Four-State Dairy Nutrition and Management Conference

June 5-6, 2024

Cooperative Extension for:
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Volume 33

2024

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Understanding Amino Acid Bioavailabilty:
My rock is bigger than your rock … ± 200%

M. D. Hanigan, K. Estes, J. Prestegaard, T. Fernandes
School of Animal Sciences
Virginia Tech

Understanding Amino Acid Bioavailabilty:
My rock is bigger than your rock … ± 200%

M. D. Hanigan, K. Estes, J. Prestegaard, T. Fernandes
School of Animal Sciences

VirginiaTech
Invent the Future

1

Milk Protein Responses to Metabolized Amino Acids and Energy

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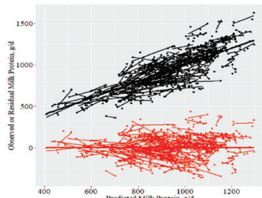
$$mPrt = \beta His + \chi Ile + \delta Leu + \varepsilon Lys + \phi Met + \varphi Thr + \lambda DEI + \kappa dNDF + \mu BW + \lambda(\sum EAA^2)$$

Predictors	Intercept	His	Ile	Leu	Lys	Met	Thr	Σ(EAA²)	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



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Amino Acid Metabolism in Ruminants

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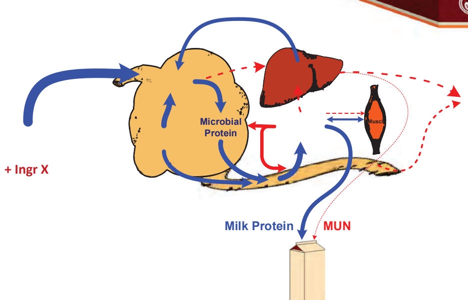

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Milk Protein Yield Response

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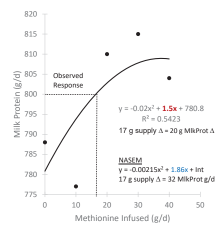

- Net delivery to milk from:
  - Infused vs ingredient
- Develop a milk response curve
  - SE_{STD_Curve} = 13.5 g/d
- Include 1 or more Ingr Eval Trt
  - Milk Prt SEM for single point ~ 20 g/d
  - 20 g SEM x 2 (P<.05) x **1.5x** = 60 g Δ in Met Supply
  - Min Δ Met for STD Curve ≈ 80 g/d
  - Min Sample Δ = 60 g/d
  - Expect 30% SE on Bio Estimate
- Infusion site?
  - Gut
    - replicates dRUP
    - Absorptive losses = 5-15%
  - Jugular
    - Misses loss during absorption

4

Within Cow Milk Protein Responses to MP

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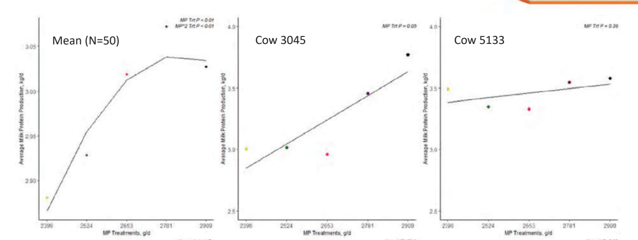

Campos et al., in progress
VT/Univ. Tn. Collaboration

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Blood Concentration Responses

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Dietary MP = 115% of Requirement

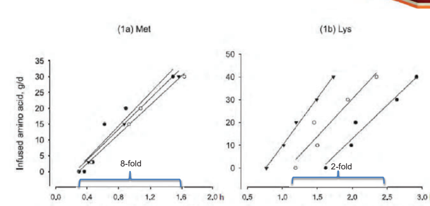

Figure 1. Individual variations of relationships between plasma of Met (1a) or Lys (1b) and amounts infused into the duodenum. Milk protein yield of cows: ● Cow 1 = 189 g/d; ○ Cow 2 = 249 g/d; ▼ Cow 3 = 358 g/d

Rulquin, H. and J. Kowalczyk. 2003

6

Blood Concentration

Rulquin, H. and J. Kowalczyk. 2003.

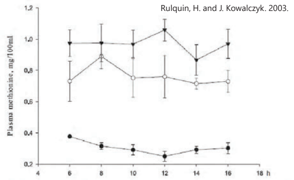

Figure 2. Diurnal variations of plasma methionine concentrations of cows supplied with graded doses of Smartamine ML™: —●— 50 g SmartamineML™, —○— 88 g SmartamineML™, —▼— 132 g Smartamine ML™

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

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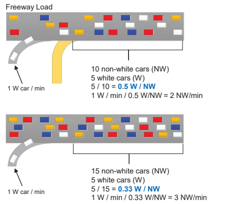
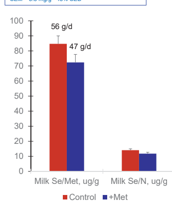
Efficacy by Dilution



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% SED



Weiss and St-Pierre, 2009

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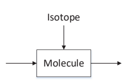
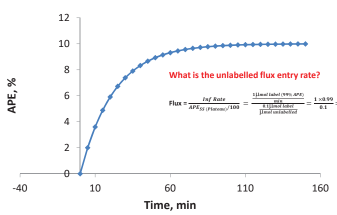
Constant Infusion at 1 µmol label/min (99 APE)





What is the unlabelled flux entry rate?

$$\text{Flux} = \frac{Inf\ Rate}{APE_{SS\ (Plateau)}/100} = \frac{\frac{1\mu mol\ label\ (99\%\ APE)}{min}}{\frac{0.1\mu mol\ label}{\mu mol\ unlabelled}} = \frac{1\times 0.99}{0.1} = 9.9\mu mol\ unlabelled/min$$

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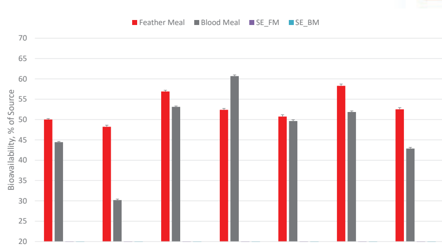
Ingredient EAA Bioavailabilities



Estes et al., 2018

10

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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Using the Values for Ration Balancing

- Bioavailability ≈ Intestinally Digested
- Intestinally Digested = DC_{RUP} * RUP_{AA}
- RUP = Kp/(Kp + Kd)*CP_B + CP_C

- Simplify:
  - DC_{RUP} = 85%
  - CP_C = BioAvail / DC_{RUP}/100
  - CP_B = 0 (avoids Kp/Kd questions)
  - CP_A = 100 – CP_B - CP_C

- Example: 64% Bioavailable
  - RUP = 64 / 0.85 = 75
  - CP_C = 75; CP_A = 100 – 0 – 80 = 25

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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 for Met at 35 g/d
    - Met only
  - Isotope Dilution
    - ± 12-15% Units when supply increases ≥ 20% (20 g/d for Met)
    - All EAA

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Take Home and Questions?

- 3 Valid and Effective Methods
  - show me the data and methods
  - My Rock is bigger than Your Rock: look at the SE

- No milk protein response?
  - Look in the mirror first!
  - Lots of stuff happening after absorption

- Check List
  - No pelleting (excepting MetaSmart)
  - Don't overmix
  - Avoid long feed exposure times
  - The usual: water, cow comfort, heat stress, health, …
  - Adequate dietary energy

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Histidine - a Limiting Amino Acid for Dairy Cows

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

Histidine – a limiting amino acid for dairy cows

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

2024 Four-State Dairy Nutrition & Management Conference, June 4-6th, Dubuque, Iowa

1

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Talk outline

- Feeding reduced-protein diets to dairy cows
- Why Histidine?
- Early research
- Research at Penn State
- Conclusions

2

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Why feeding low-protein diets?

- Reduced feed cost
- Striving for efficiency
- Reduced N emissions (nitrates, NH_3, N_2O)
- Protein overfeeding and reproduction

3

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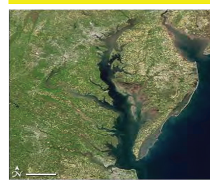
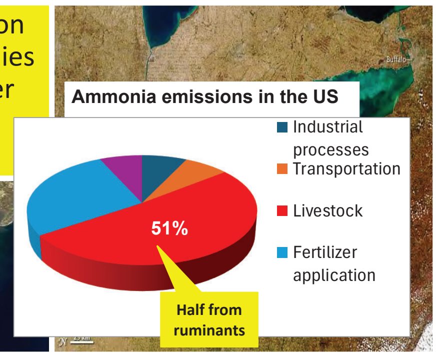
Environmental concerns with N

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





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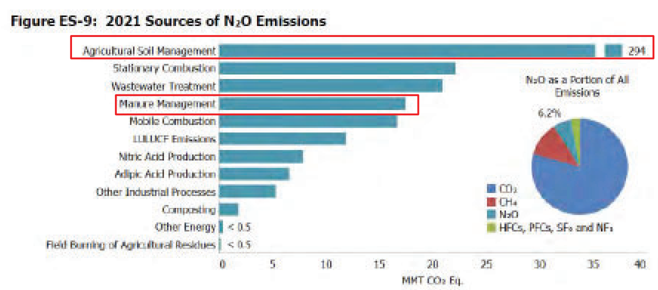
USEPA, 2024

Sources of nitrous oxide emissions in the United States



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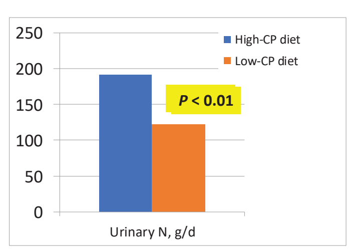
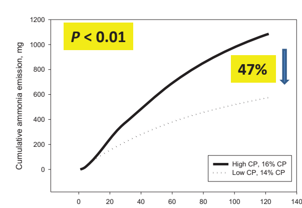
Lee et al., 2010

Decreasing urinary N/urea excretion decreases manure ammonia emissions





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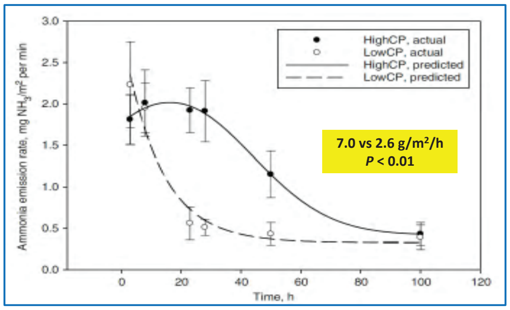
Lee et al., 2016

Dietary CP influences manure ammonia emissions as well



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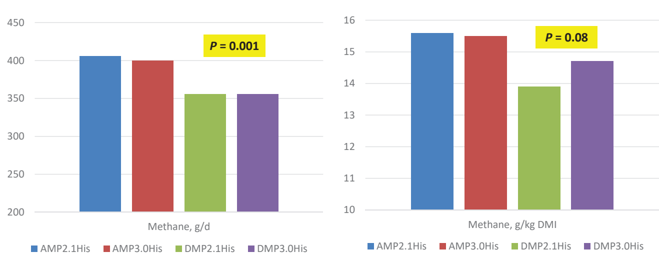
Räisänen et al., 2022

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

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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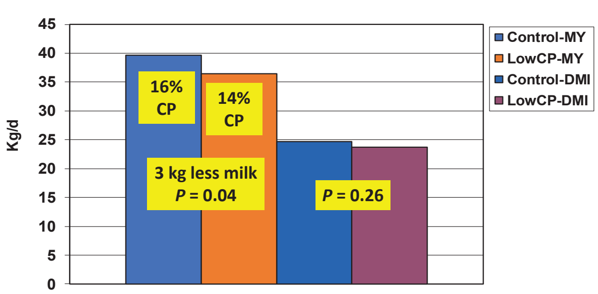
Penn State data

Severe MP deficiency (-12 to -13%, based on NRC, 2001) may decrease DMI, milk yield & components



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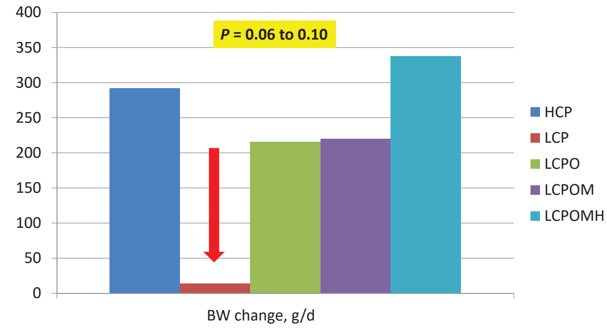
Giallongo et al., 2014

Or cows will lose BW



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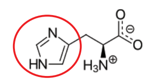
What is Histidine?



- 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 >3.5% of MP
  - Major reasons for this are:
    - endogenous His depots
    - lower His than Met in microbial protein

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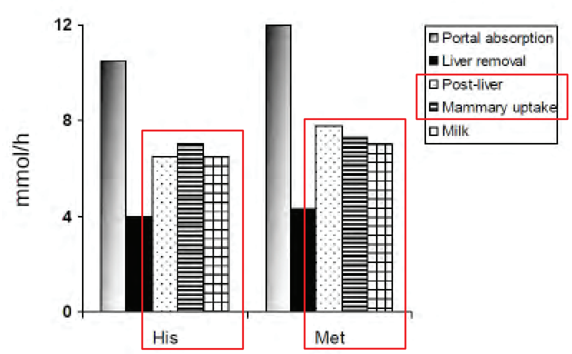
Net flux of Met and His



Lapierre et al., 2008

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Räisänen et al., 2023

Histidine research over the years

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

Guests: Dr. Bill Weiss, The Ohio State University; Dr. Helene Lapierre, Sherbrooke Research 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)

14

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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

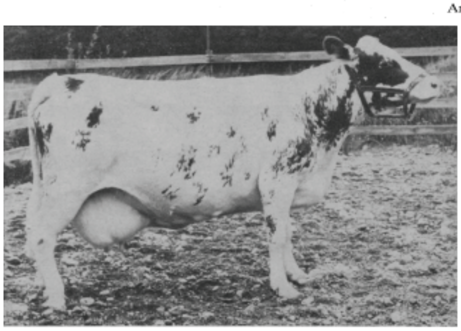

Fig. 3. Test cow Metta after being on test feed 370 days from calving.

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A. I. Virtanen; Science, 1966

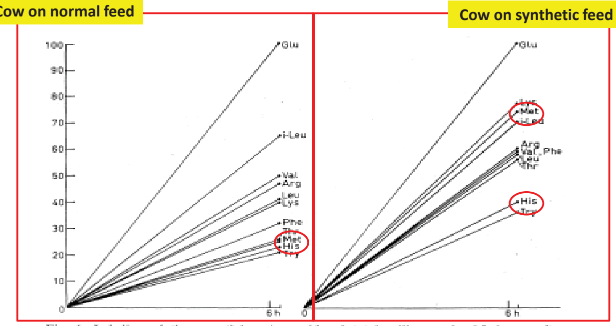

Fig. 1. Labeling of the essential amino acids of total milk protein 6.3 hours after the cow had been fed a single dose of ^{15}N-urea. The results are expressed as a percentage of the labeling of glutamic acid. At left, results of a feeding experiment with a cow on normal feed (17 March 1966); at right, 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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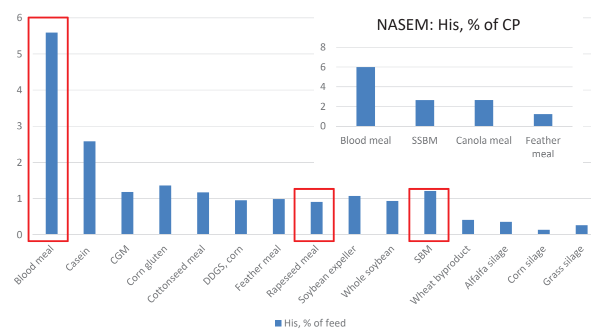
Evonik AMINODat

Histidine concentration in feeds



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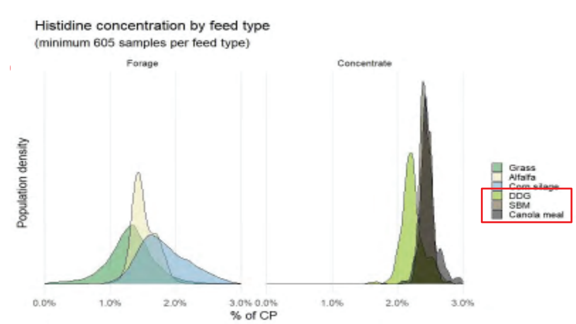
His concentration in common forages and protein feeds



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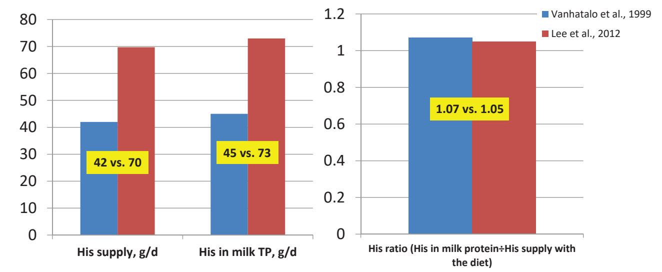
Can His be limiting on CS-based diets?

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



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Histidine work at Penn State

- Observed a consistent apparent drop in plasma His with long-term feeding of low-CP diets
- 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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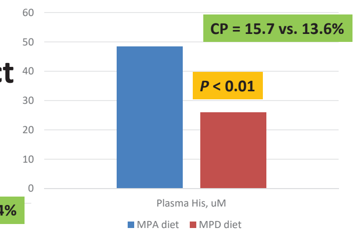
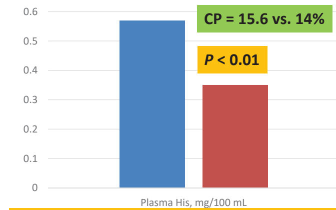
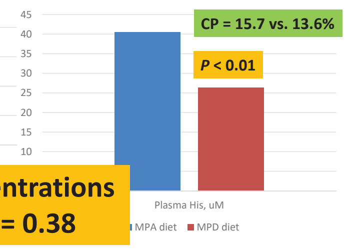
Examples of the effect of dietary CP/MP on plasma His







No change in Met concentrations in all experiments; $P = 0.38$

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

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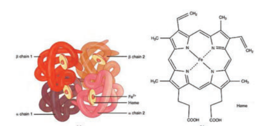
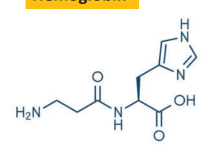
Endogenous sources of His



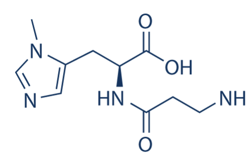
Hemoglobin

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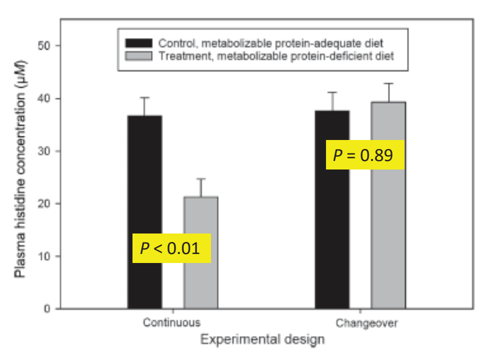
Hristov et al., 2019 (data from Lee et al., 2012, 2015)

Body reserves can hide temporary His deficiencies



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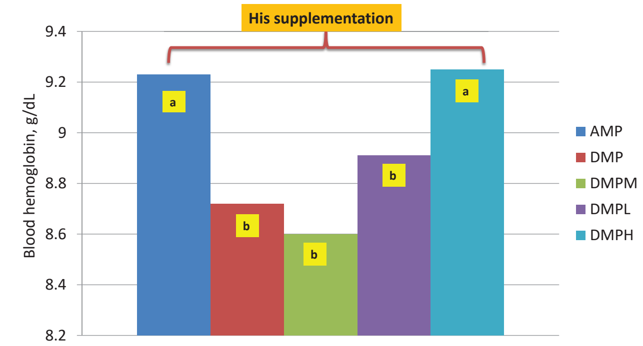
Giallongo et al., 2015

His and blood hemoglobin



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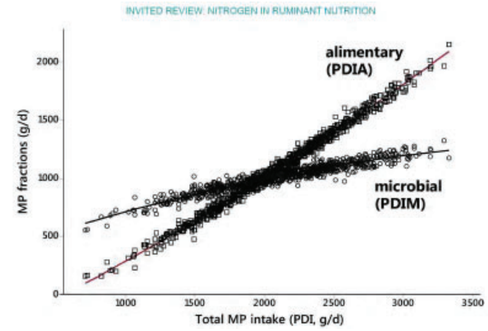
INRA data from Hristov et al., 2019

The relative contribution of microbial protein to the total MP supply increases with decreasing dietary MP



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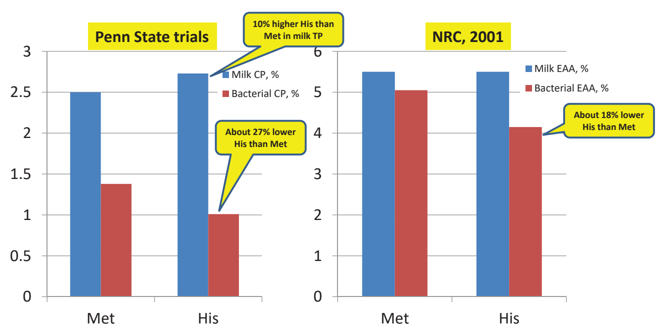
Met and His in milk protein vs. bacteria



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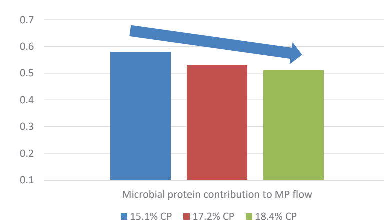
NASEM 2021 simulations

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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NASEM (2021) AA composition of microbial protein

AA	g AA/100 g CP: Duodenal Endogenous	Microbial	g AA/100 g TP: Scurf	Whole Empty Body	Metabolic Fecal	g AA/100 g TP: 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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J. Dairy Sci. 100:2784–2800
https://doi.org/10.3168/jds.2016-11992
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Histidine deficiency has a negative effect on lactational performance of dairy cows

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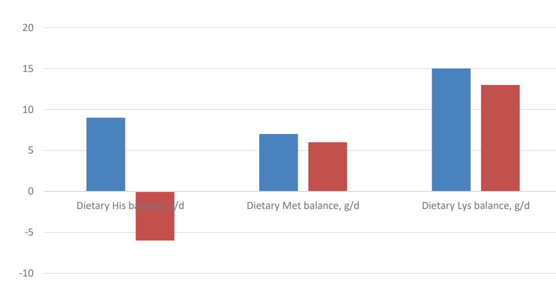

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Potential Factors for Variable Responses to Feeding Amino Acids: Emphasis on Lysine

Chanhee Lee, PhD
Department of Animal Sciences
The Ohio State University

1

Potential factors for variable responses to feeding amino acids: emphasis on lysine

Chanhee Lee, PhD

Department of Animal Sciences
The Ohio State University

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Balancing a diet for amino acids (AA)

- AA-based requirement models in the US
  - NASEM (2021) and CNCPS (2015)
- The goal of balancing for AA
  - Efficient protein synthesis
    - Avoiding excessive supply of N
    - Reducing N excretion

-Greater IOFC
-Lower environmental impacts

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The updated model still identifies that **Met, Lys, and His** could be limiting AA

- Historically, a diet meeting the MP requirement has been often assumed to be deficient in Met and Lys (NRC, 2001)
  - Lots of publications with RP-Met and RP-Lys
  - Studies with RP-His are relatively recent

Meta analyses!

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Results of meta-analyses about feeding RP-AA are compelling

Meta-analyses	RP-AA	Response
Robinson (2010)*	Met	Increased protein %
	Lys	-
	Met and Lys	Increased milk yield, protein %, fat%,
Patton (2010)	Met	Increased MY and MPY
Zanton et al. (2014)	Met	Tended to increase MY, Increased MPY
Wei et al. (2022)	Met	Increased MF% and MP%
Räisänen et al. (2023)*	His	Increased DMI, MY, MPY
Arshad et al. (2024)	Lys	Increased MY and MPY

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Meta-analyses about Lys supplies

- Robinson (2010; Lives. Sci.)
  - 7 studies with about 24 treatments
  - Includes studies with Lys infusion and RP-Lys
- Arshad et al. (2024; JDS in press)
  - 13 experiments with 40 treatments
  - Includes Only RP-Lys studies

Results are quite different!! Why??

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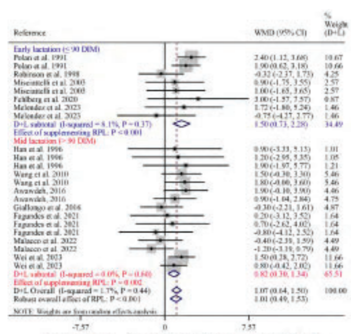
Various responses between studies



Early lactation cow trials (< 90 DIM)
- 5 experiments
- 15 treatments
- 1.5 kg/d increase

Early- and mid-lactation cow trials (> 90 DIM)
- 8 experiments
- 25 treatments
- 0.82 kg/d increase

(Arshad et al. 2024 in press)

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Things to think about for feeding AA

- Responses to RP-AA are likely variable, especially RP-Lys
- Supplementation of RP-AA is common in commercial dairy farms
  - RP-AA are not cheap…

Future focus on Lys research in lactating cows

- Identifying factors causing variable responses to feeding RP-Lys

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1. Potential factor:

Flexibility of AA utilization by tissues

- Lys is one of the Group 2 AA

(mmol/h)	PDV	HEP	TSP	MG	Milk	U:O
Lys	36.3	0.5	36.7	-30.0	23.6	1.27
Leu	48.1	2.2	50.2	-34.6	28.8	1.20
Ileu	29.2	2.1	32.2	-21.3	17.4	1.22
Val	36.2	2.3	38.8	-26.1	21.8	1.20

(Lapierre et al., 2012)

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Where does Lys go in the mammary glands

	Artery		Casein	
	Lys-	Lys+	Lys-	Lys+
Ala	2.6	9.5	4.3	16.8
Arg	1.6	2.9	nd	nd
Asp	nd	nd	6.1	25
Glu	3.9	5	7.3	28.2
Gly	1.2	2.8	2.2	3.3
Hi	[illegible]	[illegible]	[illegible]	.1
Ile	[illegible]	[illegible]	[illegible]	2.5
Le	[illegible]	[illegible]	[illegible]	.4
Ly	[illegible]	[illegible]	[illegible]	1.3
Met	nd	nd	3.9	12.1
Phe	3.5	5.3	6.1	6.7
Pro	0.5*	3.1*	1.0*	3.8
Ser	3.7	8.4	6.8	20.4
Tyr	3	6.6	3.8	3.4
Val	1.4	3.2	1.8	5.7

**BCAA likely perform like Lys (Rubert-Aleman et al., 1999)

(Lapierre et al., 2009)

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Lys oxidation followed by transamination to support other AA

- It occurs in the mammary glands even when Lys supply is deficient
- Leu and Ile have a role of stimulating protein synthesis (mTOR; Yoder et al., 2020)

Understanding various roles of Lys should improve Lys supply and requirement

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2. Potential factor:

Different requirements of AA between lactation stages

Fresh cow studies

	RP-AA	Postpartum effect	Note
Osorio et al., 2013	Met	DMI ,MY, MFY, MPY	NO change in efficiency
Zhou et al., 2016	Met	DMI, MY, MFY, MPY	NO change in efficiency
Batistel et al., 2017	Met	DMI, MY, MFY, MPY	NO change in efficiency
Girma et al. 2019	Lys	DMI	Efficiency not reported
Potts et al., 2020	Met	MFY	Only multiparous cows
Overton et al. 1996	Met	MFY	
Socha et al., 2005	Met/ Met, Lys	-	
Preynat et al., 2009	Met	-	
Lee et al., 2019	Met, Lys	-	
Fehlberg et al., 2020	Lys	-	
Lee et al., 2022 (unpublished)	Met, Lys	-	
Lee et al., 2023 (unpublished)	Met, Lys	-	

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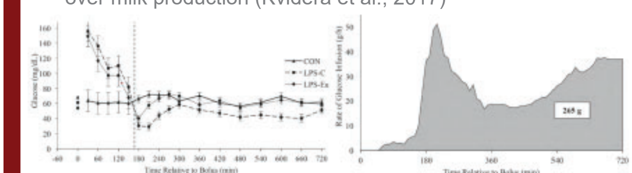
Is there a priority for AA utilization over milk protein synthesis??

