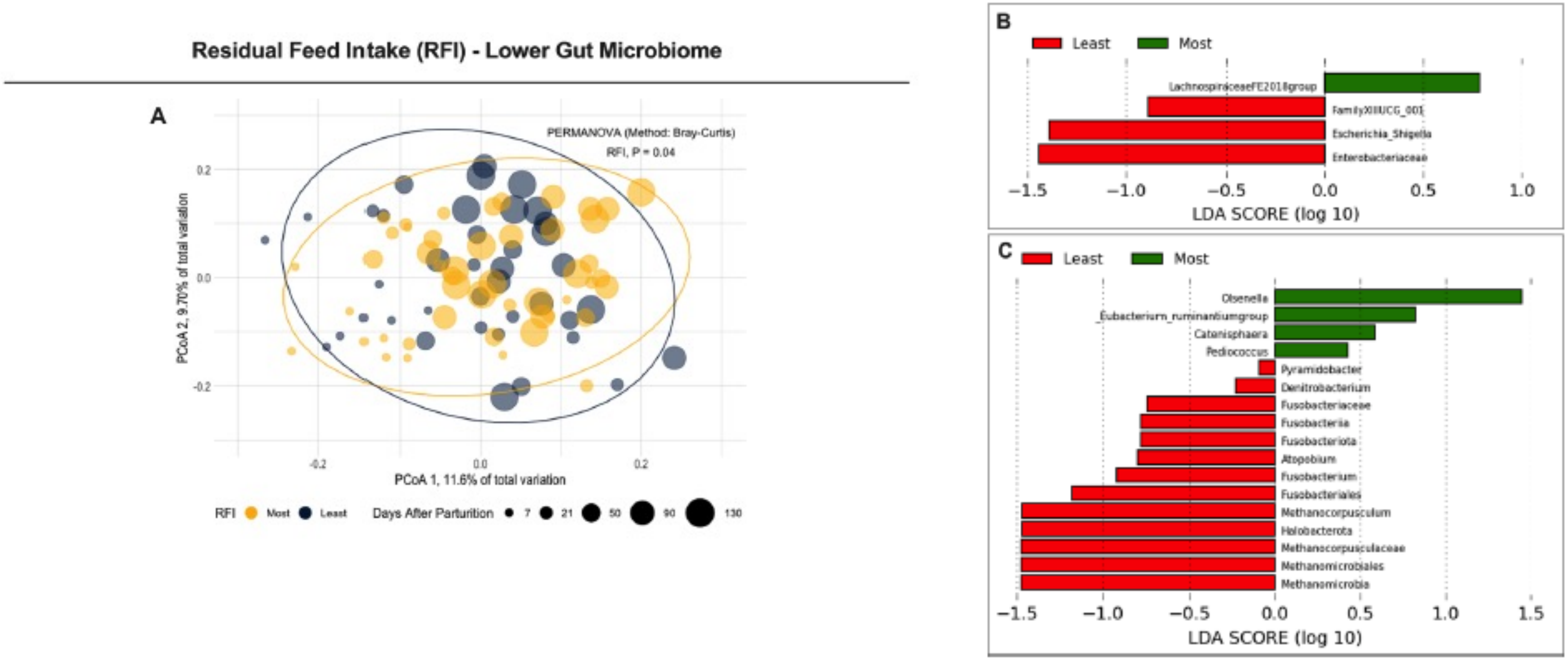
PCOA:PERMANOVA & LEFSE FOR MBW, BEC, & NESEC





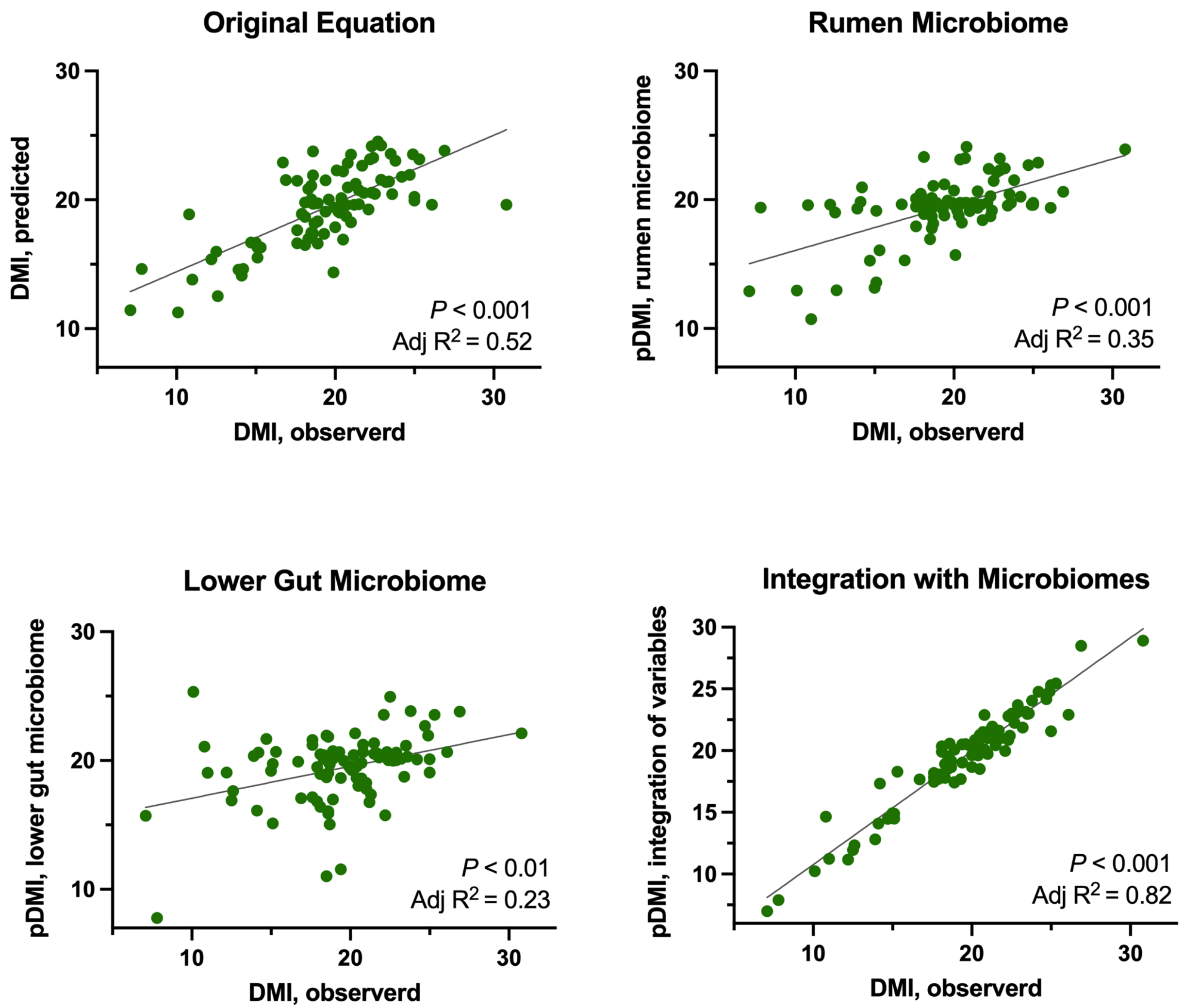
Monteiro et al., 2022. Sci Rep. PMID: 35318351

PCOA:PERMANOVA & LEFSE FOR BEC, & NESEC

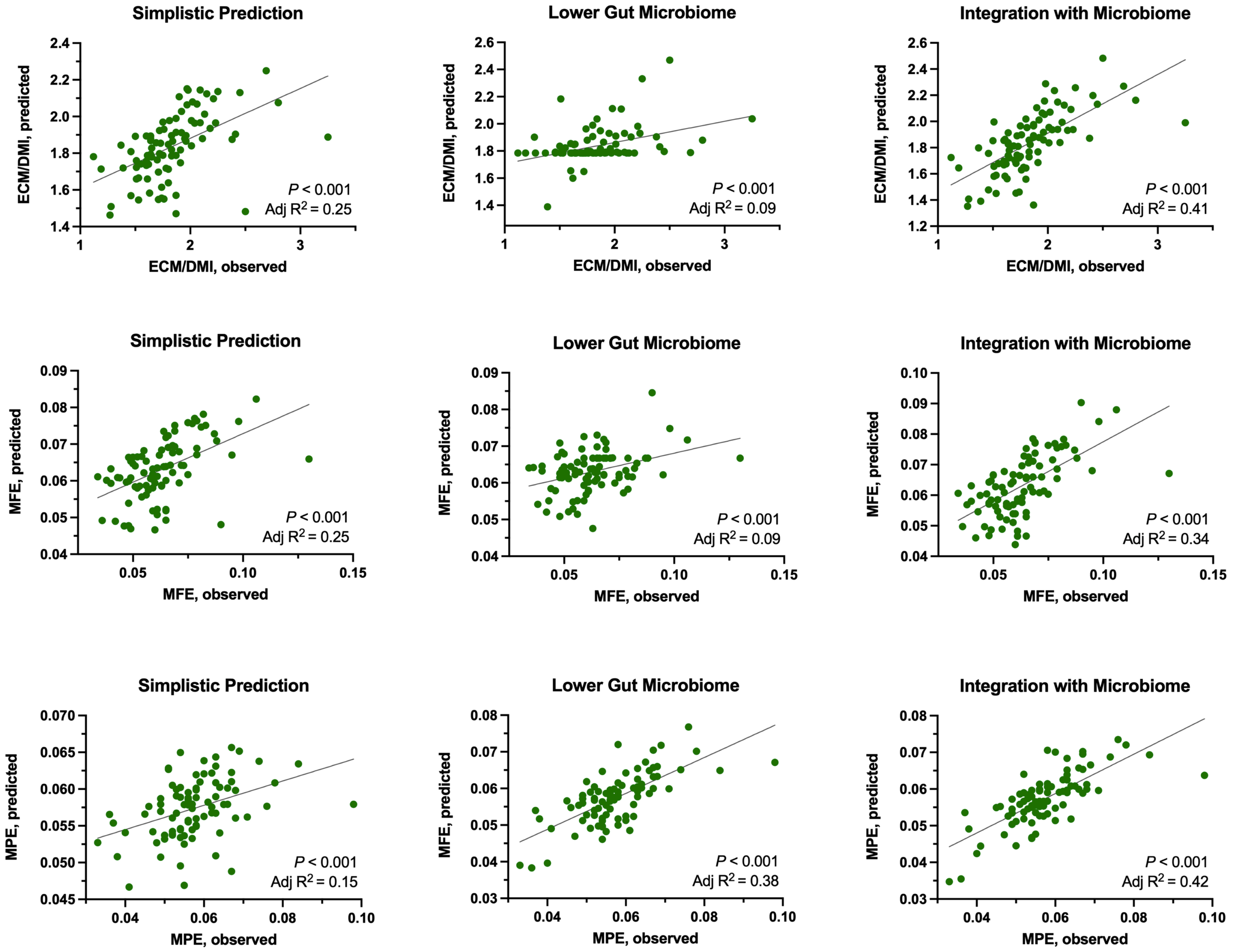


Monteiro et al., 2022. Sci Rep. PMID: 35318351

CORRELATION OF RUMEN & LOWER GUT MICROBIOME WITH DMI



Monteiro et al., 2022. Sci Rep. PMID: 35318351



CORRELATION OF RUMEN & LOWER GUT MICROBIOME WITH DMI

Monteiro et al., 2022. Sci Rep. PMID: 35318351

CONCLUDING REMARKS

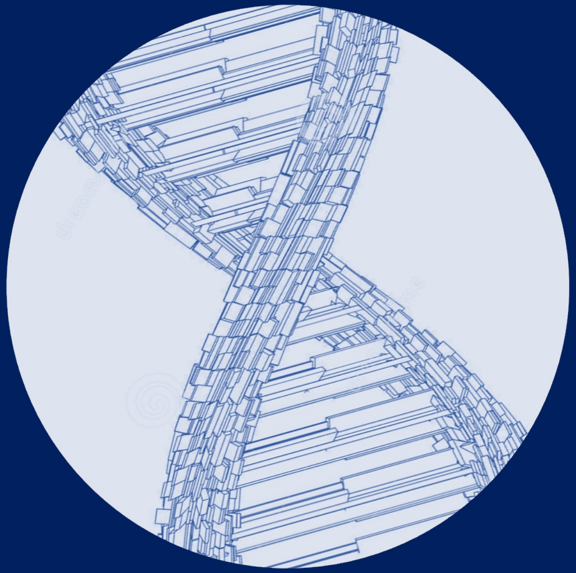
- The microbiome from both locations has temporal stability throughout lactation.
- Yet factors such as feed intake levels significantly shape microbiome diversity.
- The composition of the rumen microbiome was dependent on feed intake.
- In contrast, the lower gut microbiome was less dependent on feed intake and associated with a potentially enhanced ability to digest dietary nutrients.
- Therefore, milk production traits may correlate more with microorganisms in the lower gut than previously expected.

Monteiro et al., 2022. Sci Rep. PMID: 35318351

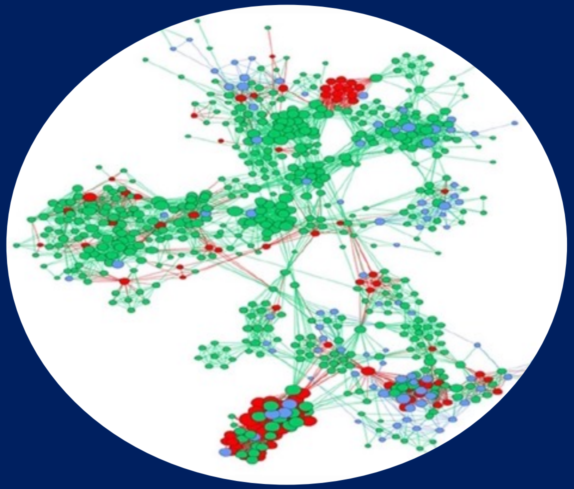
TAKEAWAYS

- ASSOCIATIONS WITH PRODUCTION
- ASSOCIATIONS WITH RFI
- CONTRIBUTIONS TO PREDICTIONS OF PRODUCTIVE TRAITS
- GENOME-MICROBIOME LINKS TO RFI

SOURCES OF VARIATION FOR FEED AND MILK PRODUCTION EFFICIENCY



Animal Genetics

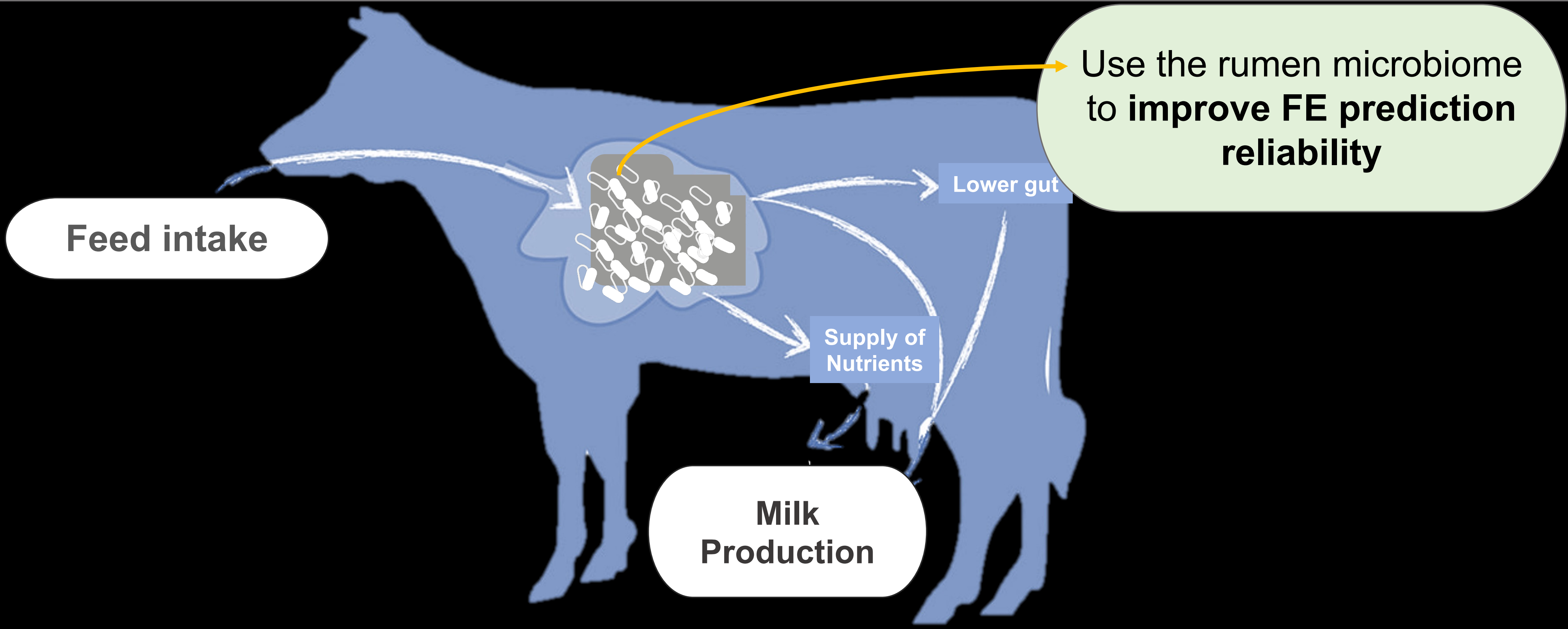


Gastrointestinal Fermentation

Management

HYPOTHESIS

The **rumen microbiome** plays a **major role in feed efficiency** variation and can be a **path to identify highly feed-efficient dairy cows.**



COLLABORATION US - CANADA

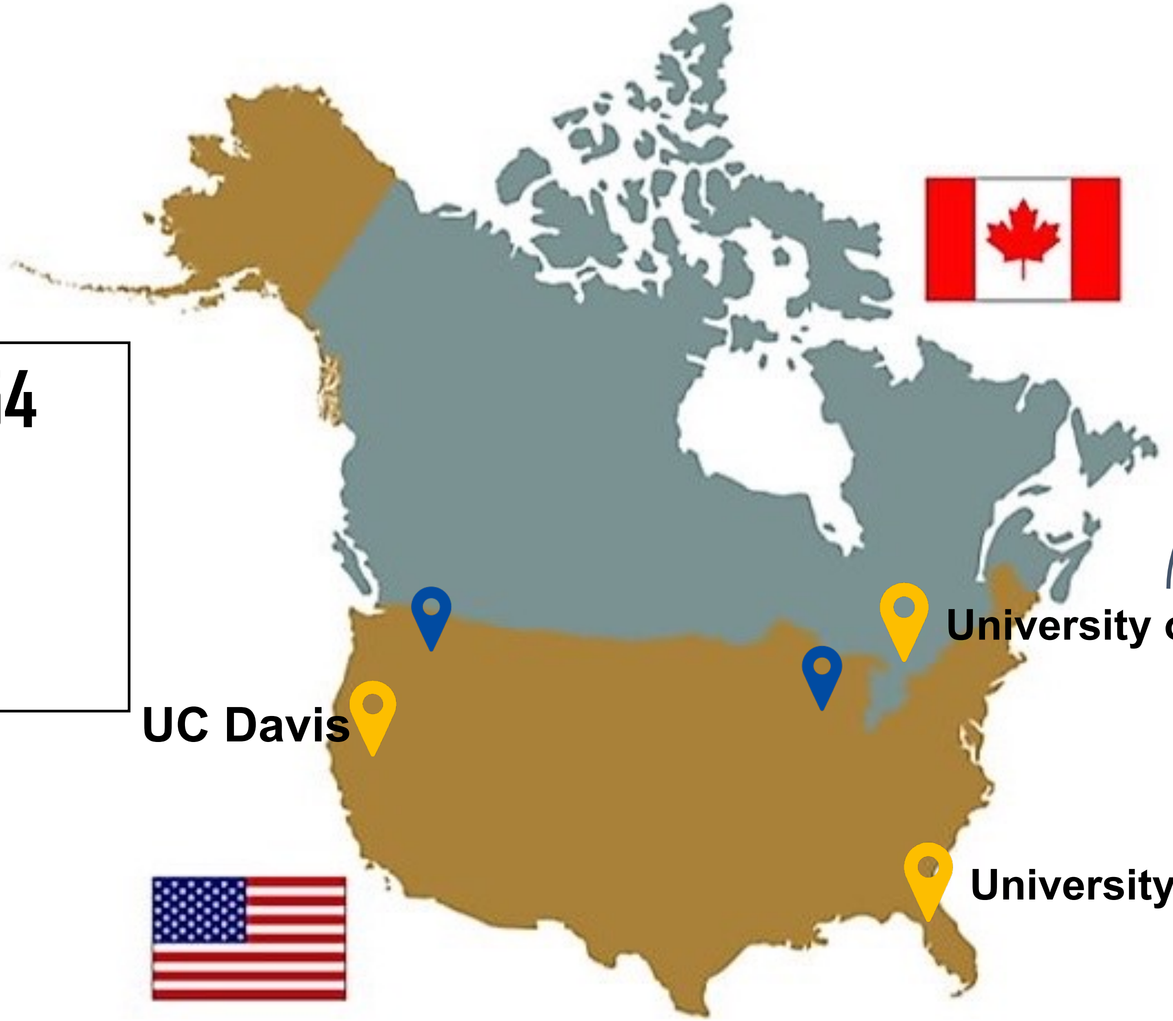
Total dairy cows: 454

<u>All characterized for:</u>

Feed efficiency

Genomic transmitting ability

Rumen microbiome



n = 219

n = 235

Artificial intelligence opportunities

MULTICOLINEARITY

Monteiro *et al. Animal Microbiome* (2024) 6:5
https://doi.org/10.1186/s42523-024-00289-5

Animal Microbiome

RESEARCH Open Access

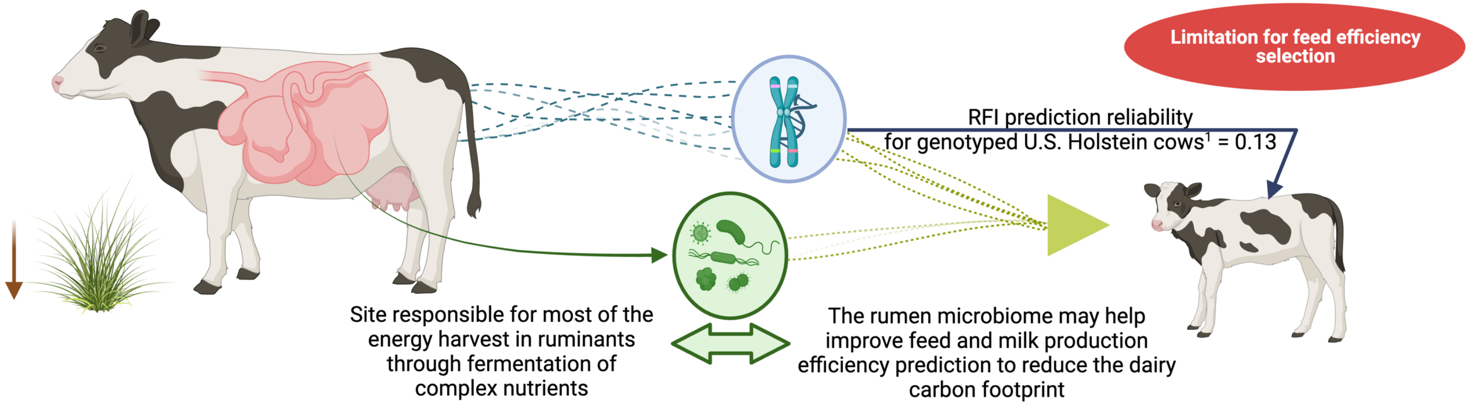
An artificial intelligence approach of feature engineering and ensemble methods depicts the rumen microbiome contribution to feed efficiency in dairy cows