- Fresh cows may be under an inflammation state and immune suppression to some degree (Bradford et al., 2015).
- Energy use for the immune functioning might be a priority over milk production (Kvidera et al., 2017)



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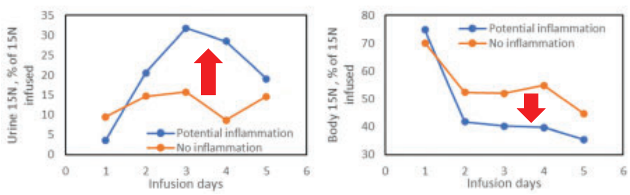
Is there a priority for AA over milk protein synthesis??

(Rebelo et al., 2022; unpublished)



15N, % of 15N infused as Lys

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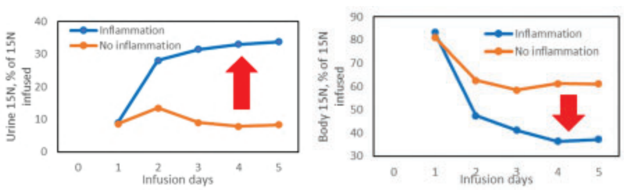
Is there a priority for AA over milk protein synthesis??

(Kim et al., 2023; unpublished)



15N, % of 15N infused as Lys

More studies are needed to understand AA utilization in fresh cows

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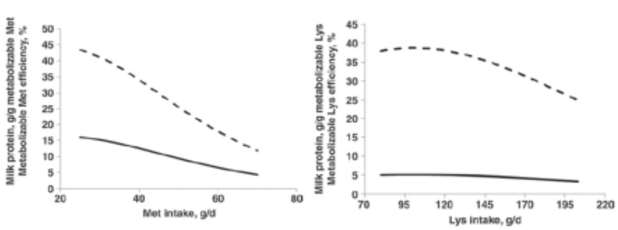
3. Potential factor:

Varying prediction results between models



(Vyas and Erdman, 2009)

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Differences in predictions of the Req. and Supp. are not small for some AA

	NASEM, 2021			CNCPS, 2015		
g/d	HCP	LCP	LLCP	HCP	LCP	LLCP
Lys	203	183	169	203	190	180
Met	52	48	45	60	56	54
His	64	56	51	75	69	65
Lys Req.	195	195	195	195	196	197
Met Req.	62	62	62	69	69	70
His Req.	66	67	67	65	65	66
Lys Balance	8	-12	-26	9	-6	-17
Met Balance	-10	-14	-17	-9	-13	-16
His Balance	-2	-11	-16	10	4	-1

HCP: 17% CP
LCP: 15.5% CP
LLCP: 14.0% CP

More information about models
: Martineau et al., 2024 JDS in press

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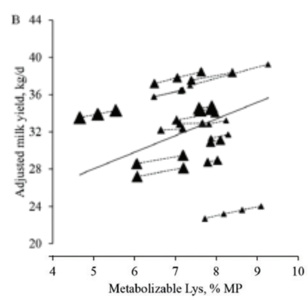
Lys requirement might be greater than predicted by the current models

Meta-analysis by Arshad et al. (2024; JDS in press)



Milk yield increased linearly from 6.5 to 8.5% Lys of MP

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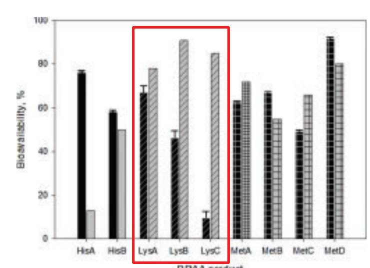
4. Potential factor:

Bioavailability of RP-AA

- Feeding RP-AA with incorrect bioavailability leads to deficient or excessive supply of certain AA



(Räisänen et al., 2020)

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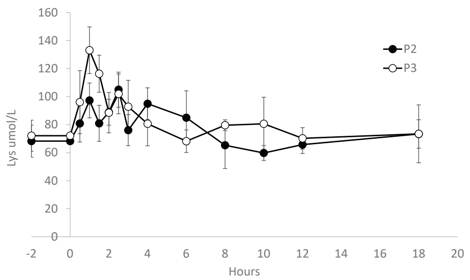
Caution for absolute bioavailability from plasma AA appearance



(Rebelo et al., 2022; unpublished)

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Summary

- Feeding RP-AA is common in practice
  - Consistent responses are critical
- Reponses to RP-Lys are likely more variable
  - Results from the recent meta-analysis are promising but a small number of studies
  - Cows responded to RP-Lys for Milk yield more than milk protein
- Factors for more consistent responses to RP-Lys
  - Understanding the roles of Lys in the mammary glands
  - Understanding the requirement of AA for fresh cows
  - Determining accurate bioavailability of RP-Lys
    - A gold standard in vivo technique is needed to improve in vitro methods

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

Dr. José Santos
University of Florida

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

José Eduardo P. Santos
University of Florida
Gainesville, USA

UF ANIMAL SCIENCES

UF UNIVERSITY of FLORIDA
Department of Animal Sciences

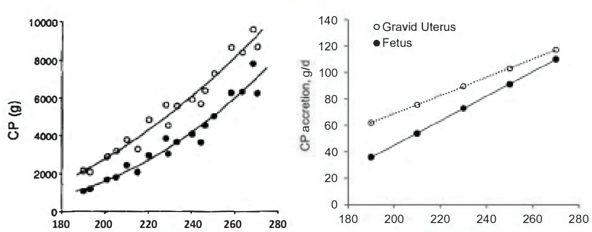
1

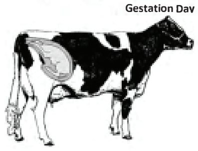
Outline

- ✓Contrast the NASEM (2021) with empirical data on protein needs for prepartum cows
- ✓Mobilization of protein in early lactation
- ✓Disease effects on AA partition
- ✓Contributions of AA to gluconeogenesis in periparturient cows
- ✓Responses to AA infusions in early lactation

2

Accretion of CP in Gravid Uterus of Pregnant Cows





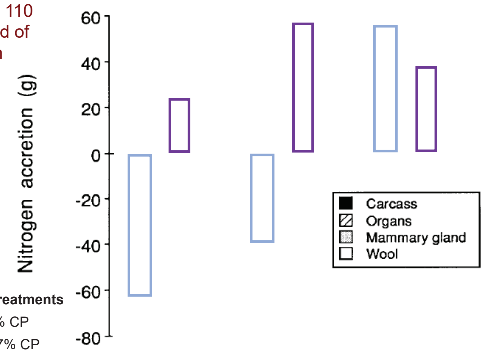
Bell et al. (1995) J. Dairy Sci. 78:1954-1961

3

Tissue N Accretion in Late pregnancy

Incorporation into mammary tissue

Between 110 and 140 d of gestation

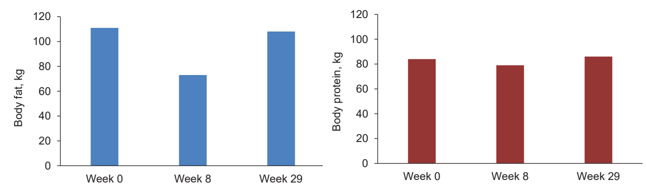


Dietary treatments
LP = 7.9% CP
MP = 11.7% CP
HP = 15.9% CP

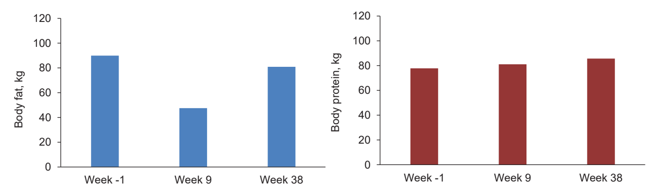
McNeil et al. (1997) J. Anim. Sci. 75:809-816

4

Body Composition



Gibb et al. (1992) Anim. Prod. 55: 339-360



Andrew et al. (1995) J Dairy Sci 78:1083-1095

5

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) = $[(0.20 \times BW^{0.60}) \times 0.85]/ 0.69$
  - ✓ 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%

6

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

7

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

8

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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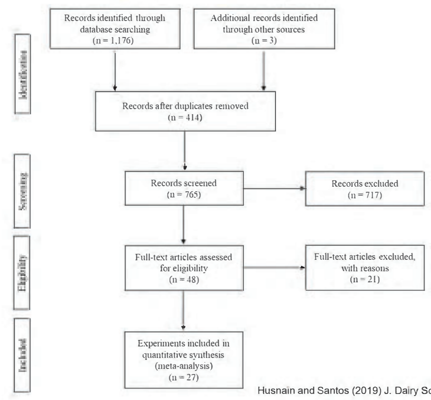
Prisma Diagram



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

10

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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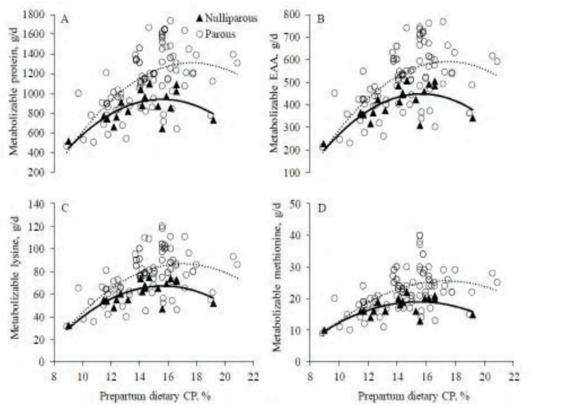
Predicted Supply of Metabolizable Amino Acids According to Prepartum Dietary CP



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

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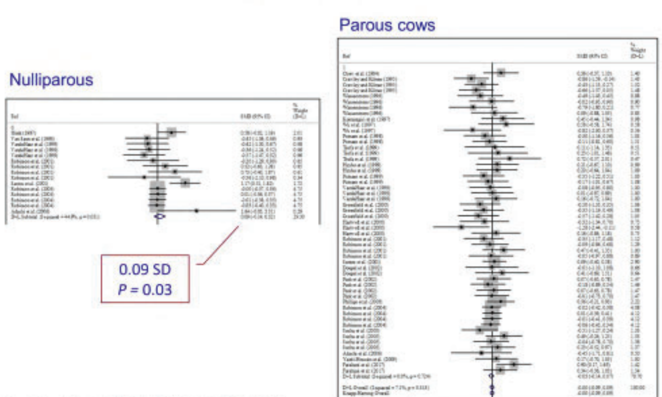
Milk Yield Responses to Increasing Metabolizable Protein Prepartum



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

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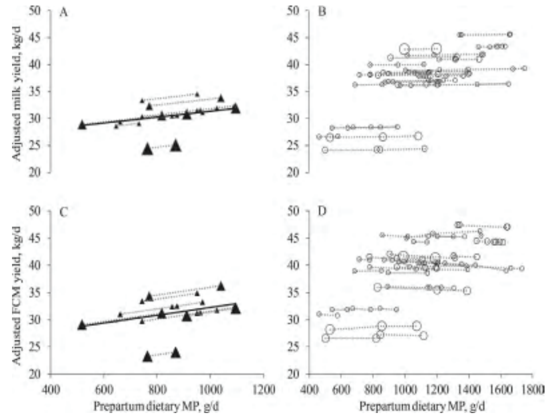
Yields of Milk and FCM



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

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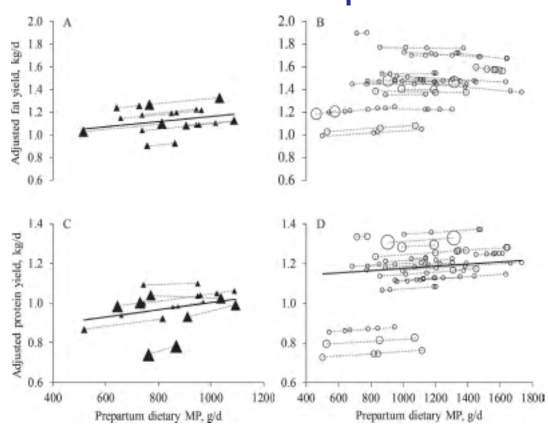
Yields of Milk Components



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

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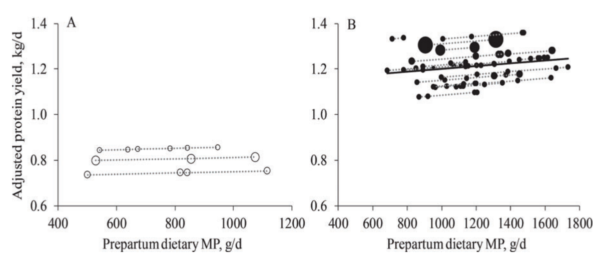
Yields of Milk Components



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

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Recent Work at Cornell University

96 parous Holstein cows. 28 d prepartum to 21 DIM

	Treatment			
Item	CC	CH	HC	HH
Prepartum				
MP, % diet DM	8.7	8.7	11.5	11.5
Metabolizable MET, g/Mcal of ME	1.24	1.24	1.24	1.24
Metabolizable LYS, g/Mcal of ME	3.86	3.86	3.86	3.86
Postpartum				
MP, % diet DM	10.3	13.3	10.3	13.3
Metabolizable MET, g/Mcal of ME	1.15	1.15	1.15	1.15
Metabolizable LYS, g/Mcal of ME	3.20	3.20	3.20	3.20

	Treatment				
Item	CC	CH	HC	HH	SEM
Milk, kg/d	39.2	42.4	38.0	44.7	1.0

Prepartum C vs. H: 40.8 vs. 41.4 kg/d

Postpartum C vs. H: 38.6 vs. 43.6 kg/d

Westhoff et al. (2023) J. Dairy Sci. 106 (Suppl. 1): 37 (Abstr.)

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Summary 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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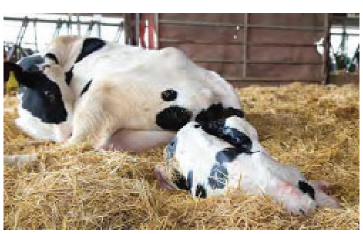
Issues Start Before or Around Calving



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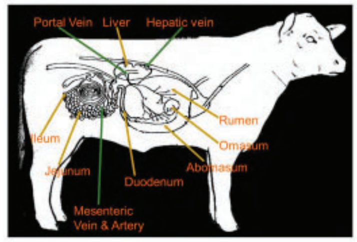
Inflammatory Disease and Nutrient Flux

- ✓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



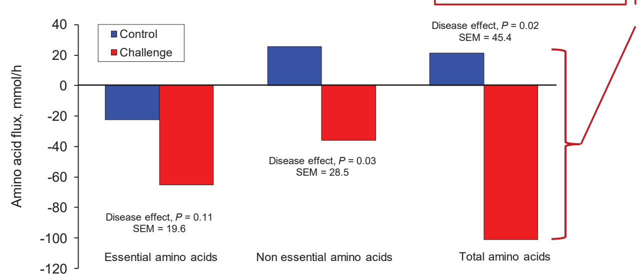
Burciaga-Robles et al. (2009)

22

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

	Treatment		
Ingredients	**Control**	**High MP**	**High MP + AA**
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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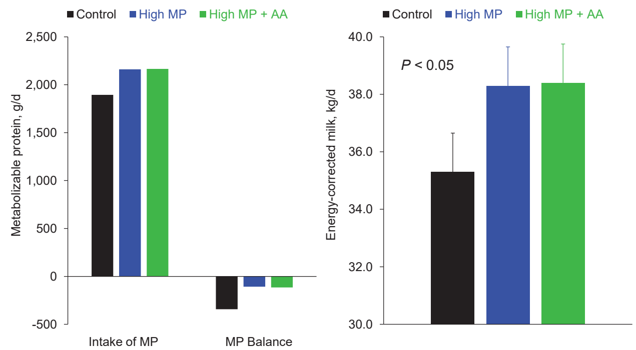
Responses in the First 3 Weeks of Lactation



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

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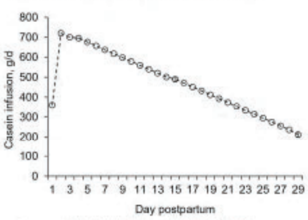
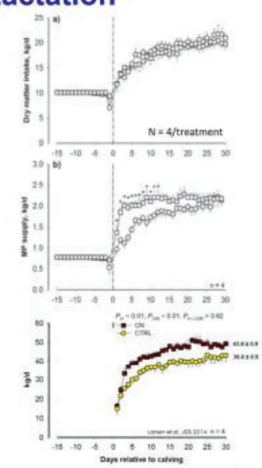
Protein in Early Lactation

Item	Prepartum	Postpartum
NE_L, Mcal/d	16.0	30.3
Crude protein, % DM	14.1	15.9
NDF, % DM	38.4	29.9
Starch, % DM	20.2	23.6
Metabolizable protein, g/d	775	1760

Treatment: ± abomasal infusion of casein (91% protein) to supply 360 g/d at 1 DIM, 720 g/d at 2 DIM, followed by daily reductions of 19.5 g/d ending at 194 g/d at 29 DIM.



Larsen et al. (2014) J. Dairy Sci. 97:5608–5622



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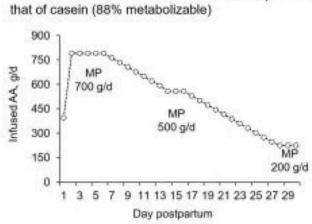
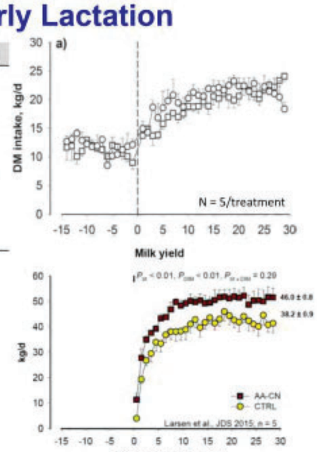
Protein in Early Lactation

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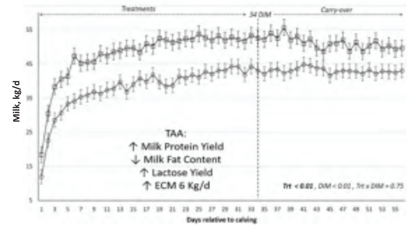
Effect of Abomasal Infusion of EAA or TAA on Production in Early Lactation Cows

- 9 Holstein cows received abomasal infusion of EAA (n=5) or TAA (n=4) from calving to 34 DIM
- 400 g/d day 1, 805 g/d on d 2 to 5, then daily reductions until 35 DIM when they received 0 g/d



	Treatment			
Item	EAA	TAA	SEM	P <
Milk yield, kg/d	39.3	47.9	1.4	0.01
Milk protein, %	4.70	4.11	0.30	0.06
Milk protein yield, g/d	1,393	1,635	50	0.001

Bahloul et al. (2021) J. Dairy Sci. 104 (Suppl. 1):149 Abstr.

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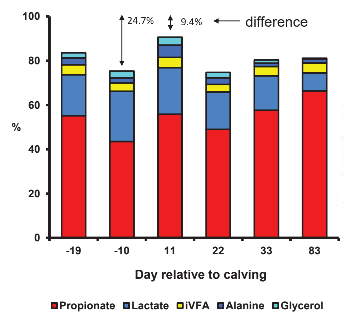
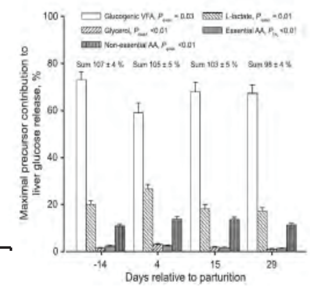
Contributions to Hepatic Gluconeogenesis in Transition Cows



Reynolds et al. (2003) J. Dairy Sci. 86:1201–1217



Larsen and Kristensen (2013) Animal 7,10:1640–1650

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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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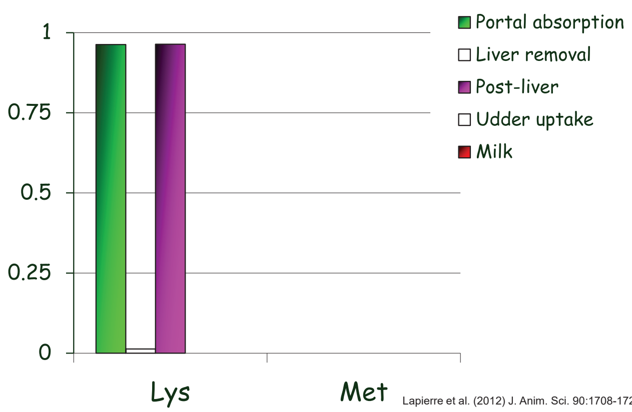
Partition of Digestible AA



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

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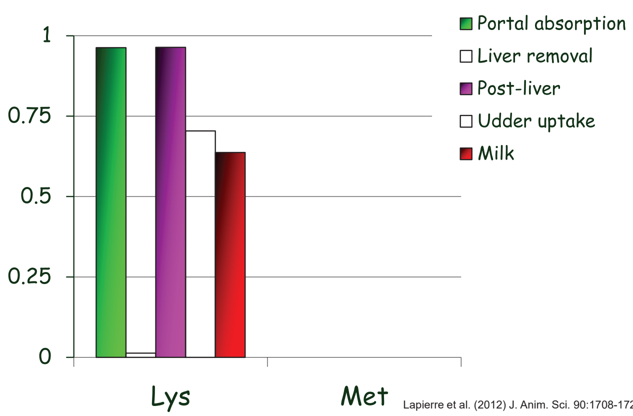
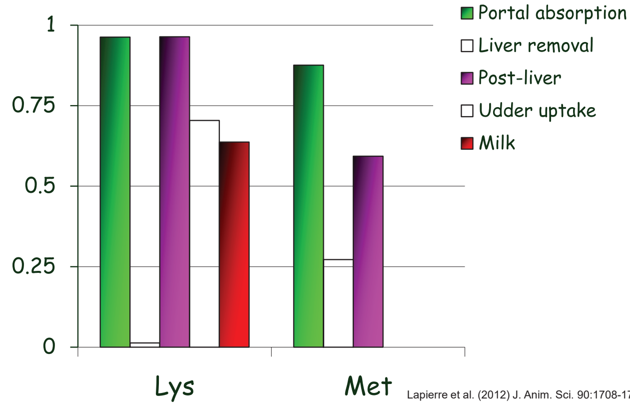
Partition of Digestible AA



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

33

Partition of Digestible AA



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

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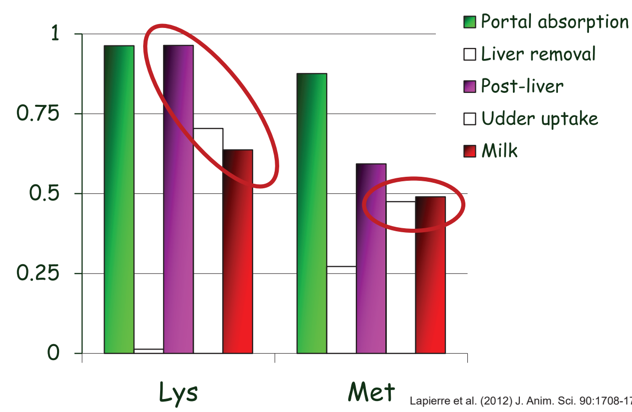
Partition of Digestible AA



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

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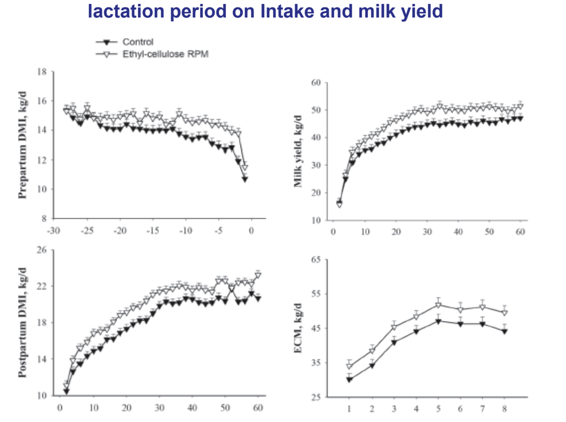
Effect of RP-Met supplementation during the prepartum and early lactation period on Intake and milk yield



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

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Responses to Supplemental RP Methionine During Transition

Table 1. Responses to initiating supplemental rumen protected Met (sRPMet) feeding to transition cows[1]

	Controls				Response to sRPMet				
Item	N[2]	n[2]	Mean	SD	N[2]	n[2]	Mean	SEM	P
Prepartum[3]									
DMI, kg/d	22	309	13.1	1.68	26	362	0.19	0.140	0.184
BW, kg	15	221	713	57.4	19	274	−0.08	2.40	0.974
BCS	14	207	3.51	0.231	18	260	−0.01	0.020	0.846
Postpartum[4]									
DMI, kg/d[5]	29	387	19.4	3.54	40	510	0.45	0.156	0.006
DMI_{21DIM}							1.38	0.283	<0.001
BW, kg	21	303	620	40.9	29	404	−2.13	3.10	0.498
BCS	16	238	2.92	0.326	20	291	0.01	0.031	0.707
Yield									
Milk[5], kg/d	29	387	35.6	6.44	40	510	0.80	0.271	0.006
$Milk_{21DIM}$							2.13	0.515	<0.001
Fat[5], g/d	29	387	1288	285.8	40	510	75.8	11.63	<0.001
Fat_{21DIM}							117.6	23.32	<0.001
True Protein[5], g/d	26	362	1032	168.8	34	456	43.4	10.4	<0.001
$True Protein_{21DIM}$							92.1	18.39	<0.001

[1]Control and response estimates weighted by the √n, where n is the number of cows for control or sRPMet groups.
[2]n = Number of control means or sRPMet responses. n = Number of control or sRPMet cows.
[3]Length of prepartum sRPMet feeding averaged 19.3 d (±4.23 SD) with 8.20 g (±2.94 SD) of metabolizable Met.
[4]Length of postpartum observations averaged 85.9 d (±38.36 SD) with 10.53 g (±3.30 SD) of metabolizable Met.
[5]Dependent on the duration of measurement (final DIM P < 0.05).

Zanton and Toledo (2024) J. Dairy Sci. Commun. https://doi.org/10.3168/jdsc.2023-0512

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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
Net energy								
Mcal/kg	1.55[b]	1.34[c]	1.75[a]	1.37[c]	0.06	0.02	< 0.001	0.09
Mcal	10.2	8.9	14.8	11.7	1.6	0.005	0.12	0.50
Somatic cell score	6.35	7.15	6.51	6.58	0.38	0.50	0.22	0.22
Brix, %	26.2	27.3	26.4	26.4	1.0	0.67	0.55	0.51
Immunoglobulin G, g	494	559	790	704	115	0.02	0.98	0.42

[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.)

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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 (not available in Brazil!)
  - ✓ 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 might likely increase body fat mobilization in the first 2 to 4 weeks of lactation

39

40

Feeding and Managing Cows for a Healthy and Productive Life

Dr. Mike VandeHaar
with help from Barry Bradford and Miel Hostens
Professor of Nutritional Physiology
Department of Animal Science
Michigan State University

Feeding and managing cows for a healthy and productive life.

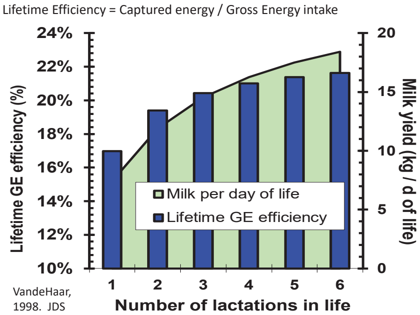
Mike VandeHaar
Department of Animal Science
Michigan State University
With help from: Barry Bradford and Miel Hostens and discussions at DC-45

1

What is optimal for productive life?

Energy is captured in milk, body tissues, and conceptus.

Lifetime Efficiency = Captured energy / Gross Energy intake



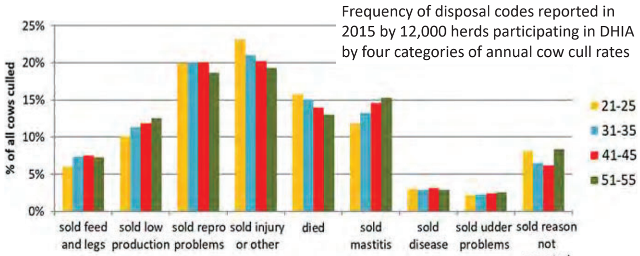
These calculations are for a cow that calves at 24 months, produces 9000 kg (20,000 lb) milk/year at maturity, and leaves the farm as quality beef that will be harvested.

Lifetime profit will depend on feed and other costs associated with raising heifers and producing milk and the price of milk and cull cows.

2

Why are cows culled?

Frequency of disposal codes reported in 2015 by 12,000 herds participating in DHIA by four categories of annual cow cull rates



- Cull reasons for herds with low or high cull rates are generally similar.
- High production protected cows from culling.

Data from CDCB as shown in De Vries and Marcondes, 2020.

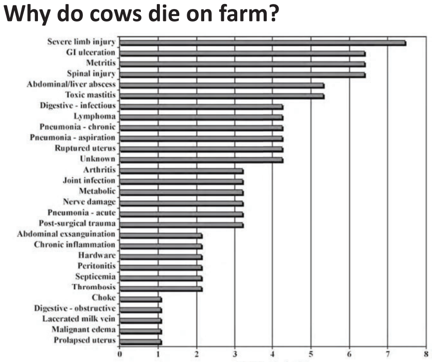
3

Which trait matters more: Productive Life or Livability?

- Cows that are healthy and in good body condition can be marketed with pride (~40% of culled cows based on disposal codes).
- Cows that are skinny and sick can be marketed and we hope consumers don't see them (40-50%)
- Selling a cow is the most profitable day of her life.
- Euthanizing a cow is the most expensive day of her life (lost opportunity).
- Cows that die on the farm (14%) may never recover their rearing costs.

4

Why do cows die on farm?



Cow deaths on a Colorado dairy. McConnel at al., 2008. JDS

Inflammatory and infectious diseases were the main causes of death.

Injuries accounted for ~20%

We need more data on reasons for cow mortality!

5

When do cows die on farm?

Cow deaths on a Colorado dairy. McConnel at al., 2008. JDS

Table 2. Descriptive statistics and Chi-square analysis of 94 dairy cow deaths by source and parity

Category	Description	Cows, n	Deaths, n	Mortality,[1] %	Chi-square *P*-value
Source	Home-raised	851	47	5.5	0.12
	Purchased	612	47	7.7	
Parity	1	645	28	4.3	<0.001
	2	393	24	6.1	
	3	245	16	6.5	
	≥4	180	26	14.4	

[1]Mortality percentage is calculated as the number of deaths divided by the herd inventory on March 1, 2006, per respective category.

- 21 % of deaths occurred by 6 d after calving
- 45 % of deaths occurred by 30 d after calving

→ ***Maybe culling at end of 3rd lactation is a good target***

6

Feeding Dairy Cows for Longevity. Randy Shaver, 2006

Randy's Take-home points (my paraphrase). My additions in red.

- To increase longevity, we must focus on preventing calving/transition problems, mastitis, reproductive problems, and lameness.
- To improve transition health, feed to minimize metabolic and digestive disorders. Common sense and cow sense are needed. Provide plenty of forage fiber, including some slowly digested fiber. Don't let cows get fat.
- To reduce mastitis, supplement with vitamin E and selenium.
- To improve reproduction, make sure energy and protein nutrition are optimal. Specific fatty acids and amino acids may help.
- To reduce lameness, diet formulation, preparation and delivery, feed bunk management, cow management, and cow comfort are all important. Supplemental biotin also helps.
- Bioactive nutrients can improve immune function and decrease inflammation.

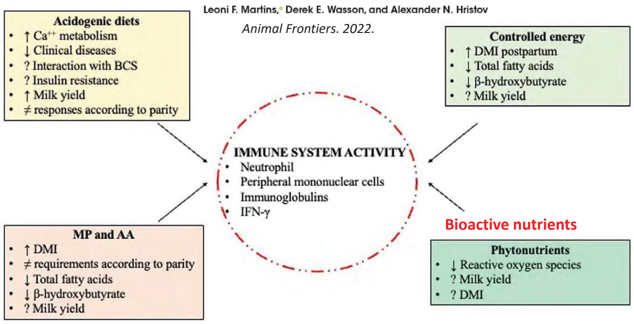
7

A nice review.

Feeding dairy cows for improved metabolism and health

Leoni F. Martins, Derek E. Wasson, and Alexander N. Hristov

Animal Frontiers. 2022.



8

Are we feeding too much starch?

- Laminitis is usually caused by sub-acute ruminal acidosis (SARA). SARA is increased in diets that contain high fermentable starch and low forage NDF.
- High starch content, especially abrupt increases in highly fermentable starch, increases systemic inflammation. Cows with systemic inflammation are more prone to disease.
- High starch content can cause excess body condition gain.

BUT ➔ feeding more starch enables greater milk production

So, how much is too much starch?

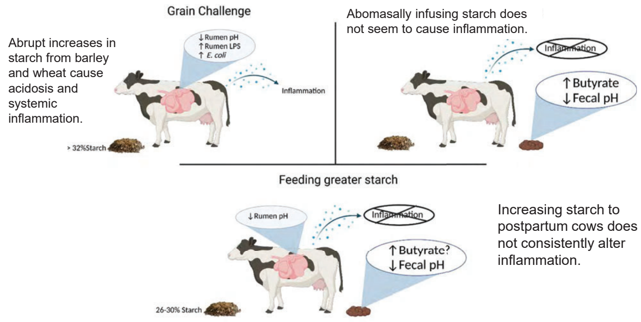
This is a balancing act.

9

Starch and risk of systemic inflammation.

Krogstad and Bradford (2023)

JDS Communications® 2023; 4:14–18



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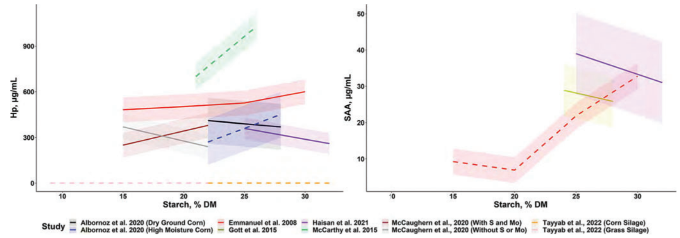
Responses in markers of inflammation to dietary starch



Plasma haptoglobin (Hp) and serum amyloid A (SAA) concentrations in chronic starch feeding experiments where lactating cows were fed varying starch concentrations. *Dashed lines indicate statistical significance in the experiment; solid lines indicate lack of significance*. The Albornoz, Haisan, and McCarthy studies used periparturient cows; others used cows ranging from 30 to 150 DIM. From Krogstad and Bradford, 2023. JDSC.

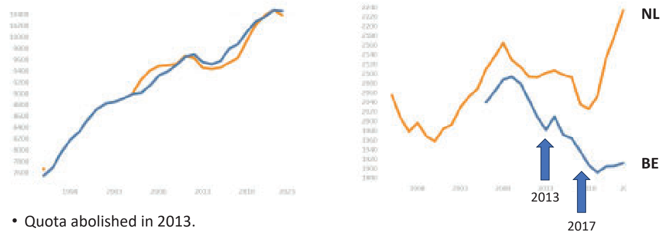
11

Netherlands vs Belgium: is starch the reason BE culls cows earlier?

- Dairy cows are 90% Holstein with average milk production at ~10,000 kg/yr in both countries
- Average number lactations in 2022
  - NL: 3.9 calvings, productive life 1433 days, age at culling 2233 days of age
  - BE: 3.1 calvings, productive life 1109 days, age at culling 1911 days of age
- Typical %starch – Belgians feed more starch!
  - NL: ~15% starch, Less than 25% of forage is Corn silage
  - BE: ~20% starch, ~75% of forage is corn silage
- Reasons for culling
  - NL: Fertility 22%, Legs 18%, SCC 14% — NL has 40:60 heifers:cows
  - BE: Fertility 14%, Surplus 14%, Beef cull 12% — BE has 50:50 heifers:cows

12

Netherlands vs Belgium: is starch the reason BE culls cows earlier?



- Quota abolished in 2013.
- In NL, but not BE, farms are paid a small premium for a higher age at culling.
- In 2017, the NL began charging farms for P waste. 2 heifers = 1 cow for manure P

→ ***The difference in age at culling is probably not due to starch.***

13

Starch in parlor-grain feeding vs TMR

Grazing/free-choice forage with corn-based grain in the parlor and a magnet feeder.

We fed a lot of starch.

We had a lot of older cows.

TMR – with similar amount of starch.

Fewer older cows.

Lots of replacements.

14

The importance of managing body condition

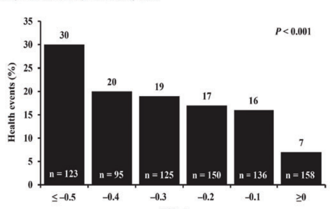
J. Dairy Sci. 102:5577–5587
https://doi.org/10.3168/jds.2018-15828
© American Dairy Science Association®, 2019.

The high-fertility cycle: How timely pregnancies in one lactation may lead to less body condition loss, fewer health issues, greater fertility, and reduced early pregnancy losses in the next lactation

E. L. Middleton, T. Minela, and J. R. Pursley*
Department of Animal Science, Michigan State University, East Lansing 48824

Cows with shorter previous calving intervals
- Have lower body condition at calving
- Lose less condition in the first 30 days postpartum

Compared to cows that lose condition, those that maintain or gain condition:
- Have fewer health events in the first 30 DIM
- Produce 6% less milk at 60 DIM
- Are more likely to be pregnant by 130 DIM



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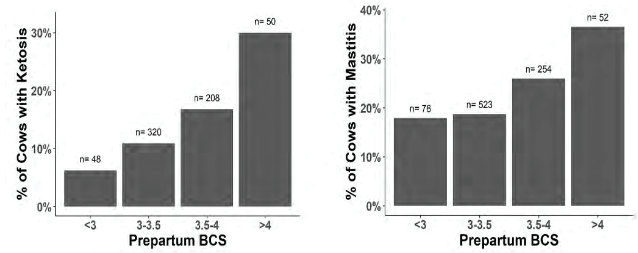
Fatter cows have more transition disease



Krogstad et al., MSU, unpublished

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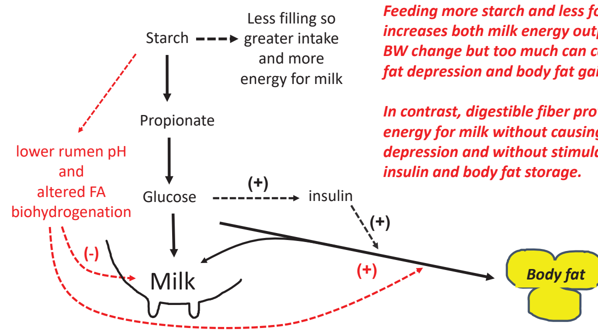
Feeding to manage body condition



Feeding more starch and less forage fiber increases both milk energy output and BW change but too much can cause milk fat depression and body fat gain.

In contrast, digestible fiber provides energy for milk without causing milk fat depression and without stimulating insulin and body fat storage.

17

Partitioning in cows fed beet pulp in place of barley grain

18 Holstein cows in last 2 months of lactation
- **171 ± 16 days pregnant**
- **289 ± 35 days in milk**

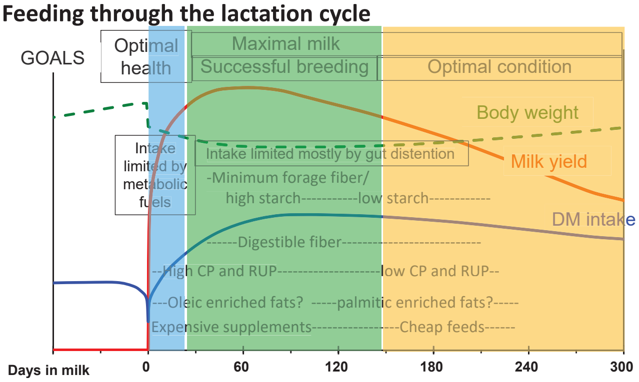
Treatments:
0% beet pulp, 24% barley (19% starch)
9% beet pulp, 15% barley (15% starch)
17% beet pulp, 6% barley (12% starch)

	Beet pulp in diet			
	0%	8.6%	17%	*P*
DMI, kg/d	18.1	17.5	17.7	NS
Milk E, MJ/d	58.2	60.0	63.5	0.1, L
BCS change/per.	+0.13	-0.09	-0.12	0.01, L
BFT, mm/per.	+2.5	-0.4	-1.6	<0.01,L
Insulin, ng/ml	0.93	0.75	0.72	0.05, L
pH	5.77	5.96	6.21	0.001, L

Mahjoubi et al., 2009, AFST 153:60-66

18

Feeding through the lactation cycle



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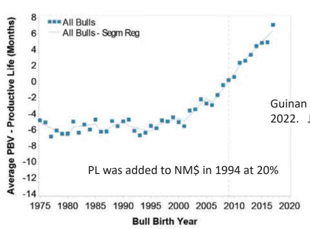
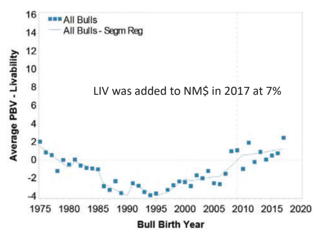
Focusing too much on productive life now may hinder progress.

- Replacement should occur when the challenger is better than the incumbent (De Vries, 2021)
  - *Better based on the all the traits we care about, considering phenotype and genotype.*
- Based on current NM$, the next generation will have the genetics to produce more fat and protein, live longer, be healthier, be more efficient, and be more fertile.
- Goal should be to replace a cow before she gets sick, especially before she dies on the farm.





20

Net Merit (NM$) – Selection Index

	1971	2018	2021
Milk Yield	52	-1	0
Fat Yield	48	27	22
Protein Yield		17	17
Udder Composite		7	3
Feet/legs Composite		3	1
Daughter Pregnancy Rate		7	5
Conception Rate (HCR + CCR)		3	2
Calving Ability		5	3
Somatic Cell Score		-4	-3
Health trait subindex		2	2
Productive Life		12	15
Livability (LIV + HLIV)		7	5
Early first calving			1
Body Weight Composite		-5	-9
Residual Feed Intake			-12

Feed Saved

21

Breeding for Productive Life and Livability

Van Raden et al, 2021. USDA AIP reports.

Heritabilities of selected traits

Milk yield	Fat yield	Protein yield	BW comp	RFI	Udder traits	Feet/ legs	Somatic cells	Heath traits $	**Prod. life**	**LIV**	Calving ability	Fertility traits
0.20	0.20	0.20	0.40	0.14	0.27	0.25	0.12	0.01	**0.08**	**0.013**	0.07	~0.03

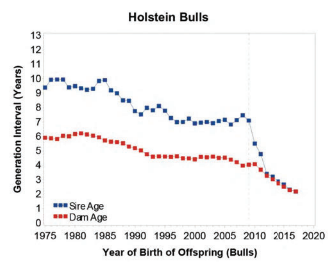
Genetic correlations of PL and LIV with other traits

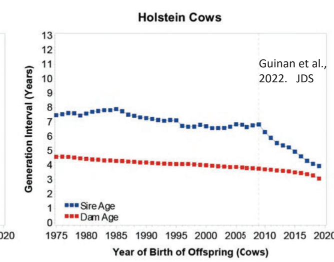
	Milk yield	Fat yield	Protein yield	BW comp	RFI	Udder traits	Feet/ legs	Somatic cells	Heath traits $	Prod. life	LIV	Calving ability	Fertility traits
PL	0.11	0.09	0.13	-0.22	-0.08	0.00	-.01	-.46	0.66	1	0.73	0.36	~0.5
LIV	-0.19	-0.12	-0.18	-0.21	-0.07	-0.29	-0.11	-0.29	0.49	0.73	1	0.20	~0.4

If you want cows that have longer productive lives, breed for it and also breed for smaller cows that produce more milk. Breeding for livability may not make much difference.

22

Genetic progress is rapid compared to 20 years ago





23

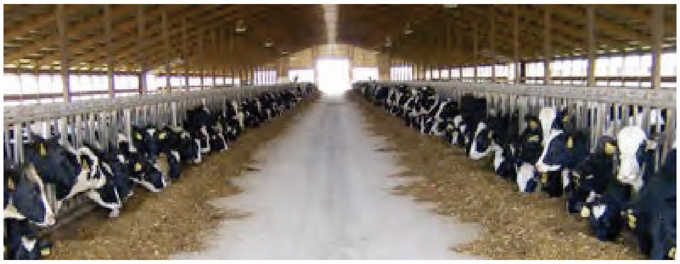
Summary

- Replacement heifers from high NM$ bulls will have the genetics to produce more fat and protein, live longer, be healthier, be more efficient, and be more fertile. Focusing too much on longevity now may delay its improvement in the long term.
- Livability is more important than longevity. Older cows are more likely to die on farm. The goal should be to sell cows while they are still healthy and fit to make quality beef.
- Follow NASEM recommendations for minerals, vitamins, and prepartum acidogenic diets.
- Cows that are too thin or too fat, that are lame, and that have systemic inflammation seem more likely to contract serious disease or suffer from serious injury, and then die on farm.
- High starch is useful at peak lactation to maximize milk and promote positive energy balance for successful breeding. However, high starch in late lactation will promote excessive body condition gain. Too much starch in fresh cows and late lactation cows may cause ruminal acidosis, overconditioning, systemic inflammation, and laminitis.
- One diet can never be optimal for all lactating cows!

24

Questions

- Will feeding to reduce inflammation benefit longevity?
- Can we refine maintenance diets to confidently prevent condition gain?
- Why do cows die on farms and what can we do to prevent it?

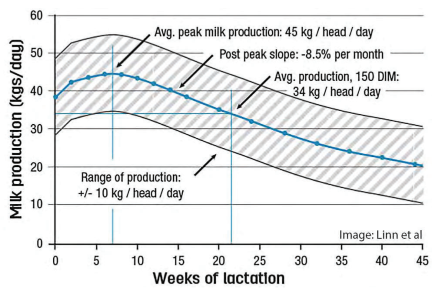


25

Feeding Cows to Reach Higher Peaks

Dr. Bill Weiss
Ohio State University

Feeding cows to reach higher peaks



Bill Weiss

The Ohio State University
College of Food, Agricultural, and Environmental Sciences

1

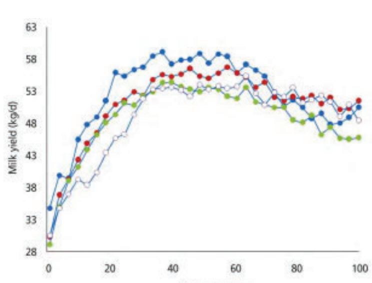
High peaks

1. Cows must calve healthy
2. Calve cows in proper body condition
3. Avoid metabolic disorders in early lactation
4. Keep mobilization of body reserves acceptable

Female mammals are designed to mobilize body reserves to provide for the offspring

2

Dry off and calve at correct BCS



3-3.25
3.5-3.75
4-4.25
>4.25

Zhao et al., 2019

3

Dry off and calve at correct BCS

1. BCS at calving < 2 = ⬇milk
2. Cows > 3 at dry off, increasing BCS = ⬇milk
3. If cows < 3 at dry off, increasing BCS = ⬆milk

Mishra et al., 2016

4

Specific carbohydrate needs for prefresh ?

✓ Increasing prefresh energy (more starch less NDF)
- Increases prepartum DMI
- Generally little effect on postpartum DMI
- Most studies show no effect on milk yield

✓ ". . . benefits of feeding a diet of moderate starch and fiber to transition ruminal cells and rumen tissue morphology from a high-forage gestation diet to a higher-starch lactation diet are not evident." (NASEM, 2021)

In total, data do not support the need for a higher starch prefresh diet

5

Prefresh Protein (Lean et al., 2013)

Response (Control vs +CP)

Range: -0.6 to 1.2 kg/day milk
Average: 0.1 kg/day milk
Negative:Positive comparisons: 46:54

Diets	CP Range	CP Average
Control	9.7 to 14.1%	12.3%
Treatment	11.7 to 23.4%	15.9%

6

Dry Cow Diet MP and Milk Production

Meta-analysis (Husnain and Santos, 2019)
~27 comparisons for heifers
~97 comparisons for cows
Mostly prefresh experiments

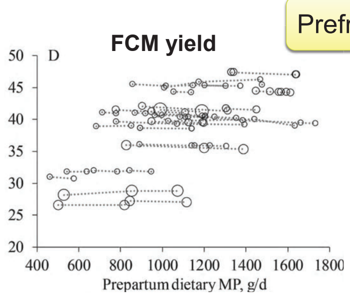
Diets: ~9 to 21% CP (**avg = 14**)
: 6 to 13% MP **(avg = 9.3)**

MP calculated using NRC 2001

7

Increased prepartum MP did not affect milk yield by cows with minor effect on milk protein yield in cows >36 kg/d)

Prefresh **COWS**: ~12-13% CP



Milk protein yield by cows producing >36 kg
60 g/1000 g MP intake

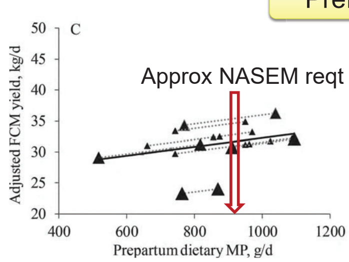
No effect for cows <28 kg/d

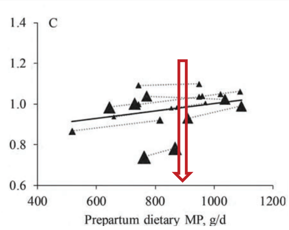
(Husnain and Santos, 2019)

8

Increased prepartum MP increased FCM and protein yield by 1st lactation cows

Prefresh **HEIFS** ~15% CP





(Husnain and Santos, 2019)

9

Fresh Group (0- ~21 DIM)

Potential costs

1. Need another diet (inventory, labor)
2. Another pen move for cows (regrouping)
   – may reduce DMI and milk
3. Expensive diet

10

Fresh Group (0- ~21 DIM)

Potential benefits

1. Increased milk
2. Increased peak (carry over effects)
3. Targeted use of expensive additives
   - RP-choline in fresh period increased milk for next 9 weeks

11

Pen Moves/Regrouping for Fresh Cows

- Research not available to answer question
- If having true fresh group causes regrouping issues, need to make it worthwhile

Diet must be different enough to yield responses

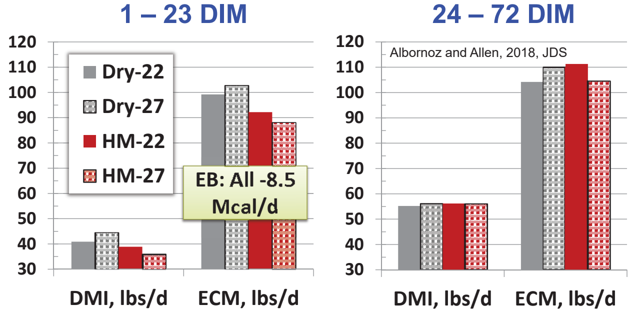
12

Nutrition for Fresh Group (~3 wks)

- Carbohydrates
- Fat
- Protein/amino acids

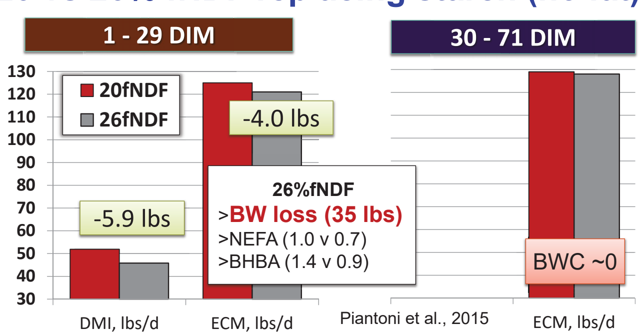
13

Starch (vs. SH) for Fresh (29% in CO diet)



14

20 vs 26% fNDF replacing starch (no fat)