Hugo F. Monteiro[1], Caio C. Figueiredo[2,3], Bruna Mion[4], José Eduardo P. Santos[5], Rafael S. Bisinotto[3], Francisco Peñagaricano[6], Eduardo S. Ribeiro[4], Mariana N. Marinho[5], Roney Zimpel[5], Ana Carolina da Silva[5], Adeoye Oyebade[5], Richard R. Lobo[5], Wilson M. Coelho Jr[1], Phillip M. G. Peixoto[3], Maria B. Ugarte Marin[3], Sebastian G. Umaña-Sedó[3], Tomás D. G. Rojas[3], Modesto Elvir-Hernandez[3], Flávio S. Schenkel[4], Bart C. Weimer[1], C. Titus Brown[1], Ermias Kebreab[7] and Fábio S. Lima[1*]

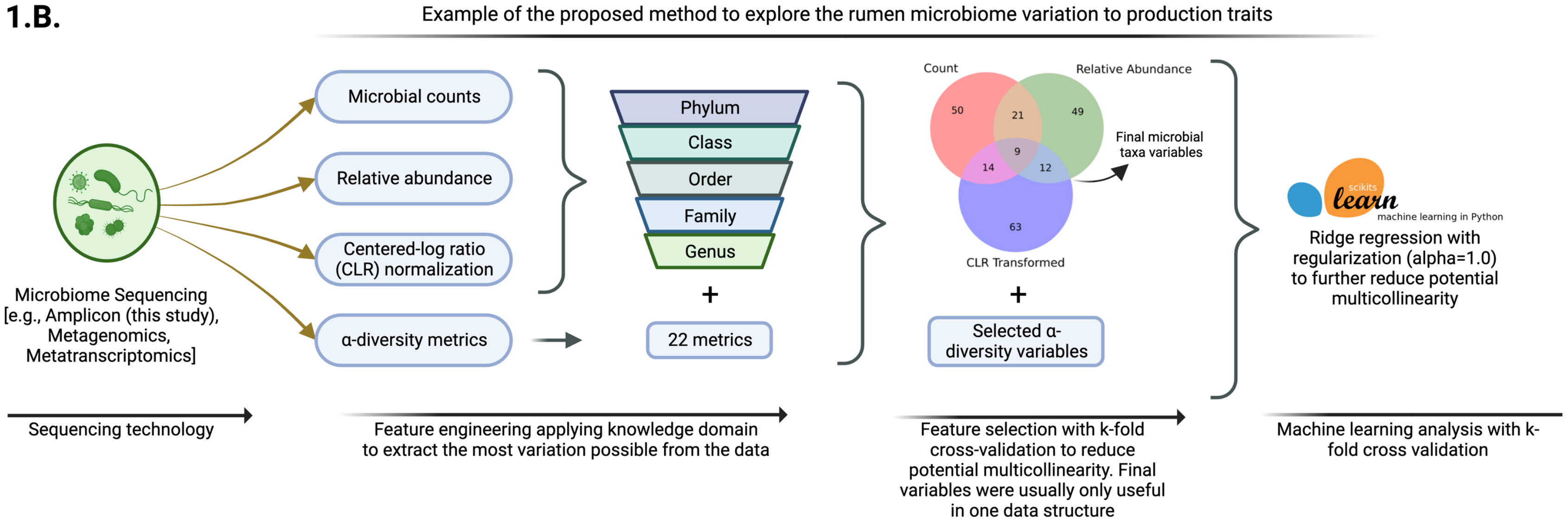
HIDDEN PATTERNS IN COMPOSITIONAL DATA

UCDAVIS VETERINARY MEDICINE

1.A.



1.B.



Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

PREDICTING DRY MATTER INTAKE (DMI)

Table 1. Results from a mixed model based on Type 3 sum of squares for dry matter intake and gross milk production efficiency traits in 454 lactating Holstein cows in the US and Canada

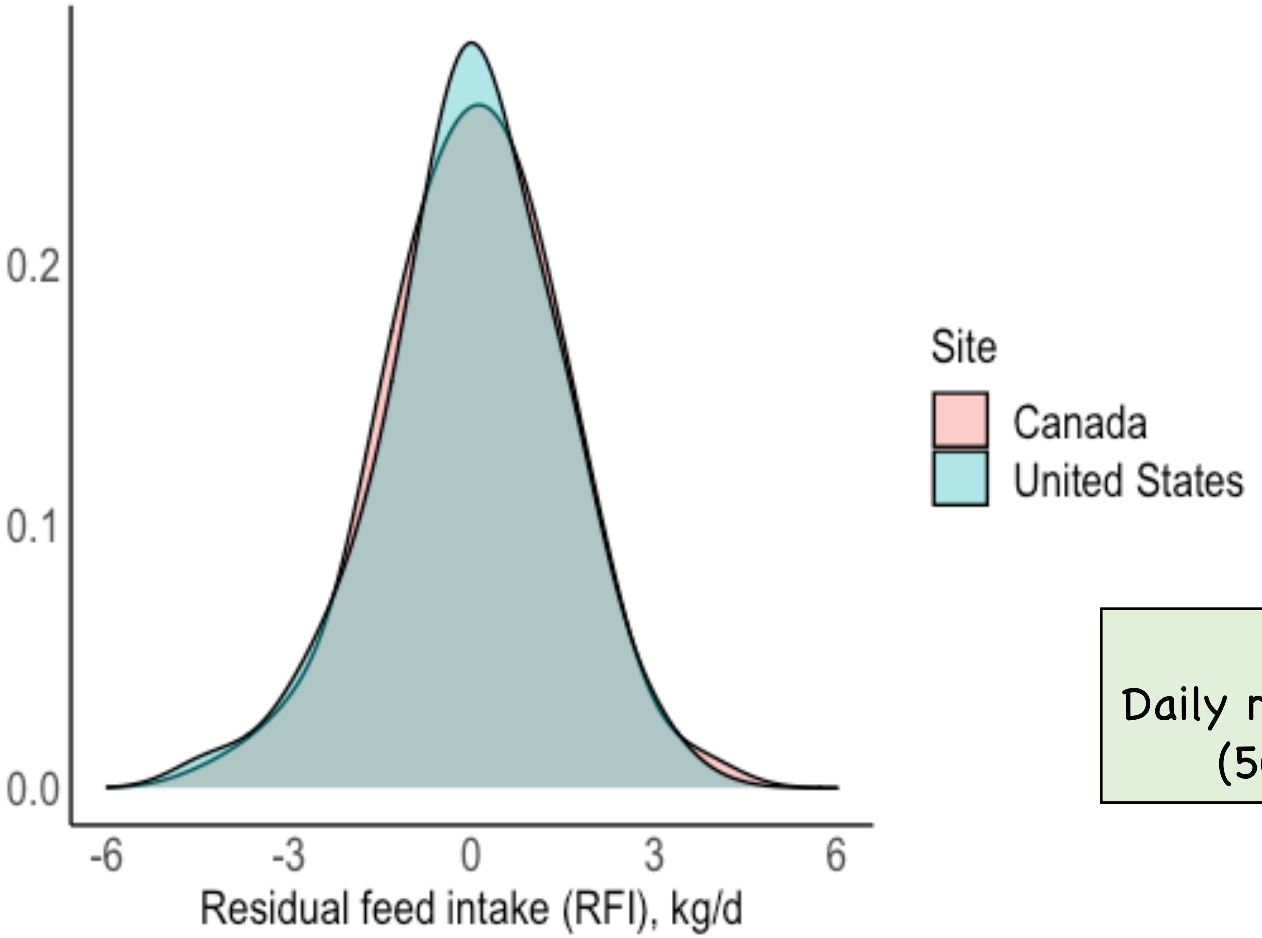
Item	R^2	Estimate	SE[1]	*P*-value
Dry matter intake, kg/d				
Parity[2]	0.02	0.87	0.22	< 0.001
MBW, kg	0.12	0.09	0.01	< 0.001
BEC, Mcal/d	0.05	0.17	0.02	< 0.001
NESec, Mcal/d	0.39	0.37	0.02	< 0.001
Treatment (random effect)	0.07			
Residual (residual feed intake; RFI)	0.36			

$R^2 = 0.64$

Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

UCDAVIS VETERINARY MEDICINE

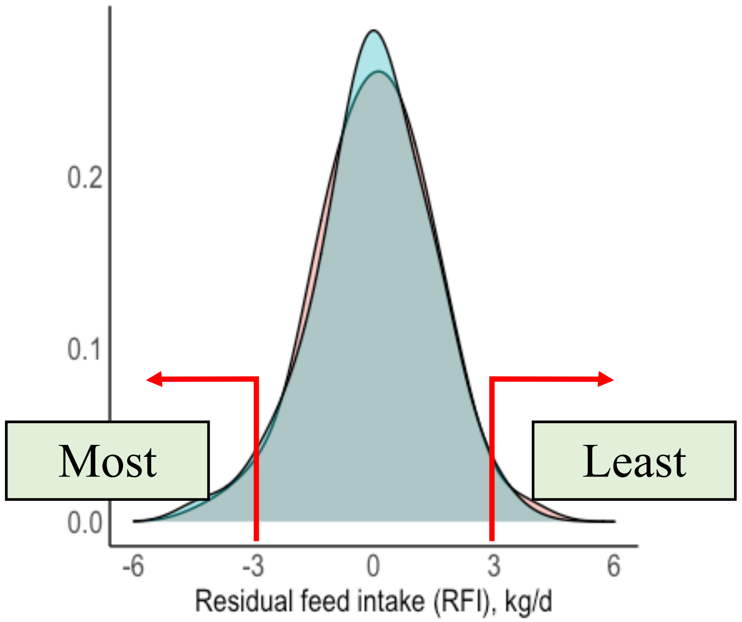
DISTRIBUTION OF RFI IN THE STUDIED POPULATION

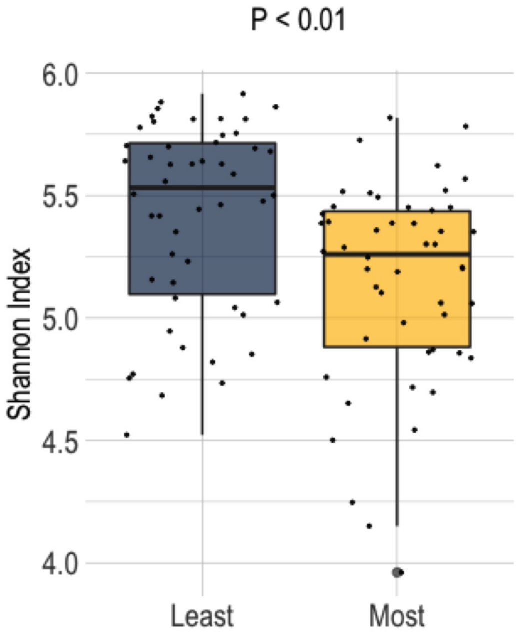


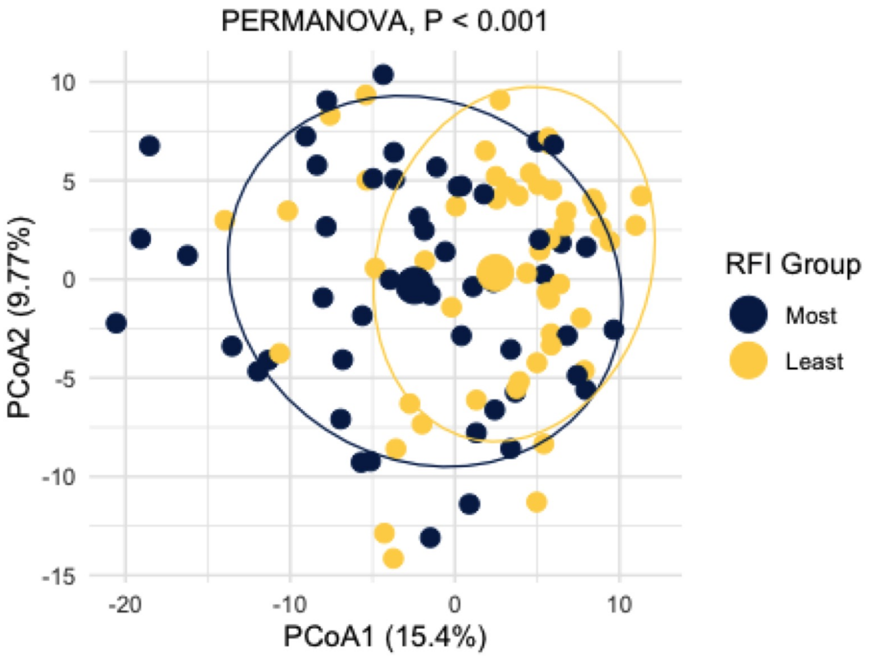
454 lactating cows
Daily measurements for 50 days
(50 to 100 days in milk)

Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

RUMEN MICROBIOME DIFFERENCES (*N* = 454)