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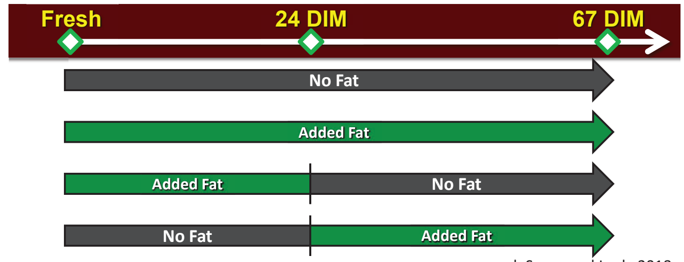
Supplementing 0 or 1.5% palmitic acid to fresh vs later lactation cows



deSouza and Lock, 2018

16

Supplementing palmitic acid to fresh vs later lactation cows (24% fNDF)

- All vs no fat (67 days)
  - 24 lbs more milk protein
  - 33 lbs more milk fat
  - Lost 53 lbs more BW
- Fat after 24 day vs no fat
  - 9 lbs more milk protein
  - 26 lbs more milk fat
  - No difference in BW change

Delaying fat until 25 days

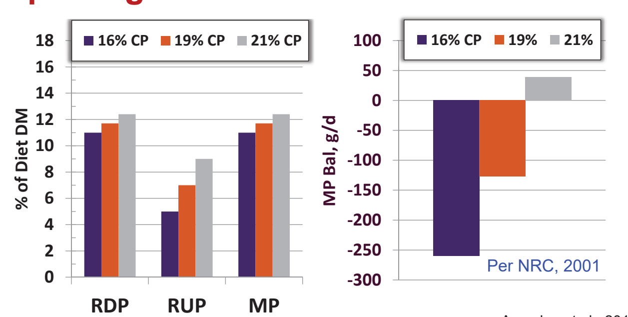
Cost 15 lbs of milk protein and 7 lbs of milk fat

Saved 18 lbs PA (not fed) **and 53 lbs of BW**

deSouza and Lock, 2018

17

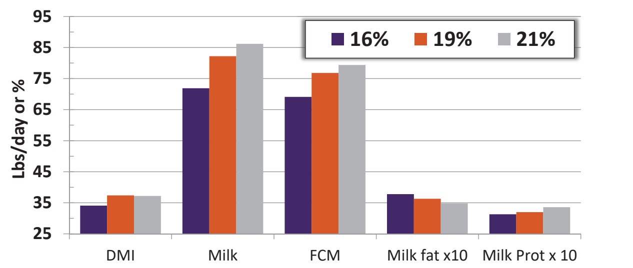
Replacing starch with MP to fresh cows



Amanlou et al., 2017

18

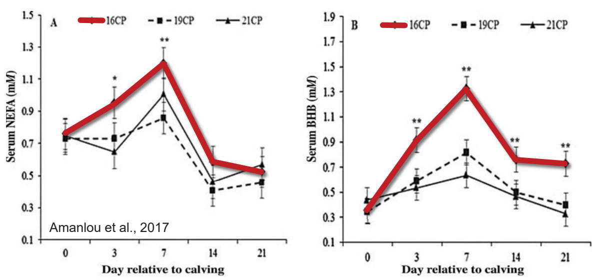
Replacing starch with CP for fresh cows



Amanlou et al., 2017

19

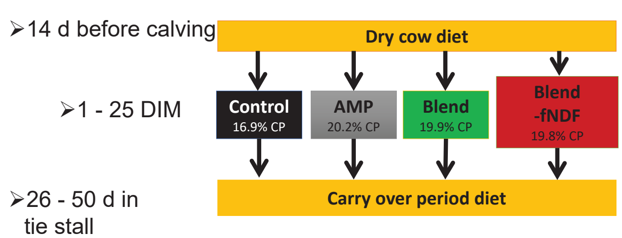
Because high CP increased DMI and digest, higher milk ≠ ketosis



20

High CP and AA on fresh cows and carryover

Tebbe and Weiss, 2021



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Treatments

Tebbe and Weiss, 2021

Control: Supplemental CP from SBM
AMP: Supplemental CP from SBM and treated SBM
Blend: Supplemental CP from SBM, treated SBM, corn gluten meal, canola meal, RP-his, RP-met, RP-lys
Blend-fNDF: Byproduct NDF replaced forage

All diets provided ~20 g of RP-met

22

Nutrient composition

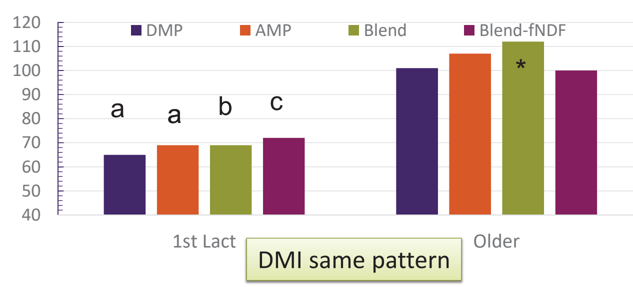
Tebbe and Weiss, 2021

	Control	AMP	Blend	Blend -fNDF
CP, %	16.9	20.2	19.9	19.7
MP, %	**11.3**	**14.3**	**14.3**	**14.3**
NDF, %	32.4	30.9	31.1	30.9
fNDF, %	24.3	24.4	24.3	19.6
Starch	23.7	22.8	23.7	25.4
Lys, % of MP	6.6 (0.75)	6.2 (0.89)	6.6 (0.94)	6.6 (0.94)
Met, % of MP	2.3	2.0	2.3	2.3
His, % of MP	2.2	2.2	2.3	2.3

23

High CP and AA on fresh cows and carryover

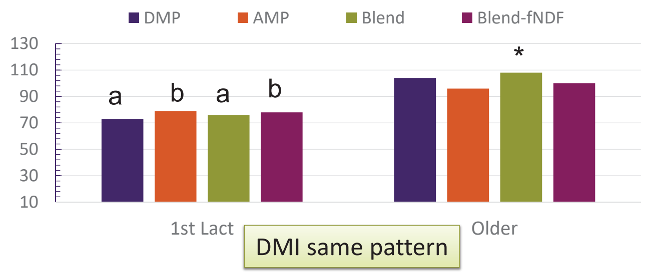
Fresh ECM (Tebbe and Weiss, 2021)



24

High CP and AA during fresh on carryover

ECM 26-92 DIM (Tebbe and Weiss, 2021)



25

High CP and AA on fresh cows and carryover

(Tebbe and Weiss, 2021)

Control:	9508 lbs
AMP:	9121 lbs
Blend:	10,005 lbs
Blend-fNDF:	9209 lbs

Feeding 21% CP diet with good AA balance for 24 d yielded **500 lbs** more ECM first 92 days with about 160 lbs more DMI

26

Summary: For high peaks

- Proper energy balance starting at dry off
- Feed to prevent metabolic disorders
- Have a fresh group (3-4 weeks)
- Moderate starch (25%) and fNDF (20%) in fresh group
- High MP (12%) with good AA profile in fresh group

27

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Dietary Interventions for Prevention of Mineral Related Disorders Postpartum

Dr. José Santos
University of Florida

Dietary Interventions for Prevention of Mineral Related Disorders Postpartum

José E.P. Santos
Department of Animal Sciences
University of Florida

ANIMAL SCIENCES

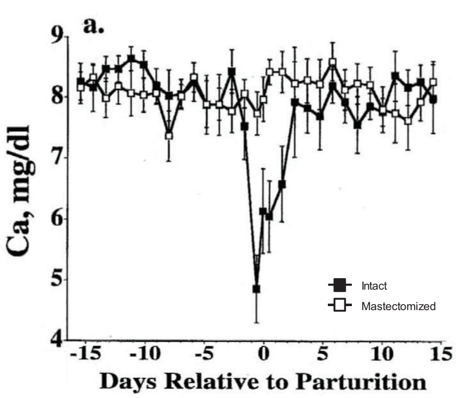
1

Outline

- ✓ Why dairy cows develop hypocalcemia
- ✓ Impacts of hypocalcemia on dairy cow health
- ✓ Methods of prevention of hypocalcemia
  - ✓ Induction of compensated metabolic acidosis
  - ✓ Restricted Ca absorption
  - ✓ Reduced P intake and blood phosphate
  - ✓ Oral Ca dosing
- ✓ Application of DCAD for prevention of mineral-related disorders

2

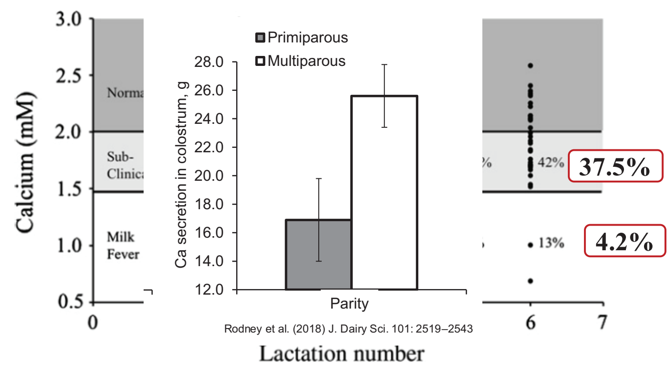
Why Dairy Cows Develop Hypocalcemia



Goff et al. (2002) J. Dairy Sci. 85:1427-1436

3

Why Dairy Cows Develop Hypocalcemia



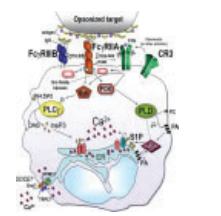
Reinhardt et al. (2011) Vet. J. 188:122-124

4

Why Dairy Cows Develop Hypocalcemia

✓ Activation of immune cells?

Neutrophils		
1. Neutrophil no.	3,000,000	per mL
2. Diameter of neutrophil	15	µm
3. Cytosol vol./cell vol.	50%	
4. Blood [iCa]	1.2	mM
5. Neutrophil [iCa] at resting	85	nM
6. Neutrophil [iCa] at activation	400	nM
In 1 mL of blood		
Volume of 1 neutrophil	1,766	cubic µm
Total volume occupied by neutrophils	5,298,750,000	cubic µm
Total volume in 1 ml of blood	1,000,000,000,000	cubic µm
Neutrophils represent	0.53%	
Total Ca in 1 mL	48,000	ng
Increment in iCa upon activation	315.00	nM
iCa used upon activ. in 1 L of neu	12,600.00	ng
iCa used upon activ. in 1 mL of neu	12.60	ng
Cytosolic neutr. vol. in 1 mL	0.26%	
Adj. for cyto neutro vol present in 1 mL	0.033	ng
Absolute iCa in 1 mL	48,000.00	ng
iCa used by neutrophil activation in 1 mL	0.033	ng



Nunes P., and Demaurex N J Leukoc Biol 2010;88:57-68

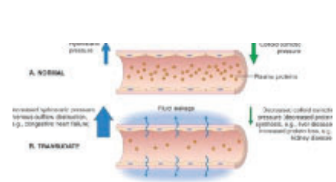
Proportion of iCa used upon activation of 50% of all neutrophils in blood

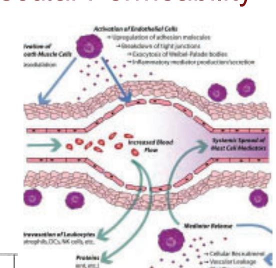
0.00007%

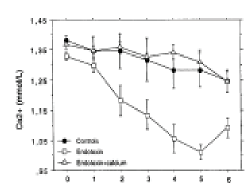
Vieira-Neto et al. (2024) Animals 14:1232. https://doi.org/10.3390/ani14081232

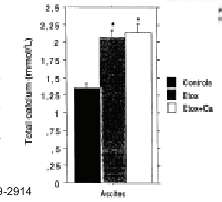
5

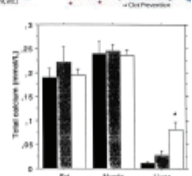
Inflammation Increases Vascular Permeability











Calrstedt et al. (2000) Crit. Care Med. 28: 2909-2914

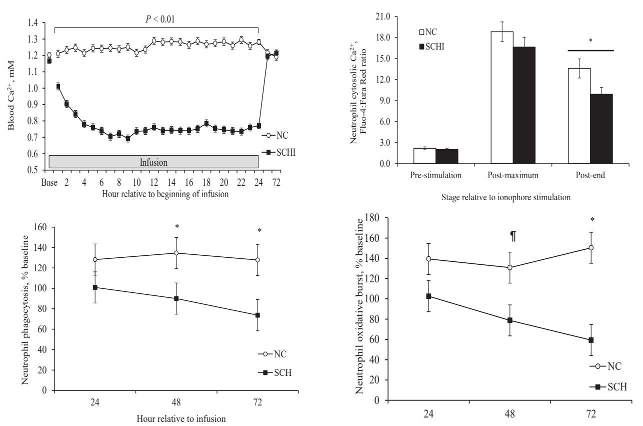
6

Prepartum Diet

- ✓Alkalosis interferes with calciotropic hormones
  - ✓ Intake of K and Na
- ✓Dietary phosphorus
  - ✓Increased blood phosphate interferes with calciotropic hormones
- ✓Dietary magnesium
  - ✓Magnesium is required for proper activity of calciotropic hormones

7

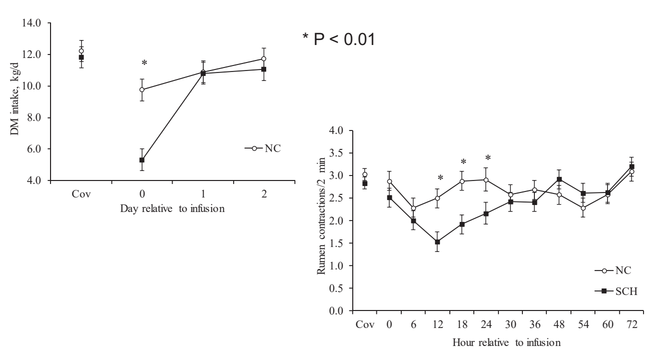
Induced Subclinical Hypocalcemia in Dairy Cows



Martinez et al. (2014) J. Dairy Sci. 97 :874–887

8

Subclinical Hypocalcemia Reduces DM Intake and Rumen Motility in Dairy Cows



Martinez et al. (2014) J. Dairy Sci. 97 :874–887

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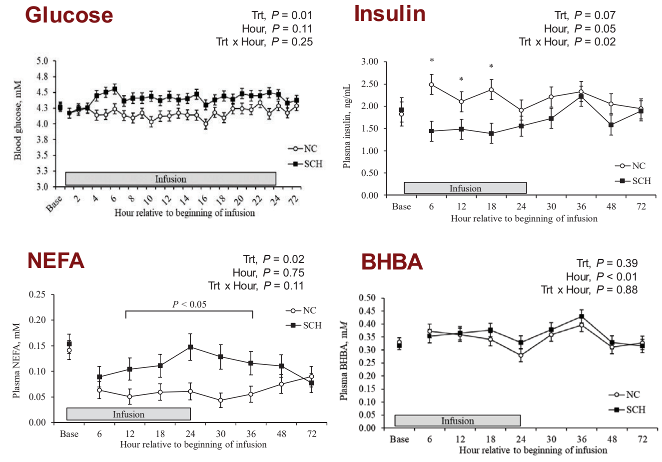

Martinez et al. (2014) J. Dairy Sci. 97 :874–887

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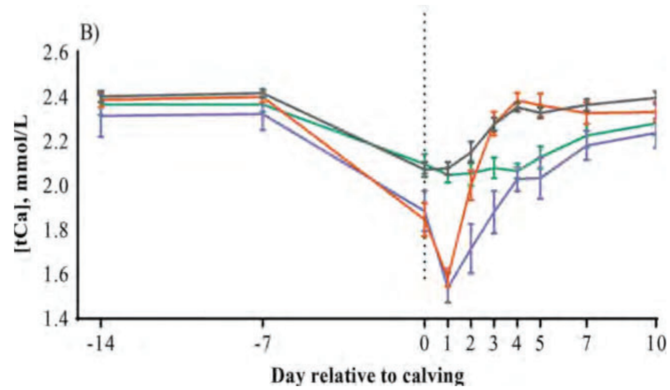


McArt and Neves (2020) J. Dairy Sci. 103:690-701

11

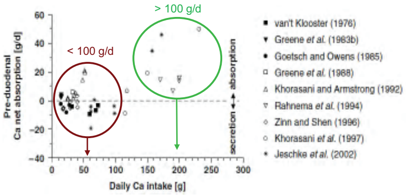
Strategies Available to Reduce the Risk of Hypocalcemia

- ✓Prepartum diets with very low Ca content
- ✓Reduced intestinal absorption of P and Ca
- ✓Altered acid-base status by dietary manipulation
- ✓Administration of Ca at calving

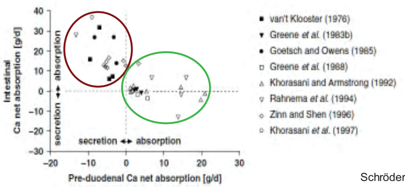
12

Site of Ca Absorption in the GIT of Bovine

Pre-duodenum Ca absorption



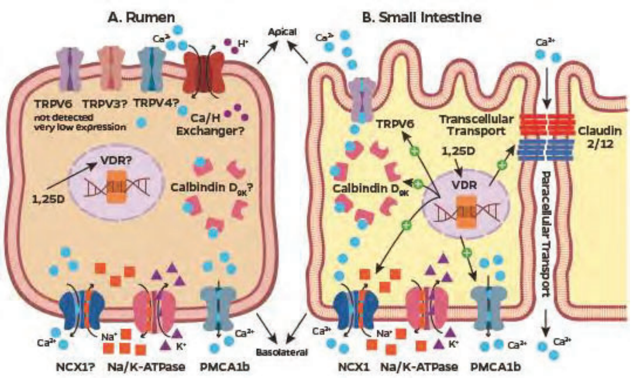
Post-abomasum Ca absorption



Schröder and Breves (2007) Anim. Health Rev. 7(1/2):31–41

13

Mechanisms of Ca Absorption in the Bovine GIT (Ruminants)

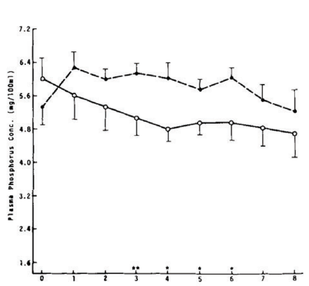


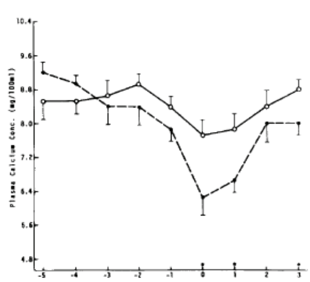
Vieira-Neto et al. (2024) Animals 14:1232. https://doi.org/10.3390/ani14081232

14

Ca-deficient diets prepartum prevent milk fever

Solid line = 8 g Ca/day prepartum
Dashed line = 80 g Ca/day prepartum



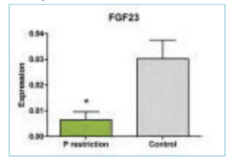


Green et al. (1981) 1981 J Dairy Sci 64:217-226

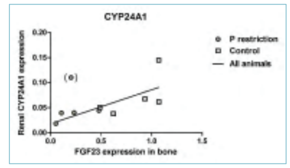
15

Dietary P and Ca Homeostasis – Lessons from Sheep

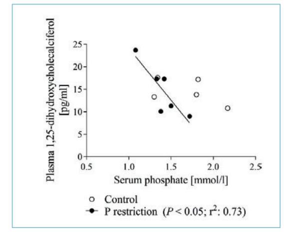
Dietary P restriction reduces FGF23



FGF23 is associated with CYP24A1 expression



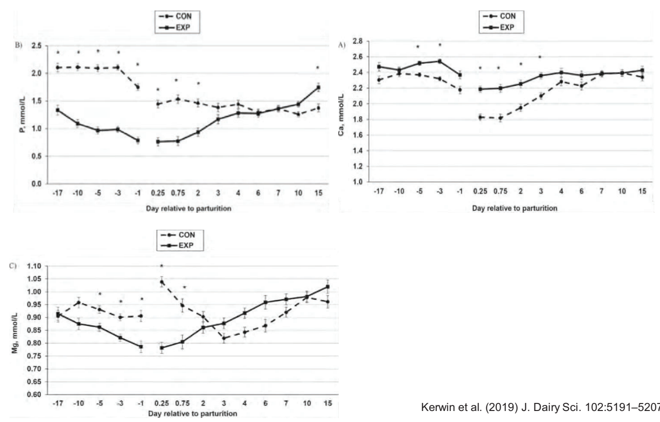
Plasma calcitriol is associated with serum P



Köhler et al. (2021) J. Anim. Physiol. Anim. Nutr. 105:35-50

16

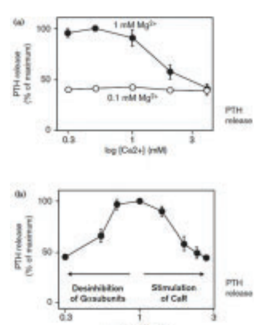
Feeding Zeolite Reduces Blood P and Improves Blood Ca



Kerwin et al. (2019) J. Dairy Sci. 102:5191–5207

17

Adequate Plasma Mg Improves Ca Resorption from Bones



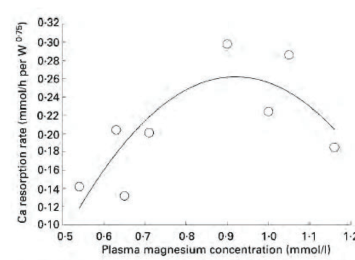


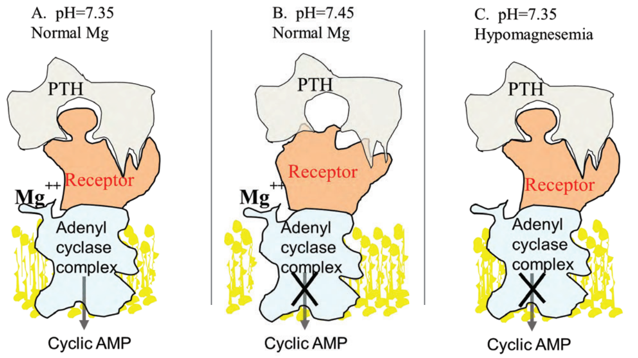
Fig. 4. Mean calcium resorption rate from bone corrected for metabolic live weight (R', mmol/h per kg live weight $(W)^{0.75}$), as a function of plasma magnesium concentration (mmol/l). O, Data from Table 1; —, fitted quadratic equation.

Robson et al. (2004) Brit. J. Nutr. 91: 73-79

Vetter and Lohse (2002) Curr. Opin. Nephrol. Hypertens. 11:403-410

18

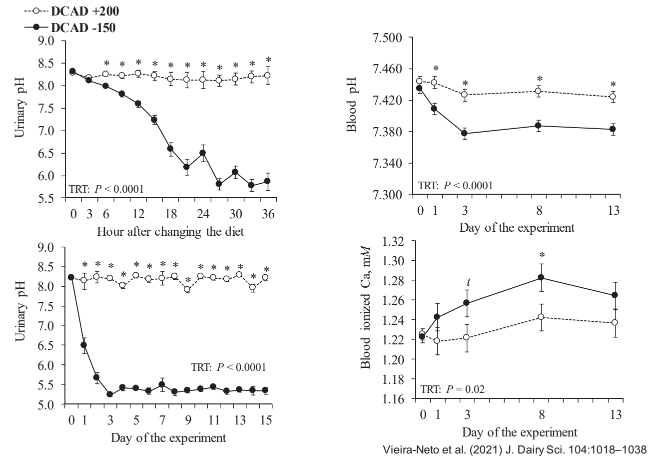
Illustration of the Role of Acid-Based Balance and Mg Status on PTH Action



Courtesy of Jesse P. Goff

19

Diet effects on acid-base status



Vieira-Neto et al. (2021) J. Dairy Sci. 104:1018–1038

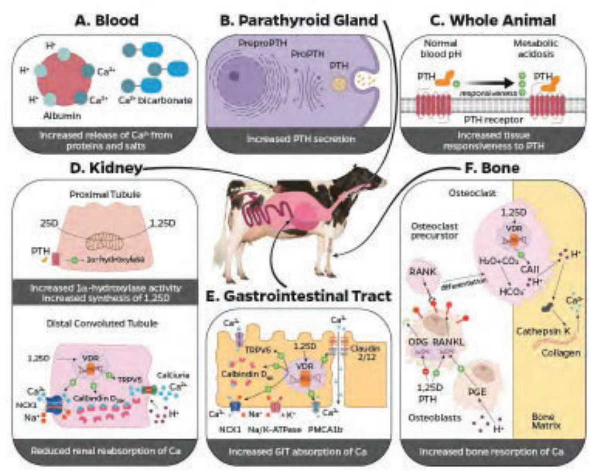
22

Peter Stewart's Strong Ion Difference

- ✓ Concept of Electroneutrality
  - ✓ In an aqueous solutions, the sum of all positively charged ions must equal to the sum of all negatively charged ions
- ✓ If a positive charge is added to this solution,
  - ✓ Na^+ or K^+,
  - ✓ then the positive charge necessitates loss of H^+ (a shift in the dissociation of water) making the solution alkaline.
- ✓ If a negative charge is added to the same solution,
  - ✓ such as Cl^-,
  - ✓ then the added negative change necessitates loss of HCO_3^- or gain of H^+
- ✓ Dietary cations or anions only affect blood pH if absorbed into the bloodstream in relatively large quantities and change the strong ion difference (**SID**) of blood

Stewart, PA. 1983. Modern quantitative acid-base chemistry. Can. J. Physiol. Pharmacol. 61:1444-1461

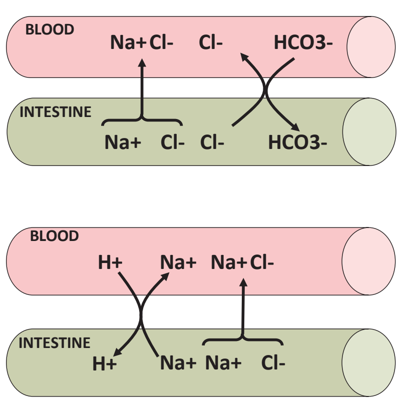
20



Vieira-Neto et al. (2024) Animals 14:1232. https://doi.org/10.3390/ani14081232

23

How DCAD Affects Blood Acid-Base Chemistry



Negative DCAD with excess of strong anions relative to strong cations

HCO_3 and pH ↓

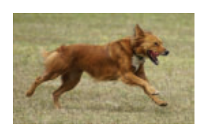
Positive DCAD with excess of strong cations relative to strong anions

HCO_3 and pH ↑

21

Metabolic Acidosis Enhances PTH Release

22 dogs randomly assigned to treatments

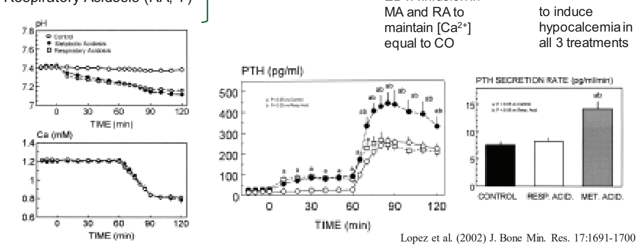


Control (CO; 7)
Metabolic Acidosis (MA; 8)
Respiratory Acidosis (RA; 7)

Baseline 20 min → Eucalcemia 60 min → Hypoalcemia 60 min

Eucalcemia: EDTA infusion in MA and RA to maintain [Ca^{2+}] equal to CO

Hypoalcemia: EDTA infusion to to induce hypocalcemia in all 3 treatments

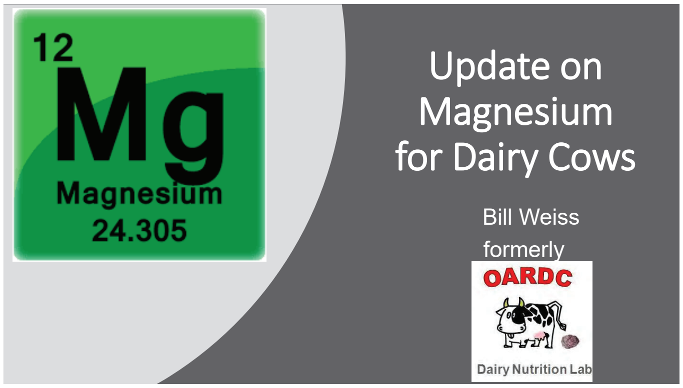


Lopez et al. (2002) J. Bone Min. Res. 17:1691-1700

24

Update on Magnesium for Dairy Cows

Bill Weiss, PhD
formerly OARDC
Dairy Nutrition Lab

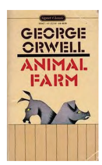


1

Why magnesium ?

All essential minerals are equally important, but <u>Mg is more equally important</u> than most other minerals

Apologies to George Orwell's *Animal Farm*



2

Why magnesium ?

- ✓ **Labile body stores**
  - Most minerals: weeks to months
  - Mg: days
- ✓ **Real world factors negatively affecting absorption**
  - Most macrominerals: Essentially none
  - Mn, Se, Zn: A few
  - Cu and Mg: A lot
- ✓ **Extra-requirement effects**
  - Most individual macrominerals: Few
  - Many TM: Some
  - DCAD, Mg: Some

3

Broad functions of magnesium

- **Muscle and nerve** transmission/function
- Cofactor for >300 **enzymes**
- **Ca/P metabolism**
  - Low Mg stimulates PTH release
  - Required by all enzymes needed to **activate vitamin D**
- Nonspecific and specific **immune** function
- **Rumen alkalizer** (source dependent)
  - Improved fiber digestibility
  - Increased milk fat

4

Mg and clinical hypocalcemia (CH)

- ✓ Hypomagnesemia is risk factor for milk fever (Sansom et al., 1983)
  - Serum Mg >2.1 ok
  - Serum Mg <1.7 hypomagnesemia
- ✓ Meta-analysis (Lean et al. JDS 2006)
  - Linear decrease in CH as Mg in prefresh increased
    - Approximate range (based on SD): 0.1 to 0.45%
  - Mg confounded with DCAD ($MgCl_2$ and $MgSO_4$)

5

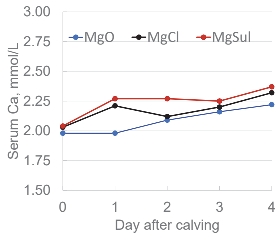
Mg and hypocalcemia (Roche et al., 2002)

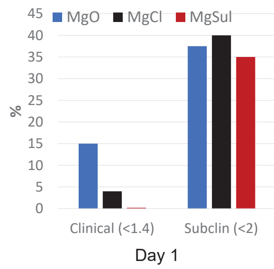
- Grazing cows
- Basal pasture: ~0.25% Mg, 3.5% K; 360 DCAD
- ~19/d Mg via drench starting -21 d
  - $MgCl_2$
  - $MgSO_4$
  - MgO
- Approximate diet Mg: ~0.4%
- Based on urine Mg: All treatments had equal absorbed Mg

6

Mg and hypocalcemia (Roche et al., 2002)

MgO not as effective as Mg anionic salts





7

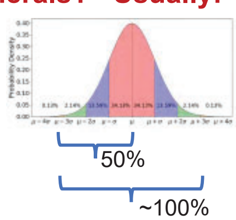
Diet formulation for minerals (including Mg)

Meet basic requirements	**NASEM**
Adjust for risks	**Group and diet variation**
Adjust for antagonism, source	**Numerous**
Any extra-requirement responses	**Ruminal**
Final diet	

8

Is a safety factor needed for minerals? Usually!

- Model requirements meet needs of 50% of population (~0.18% Mg)
- Assuming normal distributions; Mean plus 2 **SD** = 98% of population
- Assuming FHP = variation in mineral reqt: Mean X 1.2 = 98% of population



For most minerals: **~1.2 X NASEM requirement** will meet requirements of ~100% of animals in a pen. **Mg = ~0.21%**

9

Real world factors affecting Mg absorption

- **Mg source** ⟸ Solubility — Particle size, Calcination, Contaminants, Etc.
- **Dietary K**
- **Monensin**
- **NDF**
- **Starch (?)**
- **Fat (?)**
- **RDP (short term)**

10

NASEM 2021 Mg Absorption Coefficients

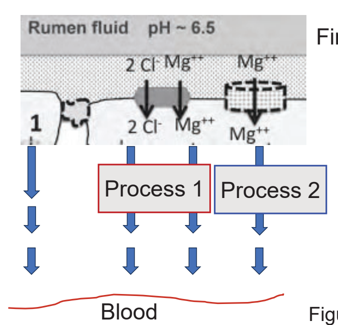
Source	AC (with 1.2% K)
Basal feeds	**0.31**
MgO	0.23*
Mg Carbonate	0.23*
$MgOH_2$	0.23*
Mg Sulfate	0.27
Mg Chloride	0.27
Dolomite	0.12*

Limited data for most supplements except MgO

* Variable: PS, calcination, contaminants, etc

11

Mg absorption



First layer of rumen wall

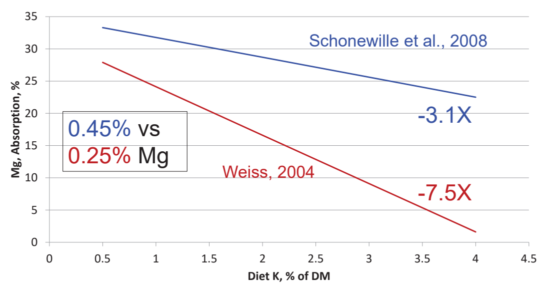
Process 1
- Requires energy
- Insensitive to K conc
- Needs high Mg (>13mM)

Process 2
- Electrochemical gradient
- Works at low Mg conc
- Inhibited by K

Figure modified from Goff, 2018

12

K and Apparent Mg Absorption in Cows: Meta-analyses



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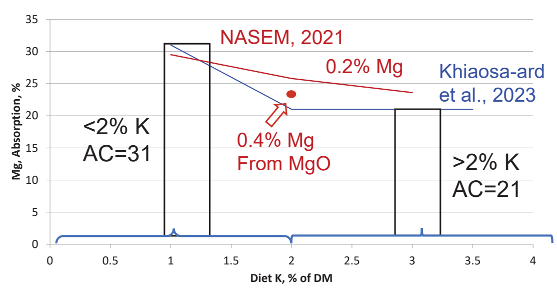
K and Estimated True Mg Absorption in Cows

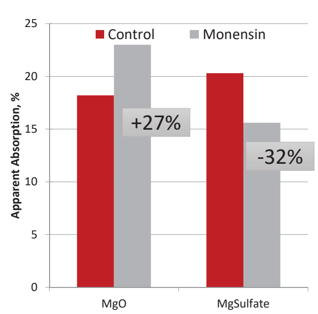


14

Monensin ⬆ and ⬇ Mg absorption

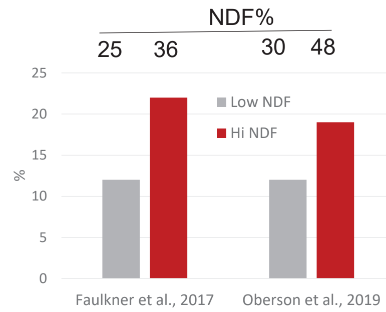
- All diets 2.1% K (0.8 from K carb)
- 0.35% Mg (0.2 basal)
- Treatments
  - MgO or $MgSO_4$
  - 0.2 vs 0.4% S
  - 0 or 14 mg/kg monensin

Tebbe et al., 2018



15

Effect of high NDF on Apparent Mg absorption



- About equal Mg and K (within expt)
- High NDF from
  - Byproducts (Faulkner)
  - Forage (Oberson)

Higher NDF may have increased ruminal retention time

16

Does starch affect Mg absorption ?

- Mg solubility increases as pH drops
- Higher starch can reduce rumen pH
- Limited real-diet, cattle data
- Confounding (K, NDF, Mg source)

	Mg absorb.
Goats, semi-purified diets: 0 vs 30% starch (Schonewille et al., 1997)	**22 vs 31%** ⬆
Lact dairy cows, 18 vs 35% starch (Faulkner et al., 2017)	**22 vs 12%** ⬇
Dry cows, 2 vs 11 vs 20% starch (Schonewille et al., 2000)	**6 vs 4 vs 5%** ⬄

17

Adjusting NASEM for absorption variation risk

- NASEM accounts for variation caused by K
- Other sources of variation not considered in model

- Typical diet AC for Mg: 0.25 to 0.3
- Approximate SD: 0.03
- 95% range: 0.19 to 0.35

- Risk adjustment: 0.25/0.19 = **1.3X NASEM**

Diet concentration: 0.18 x 1.2 x 1.3 = **~0.28%**

18

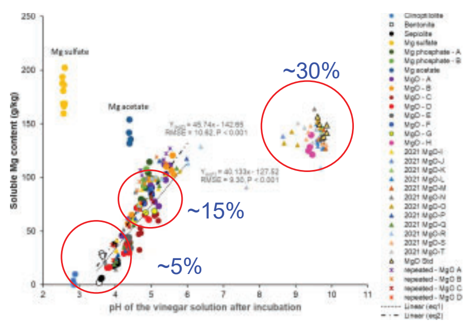
Supplemental sources vary: what can you do ?

- Solubility in different solutions
- 'Vinegar' test
- Urine Mg output

These test have value but:
- Limited data relating to in vivo absorption
- High analytical, estimation error

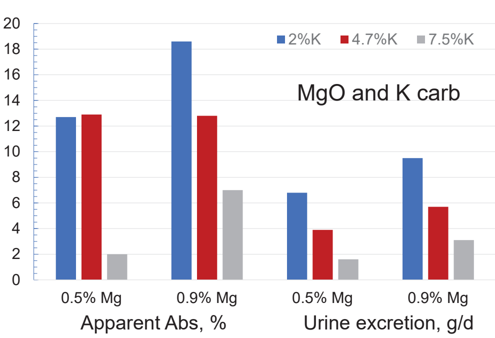
19

'Vinegar' test to evaluate MgO (Khiaosa-ard et al., 2023)



20

K reduces Mg balance; urine Mg reflects Mg absorp.

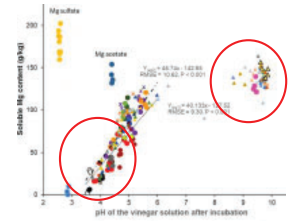


(Jittakhot et al., 2004)

21

Ruminal and cow effects of Mg

Many Mg supplements **can** act as alkalizers
- Includes MgO, MgCarb, $MgOH_2$, dolomite
- May increase milk fat with MFD
- May improve fiber digestibility



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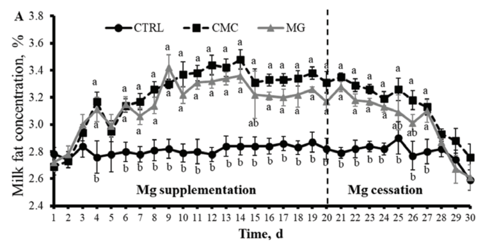
MgO or Dolomite in milk fat depressing diet



Supplemental Mg from Mgo (MG) or dolomite (CMC)

Cont: 0.23% Mg
MgO: 0.42%
CMC: 0.32%

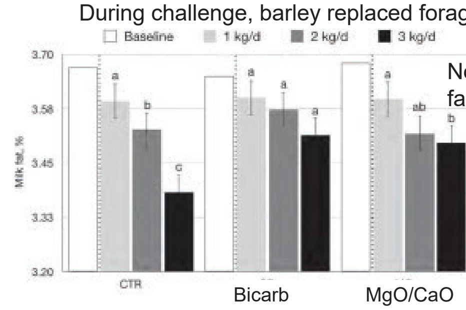
Same pattern for fat yield

Razzaghi et al., 2022

23

With acidosis challenge MgO reduced MFD

During challenge, barley replaced forage



No change in fat yield

Bach et al., 2018

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Summary

1. Cows need to consume adequate absorbable Mg daily
2. NASEM does not include safety factors (~1.5X)
   - Variation in absorption
   - Variation in pen requirements
3. Quality of sources vary greatly
   - Solubility test
   - Urine excretion
4. Some Mg sources can increase milk fat
   - More effective with milk fat depressing diets

25

Feeding Strategically Throughout the Lactation to Promote Milk Production and Health

Mike VandeHaar
(with help from Mike Allen)
Michigan State University

Feeding strategically throughout the lactation to promote milk production and health.

Best feed practices based on NASEM 2021.

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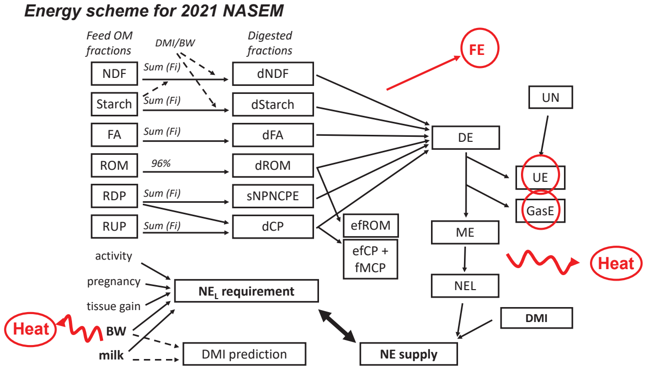
Michigan State University
mikevh@msu.edu

With help from Mike Allen

USDA National Institute of Food and Agriculture
FFAR Foundation for Food and Agriculture Research
CDCB COUNCIL ON DAIRY CATTLE BREEDING
Michigan State University AgBioResearch
MICHIGAN STATE UNIVERSITY Michigan Alliance for Animal Agriculture

1

Energy scheme for 2021 NASEM

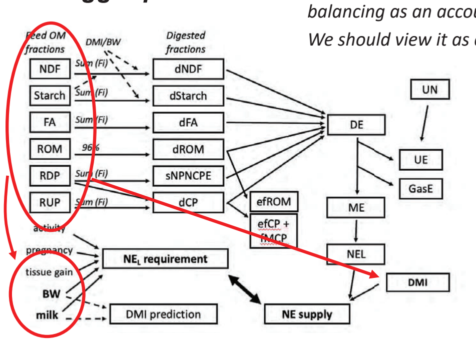


2

The bigger picture

Too often nutritionists conduct ration balancing as an accounting exercise.

We should view it as an investment strategy.



Intake and partitioning responses must be considered and monitored when balancing diets to optimize milk production.

3

Outline

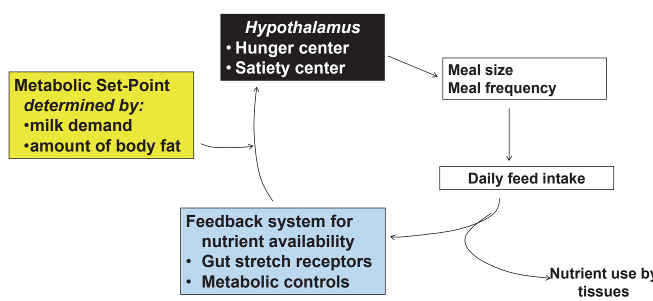
1. Effect of nutrients on voluntary feed intake
2. Effect of nutrients on nutrient partitioning.
3. Diet formulation and feeding strategies to promote milk and health over the lactation.

4

Effects of nutrients on voluntary feed intake

5

The feed intake regulatory system



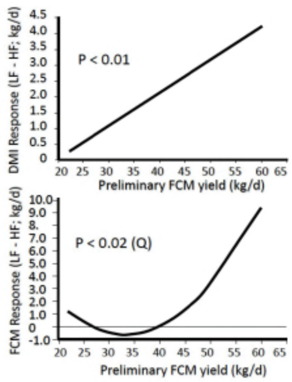
6

High starch/low forage benefits high producers but not low producers.

32 cows in a crossover design

HF = 67% forage, 31% NDF, 23% starch
LF = 44% forage, 24% NDF, 34% starch
Preliminary diet was intermediate.

Voelker et al., 2002. JDS 85:2650



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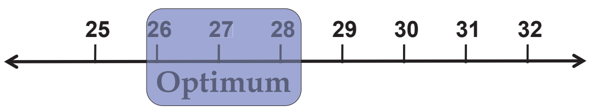
Factors that alter the optimal NDF level



First 3 weeks postpartum → ++
High inclusion of short fiber feeds→ +++
Faster clearance of forage NDF (fragility, digestion rate) → +++
High inclusion of rapidly-fermented starch→ +
+← Supplemental rumen buffers
Grain consumed rapidly and infrequently→ ++
+← Excellent quality control in feeding management

8

The optimal balance of fiber and starch

TABLE 5-1 Recommended Minimum Forage and Total NDF and Maximum Starch Concentration of Diets for Lactating Cows When a Diet Is Fed as a TMR, the Forage Has Adequate Particle Size, and Dry Ground Corn Is the Predominant Starch Source

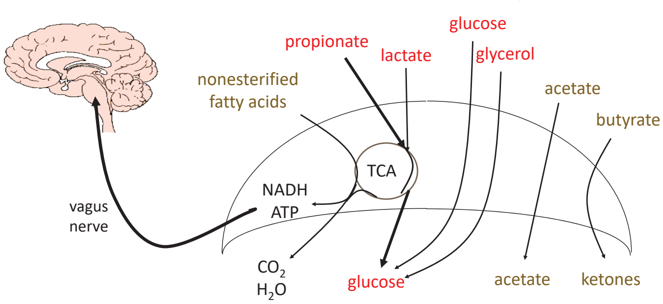
Minimum fNDF	Minimum Total NDF	Maximum Starch
19	25	30
18	27	28
17	29	26
16	31	24
15	33	22

NASEM, 2021

9

The role of the liver in the metabolic control of feed intake

Compounds that are oxidized in the liver can cause satiety.



10

Ruminal starch fermentation and feeding behavior

	High Moisture Corn	Dry Corn
DMI, kg/d	20.8[b]	22.5[a]
Meal size, kg	1.9[b]	2.3[a]
Intermeal interval, min	94	105

Both diets were identical except for the type of corn grain. High moisture corn fermented faster, increasing propionate to the liver within a meal to cause satiety. The cows ate their next meal sooner (not statistically significant) but they did not eat enough extra meals to make up for smaller meals. Thus, they ate less feed within a day.

Oba and Allen, 2003 J. Dairy Sci. 86:174

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J. Dairy Sci. 102:7961–7969
https://doi.org/10.3168/jds.2018-16166

Equation to predict feed intake response by lactating cows to factors related to the filling effect of rations

M. S. Allen,[1]* D. O. Sousa,[1,2]† and M. J. VandeHaar[1]
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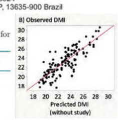
[2]Department of Animal Science, University of São Paulo, Pirassununga, SP, 13635-900 Brazil

Table 4. Fit statistics for the proposed equation using all data and for the 5-fold cross validation

Fit statistic[1]	All data	Cross validation
Observed mean, kg/d	23.0	22.5
Predicted mean, kg/d	23.0	22.3
Mean bias, kg/d	0.00	−0.26
RMSE, kg/d	1.55	1.69
RMSE, % of mean	6.71	7.53
CCC	0.827	0.768

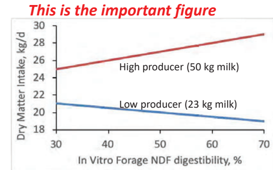
[1]RMSE = root mean square error; CCC = concordance correlation coefficient.



DMI (kg/d)
= 12.0 + 0.225 × MY − 0.107 × FNDF
+ 8.17 × ADF/NDF + 0.0253 × FNDFD
− 0.328×(ADF/NDF−0.602)×(FNDFD−48.3)
+ 0.00390×(FNDFD−48.3)×(MY−33.1)

Feed factors will improve our DMI predictions, but it's complicated and we still have more to learn.

This is the important figure



Diets that contain forage with higher NDF digestibility increase intake in high producing cows because the fiber clears the rumen faster and they can eat more sooner. But they decrease intake in low producers because the cows simply don't need to eat as much to trigger satiety.

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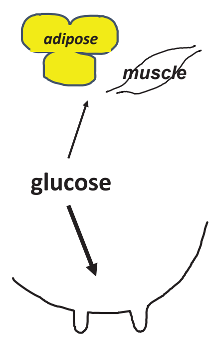
Effects of nutrients on nutrient partitioning



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Partitioning away from body tissues as soyhulls replace dry corn

Cows were 112 ± 18 days in milk at the start of the experiment (n = 15).
Soyhulls (SH) replaced dry shelled corn (DC) in the diets.

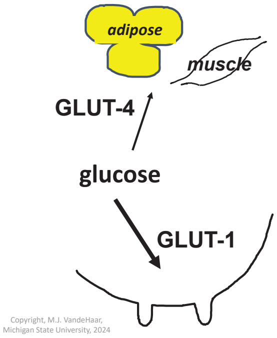
Ipharraguerre et al., 2002

Variable	0% SH 40% DC	10% SH 30% DC	20% SH 21% DC	30% SH 11% DC	40% SH 1% DC	Linear	40% SH vs. 0% SH
Intake, kg/d	23.8	24.8	24.4	22.9	22.7	0.06	NS
Yield, kg/d							
Milk	29.5	29.3	29.9	29.3	28.3	NS	0.07
3.5% fat-corrected milk	29.0	29.0	30.1	30.6	29.7	NS	NS
Fat	0.99	1.00	1.06	1.11	1.08	<0.01	NS
Protein	1.05	0.92	0.97	0.94	0.92	NS	0.09
Body weight change, kg/21 d	21.3	15.8	10.6	-3.3	-3.0	<0.01	<0.01

As soyhulls replaced dry corn, cows ate slightly less but produced slightly more milk fat and gained less body tissue. Body gain was 1.0 kg/d on the high corn grain diet but dropped to a 0.1 kg/d loss on the high soyhulls diet.

14

Insulin and nutrient partitioning: Glucose transporters



GLUT-4 is insulin-dependent but GLUT-1 is not.

In early lactation, when somatotropin is high, insulin is low and tissues are relatively insulin-resistant, GLUT-4 is not active. Most of the glucose is used by the mammary gland.

When high grain is fed, especially with rapidly fermented starch in a slug and later in lactation, insulin increases and GLUT-4 is activated. Thus, more glucose is partitioned to body tissues.

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Forage fiber content and digestibility in peak lactation

Variable*	~29% NDF ~37% starch BMR	~29% NDF ~37% starch Control	~38% NDF 26% starch BMR	~38% NDF 26% starch Control	P-values NDF	P-values CS	P-values NDF x CS
Intake, kg/d	24.7	23.9	22.9	21.5	<0.01	0.02	NS
Yield, kg/d							
Milk	36.9	33.5	33.7	30.4	<0.01	<0.01	NS
3.5% fat-corrected milk	35.6	34.3	35.8	32.6	NS	0.06	NS
Fat	1.22	1.23	1.32	1.20	NS	NS	NS
Protein	1.15	1.05	1.04	0.93	<0.01	<0.01	NS
Body weight change, kg/21 d	1.10	0.79	0.00	-0.02	<0.01	NS	NS
Condition score change/21 d	0.17	0.22	0.10	0.04	0.07	NS	NS

Oba and Allen, 2000

*Cows were 70 ± 7 days in milk at the start of the experiment (n = 8). Dry ground corn replaced corn silage to decrease NDF.

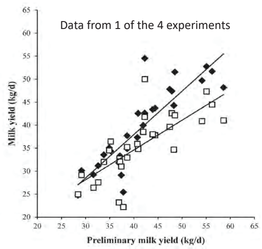
19

Partitioning as soyhulls replace dry corn.

Potts et al., 2015
Boerman et al., 2015

Variable*	26% NDF 30% Starch	40% NDF 14% Starch	Trt
Intake, kg/d	25.7	25.2	0.09
Milk yield, kg/d	42.3	40.2	0.03
Milk energy, Mcal/d	29.6	28.9	NS
Body wt change, kg/d	0.63	0.35	0.01
Insulin, ug/L	1.11	0.89	0.01
NEFA, mEq/L	91	129	0.01

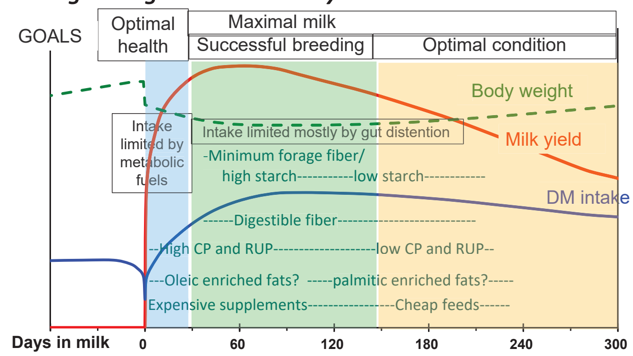
*Data are from 4 separate crossover experiments where soyhulls replaced dry ground corn to decrease starch content. Cows were 120 ± 30 days in milk at the start of the experiments (n = 109).



- *The high corn diet increased the yield of milk, 3.5% fat-corrected milk, fat, and protein more in cows that produced more before the study started.*
- *The low starch diet had little impact on milk production in low producing cows.*

16

Feeding through the lactation cycle

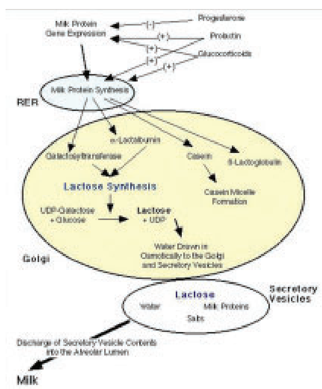


20

Protein synthesis and lactose synthesis are linked.

Feeding diets that provide the right blend of amino acid might stimulate milk protein synthesis, which will in turn stimulate lactose synthesis.