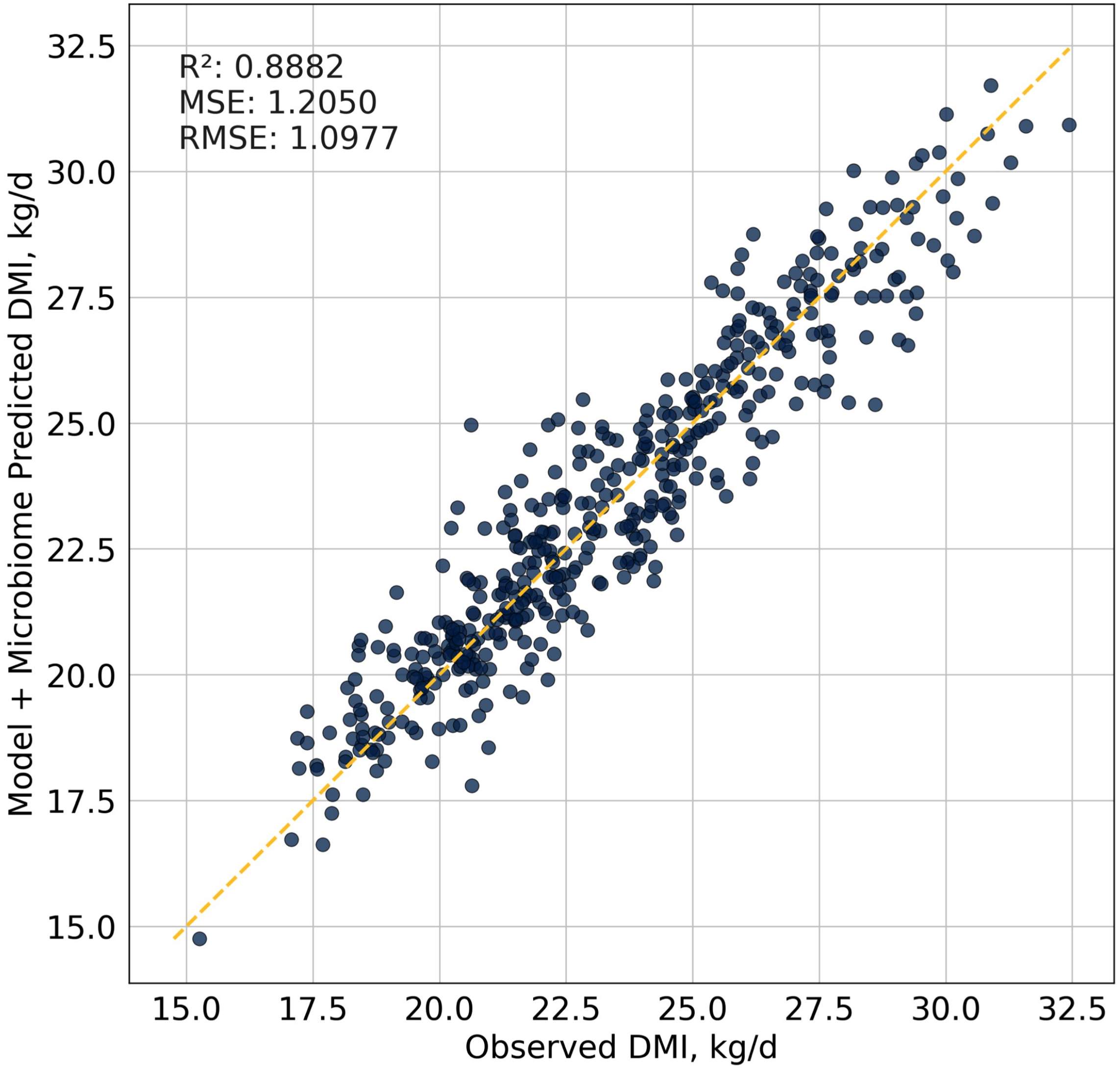






Monteiro et al., 2022. J Dairy Sci. 106(1):141-142

INCLUDING THE MICROBIOME ON DMI PREDICTION

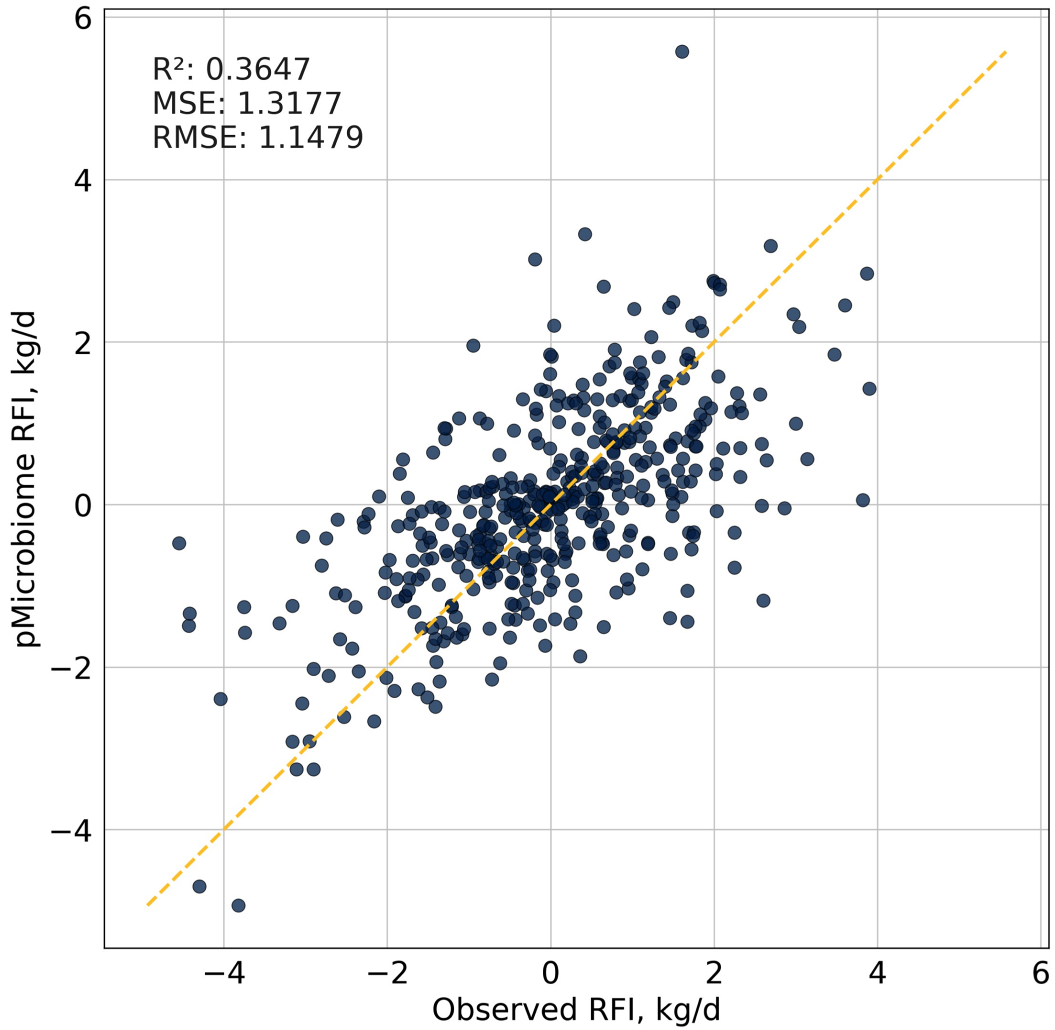


DMI, kg/d = Parity + NESec + $BW^{0.75}$ + BEC + Treatment + Microbiome + e

Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

UCDAVIS VETERINARY MEDICINE

USING THE MICROBIOME TO PREDICT RFI

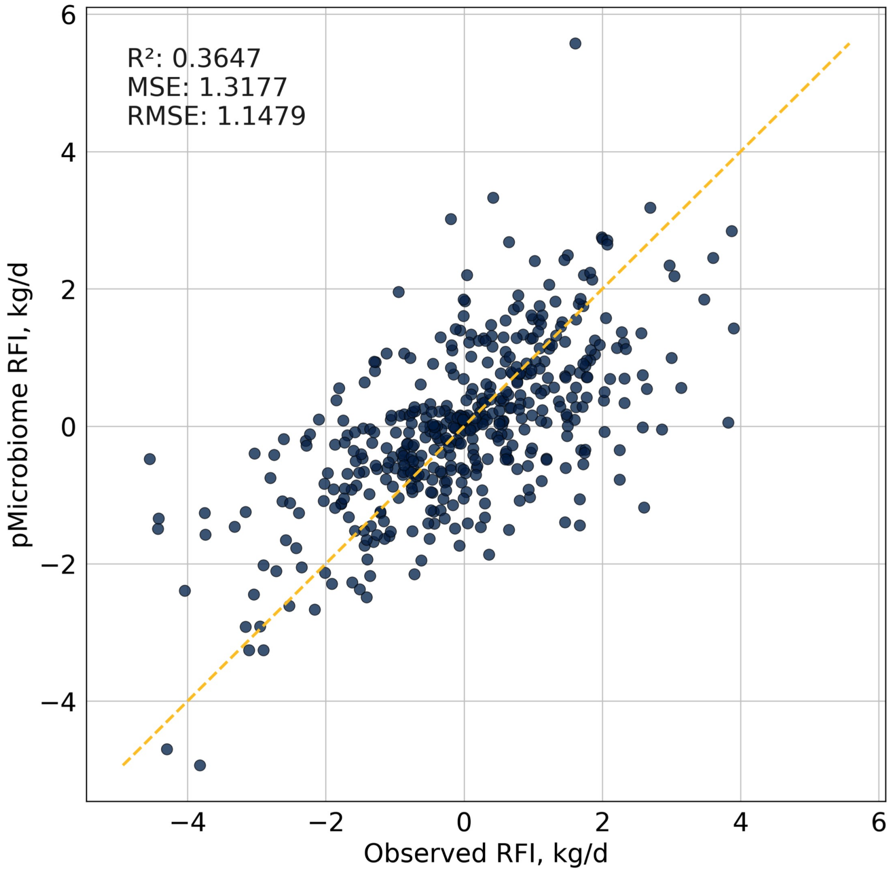


Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

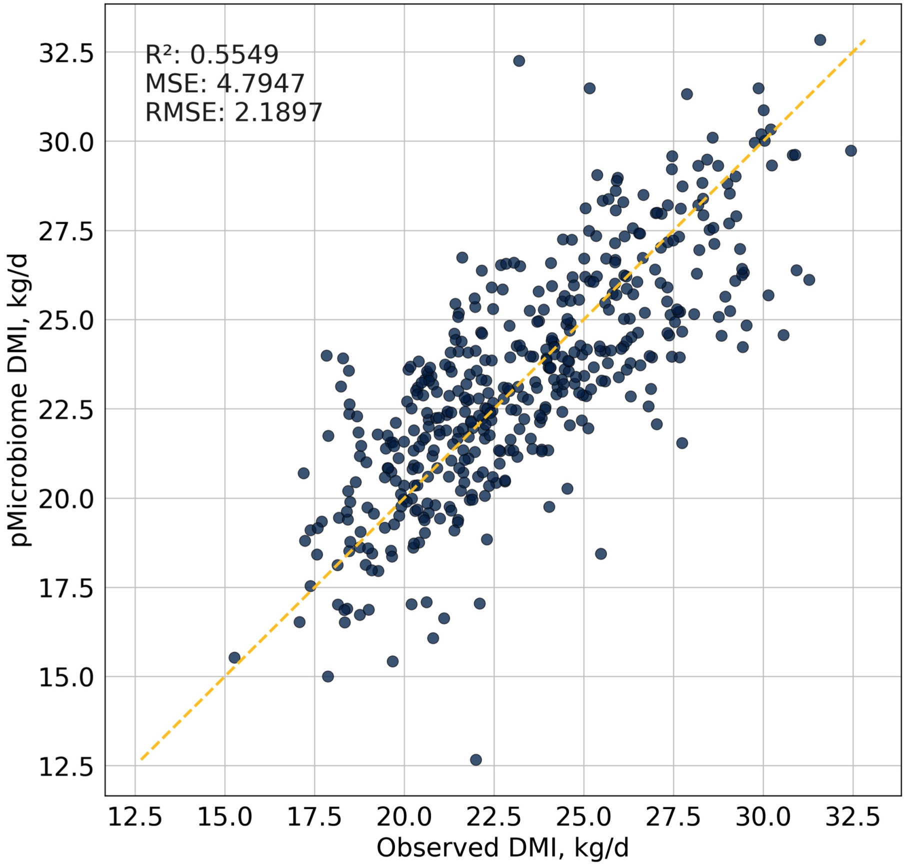
RFI, kg/d = Microbiome + e

USING THE MICROBIOME TO PREDICT RFI

RFI



DMI



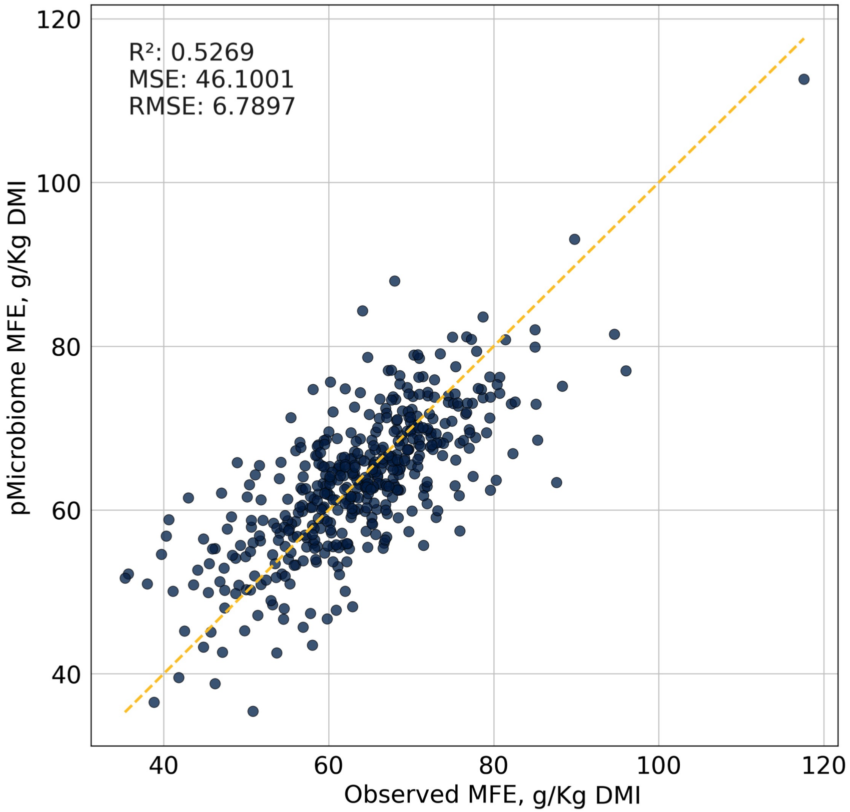
RFI, kg/d = Microbiome + e

Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

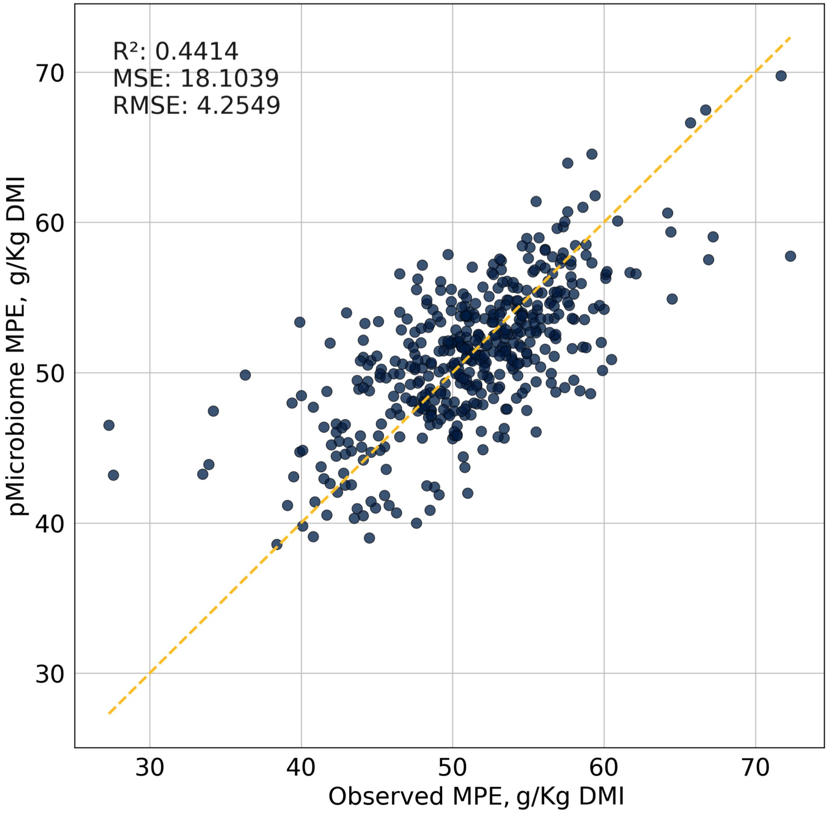
DMI, kg/d = Microbiome + e

THE MICROBIOME AND MILK PRODUCTION EFFICIENCY

MILK FAT EFFICIENCY

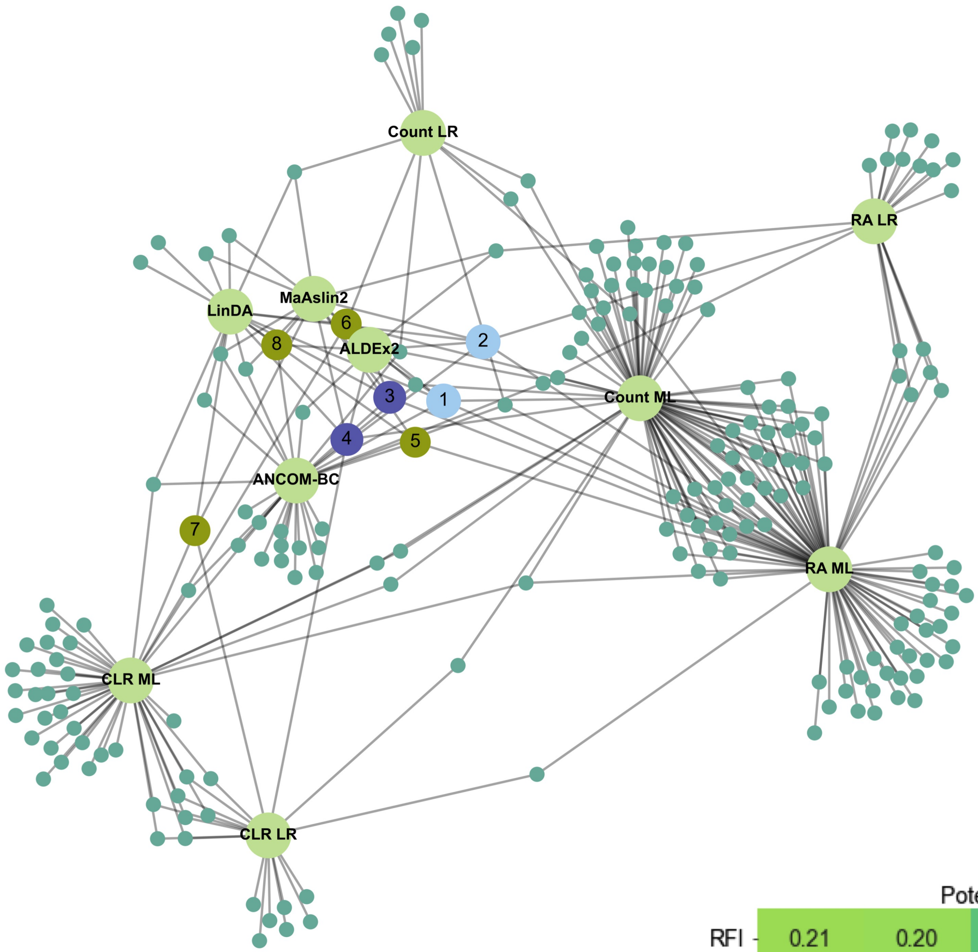


MILK PROTEIN EFFICIENCY



Monteiro et al., 2022. J Dairy Sci. 106(1):141-142

BACTERIA ARE ASSOCIATED WITH RFI



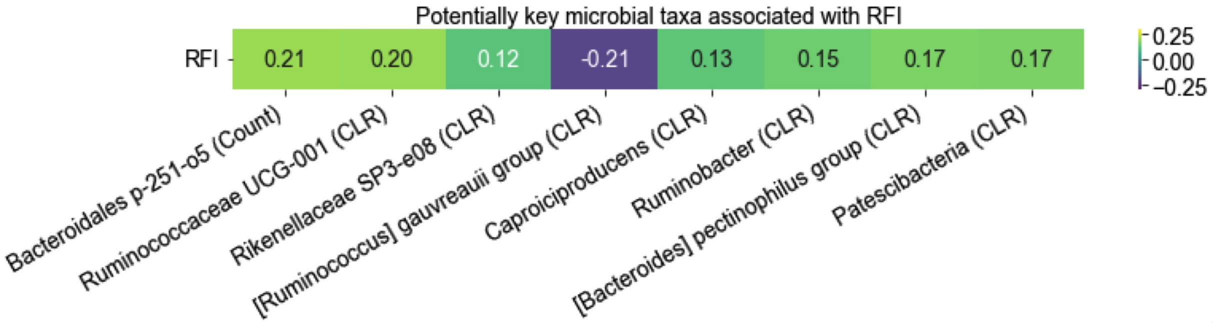
Potentially key rumen microbial taxa for residual feed intake (RFI). Number of times the microbial taxa was significant across different statisitcal tests:

6 Tests:
1. p-251-o5
2. UCG-001

5 Tests:
3. SP3-e08
4. [Ruminococcus] gauvreauii group

4 Tests:
5. Caproiciproducens
6. Ruminobacter
7. [Bacteroides] pectinophilus group
8. Patescibacteria

DAA Method
6 Tests
5 Tests
4 Tests
≤ 3 Tests



Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

HYPOTHETICAL SELECTION FOR RFI, AND THE RUMEN MICROBIOME INTERPLAY WITH GENOMIC PTA, AND PHENOTYPIC RFI



		Measured RFI	Microbiome RFI	Genomic PTA RFI
Performance	Dry Matter Intake, kg/d	-4.82	-2.61	-2.05
	NE Secreted in Milk, Mcal	No Effect	No Effect	No Effect
	Metabolic Body Weight, kg	No Effect	No Effect	No Effect
	Body Energy Changes, Mcal	No Effect	No Effect	-1.64
Carbon Footprint	CH_4 production, g/d per cow	-20.7%	-12.2%	-10.9%
	CH_4 yield, g/kg DMI	-3.39%	No Effect	-3.20%
	CH_4 intensity, g/Mcal NESec	-24.3%	-12.0%	-15.3%
	CH_4 production, g/d GFE	-37.5%	-21.2%	-21.7%
	Residual feed Intake, kg/d	-4.98	-3.02	-2.13

Interplay of rumen microbiome and genomic PTA linked to phenotypic RFI

Microbiome RFI	Genomic PTA RFI	Phenotypic RFI
Not efficient	Not efficient	Not Efficient or Average
Not efficient	Average	Not Efficient or Average
Not efficient	Efficient	Not Efficient or Average
Average	Not efficient	Not Efficient or Average
Average	Average	Majority average
Average	Efficient	Average or Efficient
Efficient	Not efficient	Average
Efficient	Average	Average or Efficient
Efficient	Efficient	Average or Efficient

Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

CONCLUDING REMARKS

- **Rumen microbiome composition explains a significant portion of the variation in RFI, presenting a promising site of exploration for future improvements in predictive models to decrease the dairy sector's carbon footprint.**
- **The associations of RFI, as well as MFE, MPE, and their residuals with the rumen microbiome, unraveled through an ensemble method, further indicate key microbial players that could be targeted further to evaluate their effect on the efficiency of dairy cows.**
- **Additionally, the predictability of heritable traits by the rumen microbiome underscores the need for future research to dissect host-microbiome interactions in shaping feed and milk production efficiency.**

Monteiro et al., 2024. Animal Microbiome. 6:5 PMID:38321581

TAKEAWAYS

ASSOCIATIONS WITH PRODUCTION

ASSOCIATIONS WITH RFI

CONTRIBUTIONS TO PREDICTIONS OF PRODUCTIVE TRAITS

GENOME-MICROBIOME LINKS TO RFI

UCDAVIS VETERINARY MEDICINE REPRODUCTION Lima Lab

J. Dairy Sci. TBC
https://doi.org/10.3168/jds.2023-23869

Host and rumen microbiome contributions to feed efficiency traits in Holstein cows

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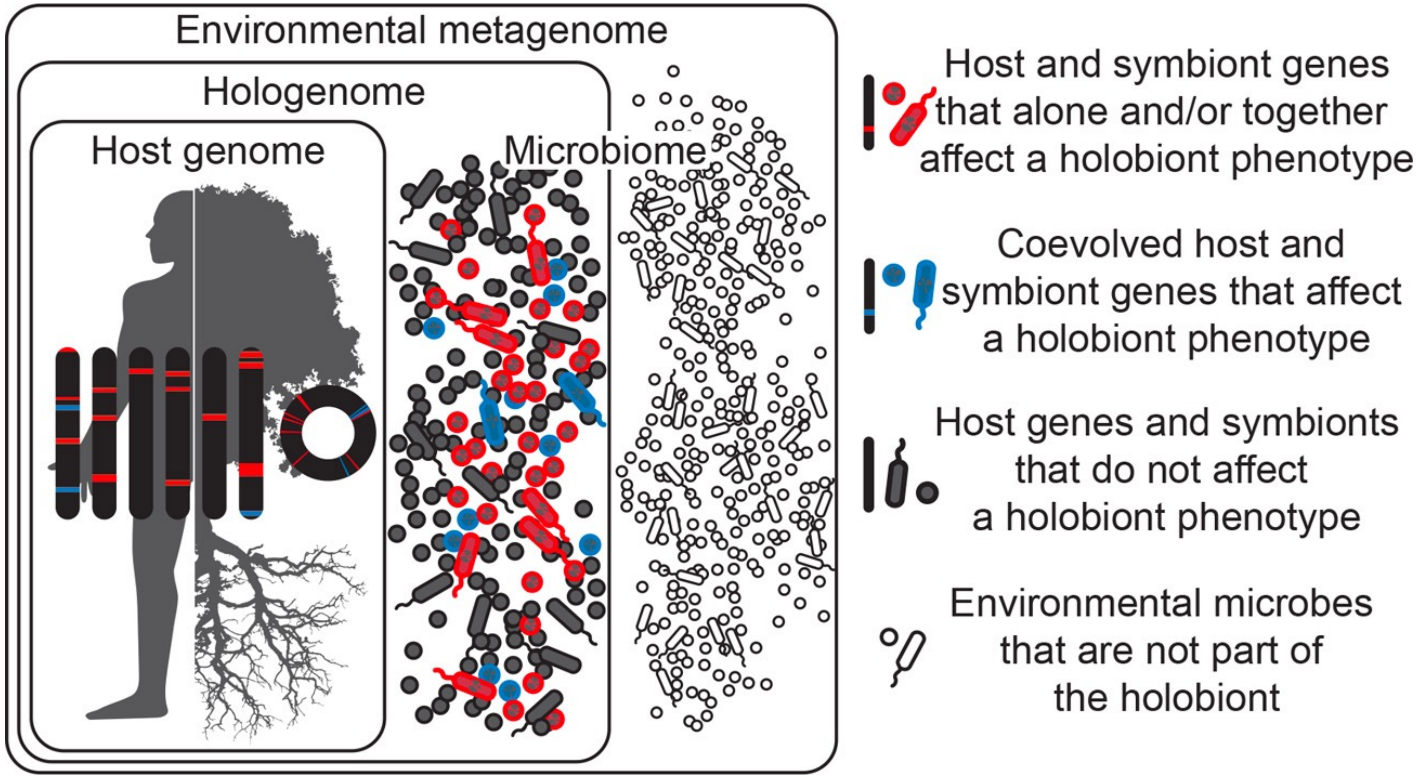
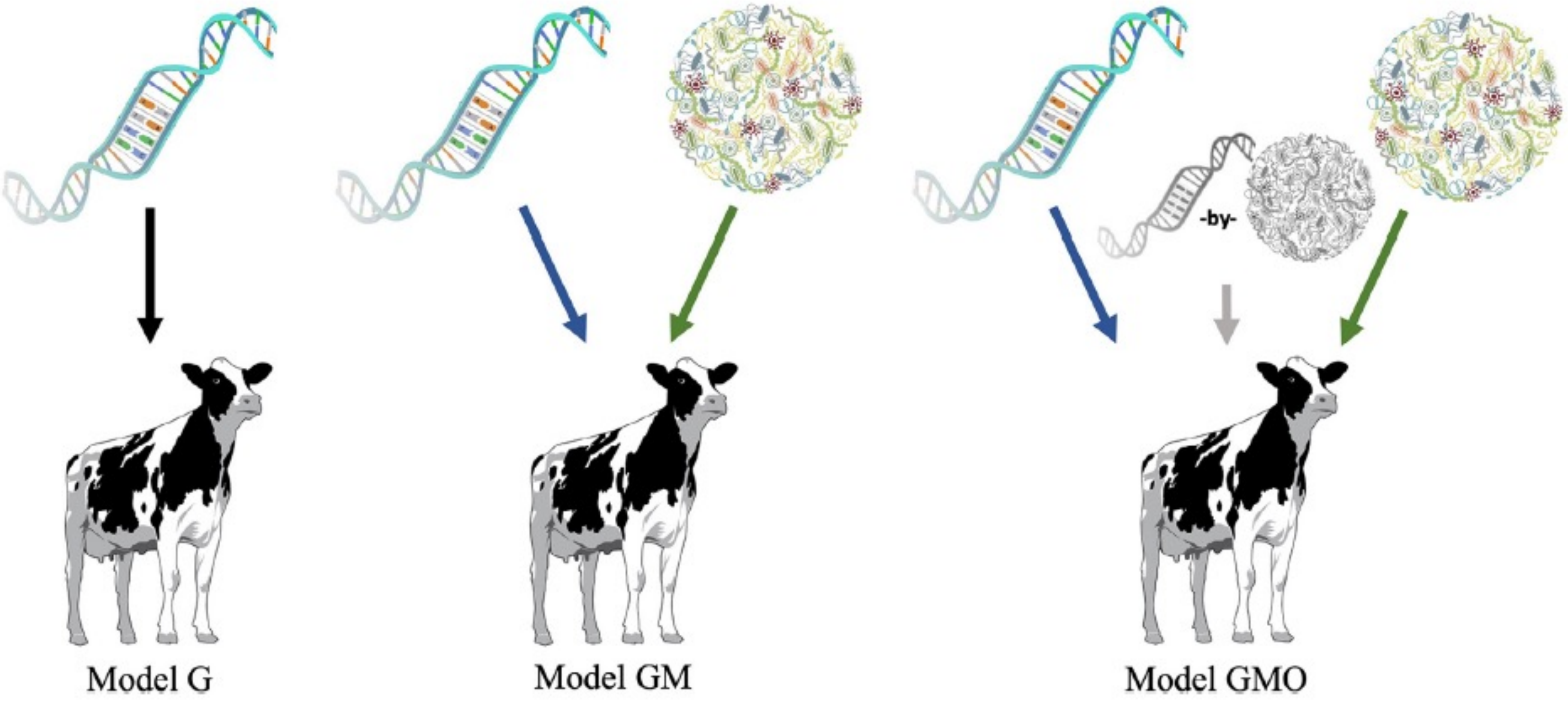