The right protein blend might partition nutrients toward milk.



17

Nutrient concentrations for lactating cows

	Fresh	Peak	Late
NEL Mcal/kg	1.7	1.8	1.7
NDF %DM	30	25 - 36	30 - 44
forNDF %DM	22	16 - 21	14 - 21
nf NDF %DM	8	4 - 20	9 - 26
starch %DM	26	22 - 34	15 - 25
fatty acid %DM	2 - 3	2 - 4	2 - 3
CP %DM	18	17	15 - 16
RDP %DM	>10	>10	>10
RUP %DM	8	>7	>5
MP %DM	11	10	9

One diet cannot be optimal for all stages.

Feeding management of that optimal diet is also key.

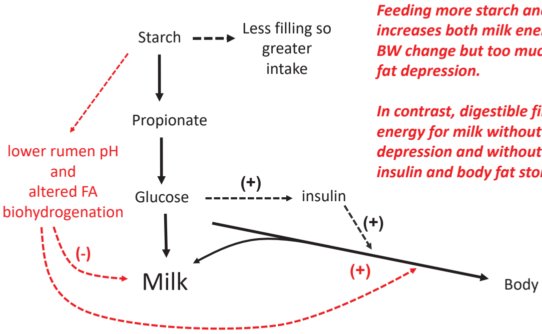
- *Maximize intake*
- *Minimize sorting*
- *Monitor the cows*

(based on NASEM Table 21-1)

This is subject of break-out talk.

21

Putting it all together



Feeding more starch and less forage fiber increases both milk energy output and BW change but too much can cause milk fat depression.

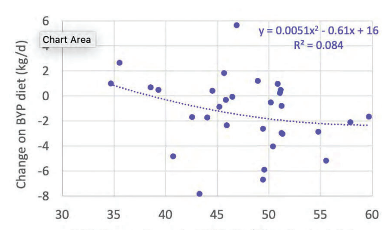
In contrast, digestible fiber provides energy for milk without causing milk fat depression and without stimulating insulin and body fat storage.

18

Effect of a high byproduct diet in mid-lactation

32 cows were fed 1 of 2 diets starting between 50 and 150 DIM with half fed Control and half fed Byproduct diet for 28 days followed by 28 d fed the opposite diet.

	CON	BYP
Wheat straw chopped	0.0%	7.5%
Corn Silage BMR, 41%NDF	36.0%	25.0%
Haylage cut 3, 38%NDF, 23%CP	12.9%	0.0%
Corn gluten feed, dried	0.0%	16.9%
Beet pulp, wet	0.0%	11.5%
Bakery byproduct, meal	0.0%	15.0%
Cotton seed, whole with lint	10.0%	10.0%
Corn grain, ground, dry	24.0%	0.0%
SoyPlus soybean meal	8.0%	5.0%
Protein (DDGS,blood,urea,AA)	6.6%	6.6%
Mineral Vitamin Premix	2.4%	2.4%
aNDFom %DM	29	37
ForageNDF %DM	20	16
Starch %DM	31	20
WSC, %DM	6.0	8.4
CP %DM	17	17
RUP %CP	6.4	6.2
FA %DM	4.8	4.7



22

Take-home points: basic principles

- Maximum feed intake over a lactation generally results in maximum milk, efficiency, and profitability, unless feeds are expensive relative to milk price.
- Multiple factors can control intake and partitioning at the same time. These controls vary over a lactation.
- The rate of digestion for feed fractions and the end products of digestion determine the effects of different diets on intake and partitioning.
- Nutrients are not simply building blocks and fuels; they can alter hormonal signals, tissue responsiveness to hormones, and liver and mammary metabolism to affect intake and partitioning depending on physiological state.
- Understanding the biology of these interactions can help nutritionists better group and formulate diets for cows at various physiological states. One

23

23

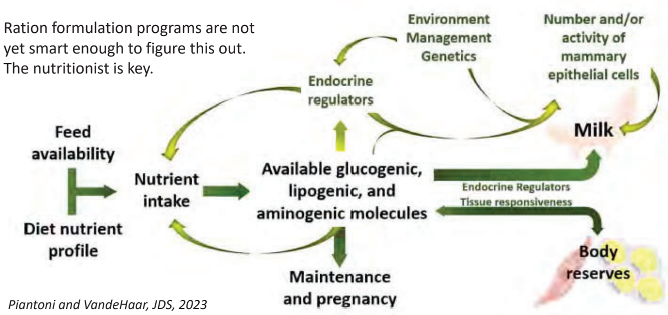
Take-home points: application

- Once maintenance is supplied, every extra Mcal of feed will likely result in more milk. In general, 1 more kg of feed means 2 more kg of milk.
- To increase feed efficiency, feed diets that promote milk synthesis and supply the needed nutrients.
- Effective feeding to increase feed efficiency requires consideration of nutrient interactions for digestion and metabolism and diet effects on the regulation of feed intake and nutrient partitioning. One diet cannot be optimal for all lactating cows.
- The only way to really understand how a diet will affect milk production is to monitor the response! ***No nutrition model can accurately predict responses in intake, partitioning, and milk production.***

24

The right nutrient profile controls intake and partitioning to optimize milk production

Ration formulation programs are not yet smart enough to figure this out. The nutritionist is key.



Piantoni and VandeHaar, JDS, 2023

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Questions?

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Feeding Corn Distillers Grains in Dairy Cattle

Chanhee Lee, PhD
Department of Animal Sciences
The Ohio State University

Feeding corn distillers grains in dairy cattle

Chanhee Lee, PhD

Department of Animal Sciences
The Ohio State University

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1

CFAES

DDG and different types of DDG

- Traditional DDG
  - About 30% CP, 12% Fat, > 30% NDF
- Reduced fat DDG
  - About 35% CP, 7% Fat, > 30% NDF
- High protein DDG
  - About 40-45% CP, 7% Fat, > 30% NDF
- Wet DDG

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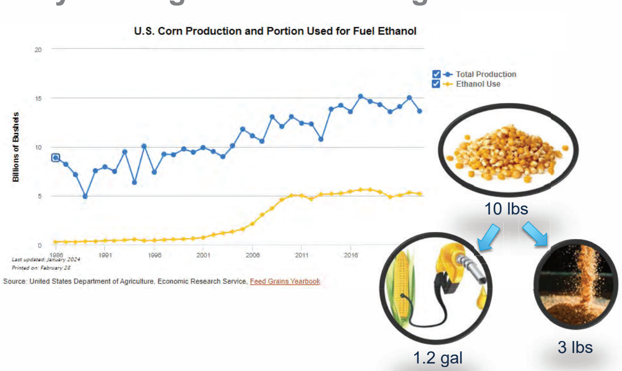
2

CFAES

Why feeding DDG to lactating cows



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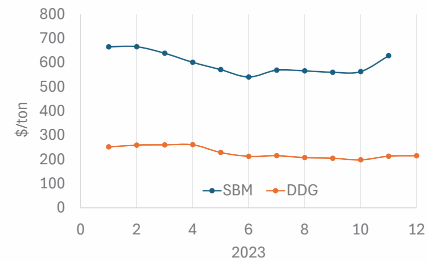
3

CFAES

Why feeding DDG to lactating cows

- Price and nutrition



(USDA NASS)

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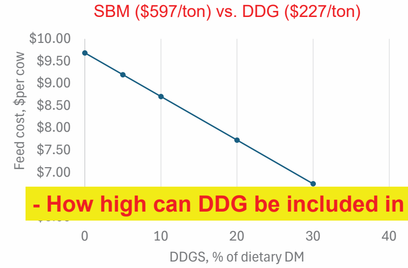
4

CFAES

An expected benefit from feeding DDG

- Reducing feed costs
  - Depending on the inclusion of DDG in a ration

SBM ($597/ton) vs. DDG ($227/ton)



DMI: 60 lbs.
Ingredients
- corn silage
- alfalfa silage
- hay
- **SBM**
- **corn grain**
- ...ement
- minerals & vitamins

- How high can DDG be included in a ration?

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5

CFAES

Production responses to DDG

	DDG	Design	Milk Yield	Fat Yield	Protein
Benchaar et al., 2013	0, 10, 20, 30%	LS	↑		↑
Ramirez-Ramirez et al., 2016	30%	LS	↑	↓	↑
Morris et al., 2018	30%	RCBD		↓	↓
Zy... 20...					

- Inclusion of DDG often decreases milk fat and feed digestibility
- Optimal inclusion rate of DDG??
< 10%

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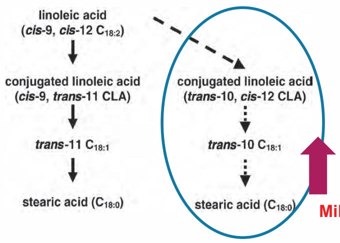
6

CFAES

What causes milk fat depression?

- The type of fatty acids in DDG
  - Rich in polyunsaturated fatty acids (PUFA)



Milk fat depression

Traditional DDG
: 12% fat

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CFAES

Reduced-fat DDG

- Fat: 6-8%
- Protein: 30-40%

Lowering the risk of milk fat depression with high DDG in a ration

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8

CFAES

Feeding reduced-fat DDG to lactating cows

Experiment 1

Item, % of DM	SBM	DDG
Corn silage	41.6	41.6
Alfalfa silage	9.7	9.7
Alfalfa hay	5.0	5.0
DDG	—	28.8
Corn grain	12.9	13.2
Soybean meal	15.1	—
Soyhulls	12.3	—
Fat	1.3	—
Calcium phosphate	0.2	—
Mineral/vitamin mix	1.8	1.8

(Morris et al., 2018)

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9

CFAES

Feeding reduced-fat DDG to lactating cows

Experiment 1

Item, % of DM	SBM	DDG
Crude protein	17.6	17.7
NDF	30.5	31.0
Starch	20.4	21.6
Fat	4.2	4.7
Phosphorus	0.36	0.48
Sulfur	0.21	0.41
PUFA, % of fat	38	49

(Morris et al., 2018)

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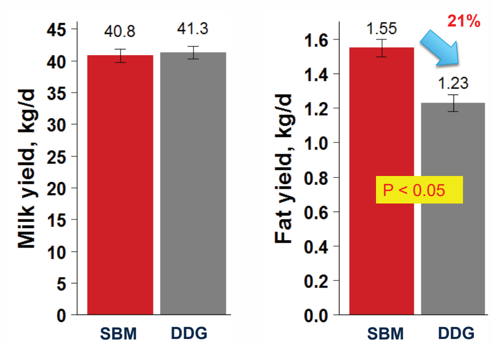
10

CFAES

Feeding reduced-fat DDG to lactating cows



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11

CFAES

Feeding reduced-fat DDG to lactating cows

Experiment 2

Item, % of DM	SBM	DDG
Corn silage	43.0	43.0
Alfalfa silage	9.7	9.7
Corn grain, ground	15.1	17.8
Soybean meal	10.7	0.4
SoyPlus	4.2	—
Fat	1.2	—
Soyhulls	8.1	—
DDG	0	20

(Zynda et al., 2022)

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12

CFAES

Feeding reduced-fat DDG to lactating cows

Experiment 2

Item	SBM	DDG	P- values
DMI, lbs/d	53.2	53.2	
Milk yield, lbs/d	93.3	87.8 ↓	0.06
Milk fat yield, lbs/d	3.41	2.73 ↓	0.03
Energy-corrected milk, lbs/d	95.3	83.6 ↓	0.02

(Zynda et al., 2022)

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Conclusions from the 2 experiments

- Feeding reduced-fat DDG
  - 20 and 30% in dietary DM are still too high
  - Risk of milk fat depression
  - Low fiber digestibility
- PUFA is not likely the only factor causing milk fat depression
  - What other factors??

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Potential factors of DDG causing milk fat depression

- PUFA
- S concentration??

Item, % of DM	SBM	DDG
Phosphorus	0.36	0.48
Sulfur	0.21	0.41
PUFA, % of fat	38	49

(Morris et al., 2018)

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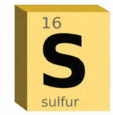
What is wrong with high S in a diet?

- Direct effect of high S
  - Excess S may reduce rumen fiber digestibility
  - Maximum tolerable S level in lactating diet = 0.40% (NRC, 2001)
- Indirect effect of high S
  - Dietary cation-anion difference (DCAD)



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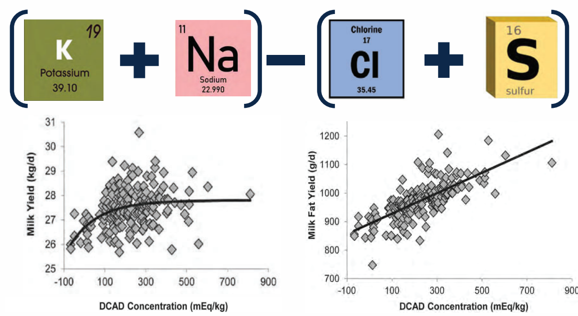
Dietary Cation and Anion Difference (DCAD)



(Iwaniuk and Erdman, 2015)

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CFAES

Potential factors of DDG causing milk fat depression

- PUFA
- Direct S effect
- Indirect S effect

1. **Is High S in a ration a problem?**
2. **Which one is the major factor causing milk fat depression?**
3. **Can we eliminate some of the factors to alleviate milk fat depression?**

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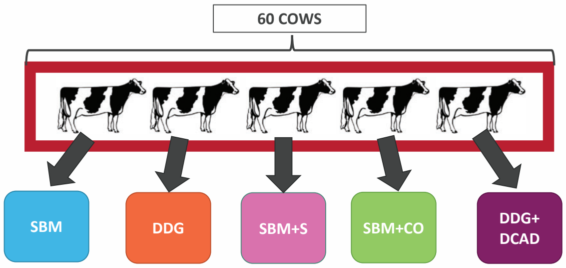
CFAES

Experiment (Clark et al., 2024 in press)



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CFAES

Experiment (Clark et al., 2024 unpublished)

Ingredient Composition (% DM)

	SBM	DDG	SBM+S	SBM+CO	DDG+DCAD
Corn and alfalfa silage	52.4	52.4	52.4	52.4	52.4
Corn grain	13.3	11.0	12.7	13.3	10.1
SBM	16.1	0.8	16.1	16.1	0.8
Soyhulls	13.1	2.6	12.3	13.1	1.9
DDG	0.0	29.6	0.0	0.0	29.6
Corn oil	0.0	0.0	0.0	2.1	0.0
Fat	2.1	0.0	2.1	0.0	0.0
Sodium bisulfate	0.00	0.00	1.74	0.0	0.0
Potassium carbonate	0.14	0.14	0.14	0.14	0.35
Sodium bicarbonate	0.0	0.0	0.0	0.0	1.80
S, %	0.22	0.44	0.38	0.23	0.40
DCAD, mEq/kg	178	42	198	165	330

2. High PUFA effect: milk fat depression

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CFAES

Experiment (Clark et al., 2024 unpublished)

Ingredient Composition (% DM)

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CFAES

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3. Direct effect of high S

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CFAES

Experiment (Clark et al., 2024 unpublished)

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3. Direct effect of high S

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CFAES

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SBM	16.1	0.8	16.1	16.1	0.8
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Sodium bisulfate	0.00	0.00	1.74	0.0	0.0
Potassium carbonate	0.14	0.14	0.14	0.14	0.35
Sodium bicarbonate	0.0	0.0	0.0	0.0	1.80
S, %	0.22	0.44	0.38	0.23	0.40
DCAD, mEq/kg	178	42	198	165	330

4. Indirect effect of high S (DCAD)

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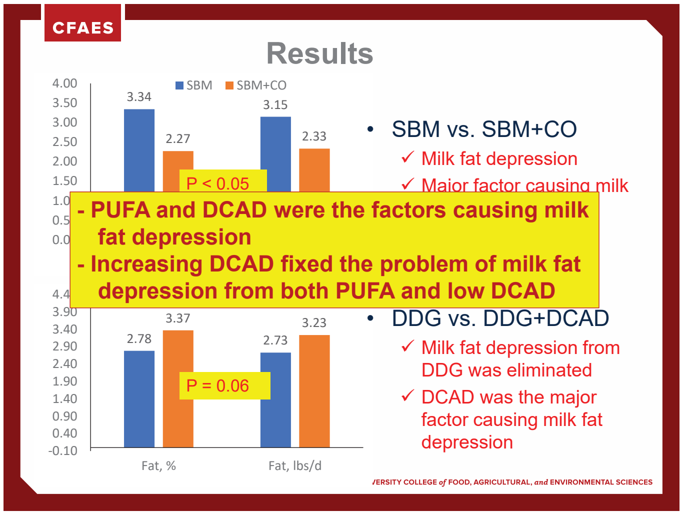
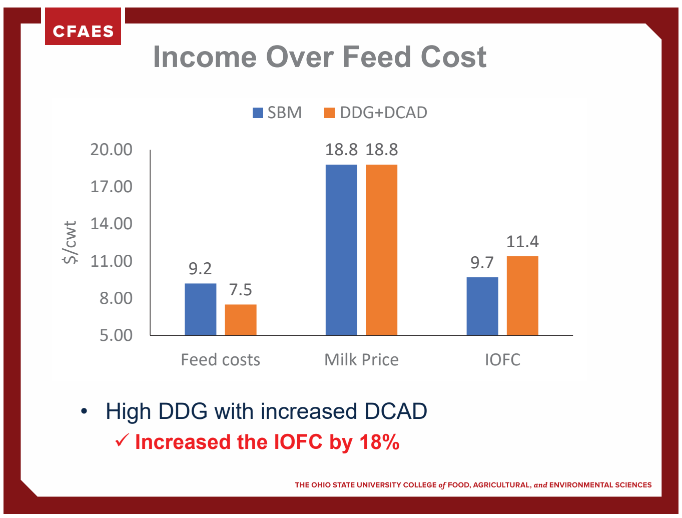

CFAES
Results
SBM
SBM+CO
4.00
3.50
3.00
2.50
2.00
1.50
3.34
2.27
3.15
2.33
P < 0.05
SBM vs. SBM+CO
Milk fat depression
- PUFA and DCAD were the factors causing milk fat depression
- Increasing DCAD fixed the problem of milk fat depression from both PUFA and low DCAD
3.90
3.40
2.90
2.40
1.90
1.40
0.90
0.40
-0.10
2.78
3.37
2.73
3.23
P = 0.06
Fat, %
Fat, lbs/d
DDG vs. DDG+DCAD
Milk fat depression from DDG was eliminated
DCAD was the major factor causing milk fat depression

25


CFAES
Income Over Feed Cost
SBM
DDG+DCAD
$/cwt
20.00
17.00
14.00
11.00
8.00
5.00
9.2
7.5
18.8
18.8
9.7
11.4
Feed costs
Milk Price
IOFC
High DDG with increased DCAD
Increased the IOFC by 18%
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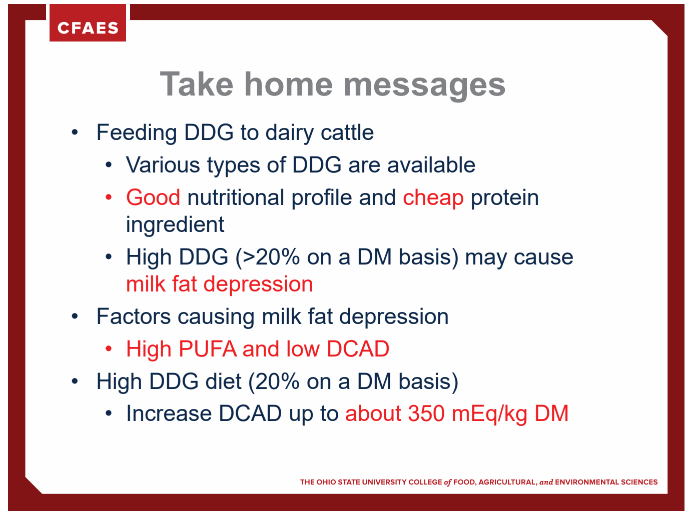
CFAES
Take home messages
Feeding DDG to dairy cattle
Various types of DDG are available
Good nutritional profile and cheap protein ingredient
High DDG (>20% on a DM basis) may cause milk fat depression
Factors causing milk fat depression
High PUFA and low DCAD
High DDG diet (20% on a DM basis)
Increase DCAD up to about 350 mEq/kg DM
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CFAES
CFAES Wooster
College of Food, Agricultural, and Environmental Sciences
The Ohio State University
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES
Thank you!
Chanhee (Chan) Lee
Department of Animal Sciences
Lee.7502@osu.edu
THE OHIO STATE UNIVERSITY COLLEGE of FOOD, AGRICULTURAL, and ENVIRONMENTAL SCIENCES
CFAES

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Understanding the Complexity of Hyperketonemia: Beyond the Norm, Before the Storm

Luciano Caixeta, DVM PhD
University of Minnesota

Understanding the complexity of hyperketonemia: beyond the norm, before the storm

Luciano Caixeta, DVM PhD

4-State Dairy Nutrition & Management Conference
June 2024

University of Minnesota
Driven to Discover®

1

> **"Milk production is the absence of stress in the life of a dairy cow."**
>
> **Dr. Gordie Jones**

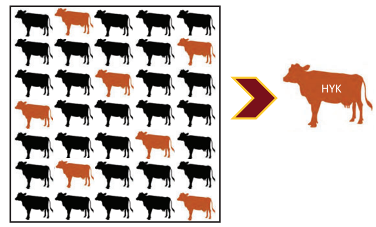
2

Hyperketonemia and ketosis are two different things

Hyperketonemia	**Ketosis**
"Any increase in the concentrations of ketone bodies (acetone, acetoacetate, beta-hydroxybutyrate) greater than those considered physiologically normal."	"Increase in the concentrations of ketone bodies (acetone, acetoacetate, beta-hydroxybutyrate) in conjunction with other visible clinical signs, such as decreased appetite, obvious rapid weight loss, and dry manure."

3

Why do we care about hyperketonemia/ketosis?

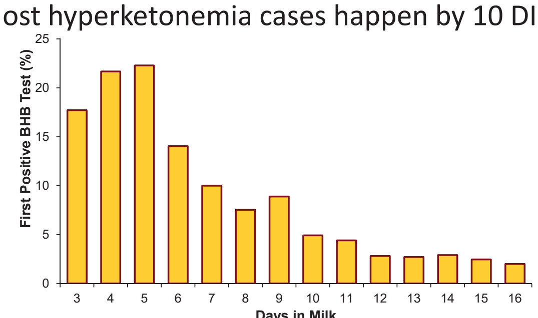


Hyperketonemia has been associated with decreased health and performance

- ↓ milk production
- Impaired reproductive performance
- ↑ prevalence of other diseases
- ↑ herd removal

4

Most hyperketonemia cases happen by 10 DIM



Courtesy of Dr. Jessica McArt

5

Image Generated by DALL-E Generative AI

6

Are all cows with hyperketonemia the same?

7

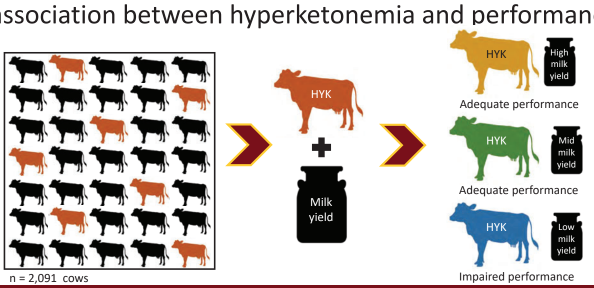
What does this mean?

Knowing the BHB concentration is important, but it cannot be used as the sole parameter to determine the likelihood of a cow's success.

Source: http://vadlo.com/cartoons.php?id=71

11

Early lactation milk production plays a role in the association between hyperketonemia and performance



n = 2,091 cows

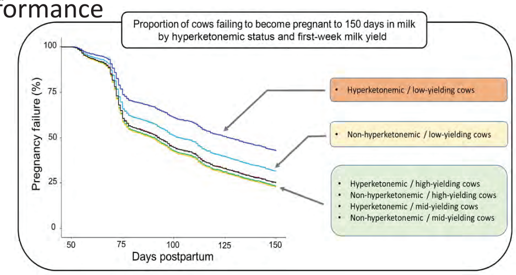
Rodriguez et al., 2022

8

What about the timing when hyperketonemia is observed?

12

Low yielding HYK+ cows had the worst reproductive performance



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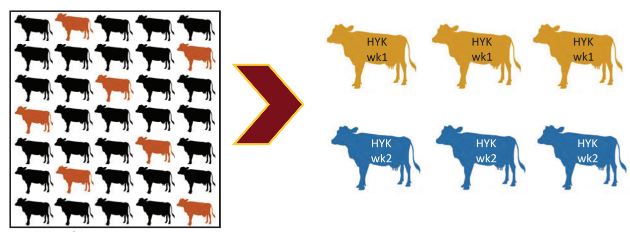
The timing when HYK is diagnosed is important when investigating its association with performance outcomes



n = 362 multiparous cows

Rodriguez et al., 2022

13

What does this mean?

Knowing the BHB concentration is important, but it cannot be used as the sole parameter to determine the likelihood of a cow's success.

Source: http://vadlo.com/cartoons.php?id=71

10

Week 1 HYK+ cows produced less milk than week 1 HYK- cows.

1,128 kg per cow = 8% decline over 305 d of lactation

Week 1 HYK+ cows took longer to get pregnant than week 1 HYK- cows.

Days to pregnancy:
HYK+ = 116 vs HYK- = 95
Cows pregnant by 150 DIM:
HYK+ = 49% vs. HYK- = 63%

More week 1 HYK+ cows left the herd than week 1 HYK- cows.

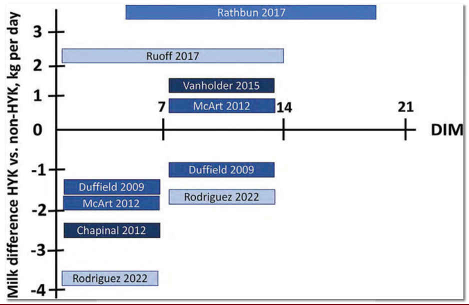
% of animals removed from herd by 300 DIM:
HYK+ = 55.1% vs. HYK- = 29.5%
2.5 times higher risk of being removed

No evidence of a difference in any of the parameters measured when comparing HYK+ and HYK- cows when high BHB observed in Week 2

Rodriguez et al., 2022

14

Others have shown similar associations



© Luciano Caixeta 2024 Mann and McArt., 2024

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What have we learn?

- Hyperketonemia diagnosed in week 1 postpartum is associated with negative performance throughout lactation
- No evidence of association when hyperketonemia is diagnosed in week 2 postpartum
- Practical knowledge: hyperketonemia monitoring should happen in the first week postpartum

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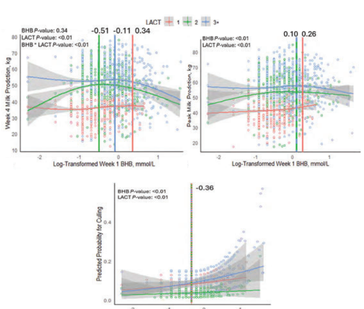
What about the 1.2 mmol/L threshold?