Boggio et al., 2024. J Dairy Sci. TBC. PMID: 38135048

MODELS INCLUDING GENOME, MICROBIOME, AND GENOME-BY-MICROBIOME INTERACTION EFFECTS TO EXPLAIN THE PHENOTYPE



Boggio et al., 2024. J Dairy Sci. TBC. PMID: 38135048

VARIANCE, HERITABILITY, DIRECT HERITABILITY, MICROBIALITY, AND HOLOBIABILITY

Table 2. Estimates of variance components, and heritability, direct heritability, microbiability, genome-by-microbiome interaction, and holobiability for dry matter intake, milk energy, and residual feed intake using three different models

Model	Trait	DIC	σ^2_g	$\sigma^2_{g_d}$	σ^2_m	σ^2_{gxm}	σ^2_{ho}	σ^2_e	h^2	h^2_d	m^2	$g\times m^2$	ho^2
G	DMI	1968.6	2.37 ± 0.58					3.33 ± 0.50	0.41 ± 0.09				
GM	DMI	1909.1		1.56 ± 0.42	1.37 ± 0.36		2.92 ± 0.51	2.68 ± 0.43		0.28 ± 0.07	0.24 ± 0.06		0.52 ± 0.07
GMO	DMI	1882.3		1.31 ± 0.39	1.18 ± 0.33	0.84 ± 0.26	3.33 ± 0.50	2.37 ± 0.41		0.23 ± 0.06	0.21 ± 0.05	0.15 ± 0.04	0.58 ± 0.07
G	NESec	2478.5	8.16 ± 2.00					10.1 ± 1.72	0.45 ± 0.09				
GM	NESec	2415.6		5.56 ± 1.55	4.88 ± 1.33		10.4 ± 1.87	8.04 ± 1.49		0.30 ± 0.08	0.26 ± 0.06		0.56 ± 0.08
GMO	NESec	2384.7		4.50 ± 1.39	4.20 ± 1.23	2.77 ± 0.95	11.6 ± 1.77	7.07 ± 1.40		0.24 ± 0.07	0.22 ± 0.06	0.15 ± 0.05	0.62 ± 0.08
G	RFI	1556.9	0.61 ± 0.17					1.46 ± 0.17	0.29 ± 0.08				
GM	RFI	1529.3		0.40 ± 0.13	0.38 ± 0.11		0.78 ± 0.18	1.30 ± 0.17		0.19 ± 0.06	0.18 ± 0.05		0.37 ± 0.08
GMO	RFI	1513.9		0.33 ± 0.13	0.31 ± 0.10	0.28 ± 0.11	0.91 ± 0.19	1.18 ± 0.18		0.16 ± 0.06	0.15 ± 0.05	0.13 ± 0.05	0.43 ± 0.08

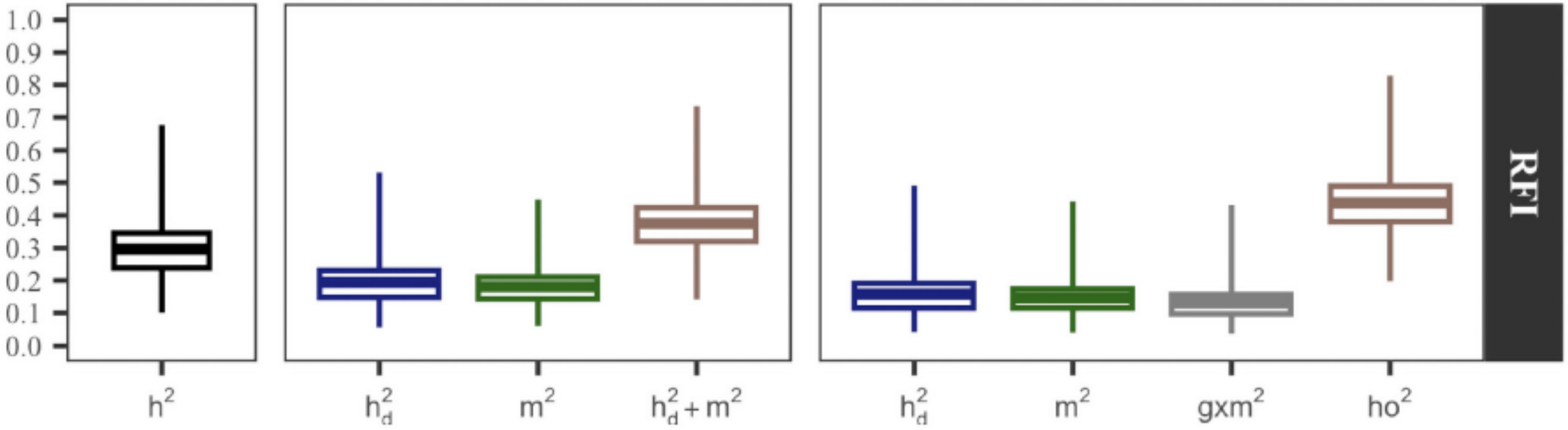
Models: G = models including only the cow genome, GM = models including cow genome and rumen microbiome; GMO = models including cow genome, rumen microbiome, and genome-by-microbiome interaction.

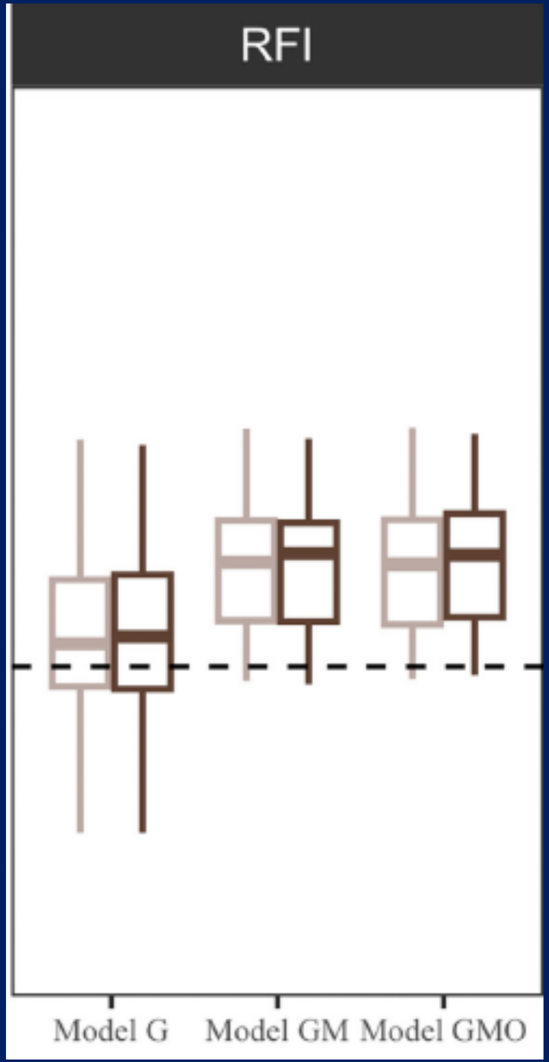
Variance components and parameters: σ^2_g = additive genetic variance; $\sigma^2_{g_d}$ = direct additive genetic variance; σ^2_m = microbiome variance; σ^2_{gxm} = genome-by-microbiome interaction variance; σ^2_{ho} = for model GM is the total variance explained by genome and microbiome, and for model GMO is the variance explained by the holobiont; σ^2_e = residual variance; h^2 = heritability; h^2_d = direct heritability; m^2 = microbiability; $g\times m^2$ = genome-by-microbiome interaction; ho^2 = for model GM is the sum of h^2_d and m^2, and for model GMO is holobiability.

Traits: DMI = dry matter intake; NESec = net energy secreted in milk; RFI = residual feed intake.

Boggio et al., 2024. J Dairy Sci. TBC. PMID: 38135048

PROPORTION OF VARIANCE EXPLAINED BY MODELS





PREDICTIVE ABILITY OF KERNEL-BASED MODELS

Boggio et al., 2024. J Dairy Sci. TBC. PMID: 38135048

CONCLUDING REMARKS

- Incorporating the rumen microbiome information in addition to genomic data allows for revealing the relative effects of the host genome and the microbiome on feed efficiency traits in dairy cattle.
- Rumen microbiome data can be used to estimate host direct and indirect genetic effects on feed efficiency.
- Indeed, the differences obtained between the heritability and the direct heritability strongly suggest that the microbiome mediates part of the host genetic effect.
- The holobiont model, which incorporates the host genome-by-microbiome interaction, provides further insights into the biological mechanisms underlying dairy cow feed efficiency.

Boggio et al., 2024. J Dairy Sci. TBC. PMID: 38135048

REPRODUCTION HEALTH AND MICROBIOME Lima Lab

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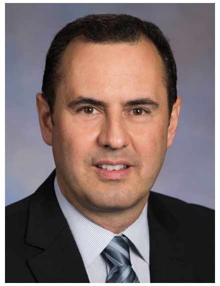

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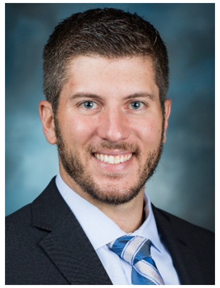

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Management and Nutrition of Beef Bulls and Impacts on Fertility

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1

Over the next 40 minutes…

- **Overview of observational studies evaluating the relationship between over conditioning and bull fertility**
- **Experimental evidence for the impact of bull over conditioning on fertility**
- **Recent developments on the impact of over conditioning on bull fertility**

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2

Variation in Sire Field Fertility in Fixed-Time Artificial Insemination Programs - GERAR

Insemination records only included cows with adequate body condition scores and sires with at least 100 inseminations.

AI Center	Number of AI	Average PR/AI	Range in Sire PR/AI
A	45,231	54.8	38.3 to 79.1
B	128,443	55.4	30.9 to 70.2
C	9,434	50.5	38.1 to 57.9
D	19,311	56.7	42.8 to 76.9
E	25,522	54.8	28.2 to 72.4
F	32,397	52.5	32.1 to 62.7
G	7,042	54.9	22.8 to 81.3

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Vasconcelos et al., 2017; SBTE Proceedings 3

3

Variation in Sire Field Fertility in Fixed-Time Artificial Insemination Programs– Controlled Study

n = 4,866

Sire	Number of AI	Average PR/AI
A	1,050	48.1
B	1,058	47.7
C	1,206	40.7
D	747	45.5
E	805	43.1

Factors influencing this variation in sire PR/AI are still poorly understood

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Zoca et al., 2020. Theriogenology, 147:146-153 4

4

Georgia Bull Evaluation Program

GEORGIA
BULL TEST
Tifton · Calhoun

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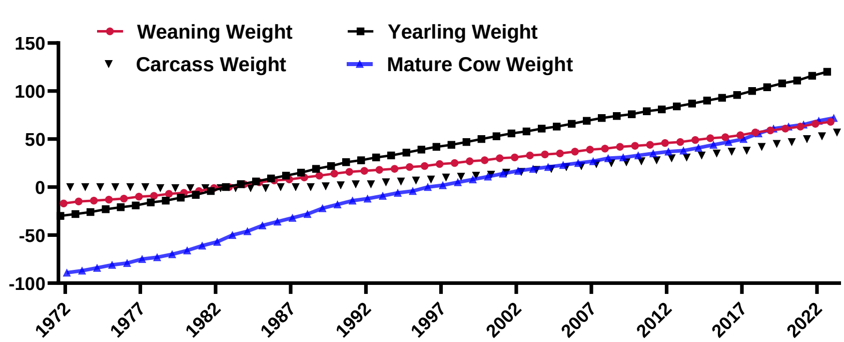
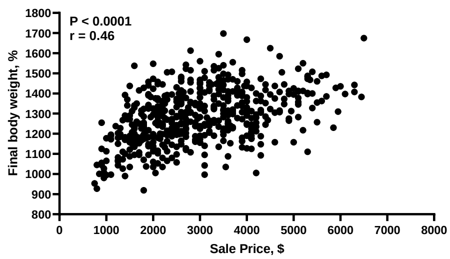
Genetic Trends in Angus Cattle

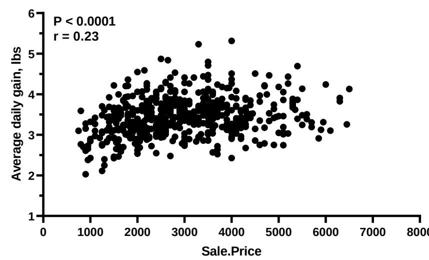


UNIVERSITY OF GEORGIA American Angus Association, 2024 6

6

Factors Influencing Sale Prices at the University of Florida NFREC Bull Test





Final BW and ADG were significantly correlated with sale price
Residual feed intake (RFI) and feed to gain ratio (F:G) were not associated with sale price

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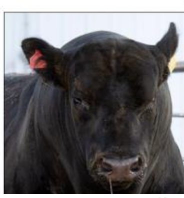
Oosthuizen et al., 2018. J. Anim. Sci. 7

7

ANGUS BEEF BULLETIN EXTRA

January 4, 2022 | Vol. 15 : No. 1



Even though buyers know that a bull should be fit, not fat, they tend to think there is something wrong with a bull that's not carrying extra weight at sale time. Bulls are likely to be too fat unless the breeder feeds just a growing ration — and some of the "growing rations" people claim to be feeding still contain too much energy.

Don't Buy a Fat Bull

Sale-season nutrition should prepare bull for work instead of beauty.

Bulls developed on growing rations usually carry more flesh than bulls raised on grass or wintered on hay, and it can be a major adjustment when they are turned out with cows. | HEATHER SMITH THOMAS PHOTO

Be leery about buying fat bulls

It may look good in the sale ring, but too much fat can lead to permanent damage

Grainews

Published: February 27, 2018
Cattleman's Corner, Livestock

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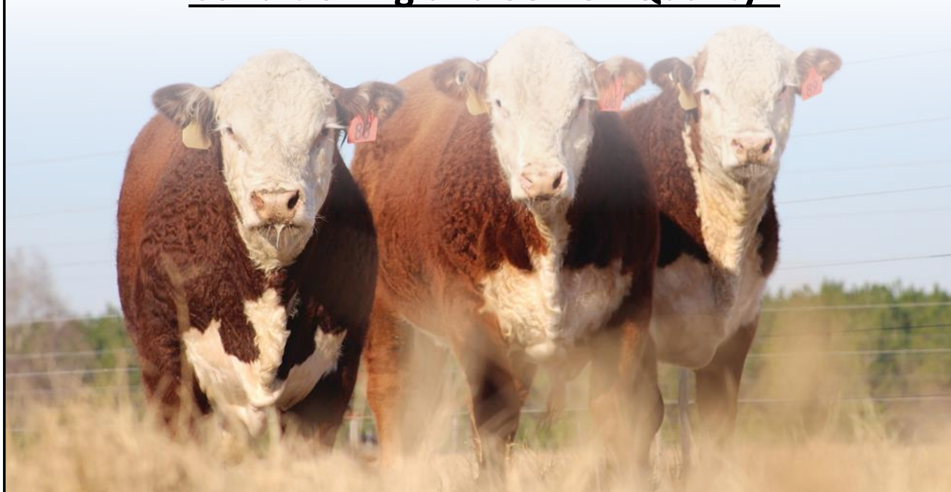
8

8

Is There a Relationship Between Sire Over Conditioning and Semen Quality?



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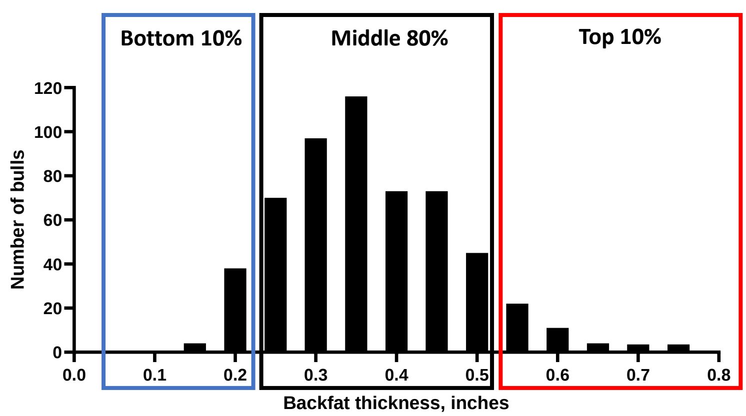
9

Distribution of Bulls According to Ultrasound Backfat Thickness Measurements



n = 557

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Georgia Historical BSE Data. Not published 10

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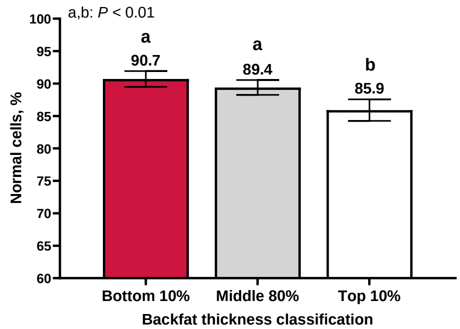
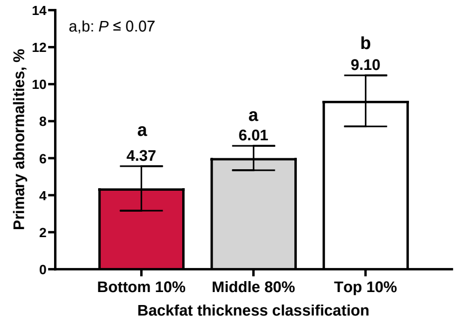
Impact of Back Fatness Classification on Sperm Morphology





No differences in secondary abnormalities (P = 0.44)

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Georgia Historical BSE Data. Not published 11

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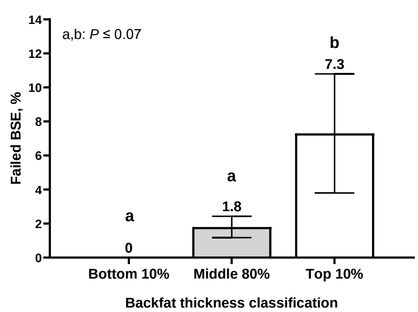
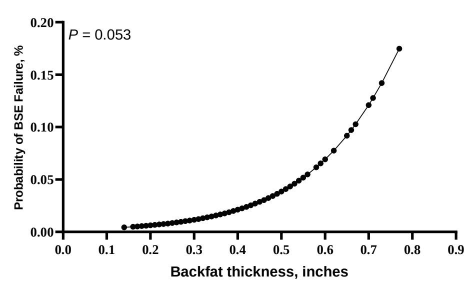
Impact of Back Fatness Classification on BSE Results





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Georgia Historical BSE Data. Not published 12

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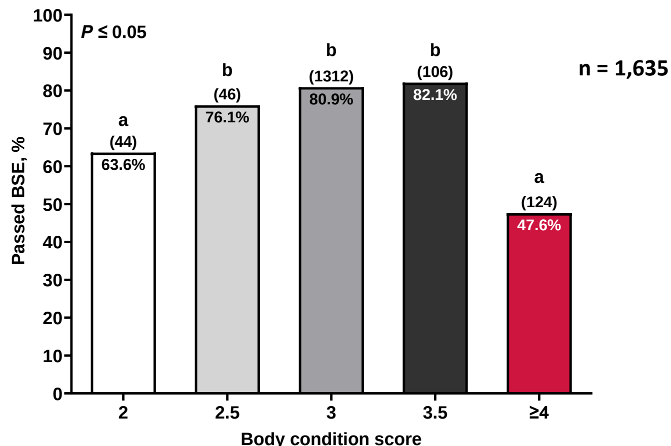
Impact of Body Condition Score on Breeding Soundness Examination Results



a,b uncommon superscripts differ: $P < 0.05$

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Barth and Waldner, 2002. Can. Vet. J. 43:274-284 13

13

Can We Experimentally Induce This Phenotype?

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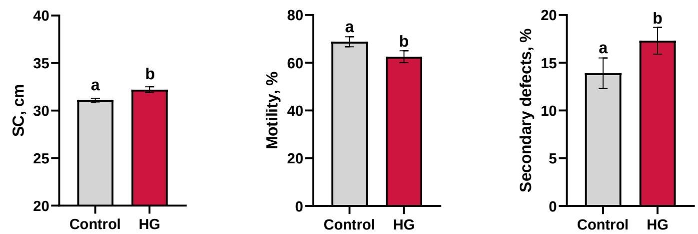
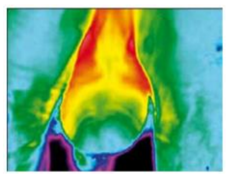
14

Effects of Dietary Energy on Sperm Parameters of Young Bulls





Infrared scrotal thermography:
HG had decreased temperature gradient compared with control bulls

Control: 100% forage
HG: 80% concentrate, 20% forage

Bulls were fed their respective diets for 165 days
a,b uncommon superscripts differ: *P* < 0.05

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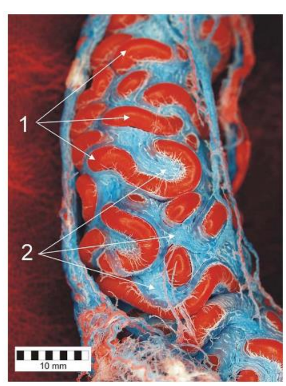
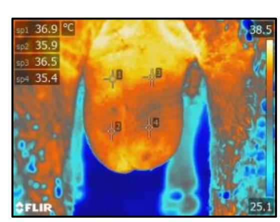
Representative Figure of Fat Accumulation in the Scrotum



Corrosion cast: 1 = testicular artery and 2 = veins of pampiniform plexus
Polguj et al., 2011. J. Morph. 272: 492-502



16

Do We Need to Push Them for Puberty Purposes?

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High BW Gain and Puberty Achievement

2 weeks of age

High
2.6 lb/d

Low
1.1 lb/d

24 weeks of age
(6 months)

UNIVERSITY OF GEORGIA Byrne et al., 2018. J. Dairy Sci. 104:3447-3459 18

18

Effects of Treatment on Bull Sexual Development

- Diets successfully induced changes in body weight
- Diets successfully induced changes in metabolic hormones (IGF-1, insulin, leptin)

	Plane of Nutrition			
Item	Hi-Hi	Hi-Lo	Lo-Lo	Lo-Hi
Age at Puberty, d	298 + 6.3[a]	283 + 5.6[a]	319 + 3.9[b]	323 + 6.5[b]
Age at sexual maturation, d	331 ± 7.1[a]	314 ± 7.5[a]	343 ± 7.1[b]	352 ± 3.7[b]
Paired testis weight at 72 wks of age, g	660 ± 28.5	659 ± 19.8	629 ± 19.7	594 ± 26.6

a,b: uncommon superscript differ ($P < 0.05$)

Age at puberty: 50 million sperm with at least 10% motility
Age at sexual maturation: Passed a breeding soundness examination

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Byrne et al., 2018. J. Dairy Sci. 104:3447-3459 19

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Influence of Diet on Semen Production in the Context of Artificial Insemination

Effects of early life nutrition on semen production from 13-15 months of age

	Plane of Nutrition			
Item	Hi-Hi	Hi-Lo	Lo-Lo	Lo-Hi
Number of straws*	308	205	177	92
Commercial value,$**	4619	3073	2662	1377

* 10 million sperm/straw
**Assumes $15 per semen straw

Take home message

Post-weaning growth have less impact on puberty than pre-weaning growth

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Dr. David Kenny. ARSBC, 2020 20

20

Bull Management After Purchase

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21

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Bull Management After Purchase

- Changing from a concentrate to forage-based diet
- Placed in larger pastures
- Hierarchy in multi-sires pastures
- Breeding cows is a physically demanding activity
- Can lose 100-200 lbs during the breeding season

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Effects of Plane of Nutrition on Mature Bull Fertility

- **Treatments (112-day feeding period):**
  - **Positive Energy Balance - gain 12.5% of body weight**
  - **Negative Energy Balance - lose 12.5% of body weight**

Item	Treatment NEG	POS	SEM	*P*-value
Rump fat, cm				
Beginning	0.42	0.48	0.09	0.68
End	0.29	0.90	0.11	0.001
Rib Fat, cm				
Beginning	0.38	0.40	0.05	0.76
End	0.25	0.64	0.10	0.02
LM area, cm				
Beginning	95.7	91.5	3.74	0.43
End	84.5	106.1	3.42	<0.001
Intramuscular fat,%				
Beginning	3.21	3.31	0.29	0.81
End	2.55	3.49	0.36	0.08

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Dahlen et al., 2020. J. Anim. Sci. (Abstract) 23

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Effects of Plane of Nutrition on Mature Bull Fertility

- **Computer assisted sperm analysis (CASA)**

  Frozen-thawed semen:
  - **Negative energy balance (NEG) bulls had greater motility**
  - **Sperm classified as motile and progressively motile had greater velocity in NEG bulls**
- **Flow cytometry**
  - **Positive energy balance (POS) bulls had a greater proportion of sperm staining positive for reactive oxygen species**
  - **POS bulls had decreased mitochondrial membrane potential compared with NEG bulls**

Over conditioning had a more pronounced detrimental effect compared with under conditioning

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Dahlen et al., 2020. J. Anim. Sci. (Abstract) 24

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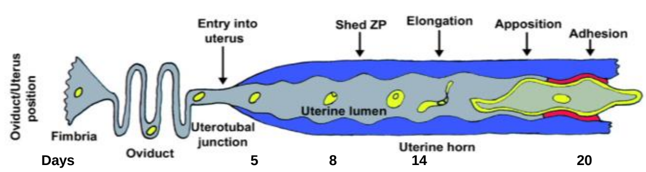
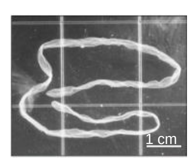
Are There Post-Fertilization Consequences of High Energy Diets?

Early Pregnancy Development in Cattle

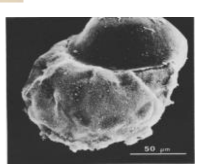


Day 7
Spherical

Day 13
Tubular



Day 17
Filamentous

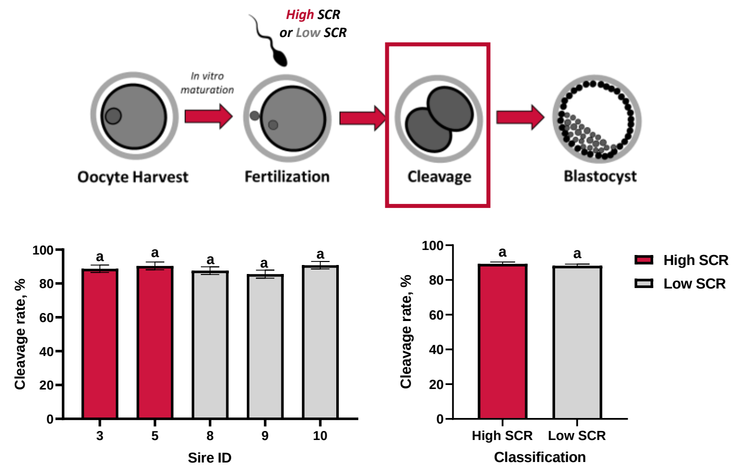


Day 8
Spherical

Day 14

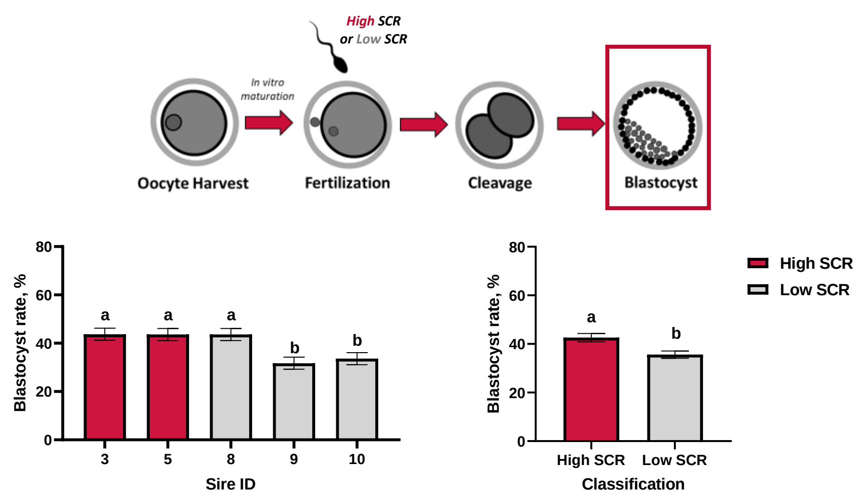
Spencer et al., 2004. Reproduction. 128:657-668
Guillomot, 1995. J. Reprod. Fert. 49: 39-51
Betteridge and Flechon, 1988. Theriogenolgy. 29:155-187
Moraes et al., 2018. PNAS. E1749-1758

Influence of Sire Conception Rate (SCR) on Post-Fertilization Outcomes – IVP



Ortega et al., 2018. Biol. Reprod. 99:1244-1254

Influence of Sire Conception Rate (SCR) on Post-Fertilization Outcomes – IVP



Ortega et al., 2018. Biol. Reprod. 99:1244-1254

High Adiposity and Male Fertility - Humans

- Erectile disfunction
- Increased scrotal temperature
- Germ cell apoptosis
- Sperm oxidative stress
- Sperm DNA fragmentation
- Altered sperm parameters
- Decrease embryo production

Male Sub-fertility

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Oliveira et al., 2017. Reproduction. 153: R173-R185 29

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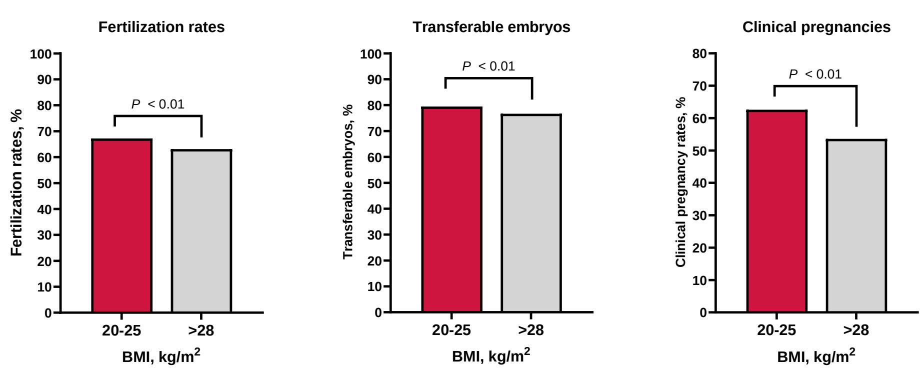
Paternal Body Mass Index (Adiposity) and Embryo Development - Human IVF Clinics



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Yang et al., 2016. Sci. Ref. 6:29787 30

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Paternal High Fat Diets and Embryo Development and Pregnancy Establishment

Item	Control	High Fat	P-value
Cleavage rate[1], %	79.1	50.5	< 0.001
Early blastocysts[2], %	57.0	26.6	< 0.001
Hatched blastocysts[3], %	46.0	25.5	< 0.001
Implantation/transfer, %	86.7	73.3	< 0.05
Fetal development/transfer, %	38.7	21.3	< 0.05

[1] Day 2 of embryo culture
[2] Day 4 of embryo culture
[3] Day 5 of embryo culture

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Mitchell et al., 2011. Fertility and Sterility. 95:1349-1353 31

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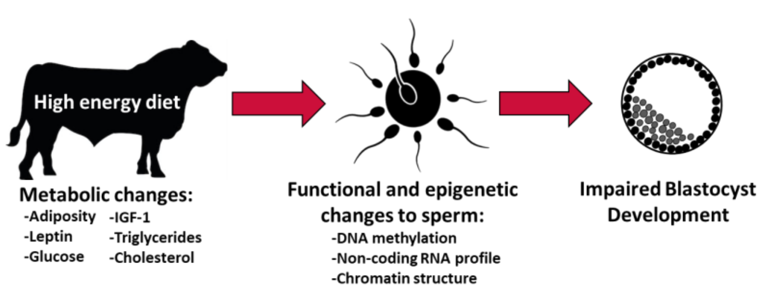
Effects of Sire High Energy Diets on Post-Fertilization Outcomes

Working hypothesis:



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Seekford et al., 2023. Reproduction. 166:149-159 32

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Influence of Sire Diet on In Vitro Embryo Production

- Eight sires were randomly assigned to the same diet (NEm = 2.10, NEg = 1.44, CP = 14.1%, NDF = 16.6%, DM basis) fed at two different inclusion rates while having ad libitum access to bermudagrass hay (NEm = 1.02, NEg = 0.45, CP = 10.2%, NDF = 71.6).

- High gain (HG): 1.25% of BW daily
- Maintenance (MAINT): 0.5% of BW daily

67 days feeding period

Seekford et al., 2023. Reproduction. 166:149-159

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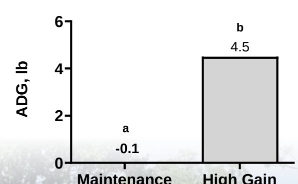
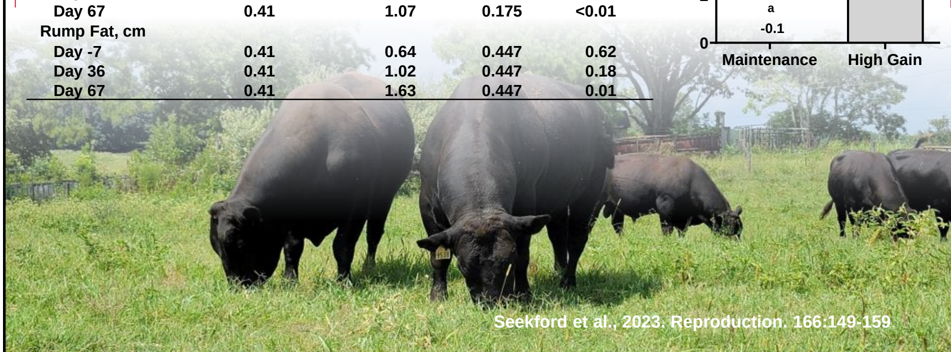
Effects of Sire Diet on Body Weight and Carcass Ultrasound Measurements

	Treatment			
	MAINT	HG	SEM	*P*-value
Body weight, kg				
Day -7	956	941	39.3	0.79
Day 36	951	1,009	39.3	0.31
Day 67	953	1,095	39.3	0.02
Subcut. Fat, cm				
Day -7	0.38	0.46	0.175	0.63
Day 36	0.36	0.64	0.175	0.13
Day 67	0.41	1.07	0.175	<0.01
Rump Fat, cm				
Day -7	0.41	0.64	0.447	0.62
Day 36	0.41	1.02	0.447	0.18
Day 67	0.41	1.63	0.447	0.01





Seekford et al., 2023. Reproduction. 166:149-159

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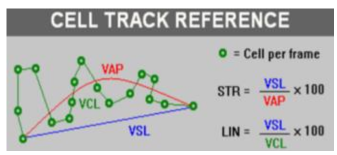
Computer Assisted Sperm Analysis (CASA)

	Maintenance		High Gain			P-value		
	Fresh	Frozen	Fresh	Frozen	SEM	TRT	Semen	TRT*Semen
Total Motility,%	73.81	29.98	72.60	21.15	8.32	0.63	<0.01	0.39
Progressive motility, %	71.58	24.39	67.38	16.28	8.58	0.53	<0.01	0.51
Local motility, %	3.65	5.16	5.13	4.96	0.75	0.75	0.35	0.26
Immotile, %	24.66	70.13	27.37	78.88	8.23	0.58	<0.01	0.46
VCL, microm/s	134.56	90.84	130.79	84.96	10.63	0.72	<0.01	0.90
VAP, microm/s	5.97	3.94	4.23	3.91	0.89	0.36	0.24	0.37
VSL, microm/s	46.04	37.42	45.55	38.14	2.84	0.97	0.02	0.83



VCL = Curvilinear velocity
VAP = Average velocity path
VSL = Straight-line velocity

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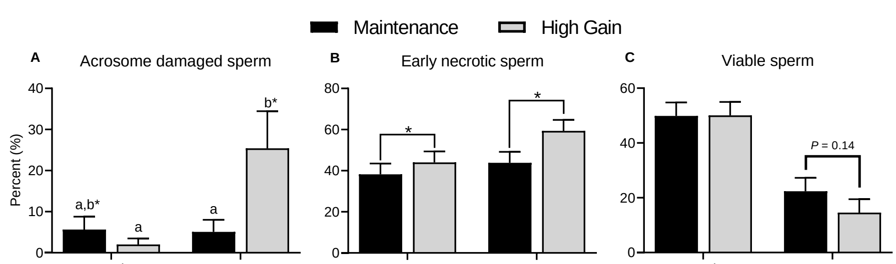
Seekford et al., 2023. Reproduction. 166:149-159 35

Impact of Treatment on Flow Cytometry Outcomes

	Maintenance		High Gain			P-value		
	Fresh	Frozen	Fresh	Frozen	SEM	TRT	Semen	TRT*Semen
Acrosome damaged sperm, %	5.64	5.09	2.00	25.42	9.04	0.62	0.02	0.02
Membrane intact sperm, %	69.69	32.31	56.62	33.60	8.77	0.59	<0.01	0.26
Viable sperm, %	47.90	22.37	50.09	14.56	4.90	0.43	<0.01	0.09
Necrotic sperm, %	0.41	0.20	0.40	0.17	0.10	0.79	<0.01	0.72
Early apoptotic sperm, %	38.21	43.86	44.03	59.38	5.31	0.09	0.09	0.41
Apoptotic sperm, %	13.18	33.18	5.23	25.05	6.99	0.17	<0.01	0.36



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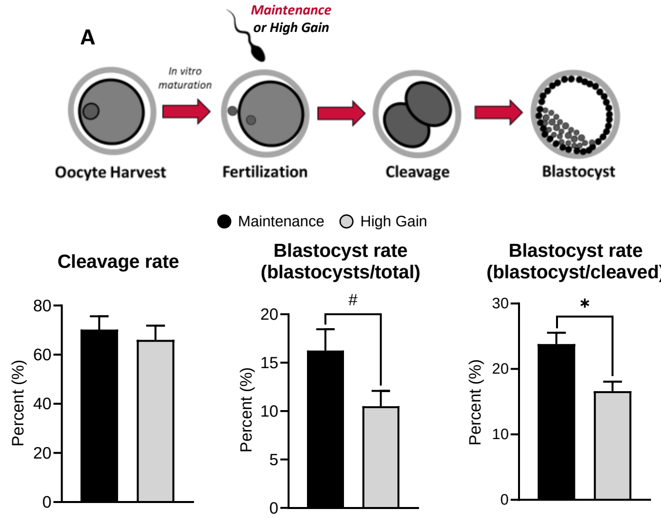
Influence of Sire Diet on In Vitro Embryo Production



# *P* < 0.10
* *P* < 0.05

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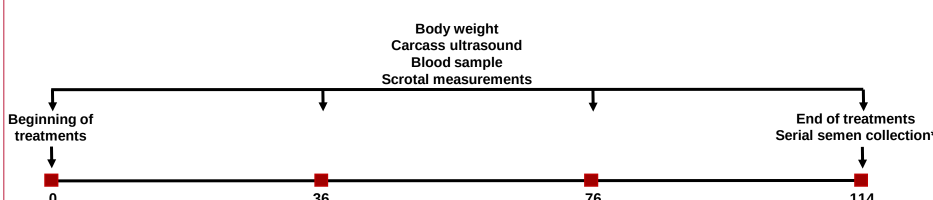
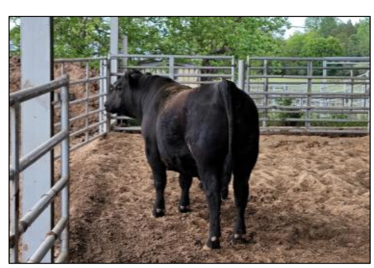
Seekford et al., 2023. Reproduction. 166:149-159

Impact of Bull Development Program on Sire Fertility – Experimental Design



- Eatonton Beef Research Unit
- n = 44 bulls – Half siblings
- Age: 359.4 ± 3.71 (mean ± SD)
- Dietary treatment was designed to achieve:
  - High gain: Target gain = 4 lbs/d (1.8 kg/d)
  - Moderate gain: Target gain = 2.7 lbs/d (1.2 kg/d)



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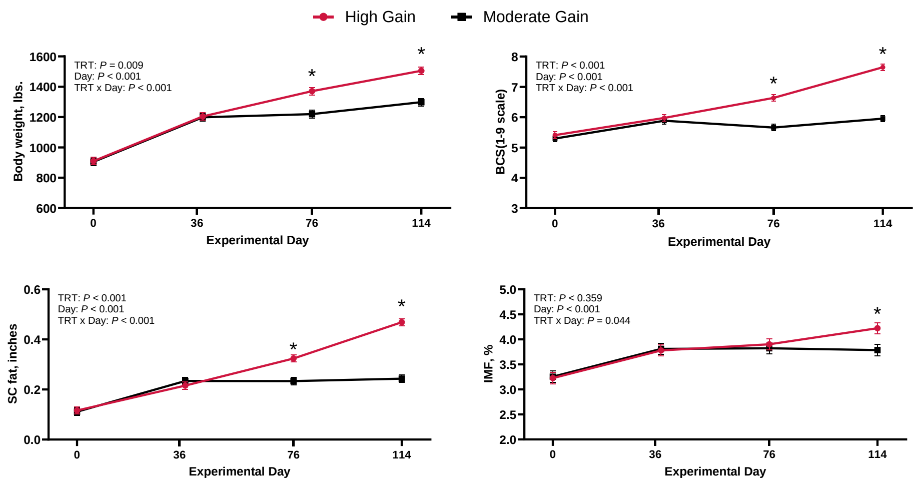
Effect of Treatment on Body Weight and Carcass Composition



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Davis et al., (not published) 39

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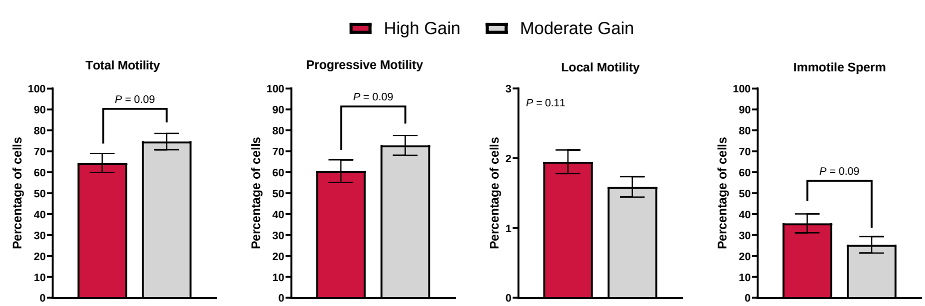
Impact of Treatment on Sperm Motility Using CASA



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Davis et al., (not published) 40

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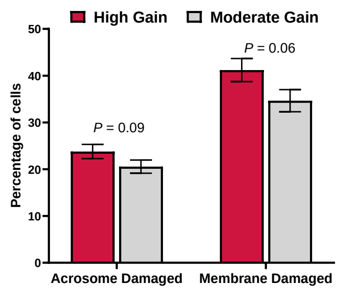
Impact of Treatment on Flow Cytometry Outputs

Item	Treatments: High Gain	Moderate Gain	SEM	*P*-value
0 min in-vitro culture				
Acrosome damaged sperm, %	14.8	12.3	1.24	0.14
Membrane damaged sperm, %	26.0	22.4	2.43	0.28
30 min in-vitro culture				
Acrosome damaged sperm, %	25.3	21.8	1.45	0.09
Membrane damaged sperm, %	41.2	34.6	2.46	0.06



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Davis et al., (not published) 41

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Summary

- Nutritional programs can focus on promoting growth: however, excessive fat deposition can have detrimental effects on fertility
- Extreme anabolic conditions can negatively impact sire fertility
  - Decreased semen quality
  - Increased sensitivity to stressors (freezing and thawing process)
- Extremely anabolic conditions appear to negatively impact early embryonic development in cattle
- Consequences of extreme anabolic conditions to conceptus development past the blastocyst stage remains unknown

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- Lucas de Melo
- Samir Burato
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- Madison Walker
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ANGUS Foundation

Georgia Beef Commission

SELECT SIRES

ABS

ESTROTECT BREEDING INDICATOR

OREGON BEEF COUNCIL

zoetis

USDA
United States Department of Agriculture
National Institute of Food and Agriculture

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Thank you!