17



Different BHB concentrations in wk1 were associated with week 4 milk yield, peak milk, and culling by 90 DIM.

Outcome	BHB level	Parity group
Wk4 milk	1.4 mmol/L	First lact
	0.6 mmol/L	Second lact.
	0.9 mmol/L	3+ lact.
Peak milk	1.3 mmol/L	First lact.
	1.1 mmol/L	Multiparous
Culling by 90 DIM	0.7 mmo/L	All cows

Data from 3,375 cows from 7 farms between 2017 and 2020

© Luciano Caixeta 2024 Ravelo et al., *in preparation*

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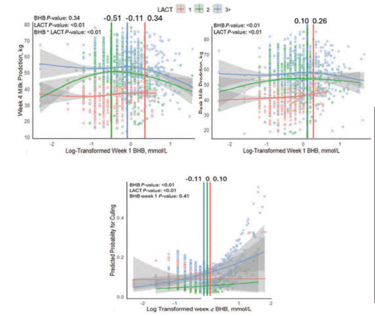

Different BHB concentrations in wk2 were associated with week 4 milk yield, peak milk, and culling by 90 DIM.

Outcome	BHB level	Parity group
Wk4 milk	0.8 mmol/L	First lact.
	1.0 mmol/L	Multiparous
Peak milk	1.5 mmol/L	First lact.
	1.0 mmol/L	Second lact.
	1.3 mmol/L	3+ lact.
Culling by 90 DIM	1.1 mmo/L	First lact.
	1.0 mmol/L	Second lact.
	0.9 mmol/L	3+ lact.

Data from 3,375 cows from 7 farms between 2017 and 2020

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Many different cut-off have been described depending on the outcome of interest

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Look beyond the 1.2 mmol/L cut-off … *biology is not clear cut like that*

© Luciano Caixeta 2024 Image source: Adobe Stock

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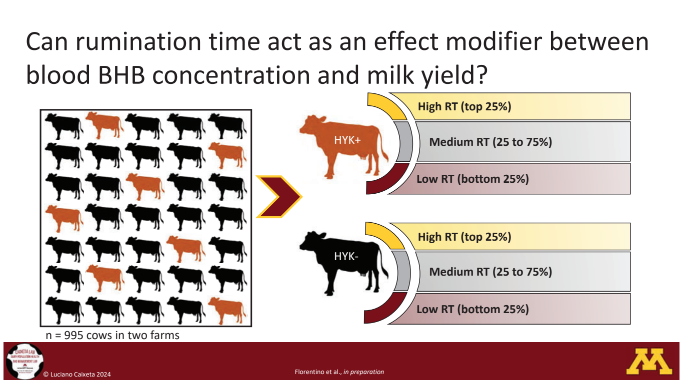
In the age of precision technology, could we use it to help us understand the effects of hyperketonemia?

22



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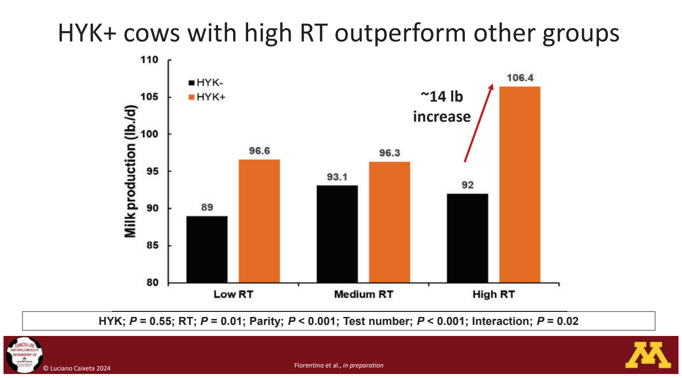

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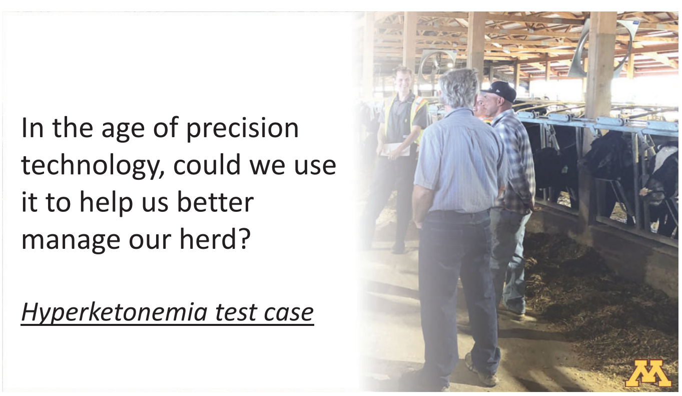

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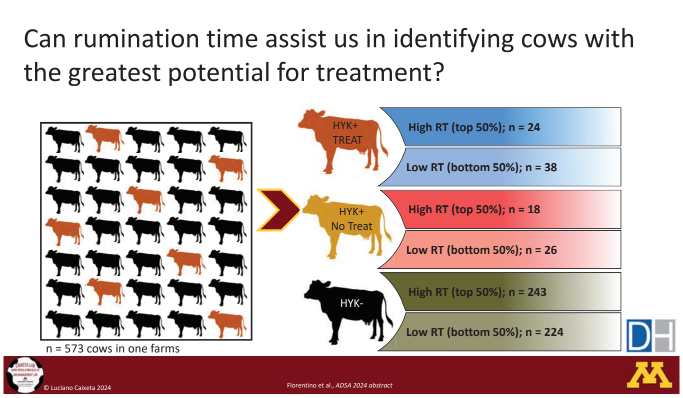

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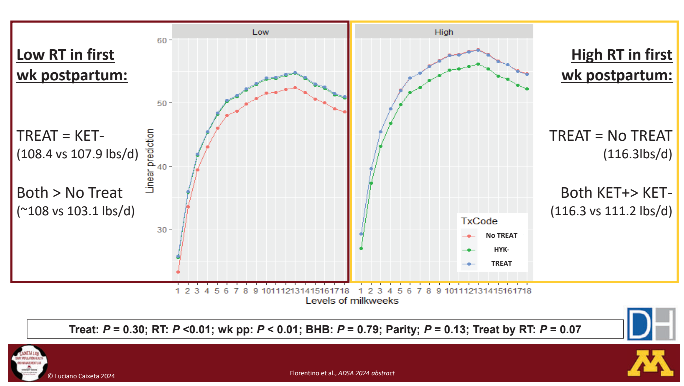

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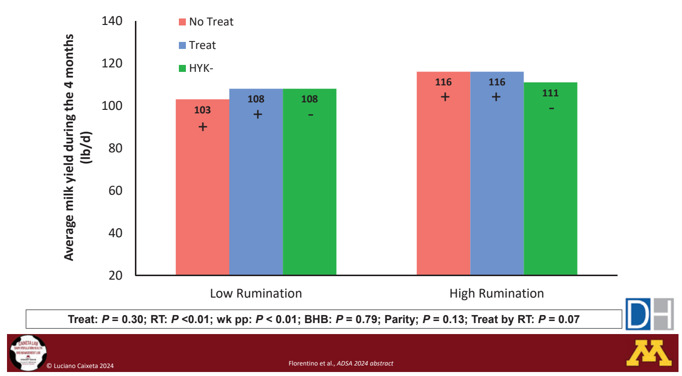

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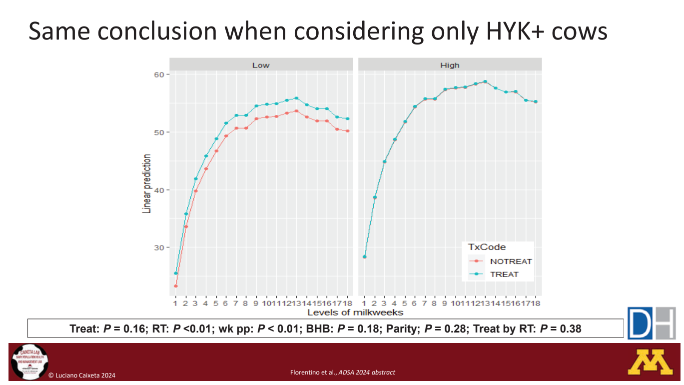

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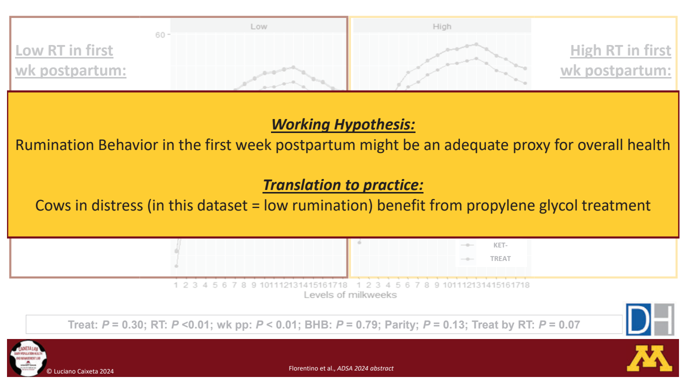

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Take home messages:

- Not all high BHB is the same
- HYK monitoring should happen in wk1
- HYK cows with high RT outperform other groups
- Cows with low RT benefit from propylene glycol

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Thank you!

Dr. Luciano Caixeta - lcaixeta@umn.edu

@caixetadairylab

https://sites.google.com/umn.edu/caixetalab/

College of Veterinary Medicine, University of Minnesota, Driven to Discover

USDA NIFA

Boehringer Ingelheim, AHV, zoetis, Ajinomoto, Merck Animal Health, Laporte, Animal Nutrition, nova biomedical, MnDRIVE, NovaVive, Zinpro, Dairy Health & Management Services

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Histidine, Lysine, and Methionine Effects on Milk Components Production and Nitrogen Efficiency

Marjorie Killerby
University of Wisconsin

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

ANIMAL & DAIRY SCIENCES
University of Wisconsin-Madison

Histidine, lysine, and methionine effects on milk components production and nitrogen efficiency

Marjorie Killerby

4-State Dairy Nutrition Conference 2024
Dubuque, IA

1

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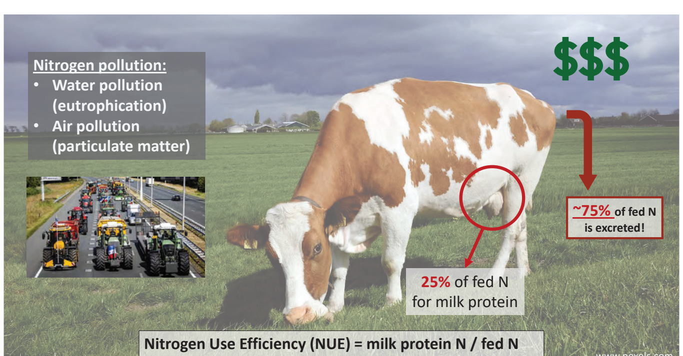
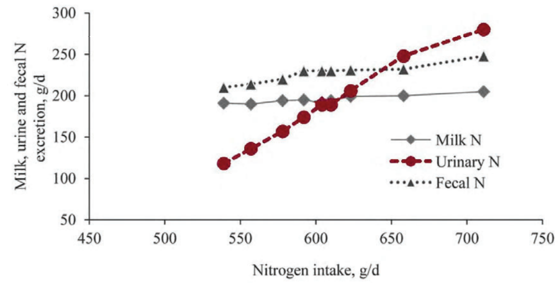


3

Reducing urea excretion by feeding less N



(Adapted from Van Amburgh et al., 2015; JDS 98:9)

4

Balancing amino acids (AA)

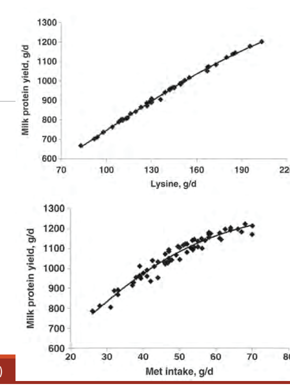
Limiting AA theory:
"The cow will produce as much as the most limiting AA allows."

Methionine and **Lysine** are considered **first limiting AA** in lactating cow diets

Low in corn silage and soybean meal

5

Balancing AA



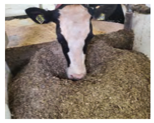
(Vyas and Erdman, 2009, JDS 92:10)

6

Histidine: third limiting AA

↓ Histidine

Microbial Protein



↓ Histidine

Low-protein diets

Greater reliance on microbial protein

- Histidine supplementation:
  - Increases DMI, milk yield, milk protein yield and content (Räisänen et al., 2023)

7

Objectives

1) Evaluate the effect of **balancing lactation diets** for His, in addition to Met+Lys, on milk production and N efficiency.

2) Determine if the response to His is conditional to the level of Met+Lys

Hypothesis

Diets balanced for His will improve milk production and N efficiency independently of Met+Lys

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Methods

- 32 cows in peak lactation
- Diets formulated using NASEM 2021
- Four different diets replacing corn gluten meal (base protein source) with blood meal (high-histidine) source:

Low MetLys		High MetLys	
Low HIS	High HIS	Low HIS	High HIS

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Ingredient composition

	Low MetLys		High MetLys	
	Low HIS	High HIS	Low HIS	High HIS
Ingredient	% of DM			
Corn silage	30.77	30.73	30.77	30.73
Alfalfa haylage	27.69	27.66	27.69	27.66
Cottonseed, whole	9.23	9.22	9.23	9.22
Corn grain dry, fine grind	20.00	19.98	20.00	19.97
Fatty acid blend	1.54	1.54	1.54	1.54
Soybean hulls	**5.23**	**5.38**	**3.85**	**4.15**
Blood meal	**0.00**	**1.69**	**0.00**	**1.92**
Corn gluten meal	**1.54**	**0.00**	**2.46**	**0.61**
Rumen protected Met+Lys	**0.23**	**0.00**	**0.69**	**0.38**
Rumen protected Met	**0.00**	**0.04**	**0.00**	**0.05**
Urea	0.15	0.15	0.15	0.15
Dried Molasses	1.54	1.54	1.54	1.54
Sodium bicarbonate	0.83	0.83	0.83	0.83
Lactation VTMM	0.34	0.34	0.34	0.34
Magnesium oxide	0.08	0.08	0.08	0.08
Calcium carbonate	0.83	0.83	0.83	0.83

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Nutrient composition

	Low MetLys		High MetLys	
	Low His	High His	Low His	High His
% DM				
CP	14.8	15.0	15.8	15.8
RDP	**10.4**	**10.1**	**10.7**	**10.3**
RUP	**4.4**	**4.9**	**5.1**	**5.5**
NDF	31.1	31.1	30.3	30.7
Forage NDF	21.9	21.9	21.9	21.9
Starch	25.4	25.1	25.7	25.1
Total FA	6.37	6.35	6.29	6.54
MP	8.01	8.31	8.74	8.95
NEL (Mcal/kg)	1.65	1.65	1.65	1.67

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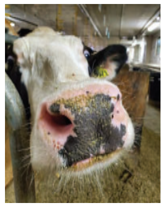
Experimental design

4 x 4 Latin Square design
- 8 replications (32 cows total)
- 4 treatments (2 x 2 factorial, HIS x MetLys)

28-day periods
- 21 days of adaptation + 7 days of sampling

Statistical analysis (R Studio, lmer package):
- Fixed effects: HIS, MetLys, HIS x MetLys, PERIOD, SQUARE
- Random effects: Cow(Square)



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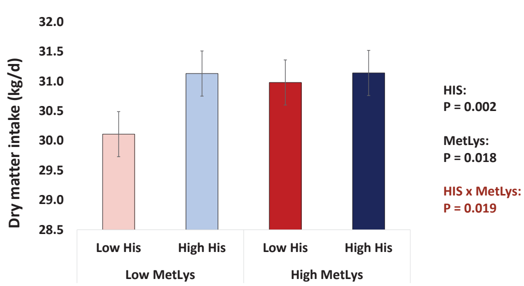
Dry matter intake



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Metabolizable AA supply (g/d; NASEM 2021)

	Low MetLys		High MetLys	
	Low His	High His	Low His	High His
His	**54**	**77**	**58**	**80**
Lys	**191**	**203**	**242**	**244**
Met	**60**	**61**	**78**	**76**
Ile	134	126	139	130
Leu	218	233	239	250
EAA	1225	1346	1387	1464
MP	2407	2581	2702	2782

Relative to Low:

High HIS:
+ 25 g/d

High MetLys:
+ 69 g/d
(+ 17 g/d Met)
(+ 52 g/d Lys)

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Milk yield (kg/d)

	Low MetLys		High MetLys		SEM	P-values		
	Low His	High His	Low His	High His		HIS	MetLys	HIS x MetLys
Milk yield	43.5	45.6	44.3	45.6	0.7	<0.001	0.194	0.161
Energy-Corrected Milk (ECM)	47.8	49.8	49.0	50.4	0.7	<0.001	0.008	0.340

High HIS diets increased milk yield **+ 1.7 kg/d**

High HIS diets increased ECM **+ 1.7 kg/d**
&
High MetLys diets increased ECM **+ 0.9 kg/d**

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Component yield (kg/d)

	Low MetLys		High MetLys		SEM	P-values		
	Low His	High His	Low His	High His		HIS	MetLys	HIS x MetLys
Protein	1.32	1.40	1.37	1.44	0.02	<0.001	<0.001	0.643
Lactose	2.07	2.16	2.11	2.15	0.04	<0.001	0.498	0.124
Fat	1.86	1.92	1.90	1.94	0.03	0.008	0.072	0.575

High HIS diets increased milk protein **+ 74 g/d**
&
High MetLys diets increased milk protein **+ 45 g/d**

High HIS diets increased lactose yield **+ 67 g/d**

High HIS diets increased fat yield **+ 45 g/d**

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Composition (%)

	Low MetLys		High MetLys		SEM	P-values		
	Low His	High His	Low His	High His		HIS	MetLys	HIS x MetLys
Protein %	3.05	3.08	3.11	3.17	0.03	<0.001	<0.001	0.132
Lactose %	4.77	4.75	4.76	4.73	0.02	<0.001	0.063	0.345
Fat %	4.34	4.23	4.36	4.30	0.07	0.032	0.217	0.491

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Component yield (kg/d)

	Low MetLys		High MetLys		SEM	P-values		
	Low His	High His	Low His	High His		HIS	MetLys	HIS x MetLys
Fat	1.86	1.92	1.90	1.94	0.03	0.008	0.072	0.575
De novo FA (g/d)	454.1	471.9	478.0	484.9	9.5	0.004	<0.001	0.377
Mixed FA (g/d)	610.3	619.9	633.1	646.4	14.0	0.060	<0.001	0.758
Preformed FA (g/d)	688.2	717.3	685.1	698.2	10.9	0.004	0.124	0.264

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Composition (%)

	Low MetLys		High MetLys		SEM	P-values		
	Low His	High His	Low His	High His		HIS	MetLys	HIS x MetLys
Fat %	4.34	4.23	4.36	4.30	0.070	0.032	0.217	0.491
De novo FA %	1.05	1.04	1.08	1.07	0.022	0.375	0.008	0.564
Mixed FA %	1.43	1.37	1.45	1.44	0.032	0.009	0.001	0.132
Preformed FA %	1.59	1.58	1.56	1.54	0.020	0.266	0.037	0.721

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Nitrogen use and output

	Low MetLys		High MetLys		SEM	P-values		
	Low His	High His	Low His	High His		HIS	MetLys	HIS x MetLys
N intake (g/d)	711	747	783	787	9.4	<0.001	<0.001	0.001
MUN (mg/dL)	8.67	9.34	10.40	10.86	0.24	<0.001	<0.001	0.396
Urine N output (g/d)	173	177	185	196	6.5	0.169	0.008	0.507
UUN output (g/d)	136	138	159	171	4.6	0.057	<0.001	0.214

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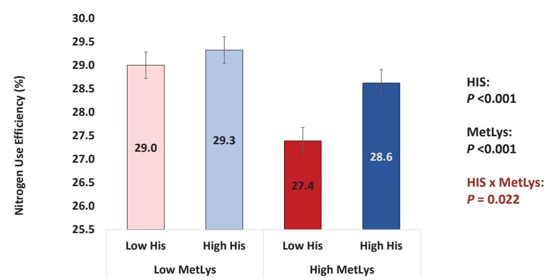
Nitrogen Use Efficiency (%)



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Conclusions

- Lactation diets balanced for **His** with blood meal improved milk production irrespective of the level of **MetLys**.
  - (Limiting AA theory is not accurate)
- **His** and **MetLys** had **additive effects** on milk production.
- **His** has less detrimental effects on N excretion than **MetLys**.

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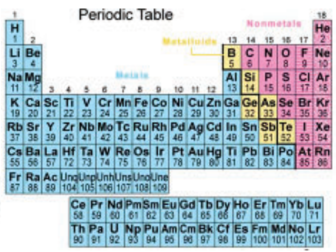
Effect of Replacing Sulfate with Hydroxychloride Sources of Trace Minerals on Performance of Dairy Cows

Dr. José Santos
University of Florida

Effect of Replacing Sulfate with Hydroxychloride Sources of Trace Minerals on Performance of Dairy Cows

José E.P. Santos
University of Florida



ANIMAL SCIENCES

Four-State Dairy Nutrition & Management Conference

1

Trace Minerals

- ✓ Inorganic trace minerals are the most commonly supplemented sources of Zn, Cu, and Mn to diets of cattle
- ✓ Of the inorganic sources, sulfates are among the most soluble
  - ✓ $ZnSO_4 \cdot H_2O$
  - ✓ $CuSO_4 \cdot 5H_2O$
  - ✓ $MnSO_4 \cdot H_2O$
  - ✓ $MnSO_4 \cdot 5H_2O$

Ionic Cu^{2+} is bactericidal

e.g.,

$CuSO_4 \cdot 5H_2O \xrightarrow{\text{In solution}} Cu^{2+} + SO_4^{2-} + 5H_2O$

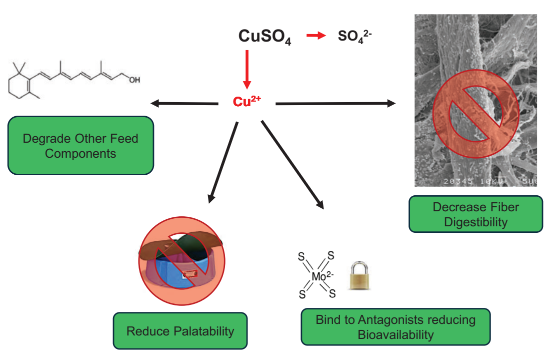
Ionic Zn^{2+} is bactericidal

e.g.,

$ZnSO_4 \cdot H_2O \xrightarrow{\text{In solution}} Zn^{2+} + SO_4^{2-} + H_2O$

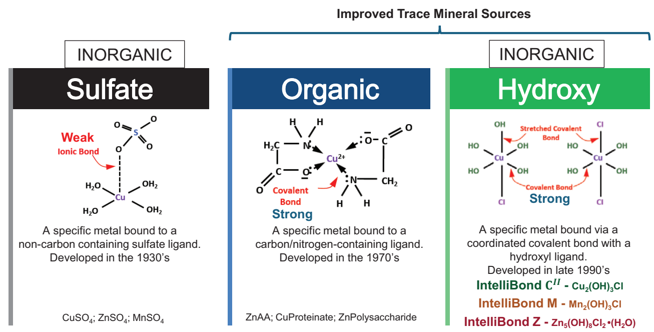
2

What Can Free Metal Ions Do?



3

Forms of Trace Minerals



4

Hydroxychloride Trace Minerals

- ✓ Tribasic copper chloride: $Cu_2(OH)_3Cl$
- ✓ Zinc chloride hydroxide monohydrate: $Zn_5(OH)_8Cl_2 \cdot H_2O$
  - ✓ Also known as tetrabasic zinc chloride hydrate
- ✓ Tribasic manganese chloride: $Mn_2(OH)_3Cl$
  - ✓ Insoluble in pH > 5.0, making them not reactive in the rumen
  - ✓ Ionize once they reach the abomasum

5

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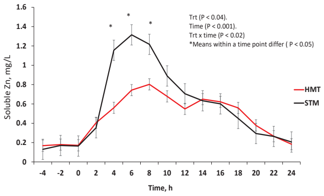
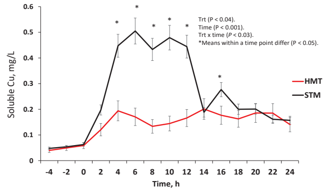
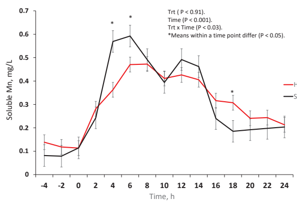
Solubility of Different Sources of Trace Minerals



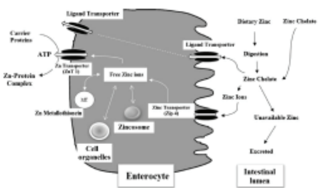




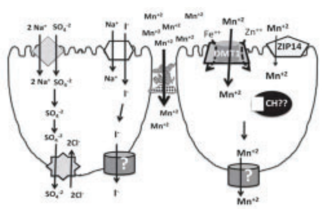
Guimarães et al. (2022) Animal 16:100500

7

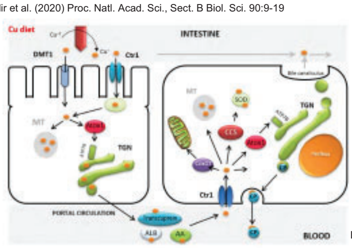
Absorption and Transport of Zn, Mn and Cu



Mir et al. (2020) Proc. Natl. Acad. Sci., Sect. B Biol. Sci. 90:9-19



Goff (2018) J. Dairy Sci. 101:2763–2813

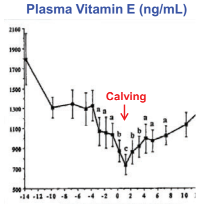


López-Alonso and Miranda (2020) Animals 10(10):1890

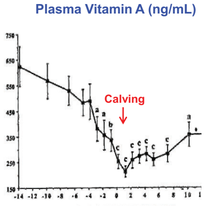
8

Calving and Onset of Lactation Reduces Concentrations of Many Nutrients in Plasma

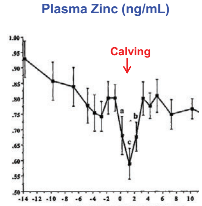
Plasma Vitamin E (ng/mL)



Plasma Vitamin A (ng/mL)



Plasma Zinc (ng/mL)



Goff and Stabel (1990) J. Dairy Sci. 73:3195

9

Effect of Source of TM on Production and Digestibility in Dairy Cows

Effect of trace mineral production performance in dairy cows

Item	Treatments				SEM	*P* values[1]	
	STM100	HTM100	STM70/OTM30	HTM70/OT30		HTM	OTM30
DMI kg/d	22.6	22.7	22.2	22.4	0.6	0.34	0.10
Yield, kg/d							
Milk	29	29.4	29.5	29.5	1.1	0.39	0.27
FPCM	31.6	32.1	32	32.3	1.0	0.21	0.31
Fat	1,328	1,350	1,346	1,358	43	0.25	0.36
True protein	1,068	1,087	1,083	1,091	34	0.19	0.34
MUN, mg/dL	12.6	13.1	12.9	13.1	0.3	0.04	0.49

[1]HTM = contrast (HTM100 + HTM70/OTM30) vs. (STM100 + STM70/OTM30);
OTM30 = contrast (STM100 + HTM100) vs. (STM70/OTM30 and HTM70/OTM30).