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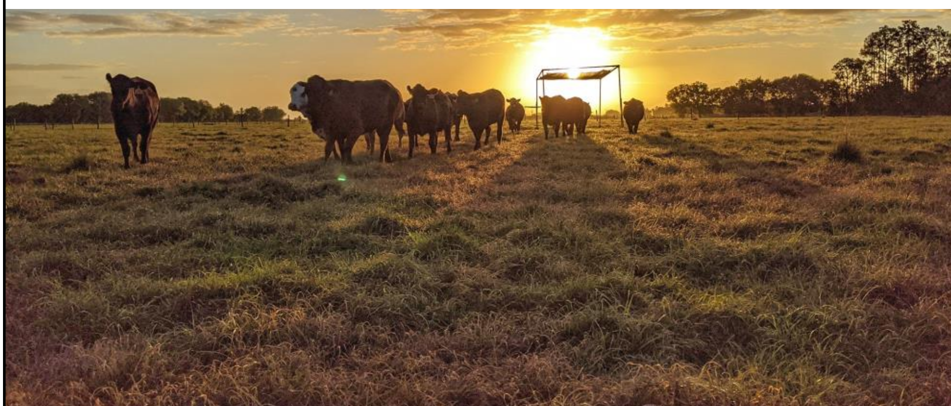
Nutritional management to optimize cow-calf production in Southeast

2024 Florida Ruminant Nutrition Symposium



Philipe Moriel - Associate Professor

Range Cattle Research & Education Center - University of Florida, Ona, FL

1

Introduction

Retrospective analyses of cow BCS vs. nutrition

- BCS at calving vs. post-calving BCS change
- BCS at weaning vs. precalving supplementation

Precalving supplementation strategies

- Timing, frequency, feed additives

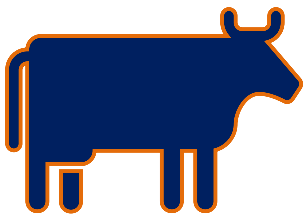
Nutrition of heat stressed heifers

- Stair-step strategy to offset heat stress

Heat stress in pregnant females

- Unexpected results in cow vs. offspring

2



Mature Cows

3

Studies across United States

$^{abc}P < 0.05$

BCS at calving vs. Pregnancy Rate, %

	Body condition score at calving		
	4	5	6
Spitzer et al. (1995)	56[a]	80[b]	96[c]
Lake et al. (2005)	64[a]	-	89[b]
Lents et al (2008)	56[a]	88[b]	-
Bohnert et al (2013)	79[a]	92[b]	-
Average	**63.8**	**86.7**	**92.5**

BCS at calving	Days to resume estrus
3	89[a]
4	70[b]
5	59[b]
6	52[b]
7	31[c]

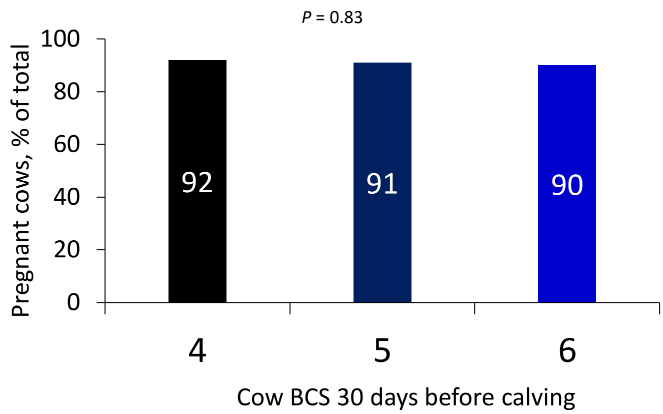
Houghton et al. (1990) JAS 68:1438

Item	Calving distribution: First 21 days	Calving distribution: Second 21 days	Calving distribution: Third 21 days	SEM	*P*-value
Weaning body weight, lb	482[a]	469[b]	434[c]	10.8	<0.01
Body weight start of breeding, lb	652[a]	643[b]	608[c]	9.2	<0.01
Pubertal at start of breeding, %	70[a]	58[b]	39[c]	9.35	<0.01
Pregnancy rate, %	90[a]	86[b]	78[c]	5.62	0.02

Funston et al. (2012; JAS 90:5118)

4

351 spring-calving, Angus & Angus x Hereford cows
(2 and 3 years of age) in New Mexico



Mulliniks et al. (2012) J. Anim. Sci. 90:2811

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Retrospective data analyses

Moriel et al. (2024) Anim. Rep. Sci. *in press*

- 6 studies from 2017 to 2022
  - UF/IFAS Range Cattle Research & Education Center, Ona, FL
- 1,188 Brangus crossbred mature cows (8 ± 3 years of age)
- Day 0 = 2 weeks after weaning
  - 92 ± 37 days before calving
  - Received or not supplementation of protein and energy from day 0 until calving (90 ± 35 days of supplementation)

Palmer et al. (2020) Livest. Sci. doi:10.1016/j.livsci.2020.104176
Palmer et al. (2022b) J. Anim. Sci. doi:10.1093/jas/skac003
Izquierdo et al. (2022) Trans. Anim. Sci. doi:10.1093/tas/txac110
Palmer et al. (2022a) J. Anim. Sci. doi:10.1093/jas/skac022
Vedovatto et al. (2022) Trans. Anim. Sci. doi:10.1093/tas/txac105
Izquierdo et al. (2023) J. Anim. Sci. doi:10.1093/jas/skad244

6

Retrospective data analyses

Moriel et al. (2024) Anim. Rep. Sci. *in press*

2 statistical analyses:

Maternal BCS at calving and postpartum BCS change

- Calving: **BCS < 5** or **BCS ≥ 5**
- Within each calving BCS group, cows that lost (**LO**), maintained (**MA**), or gained (**GA**) BCS from calving until the start of the breeding season

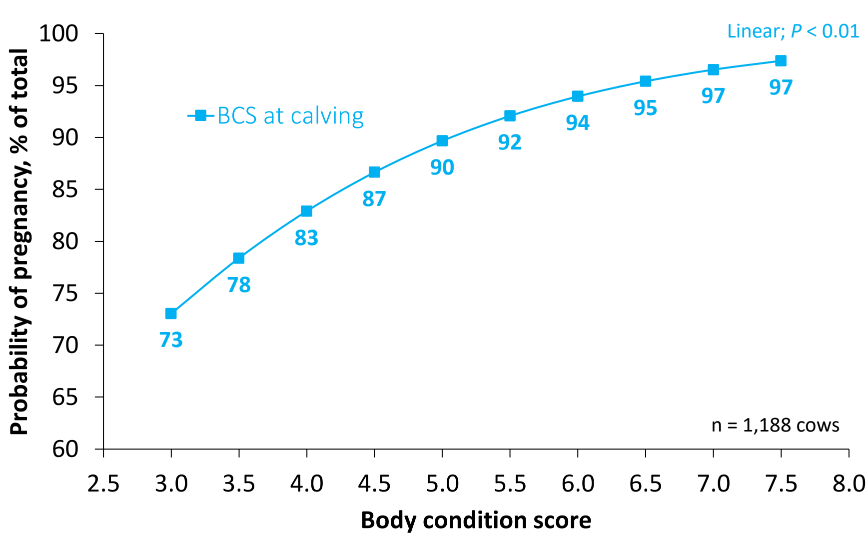
Maternal initial BCS and prepartum supplementation

- Weaning: **BCS < 5** vs. **BCS ≥ 5**
- Within each initial BCS group, cows that received (**SUP**) or not (**NOSUP**) prepartum supplementation

7

Body condition score at calving vs. Pregnancy %

Summary of 6 studies at the Range Cattle REC (2017 to 2022; Ona, FL)
1,188 Brangus mature cows grazing bahiagrass



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Body condition score at calving

Summary of 6 studies at the Range Cattle REC (2017 to 2022; Ona, FL)
1,188 Brangus mature cows grazing bahiagrass

	BCS at calving			
	BCS < 5	**BCS > 5**	**SEM**	***P*-value**
n	208	980		
Cow BCS				
Calving	4.51	5.56	0.078	<0.01
Start of breeding season	4.51	5.51	0.082	<0.01
End of breeding season	4.27	5.15	0.105	<0.01
Weaning	4.77	5.59	0.065	<0.01
First calf crop				
Body weight at birth, lb	75.2	79.3	1.12	<0.01
Body weight at weaning, lb	524	541	14.4	0.04
Pregnant with 2nd calf, %	81	91	2.53	<0.01
Calved live 2nd calf, % of total	73	82	2.95	0.005
Calving interval, days	371	364	2.4	0.02
Calving distribution, % of total calves				
First 30 days	57	63	4.0	0.18
Second 30 days	34	29	4.8	0.23
Third 30 days	9	8	2.5	0.65

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Body condition score change post-calving

Summary of 6 studies at the Range Cattle REC (2017 to 2022; Ona, FL)
1,188 Brangus mature cows grazing bahiagrass

	Post-calving BCS change				
	LOST	**MAIN**	**GAIN**	**SEM**	**P-value**
n	757	271	160		
BCS change from calving to breeding	-0.69	-0.02	0.51	0.05	<0.01
Cow BCS					
Start of breeding season	4.57[a]	4.96[b]	5.51[c]	0.08	<0.01
First calf crop					
Body weight at weaning, lb	536	529	533	15.7	0.47
Pregnant with 2nd calf, % of total	82[a]	87[b]	88[b]	2.8	0.07
Calving distribution, % of total calves					
First 30 days	52[a]	66[b]	63[b]	4.5	0.03
Second 30 days	39[b]	25[a]	31[ab]	4.9	0.03
Third 30 days	9	9	6.5	2.6	0.71

[ac] $P < 0.05$

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BCS at calving vs. Post-calving BCS change

Cow BCS at calving	Cow BCS change from calving to breeding	Pregnant, % of total	Calving within first 30 days of calving season, % of total
Below 5	Lost (n = 93)	74.5^{a}	35.0^{a}
	Maintained (n = 55)	84.8^{b}	67.2^{b}
	Gained (n = 60)	83.7^{b}	68.4^{b}
Above 5	Lost (n = 664)	88.3^{bc}	64.2^{b}
	Maintained (n = 216)	90.4^{c}	68.1^{b}
	Gained (n = 100)	93.2^{c}	57.6^{b}

BCS at calving determines the pregnancy rate and calving distribution.

Recover BCS after calving does not fully compensate for thin BCS at calving.

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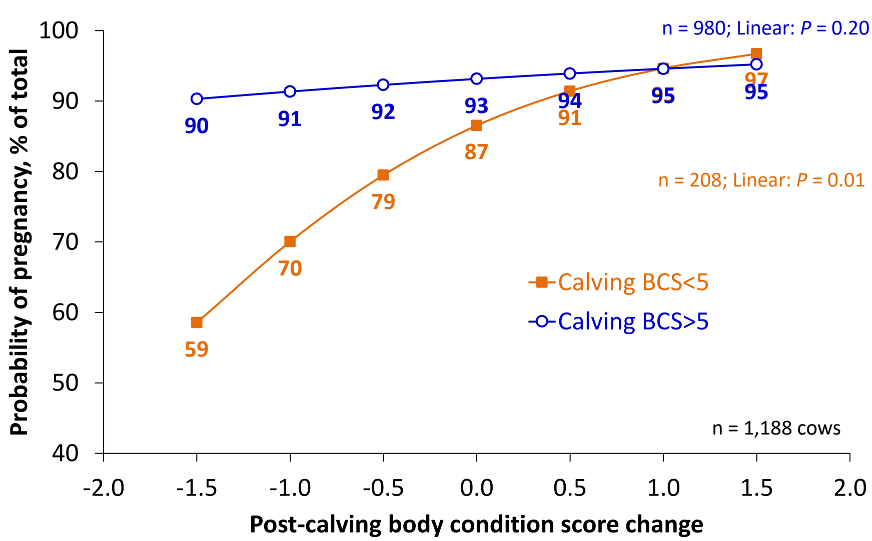
Body condition score change post-calving vs. Pregnancy %

Summary of 6 studies at the Range Cattle REC (2017 to 2022; Ona, FL)
Brangus mature cows grazing bahiagrass



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frontiers in Animal Science

REVIEW
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Improving Beef Progeny Performance Through Developmental Programming

Philipe Moriel[1]*, Elizabeth A. Palmer[1], Kelsey M. Harvey[2] and R. F. Cooke[3]

[1] Range Cattle Research & Education Center, University of Florida, Ona, FL, United States, [2] Prairie Research Unit, Mississippi State University, Prairie, MS, United States, [3] Department of Animal Science, Texas A&M University, College Station, TX, United States

Maternal nutritional management during gestation appears to modulate fetal development and imprint offspring postnatal health and performance, *via* altered organ and tissue development and tissue-specific epigenetics. This review highlighted the studies demonstrating how developmental programming could be explored by beef producers to enhance offspring performance (growth, immune function, and reproduction), including altering cow body condition score (BCS) during pregnancy and maternal supplementation of protein and energy, polyunsaturated fatty acids (PUFA), trace minerals, frequency of supplementation, specific amino acids, and vitamins. However, this review also highlighted that programming effects on offspring performance reported in the literature were highly variable and depended on level, duration, timing, and type of nutrient restriction during gestation. It is suggested that maternal BCS gain during gestation, rather than BCS *per se*, enhances offspring preweaning growth. Opportunities for boosting offspring productive responses through maternal supplementation of protein and energy were identified more consistently for pre- vs. post-weaning phases. Maternal supplementation of specific nutrients (i.e.,

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Philipe Moriel

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Precalving supplementation of protein/energy in Florida

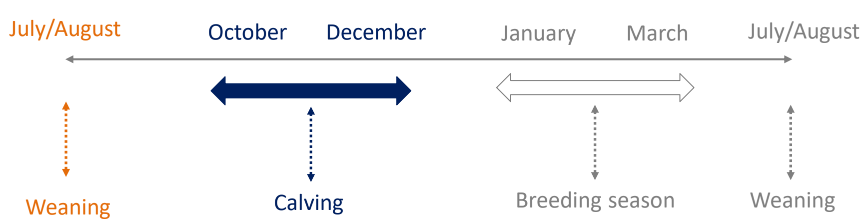
Summary of 6 studies at the Range Cattle REC (2017 to 2022; Ona, FL)

Brangus mature cows on bahiagrass and supplemented ***on average at 2.5 lb/day for 70 days before calving***

n = 1,188 cow-calf pairs

BCS at weaning (July/August) × ***Precalving supplementation***

BCS > or < 5 — *NOSUP vs SUP*



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BCS at weaning (July/August) × ***Precalving supplementation***
BCS > or < 5 — *NOSUP vs SUP*

	BCS < 5		BCS ≥ 5			
Item	**NOSUP**	**SUP**	**NOSUP**	**SUP**	**SEM**	**P-value**
n	106	125	557	400		
Cow BCS						
Weaning (July/August)	4.59[a]	4.64[a]	5.81[c]	5.72[b]	0.075	<0.01
Calving	4.51[a]	5.29[b]	5.37[b]	5.97[c]	0.172	
Start of breeding season	4.18[a]	4.82[b]	5.02[c]	5.35[d]	0.108	
End of breeding season	4.11[a]	4.54[b]	4.84[c]	5.08[d]	0.104	
Weaning (Following year)	4.56[a]	4.79[b]	5.37[c]	5.45[c]	0.087	

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Precalving supplementation of protein/energy in Florida

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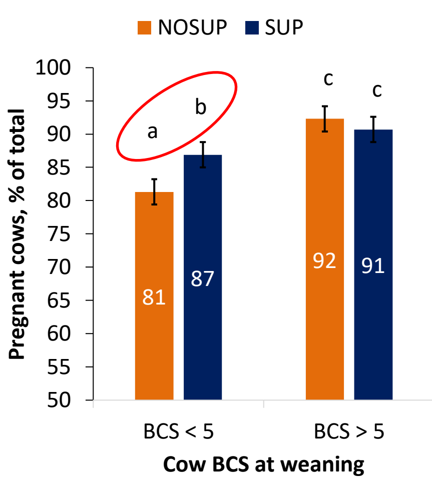

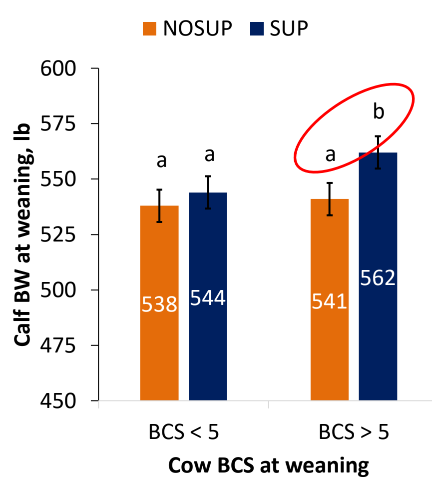

[ac]$P < 0.05$

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Precalving supplementation of protein/energy in Florida

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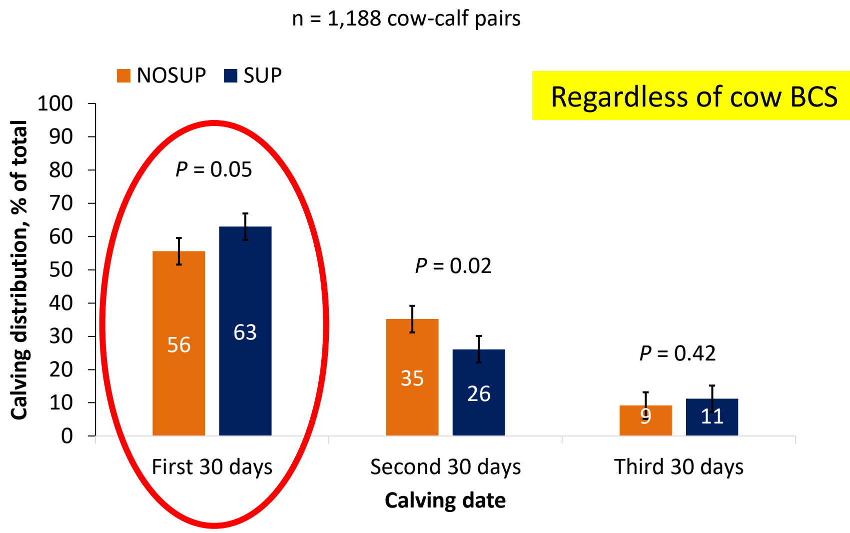

$^{ac}P < 0.05$

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Opportunities

- Nutrient restriction
  - *Long- vs. short-term?*
- Nutrient excess?
- Diet composition?
- Energy source?
- Protein source and amount?
- Minerals and fatty acids?
- Timing of supplementation?
- Frequency of supplementation?
- Feed additives
  - *Monensin & Probiotics*

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Beef Enhancement Funds

Florida Cattlemen's Association

Fetal Programming

Timing of supplementation

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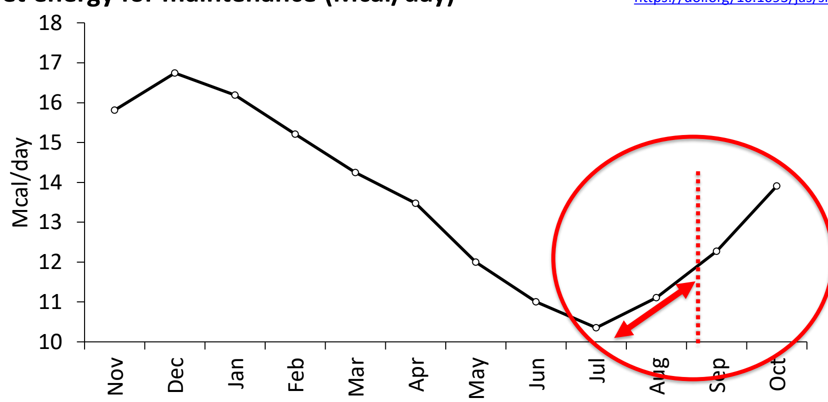
Net energy for maintenance (Mcal/day)

Palmer et al. (2022) J. Anim. Sci. **100**:1–17
https://doi.org/10.1093/jas/skac022



Supplementation offered:
Day 0 to 84 = dried distillers grains (DDG)
Day 84 end of breeding season = Molasses + urea

Day 0 = Start of study
Day 84 = start of calving
Day 140 to 224 = Breeding season

Treatments	Day of the study: Day 0 to 42	Day of the study: Day 42 to 84 (*Calving*)	Day of the study: Day 84 until end of breeding season
NO precalving supplementation	0	0	4 lb/day
Supplement day 0 to 84 – SUP84	2.2 lb/day	2.2 lb/day	4 lb/day
Supplement day 0 to 42 – SUP45	4.4 lb/day	0	4 lb/day

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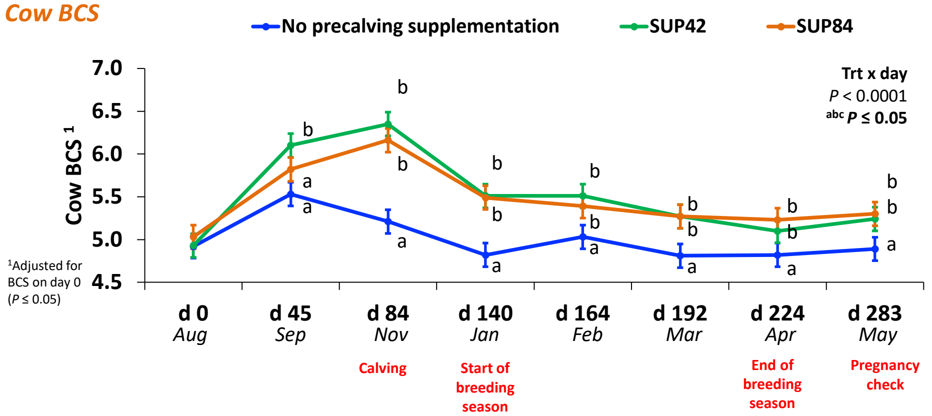
Results

Cow BCS



	Treatment				*P* - value
	NO Sup	SUP84	SUP42	SEM	Treatment
Calving date, day of the study	82	83	86	4.7	0.76
Pregnancy rate (day 283), % of total	96.3	96.2	88.0	4.81	0.39

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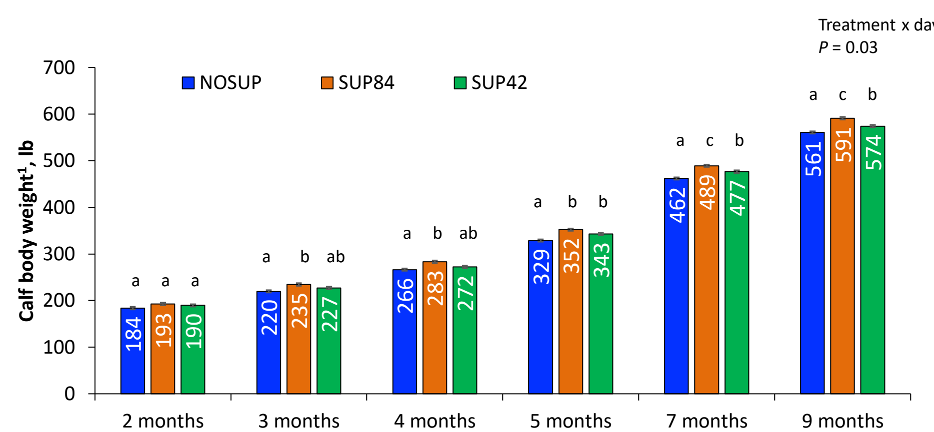
Results – Preweaning calf body weight



1Adjusted for calf sex and age ($P < 0.01$)

Treatments	Day of the study: Day 0 to 42	Day 42 to 84 (*Calving*)	Day 84 until end of breeding season
NO precalving supplementation	0	0	4 lb/day
Supplement day 0 to 84 – SUP84	2.2 lb/day	2.2 lb/day	4 lb/day
Supplement day 0 to 42 – SUP45	4.4 lb/day	0	4 lb/day

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Results – *Post-weaning immune response of steers*

Steer innate and humoral immune response

Item	Treatment CON	SUP42	SUP84	SEM	*P* - value Trt	Trt × Day
Plasma cortisol, µg/dL	2.13	2.29	2.15	0.16	0.76	0.79
Plasma haptoglobin, mg/mL	0.25	0.30	0.28	0.02	0.40	0.78
Serum BVDV-1						
Titers, log_2	3.46	4.41	3.91	0.38	0.21	0.87
Seroconversion, % total	78	85	88	7.2	0.64	0.27
Serum PI3						
Titers, log2	2.53[a]	4.30[b]	3.73[ab]	0.44	0.07	0.51
Seroconversion, % total						
day 347	21[a]	63[b]	54[b]	11	0.32	0.01
day 389	80	82	83			

[ab]*P* ≤ 0.05

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Results – *Steer carcass characteristics*

Item	Treatment CON	SUP42	SUP84	SEM	*P* - value
Hot Carcass Weight, kg	337	338	338	5.5	0.98
Dressing Percent, %	59.7	60.5	59.8	0.30	0.12
12th rib fat thickness, cm	1.77	1.69	1.62	0.089	0.49
Longissimus muscle area, cm^2	79.2	80.8	80.7	1.58	0.74
KPH, %	2.92	2.62	2.67	0.13	0.20
Yield Grade	3.8	3.6	3.5	0.14	0.33
Marbling	521[a]	570[b]	545[ab]	15	0.07
Average choice, %	5[a]	36[b]	17[ab]	9.3	0.10
Low choice, %	72	46	58	10	0.17
Select, %	23	19	25	8	0.87

[ab]*P* ≤ 0.05

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Beef Enhancement Funds
Florida Cattlemen's Association

Fetal Programming

Frequency of supplementation

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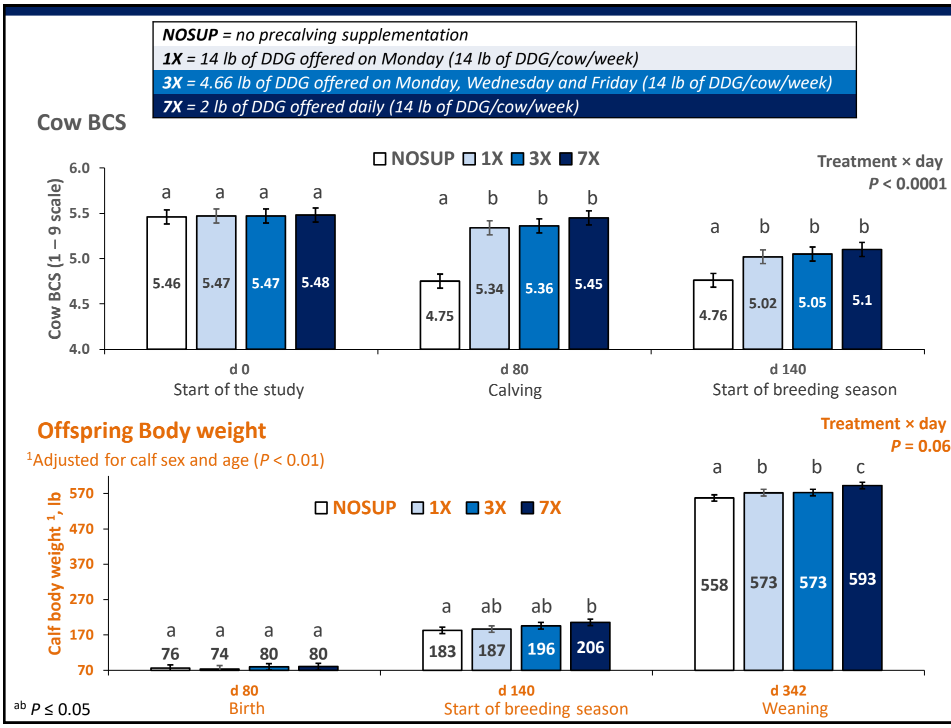
Frequency of precalving supplementation

80 days before calving:
120 Brangus cows (20 bahiagrass pastures; 6 cows/pasture)

NOSUP *= no precalving supplementation*	
1X *= 14 lb of DDG offered on Monday (14 lb of DDG/cow/week)*	
3X *= 4.66 lb of DDG offered on Monday, Wednesday and Friday (14 lb of DDG/cow/week)*	
7X *= 2 lb of DDG offered daily (14 lb of DDG/cow/week)*	

Calving to weaning:
All cows and calves managed similarly

28



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FETAL PROGRAMMING

Monensin

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Inclusion of monensin into precalving supplementation

70 days before calving:

160 Brangus cows (16 bahiagrass pastures; 10 cows/pasture)

Treatments :

NO SUP = No precalving supplementation

SUP = 2 lb of DDG daily

SUP + MON = 2 lb of DDG daily + 200 mg de monensin daily

Calving to weaning:

All cows and calves managed similarly!

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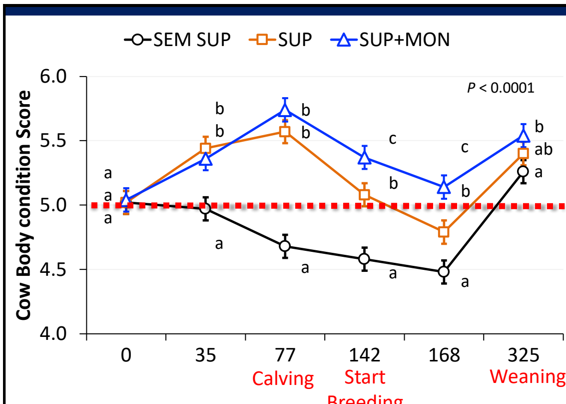

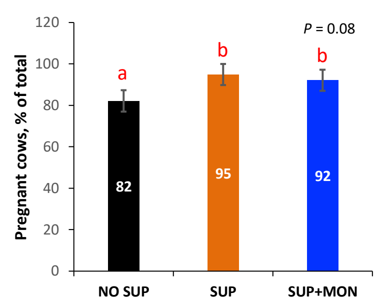

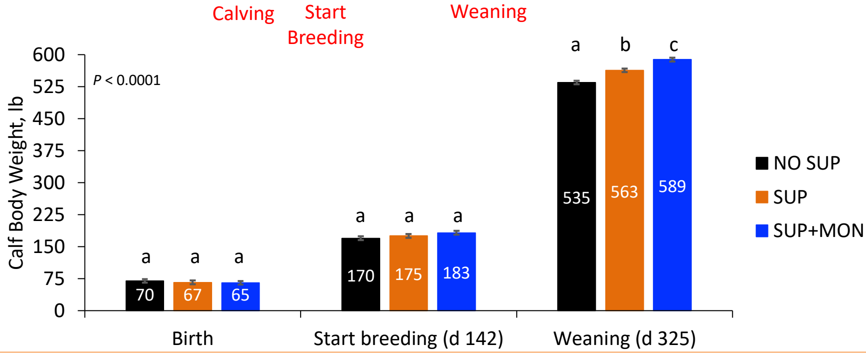

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FETAL PROGRAMMING

Probiotics

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Introduction

- Direct-fed Microbials
  - *Modulate rumen fermentation characteristics*
  - *Promote establishment of beneficial rumen microflora*
  - *Enhance fiber and overall nutrient digestibility* (Krehbiel et al., 2003; Pan et al., 2022; Cappellozza et al., 2023)

- *Bacillus* spp.
  - *Inhibition of harmful pathogens*
  - *Biofilm and mucin formation*
  - *Enhance production of wide variety of fibrolytic, amylolytic, proteolytic, and lipolytic enzymes* (Copani et al., 2020; Segura et al., 2020; Santano et al., 2020; Elshaghabee et al., 2017; Luise et al., 2022)

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Experimental Design

- Range Cattle Research and Education Center
  - May 2022 to March 2023
- 72 pregnant Brangus heifers (21 months)
  BW = 431 ± 31 kg
  BCS = 6.0 ± 0.36
- 1 of 12 bahiagrass pastures (6 heifers/pasture)
- Treatments (6 pastures/treatment)

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Experimental Design

Maternal Treatment

May day 0 — August day 90 — November day 190 — January day 242 (Start Breeding Season; Early weaning)

CALVING SEASON

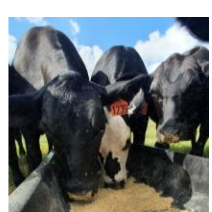
CON — 1 kg/d of soybean hulls DM

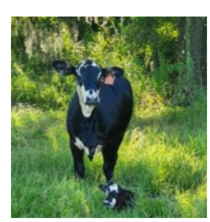
BAC — 1 kg/d of soybean hulls DM added with 3g of a *Bacillus*-based DFM mixture

(Bovacillus™; Chr. Hansen A/S, Hørsholm, Denmark)

Bacillus subtilis and *Bacillus licheniformis*

Target: 6.6×10^9 CFU





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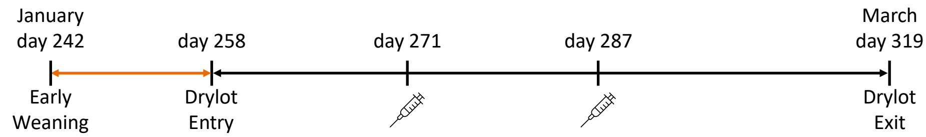
Experimental Design

Offspring Management



- 60 Calves (96 ± 30 d of age)
- 1 of 12 drylot pens (4 to 6 calves/pen)
  - Same distribution of the maternal treatment
- Soybean hulls-based diet (3.25% DM of BW)
  - CP = 21%
  - TDN = 73%

Vaccinated against pathogens associated with respiratory disease and *Clostridium*

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Maternal Results

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Maternal BW and BCS

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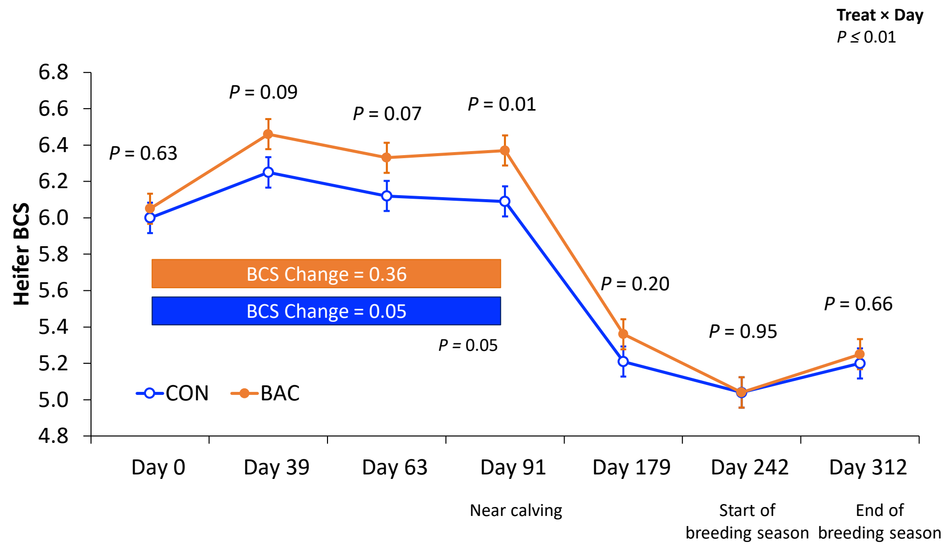
BAC = 3g of *Bacillus*-based DFM from day 0 to 242
CON = No *Bacillus* supplementation from day 0 to 242



Reproductive Data

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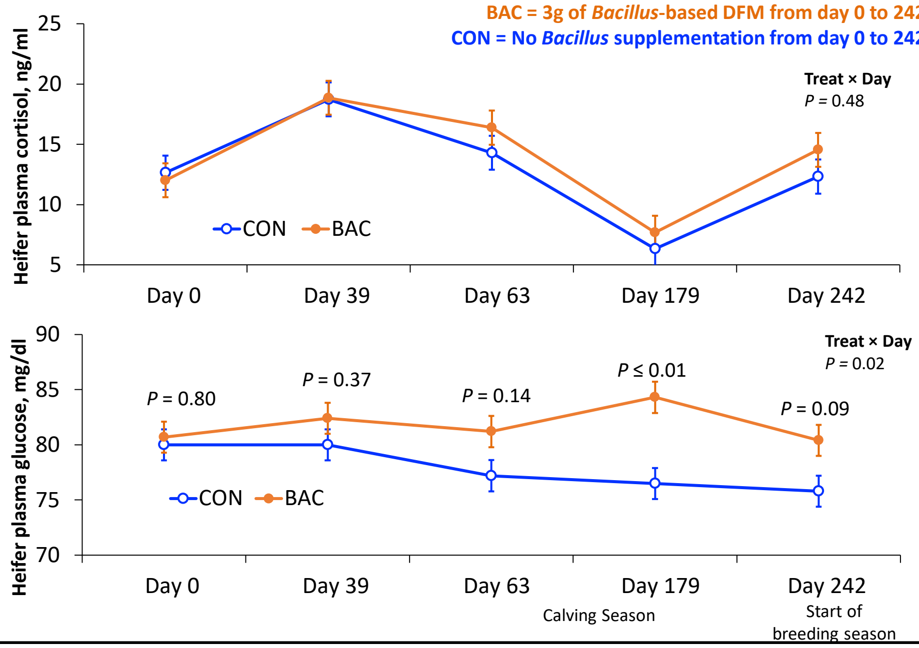
BAC = 3g of *Bacillus*-based DFM from day 0 to 242
CON = No *Bacillus* supplementation from day 0 to 242

	Maternal treatment			*P*-value
	CON	BAC	SEM	Treatment
First offspring (Calves in utero when treatments were provided)				
Calving, % of total	96	91	4.22	0.45
Calving date, day of the study	142	135	4.10	0.22
Male calves at birth, % of total	48	54	9.21	0.63
Calf birth BW, lb	62	65	0.99	0.34
Second offspring (Calves conceived from day 242 to 312)				
Pregnant, % of total	89	89	5.35	0.97
Calving, % of total	84	88	7.83	0.76
Calving date, day of the study	554	556	4.60	0.61
Male calves, % of total	52	52	12.00	0.94

Maternal Blood Data

BAC = 3g of *Bacillus*-based DFM from day 0 to 242
CON = No *Bacillus* supplementation from day 0 to 242



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Offspring Results

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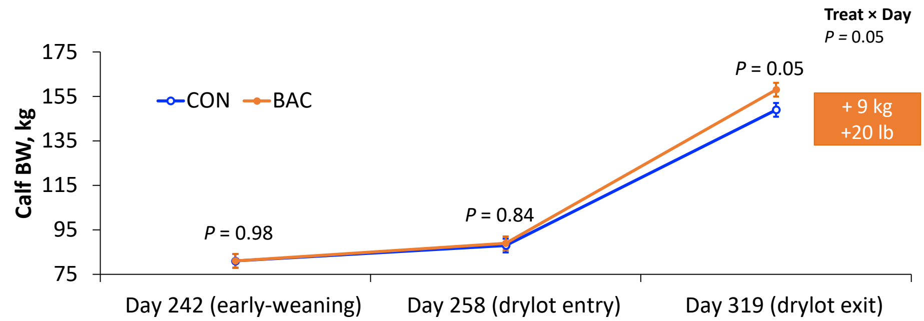
Offspring Performance



	Maternal treatment			*P*-value
	CON	**BAC**	SEM	**Treatment**
Calf ADG, lb/day				
Birth to drylot entry (day 242)	0.97	0.93	0.046	0.61
Drylot entry to exit (day 258 to 319)	2.22	2.44	0.077	0.04
Birth to drylot exit (day 319)	1.50	1.59	0.044	0.19
Total DMI, % of BW	3.24	3.27	0.038	0.73
Gain:Feed	0.25	0.27	0.004	0.05

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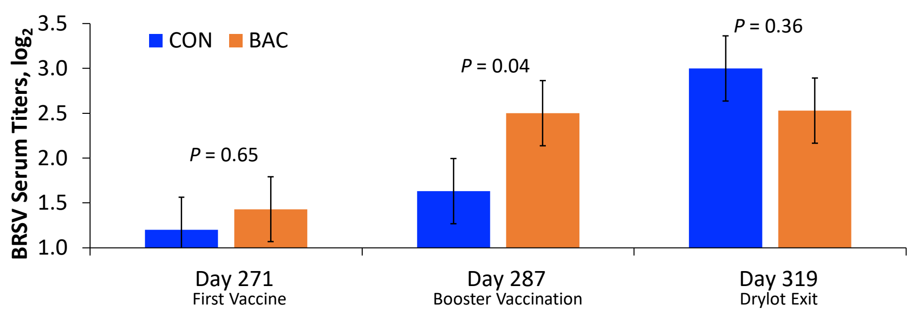
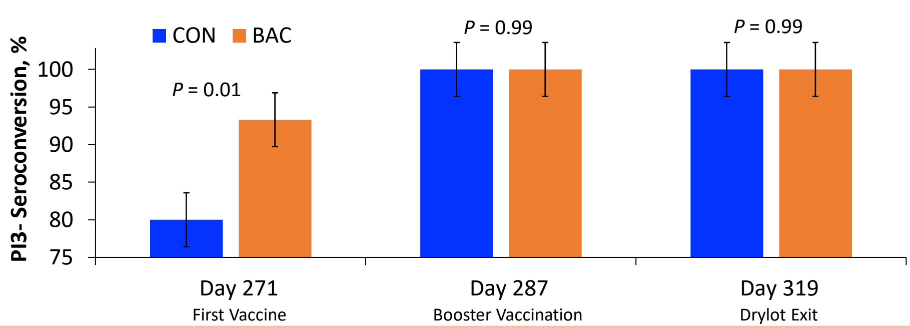
Offspring Performance





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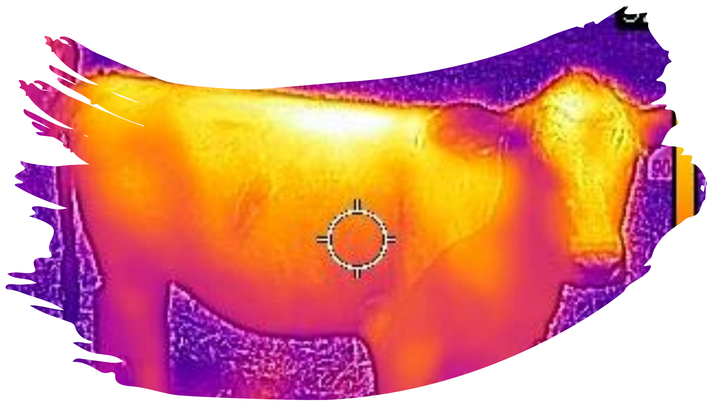

Shifting heifer nutrition to cope with heat stress

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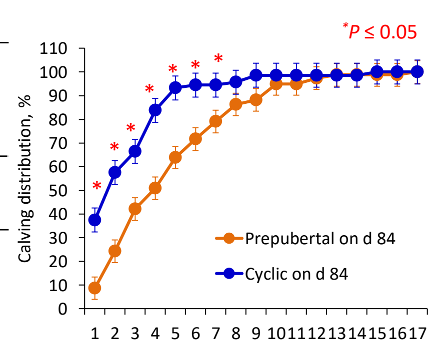
Not pubertal vs. pubertal Brangus heifers at start of breeding season

	Puberty status at the start of the breeding season			
Pregnant heifers, % of total	**Prepubertal**	**Pubertal**	**SEM**	***P-value***
Year 1	**33.9**	**78.2**	12.2	0.001
Year 2	**39.4**	**85.0**	6.1	0.005
Average	**36.2**	**81.6**	10.3	<0.0001

Moriel et al. (2020) J. Anim. Sci. https://doi.org/10.1093/jas/skaa236

	Puberty status at the start of the breeding season			
Item	**Prepubertal**	**Pubertal**	**SEM**	**P**
Pregnancy %	**55.4**	**87.4**	11.7	<0.001
Calving %	**51.0**	**72.2**	11.6	0.009

Moriel et al. (2017) J. Anim. Sci. 95:3523–3531 https://doi.org/10.2527/jas.2017.1666



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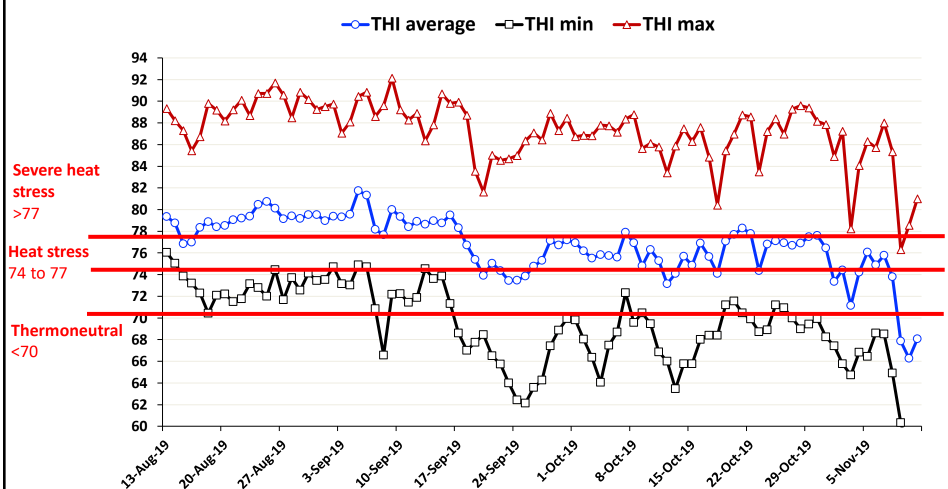
Thermal humidity-index (THI) - Ona 2019



NRC (1971): THI = $(1.8 \times T_{environ.} + 32) - [(0.55\text{-}0.0055 \times \text{Relative Humidity}) \times (1.8 \times T_{environ.} - 26)]$.

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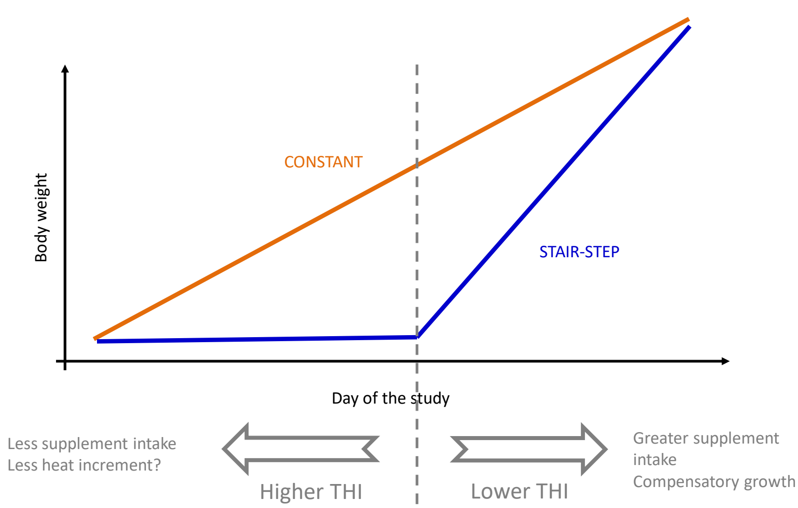
Constant vs. stair-step supplementation



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Boosting reproduction without increasing feed costs of beef heifers in Florida

Funded by Florida Cattlemen Enhancement Board - 2019/2020

Sep. 2019 to June 2020 (Yr 1) and Sep. 2020 to June 2021 (Yr 2)

- 64 Brangus heifers per year assigned to 16 bahiagrass pastures
- Treatments assigned to pastures (6 pastures/treatment/year):

CONTROL = concentrate supplementation at **1.50% of body weight** from September until the start of the estrous synchronization (November; day 0 to 100)

STAIRSTEP = concentrate supplementation at **1.05% of body weight** from Aug. to Sep. (day 0 to 49) + **1.95% of body weight** until the start of the estrous synchr. (day 50 to 100).

After day 100, all heifers were managed similarly:

AI from day 113 to 115; Timed-AI on day 115

Bulls from day 121-211

Concentrate supp. at 1.50% of BW until day 211

Moriel et al. (2022). J. Anim. Sci. 100(4):skac107. doi:10.1093/jas/skac107

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Intravaginal Temperature and Thermal Humidity Index

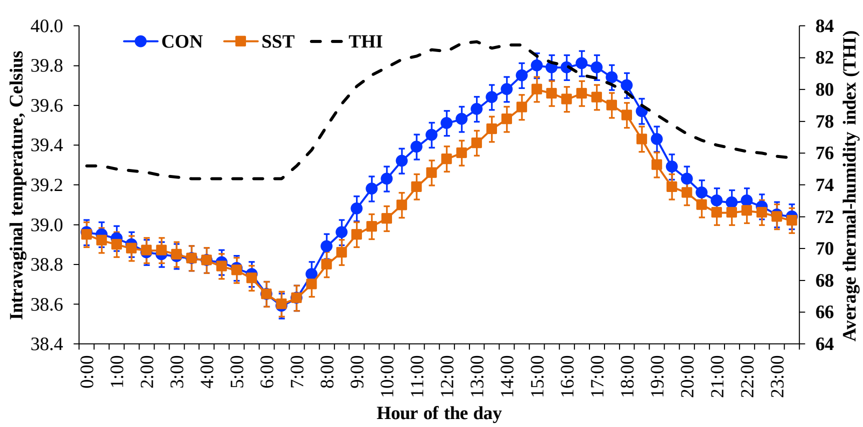
d 25-31 (Sep 7th to 13th)

CON = Suppl. 1.50% of BW d 0-100

SST = Suppl. 1.05% of BW d 0-49

Suppl. 1.95% of BW d 50-100

	Supplementation strategy			
Item	**CON**	**SST**	**SEM**	***P-value***
ADG, lb/day				
day 0 to 49	1.24	1.17	0.056	0.35
day 49 to 100				
day 0 to 100				



Moriel et al. (2022). J. Anim. Sci. 100(4):skac107. doi:10.1093/jas/skac107

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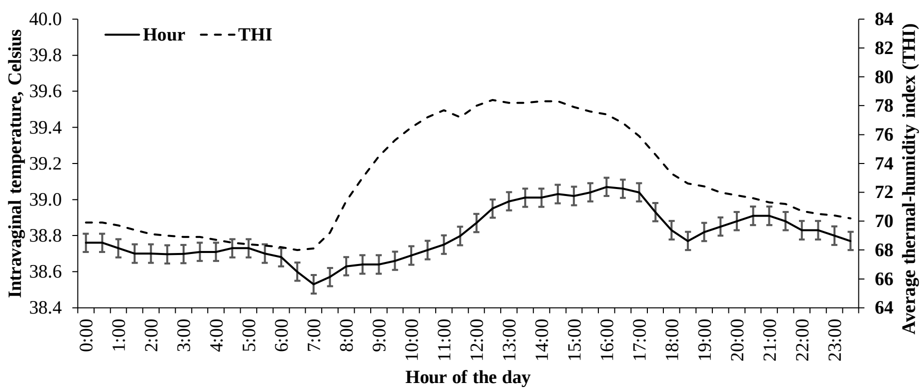
Intravaginal Temperature and Thermal Humidity Index

d 85-91 (Nov 6th to 12th)

CON = Suppl. 1.50% of BW d 0-100
SST = Suppl. 1.05% of BW d 0-49
Suppl. 1.95% of BW d 50-100

Item	Supplementation strategy CON	SST	SEM	*P-value*
ADG, lb/day				
day 0 to 49	1.24	1.17	0.056	0.35
day 49 to 100	1.22	1.61	0.061	<0.001
day 0 to 100	1.23	1.39	0.043	0.01



Moriel et al. (2022). J. Anim. Sci. 100(4):skac107. doi:10.1093/jas/skac107

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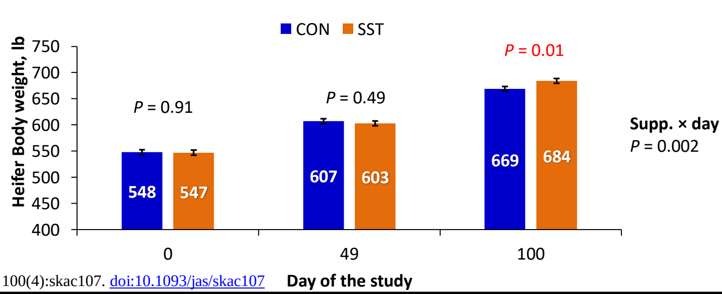
Growth performance and Supplement DM offered

d 0-100 (Aug 13th to Nov 21th)

CON = Suppl. 1.50% of BW d 0-100
SST = Suppl. 1.05% of BW d 0-49
Suppl. 1.95% of BW d 50-100

Item	Supplementation strategy CON	SST	SEM	*P-value*
ADG, lb/day				
day 0 to 49 (Aug to Sep)	1.24	1.17	0.056	0.35
day 49 to 100 (Sep to Nov)	1.22	1.61	0.061	<0.001
day 0 to 100 (Aug to Nov)	1.23	1.39	0.043	0.01
Total supplement DM offered, lb/heifer				
day 0 to 100 (Aug to Nov)	925	933	13.5	0.66



Moriel et al. (2022). J. Anim. Sci. 100(4):skac107. doi:10.1093/jas/skac107

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Reproductive performance

d 100-211 (Nov 21th to Mar 11th)

CON = Suppl. 1.50% of BW d 0-100
SST = Suppl. 1.05% of BW d 0-49
Suppl. 1.95% of BW d 50-100

	Supplementation strategy			
Item	**CON**	**SST**	**SEM**	***P-value***
Pubertal heifers, % of total				
day 91	**69.2**	**66.1**	4.82	0.67
day 101	**73.5**	**75.7**	4.82	0.76
Reproductive tract score, day 101	**4.48**	**4.54**	0.119	0.71
Heifers in estrus, % of total				
day 101 to 105	**28.3**	**28.9**	5.78	0.94
day 113 to 115	**64.9**	**63.9**	5.78	0.90
Pregnant heifers, % of total				
AI (day 154; Dec)	39.1	47.1	6.11	0.36
Final (day 275; Apr)	84.4	94.8	3.62	0.04

Stair-step strategy reduced vaginal temperature during heat stress and improved growth and reproductive performance of heifers, without increasing feed costs

Moriel et al. (2022). J. Anim. Sci. 100(4):skac107. doi:10.1093/jas/skac107

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Gestational heat stress

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Gestational heat stress – Dairy Cattle

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- **Reduced fetal growth and birth weight by 9 lb** (Tao et al., 2019)
- **Reduced weaning weights by 18 lb** (Tao et al., 2019)
  - Remained after 1 year of age (Monteiro et al., 2016ab)
- **Reduced calf postnatal body weight, passive immunity**
  - Reduced apparent efficiency of IgG absorption (Tao et al., 2012b)
  - Reduced cellular immunity and proliferation rate of peripheral blood mononuclear (Tao et al., 2012a)
  - Suggestive of underdeveloped immune organs due to maternal in utero heat stress
- **Reduced milk production of dairy heifers by 8 lb/day during first and second lactations** (Laporta et al., 2018)
  - Transgenerational effects reducing milk yield of the dam's granddaughters (Laporta et al., 2020)

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Gestational heat stress – Dairy Cattle

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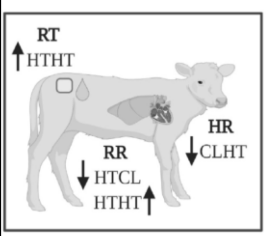
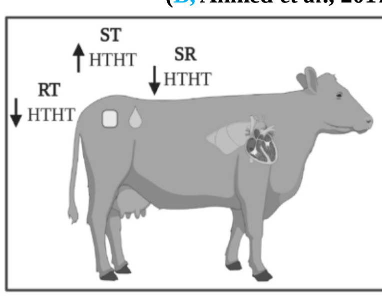
(A, Dado-Senn *et al.*, 2020a)



(B, Ahmed *et al.*, 2017)



Heat stress during late gestation decreased heat tolerance immediately after birth, but increased heat tolerance at maturity by increasing capacity to dissipate heat and maintain core body temperature.

(A) Calves exposed to in-utero heat stress then postnatal heat stress (HTHT) had a higher rectal temperature (RT) and respiration rate (RR). Calves exposed to in-utero cooling then heat stressed postnatally had the lowest heart rate (HR).

(B) Heifers exposed to in-utero heat stress and then heat-stressed during lactation had a lower RT and sweating rate (SR) but a higher skin temperature (ST).

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Impacts of pre- and postpartum heat stress abatement on physiology and performance of grazing Bos indicus-influenced cow-calf pairs

Izquierdo et al. (2023) J. Anim. Sci. 101:skad250. [doi:10.1093/jas/skad250](https://doi.org/10.1093/jas/skad250)

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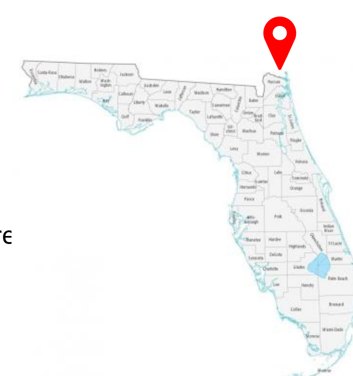
Experimental Design

- Range Cattle Research and Education Center
  - July 2021 to March 2022
- 64 pregnant Brangus heifers (21 months)
  - BW: 1000 ± 81 lb
  - BCS: 6.3 ± 0.28
- 1 of 16 bahiagrass pastures (4 heifers/pasture
- Treatments (8 pastures/treatment)



Izquierdo et al. (2023) J. Anim. Sci. 101:skad250. [doi:10.1093/jas/skad250](https://doi.org/10.1093/jas/skad250)

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Experimental Design

Maternal Treatment

July day 0 | August day 58 | November day 133 | January day 203

CALVING SEASON

Early wean

SHADE: ACCESS TO SHADE (3.7m²/Heifer) | ACCESS TO SHADE (3.7m²/Heifer)

NO SHADE: NO ACCESS TO SHADE | ACCESS TO SHADE (3.7m²/Heifer)

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Experimental Design

Offspring Management

January day 209 | March day 268

- 52 Calves (119 ± 19 d of age)
- 1 of 16 drylot pens (3 to 4 calves/pen)
  - Same distribution of the maternal treatment
- Soybean hulls-based diet (3.25% DM of BW)
  - CP: 21.0%
  - NDT: 71.5%

Izquierdo et al. (2023) J. Anim. Sci. 101:skad250. doi:10.1093/jas/skad250

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Maternal Results

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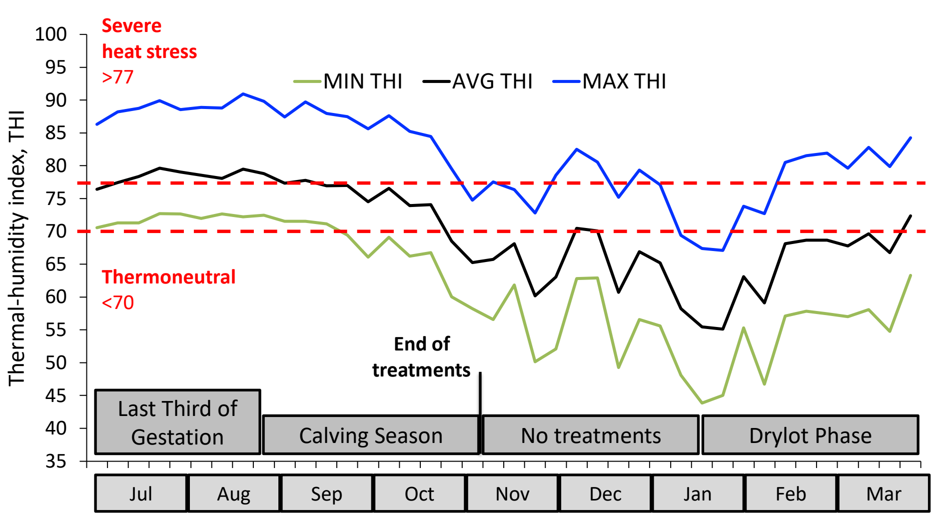
THI



Izquierdo et al. (2023) J. Anim. Sci. 101:skad250. doi:10.1093/jas/skad250

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Intravaginal Temperature and Thermal Humidity Index

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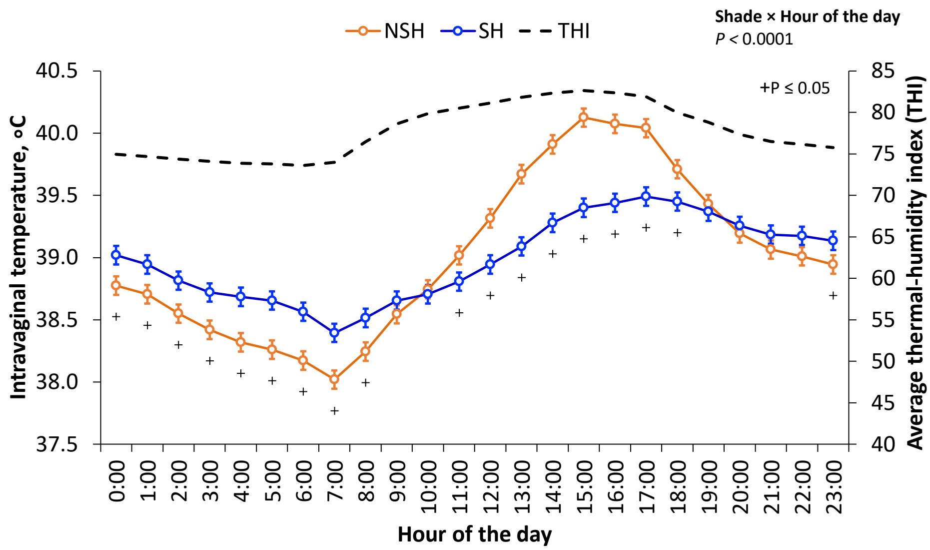
day 35-41 (Aug 4th to 10th)

Shade = Access to shade from day 0 to 133
No Shade = No access to shade from day 0 to 133



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Intravaginal Temperature and Thermal Humidity Index

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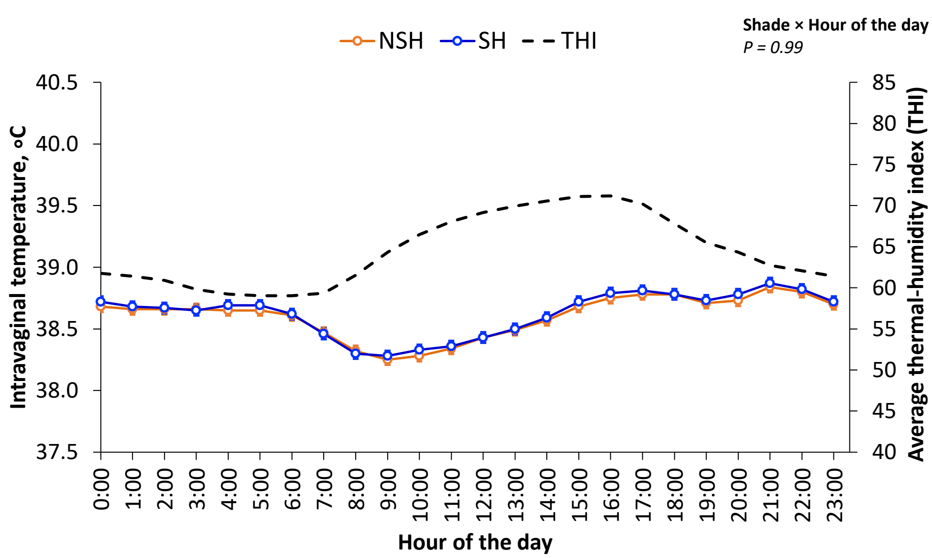
day 126-132 (Nov 3rd to 9th)

Shade = Access to shade from day 0 to 133
No Shade = No access to shade from day 0 to 133



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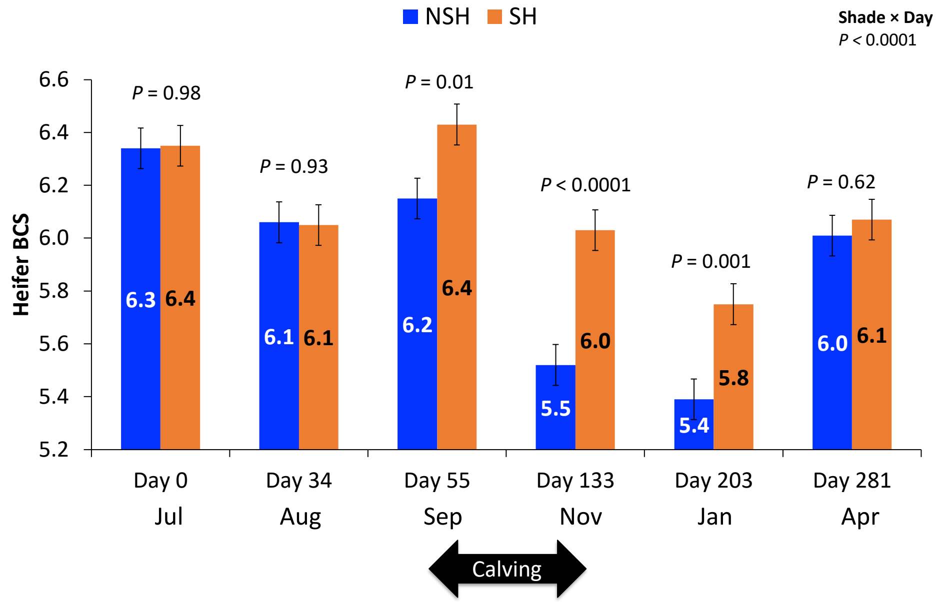
Maternal BCS



Izquierdo et al. (2023) J. Anim. Sci. 101:skad250. doi:10.1093/jas/skad250

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Offspring Results

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Offspring Performance

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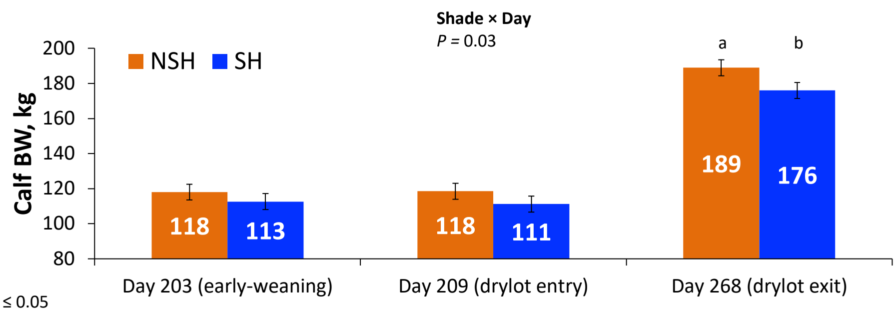

$^{ab}P \leq 0.05$

	Treatment			P-value
	NSH	SH	SEM	Shade
Calf birth BW, lb	62	66	1.8	0.05
Calves born alive, % of total	97	100	2.6	0.40
Calf ADG, lb/day				
Birth to early-weaning (day 203)	1.59	1.61	0.074	0.80
Drylot entry to exit (day 209-268)	2.60	2.40	0.079	0.07
Birth to drylot exit (day 268)	1.85	1.78	0.057	0.39

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Offspring Plasma Analyses

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	Maternal treatment			P-value	
Item	**NSH**	**SH**	**SEM**	**Shade**	**Shade × day**
Plasma cortisol, ug/dL	2.43	2.42	0.149	0.93	0.15
Plasma Hp, mg/mL	0.405	0.468	0.0235	0.06	0.80

	Maternal treatment				P-value	
Item	**NSH**	**SH**	**SEM**	*P*-value	**Shade**	**Shade × day**
BRSV						
Seroconversion, % of total						
Day 222	77	50	8.57	0.02	0.23	0.01
Day 236	69	50	8.57	0.10		
Day 268	80	96	8.57	0.19		
Serum titers, log2						
Day 222	2.00	1.31	0.285	0.08	0.26	0.09
Day 236	1.85	1.27	0.285	0.15		
Day 268	2.69	3.00	0.291	0.44		

Izquierdo et al. (2023) J. Anim. Sci. 101:skad250. doi:10.1093/jas/skad250

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USDA Study – Combining heat stress mitigation strategies during pre- and postnatal phases: Impacts on cow and heifer offspring performance

320 Brangus, pregnant mature beef cows on bahiagrass pastures

Treatments (2 x 2 factorial design): Applied during gestation and then heifer development

(1) No heat abatement (CONTROL) = No access to artificial shade

(2) Heat abatement strategy (HAST) = Unlimited access to artificial shade (40 sq ft per animal)

July Calf weaning → **November** Calving	**November** Calving → **March** End of cow breeding season	**March** →	**July** Calf weaning at 8-9 mo of age → **November** Heifer estrus synchronization
Cow Gestational Treatments			**Heifer Post-weaning**
CONTROL *4 pastures per year ; 10 cows per pasture*	Bahiagrass grazing + 2.3 kg/day molasses	Bahiagrass grazing + no concentrate	CONTROL *4 pastures per year ; 4-5 heifers per pasture*
CONTROL *4 pastures per year ; 10 cows per pasture*	Bahiagrass grazing + 2.3 kg/day molasses	Bahiagrass grazing + no concentrate	HEAT STRESS ABATEMENT *4 pastures per year ; 4-5 heifers per pasture*
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HEAT STRESS ABATEMENT *4 pastures per year ; 10 cows per pasture*	Bahiagrass grazing + 2.3 kg/day molasses	Bahiagrass grazing + no concentrate	HEAT STRESS ABATEMENT *4 pastures per year ; 4-5 heifers per pasture*

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Thank you

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