Table 3. Effect of trace mineral source on apparent total-tract digestibility (%)

Item	Treatment[1]				SEM	*P*-value[2]	
	STM100	HTM100	STM70/OTM30	HTM70/OTM30		HTM	OTM30
DM	68.2	68.5	68.0	68.1	0.2	0.32	0.09
OM	71.1	71.4	70.8	71.0	0.3	0.19	0.12
CP	61.3	60.5	59.9	59.8	0.4	0.14	<0.01
NDF	49.7	50.6	48.9	49.6	0.4	0.03	0.02
ADF	42.8	43.3	42.3	42.1	0.5	0.69	0.07

Daniel et al. (2020) J. Dairy Sci. 103:9081-9089

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J. Dairy Sci. 106:2386–2394
https://doi.org/10.3168/jds.2022-22490

Meta-analysis of the effects of sulfate versus hydroxy trace mineral source on nutrient digestibility in dairy and beef cattle

M. Ibraheem,[1] S. K. Kvidera,[2] R. S. Fry,[2] and B. J. Bradford[1*]
[1]Department of Animal Science, Michigan State University, East Lansing 48824
[2]Micronutrients USA LLC, Indianapolis, IN 46231

✓ **Inclusion criteria:** Digestibility analysis, study design, cattle type, mineral intake, days on treatment, diet NDF%, etc. and the main outcomes extracted were DM digestibility, NDF digestibility, and DMI (kg/d or % of body weight).

✓ **Statistical analysis:** Mixed-effects model meta-analysis to estimate overall effect sizes of hydroxy versus sulfate TM.

Responses to replacing sulfate trace minerals (STM) with hydroxy trace minerals (HTM)
(Comparison: HTM – STM)

Outcome	Comparisons (n)	Mean response	SEM	*P* value
DM digestibility (%)	12	+0.50	0.27	0.11
NDF digestibility (%)	12	+1.51	0.49	0.02
DMI (kg/d)	9	+0.30	0.35	0.43
DMI (%BW)	9	+0.04	0.049	0.44

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Hypotheses

✓ Replacing STM with HTM is expected to increase Zn, Cu and Mn stores in dairy cows and improve peripartum health that would benefit production in early lactation and subsequent reproduction.

Objectives

✓To evaluate the effects of two sources of trace minerals of Zn, Cu, and Mn on production, health and reproduction responses in dairy cows.

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Sample size calculation

✓Sample size was calculated based on the following assumptions:

- ✓ The sample size was calculated to provide sufficient experimental units when α = 0.05, β = 0.20, and SD = 3.50, to detect a 1.5 kg/d difference in ECM yield

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Treatments

✓ Basal diets for both treatments contained (DM basis) approximately 30 mg/kg of Zn, 6 mg/kg of Cu, and 20 mg/kg of Mn.

✓**STM (n = 70)**: Supplemented sulfate sources of Zn, Cu, and Mn to achieve approximately 65, 16, and 65 mg/kg of DM.

✓ **HTM (n = 71)**: Supplemented hydroxychloride sources of Zn, Cu, and Mn to achieve approximately 65, 16, and 65 mg/kg of DM.

Prepartum **Postpartum**

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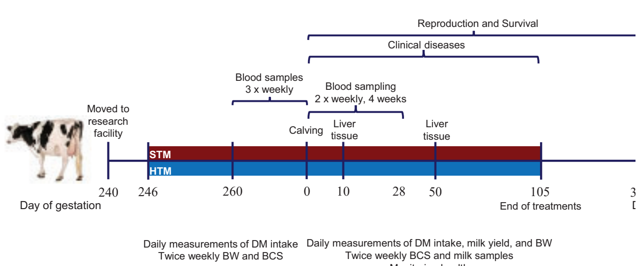
Materials and methods

- ✓ Randomized complete block design
- ✓ 61 nulliparous and 80 parous cows at 240 d of gestation were enrolled weekly cohorts and first blocked by parity, then:
  - ✓ Nulliparous: blocked by genomic PTA for ECM yield
  - ✓ Parous: blocked by recently completed lactation 305-d ECM yield
- ✓ Within block, cows were randomly assigned to **STM** or **HTM**



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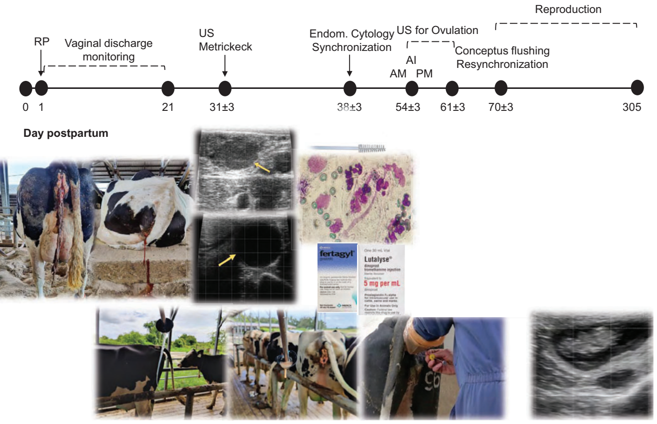
Materials and methods



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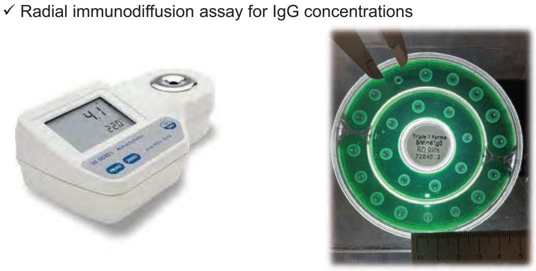
Colostrum

✓ Yield of colostrum

✓Analyzed for concentrations of fat, true protein, lactose, solids-not-fat, total solids, and somatic cells

✓ Brix refractometer

✓ Radial immunodiffusion assay for IgG concentrations



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Nutrient content of trace mineral mixtures fed pre- and postpartum

	Prepartum		Postpartum	
Nutrient, DM basis	STM	HTM	STM	HTM
Ash, %	97.2 ± 0.9	97.4 ± 0.4	97.3 ± 1.1	97.8 ± 0.7
Ca, %	31.7 ± 0.8	33.3 ± 0.5	1.16 ± 0.47	0.37 ± 0.23
Mg, %	1.18 ± 0.07	1.20 ± 0.22	0.09 ± 0.09	0.07 ± 0.05
K, %	0.55 ± 0.13	0.63 ± 0.10	32.6 ± 18.9	46.6 ± 11.2
Fe, mg/kg	780 ± 176	956 ± 201	163 ± 94	194 ± 156
Zn, mg/kg	3,212 ± 167	3,404 ± 260	7,426 ± 3,510	7,247 ± 1557
Cu, mg/kg	766 ± 46	777 ± 79	1,349 ± 622	1,413 ± 409
Mn, mg/kg	2,383 ± 229	2,482 ± 85	5,521 ± 95	6,469 ± 1634

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Nutrient content of diets fed pre- and postpartum (mean ± SD)

	Prepartum		Postpartum	
Nutrient, DM basis	STM	HTM	STM	HTM
NE_L, Mcal/kg	1.65	1.65	1.85	1.85
CP, %	13.5 ± 0.3	13.5 ± 0.3	16.6 ± 0.2	16.6 ± 0.2
Metabolizable				
Protein, %	10.6	10.6	11.0	11.0
Methionine, % MP	2.18	2.18	2.05	2.05
Lysine, % MP	7.54	7.54	7.63	7.63
Starch, %	24.9 ± 0.7	24.9 ± 0.7	32.0 ± 0.2	32.0 ± 0.2
NDF, %	38.2 ± 0.9	38.2 ± 0.9	27.2 ± 0.9	27.2 ± 0.9
Forage NDF, %	33.2 ± 0.9	33.2 ± 0.9	21.4 ± 0.8	21.4 ± 0.8
Fatty acids, %	3.0 ± 0.2	3.0 ± 0.2	5.3 ± 0.4	5.3 ± 0.4
Ca, %	1.03 ± 0.03	1.04 ± 0.03	0.81 ± 0.2	0.80 ± 0.2
P, %	0.28 ± 0.06	0.28 ± 0.06	0.42 ± 0.13	0.42 ± 0.13
Mg, %	0.48 ± 0.01	0.48 ± 0.01	0.48 ± 0.10	0.48 ± 0.10
Zn, mg/kg	**60.8 ± 5.3**	**66.4 ± 4.9**	**75.7 ± 17.4**	**78.8 ± 4.3**
Cu, mg/kg	**15.1 ± 1.1**	**15.2 ± 1.0**	**18.5 ± 3.3**	**19.3 ± 2.8**
Mn, mg/kg	**57.4 ± 3.0**	**58.2 ± 1.8**	**60.2 ± 21.7**	**70.4 ± 7.7**
DCAD, mEq/kg	-177 ± 58	-177 ± 58	407 ± 10	438 ± 23

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Statistical analyses

- ✓ Continuous data were analyzed by linear mixed-effects models using the MIXED procedure of SAS.
  - ✓ For all models with continuous data, the distribution of residuals and homogeneity of variance was evaluated after model fit.

$$\boldsymbol{Y} = \mu + \beta_1 \cdot Trt + \beta_2 \cdot Par + \beta_3 \cdot SexCalf + \beta_4 \cdot (Trt\ x\ Par) + \beta_5\ DaysTrt + \beta_6 \cdot CalfSex + \beta_7 \cdot PTACov + \beta_8 \cdot Blk(Par) + e$$

  - ✓ Data with repeated measures included the effects of time and the random effect of *cow(Trt x block)*
- ✓ Binomial data were analyzed with generalized linear mixed-effects models fitting a binary distribution with the GLIMMIX procedure of SAS.

$$\boldsymbol{Ln}\left(\frac{p_1}{1-p_1}\right) = \beta_0 + \beta_1 \cdot Trt + \beta_2 \cdot Par + \beta_3 \cdot SexCalf + \beta_4 \cdot DaysTrt + \beta_5 \cdot PTACov + \beta_6 \cdot Blk(Par)$$

- ✓ Days to morbidity, days open, and days to leaving the herd were analyzed by the Cox's proportional hazard regression.

$$\boldsymbol{h(t)} = h_0(t)\ e^{\beta_1 \cdot Trt + \beta_2 \cdot Par + \beta_3 \cdot SexCalf + \beta_4 \cdot DaysTrt + \beta_5 \cdot PTACov + \beta_6 \cdot Blk(Par)}$$

- ✓ Significance against H_0 when $P \le 0.05$; tendency when $0.05 < P \le 0.10$.

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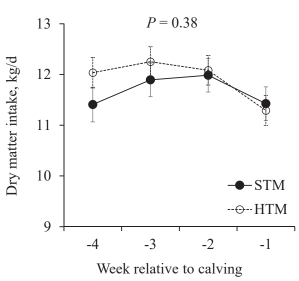
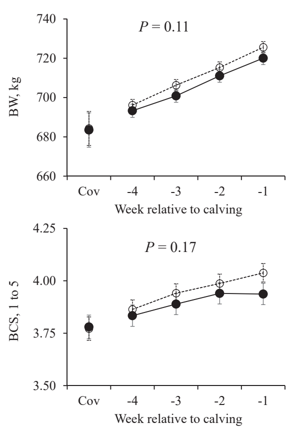
Prepartum DM intake, BW and BCS



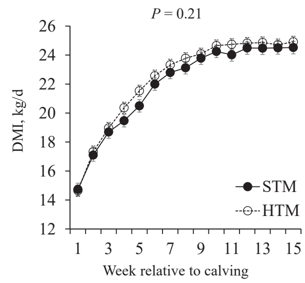


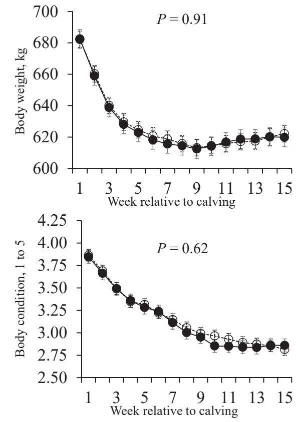
Parous cows: 14.1 ± 0.3 kg/d

Nulliparous cows: 9.5 ± 0.3 kg/d

21

Postpartum DM intake, BW, and BCS



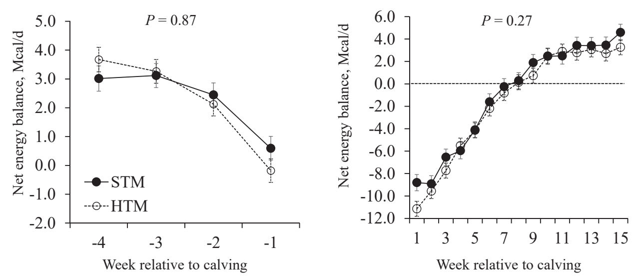


Parous cows: 24.7 ± 0.34kg/d

Nulliparous cows: 19.6 ± 0.4 kg/d

22

Pre and Postpartum NEB



23

Colostrum Yield and Composition

	Treatment						
	STM (n = 70)		HTM (n = 71)			*P*-value	
Item	Null	Parous	Null	Parous	SEM	TRT	TRT x parity
Yield, kg	5.54	4.89	7.07	5.47	0.81	0.08	0.50
Fat, kg	0.42	0.18	0.58	0.21	0.07	0.11	0.49
True protein, kg	0.84	0.77	1.04	0.85	0.12	0.15	0.59
Lactose, kg	0.14	0.12	0.19	0.13	0.03	0.17	0.37
Total solids, kg	1.53	1.19	1.97	1.53	0.22	0.08	0.54
Net energy							
Mcal/kg	1.67	1.33	1.69	1.40	0.05	0.29	0.64
Mcal	9.09	6.47	11.93	7.46	1.33	0.06	0.55
Somatic cell score	6.41	7.14	6.22	6.75	0.26	0.13	0.58
Brix, %	27.3	27.3	27.0	27.3	0.8	0.94	0.65
Immunoglobulin G, g	574	572	735	615	88	0.13	0.39

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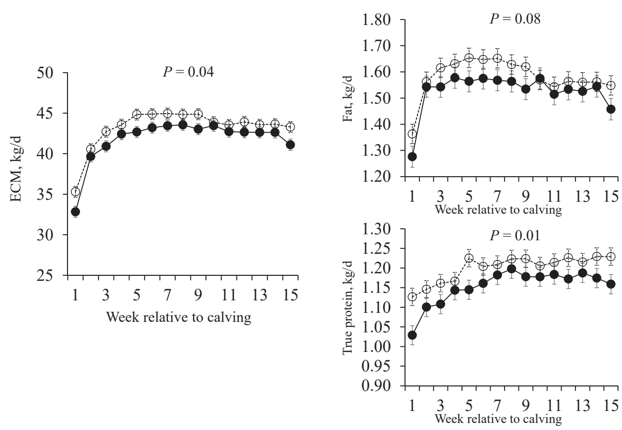
Yields of Milk, ECM, and Milk Components in the First 105 DIM

	Treatment					*P*-value		
	STM (n = 70)		HTM (n = 71)					
Item	Null	Parous	Null	Parous	SEM	TRT	TRT x parity	TRT x week
Milk, kg/d	36.1	46.8	37.3	48.0	0.8	0.08	0.96	0.31
ECM, kg/d	36.3	47.3	39.4	48.1	0.7	0.04	0.35	0.23
Fat, kg/d	1.32	1.73	1.41	1.75	0.04	0.08	0.24	0.56
True protein, kg/d	1.00	1.31	1.04	1.36	0.02	0.01	0.77	0.05
Total solids, kg/d	4.42	5.71	4.62	5.86	0.10	0.04	0.80	0.11
Fatty acids, %								
< 16 C	0.899[b]	0.927[a]	0.931[a]	0.918[ab]	0.013	0.30	0.07	0.57
16 C	1.35[b]	1.33[ab]	1.39[a]	1.31[b]	0.02	0.31	0.07	0.61
> 16 C	1.27	1.24	1.30	1.23	0.02	0.46	0.32	0.76

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

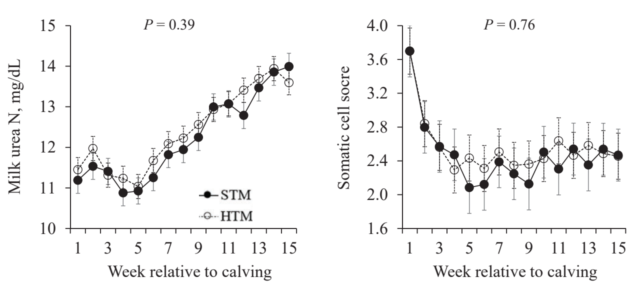
25

Yields of ECM, Fat and Protein



26

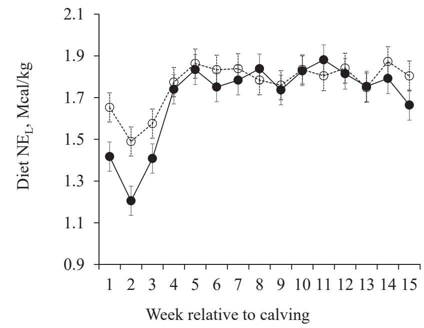
Milk urea nitrogen and SCS



27

Calculated NE_L of the diets in the first 105 DIM

- ✓Estimated diet NE_L:
  - ✓(NE_L Milk + NE_L BW Change + NE_L Maintenance) / DMI



28

Risk of diseases in the first 105 DIM

	Treatment			
Item	STM (n=70)	HTM (n=71)	AOR (95% CI)[1]	*P*-value
RFM, %	11.5 ± 6.3	3.8 ± 2.3	0.30 (0.13-0.74)	0.01
Milk fever,[2] %	1.1 ± 1.3	1.3 ± 1.3	1.12 (0.06-19.7)	0.94
Mastitis,[2] %	1.4 ± 1.0	0	---	0.49
DA,[2] %	1.4 ± 1.4	1.4 ± 1.4	0.99 (0.06-16.8)	0.99
Ketosis, %	6.4 ± 2.9	5.7 ± 2.8	0.89 (0.25-3.26)	0.86
Lameness, %	1.3 ± 1.2	6.7 ± 2.8	0.18 (0.02-1.32)	0.09

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.
[2] Analyzed by Fisher's exact test.

29

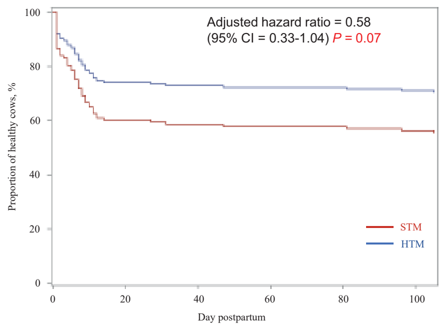
Risk of diseases in the first 105 DIM

	Treatment			
Item	STM (n=70)	HTM (n=71)	AOR (95% CI)[1]	*P*-value
Metritis, %	34.5 ± 10.5	26.4 ± 7.2	0.68 (0.26-1.77)	0.43
Clinical endometritis, %	16.4 ± 9.6	4.0 ± 2.9	0.21 (0.03-1.31)	0.09
Subclinical endometritis, %	29.8 ± 9.1	16.4 ± 5.7	0.46 (0.19-1.12)	0.09
Endometrial PMN cells, %	3.9 ± 1.2	4.5 ± 1.2	0.14 (0.68-1.92)	0.61
Morbidity, %	52.0 ± 9.0	34.2 ± 7.2	0.48 (0.23-1.01)	0.05
Multiple diseases, %	11.7 ± 6.3	10.9 ± 4.8	0.93 (0.26-3.30)	0.90

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.

30

Survival curves for the rate of morbidity in the first 105 d in milk



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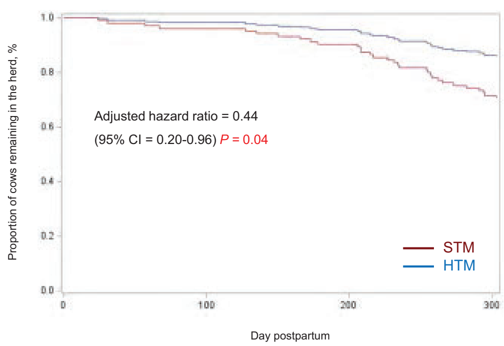
Survival curves for removal from the herd by 305 d in milk



32

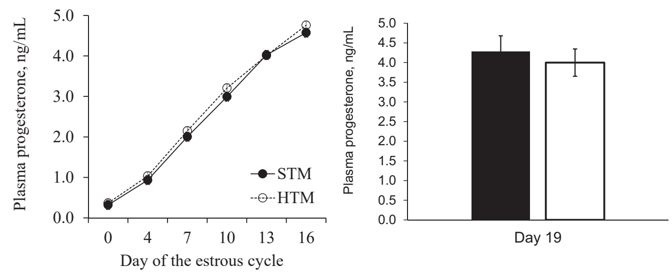
Effect of source of trace minerals on ovarian responses and conceptus development in dairy cows

Item	Treatment: STM (n=70)	Treatment: HTM (n=71)	AOR (95% CI)[1]	*P*-value
Cyclic by 38 d postpartum, %	62.2 ± 9.2	59.3 ± 8.3	0.89 (0.44-1.80)	0.73
Synchronized ovulation, %	82.7 ± 4.8	93.0 ± 3.7	2.77 (0.77-9.97)	0.12
Ovulatory follicle, mm	12.7 ± 0.5	13.4 ± 0.4	---	0.18
Luteal area d 7, mm²	344 ± 21.8	386 ± 18.7	---	0.08
Pregnant day 16, %				
All cows	56.2 ± 8.2	67.7 ± 7.1	1.63 (0.65-4.11)	0.29
Synchronized cows	63.6 ± 8.4	76.6 ± 6.8	1.88 (0.67-5.26)	0.23
Conceptus length, cm	8.22 ± 1.08	7.89 ± 0.95	---	0.70
Flush IFNt, ng/mL	11.6 ± 5.1	17.6 ± 7.6	---	0.47

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.

33

Effect of source of trace minerals on concentrations of progesterone in dairy cows



34

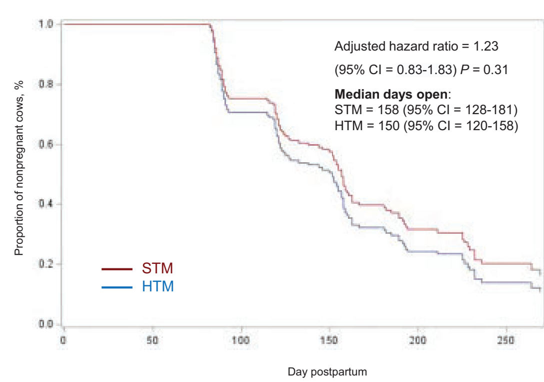
Effect of source of trace minerals on reproduction in dairy cows

Item	Treatment: STM (n=70)	Treatment: HTM (n=71)	AOR (95% CI)[1]	*P*-value
DIM first AI, d	85.5 ± 0.6	86.4 ± 0.5	---	0.14
Pregnant AI, %	38.3 ± 6.2	49.3 ± 6.3	1.57 (0.78-3.17)	0.20
21-d cycle AI rate, %	72.7 ± 3.0	75.7 ± 2.4	1.17 (0.87-1.57)	0.30
21-d cycle pregnancy rate, %	18.0 ± 4.5	22.2 ± 4.5	1.30 (0.73-2.32)	0.37
Pregnant by 305 DIM, %	69.2 ± 5.7	82.1 ± 4.7	2.05 (0.92-4.56)	0.08

[1] Adjusted odds ratio and 95% confidence interval. STM is the reference for comparison.

35

Survival curves for days open in the first 305 d in milk



36

Summary

- ✓ Replacing sulfate sources of Zn, Cu and Mn with hydroxychloride sources of the same trace minerals:
  - ✓ Tended to increase the yield of colostrum with no changes in the composition of colostrum. The increased colostrum yield resulted in increased yield of solids in colostrum
  - ✓ Increased yields of ECM in the first 15 weeks of lactation without affecting DMI postpartum.
- ✓ The diet consumed by cows receiving HTM supplied more 3.6% energy than that containing STM sources of trace minerals
  - ✓ Reduced morbidity
  - ✓ Perhaps changes in digestibility

37

Summary

- ✓ Replacing sulfate with hydroxychloride sources of trace minerals :
  - ✓ Reduced the risk of some uterine diseases (RFM and clinical and subclinical endometritis)
  - ✓ Reduced the risk and the rate of morbidity in the first 105 DIM
  - ✓ Increased survival of cows in the herd
  - ✓ Increased the proportion of cows pregnant at 305 DIM, although the rate of pregnancy was not affected by treatment
- ✓ Source of trace minerals did not affect the proportion of pregnant cows on day 16, conceptus size, or IFNt in the uterine flush
- ✓ Feeding HTM benefited health with some improvements in reproduction in dairy cows

38

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39

Optimizing Ratio of Corn Silage and Alfalfa/Grass in Dairy Feeding Programs

Rick Grant, Trustee and Retired President
William H. Miner Agricultural Research Institute
Chazy, NY

Optimizing ratio of corn silage and alfalfa/grass in dairy feeding programs

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1

Optimal forage blends:

Essential nutritional concepts

*Corn silage and alfalfa
*Alfalfa, alfalfa-grass, grass
*Dynamic chop length

2

Alfalfa and corn silage

- Alfalfa and corn silage are predominant forages in US
  - Between 1982 and 2012
    - Corn silage production **increased 33%**
    - Alfalfa hay production **declined by 75%**
- **Intensification** has driven greater reliance on corn silage
- **Benefits of alfalfa (and other perennials)** for soil health, N fixation, and sustainability

(Robinson, 2014; Martin et al., 2017; Gamble et al., 2021)

3

Alfalfa and corn silage

- Corn silage and alfalfa are complementary forages in many ways
  - **Fiber** characteristics
  - **Protein** content and degradability; Lysine content
  - **Starch** content and fermentability
  - Potential positive effect on **microbial protein synthesis**

4

Fiber pool size and rates: Corn silage, alfalfa, grass

Forage type	Fast	Slow	uNDF240	Fast K_d	Slow K_d
	% of NDF			h^{-1}	
Conventional CS	60.7	18.7	20.6	0.072	0.016
Grass	54.5	24.4	21.1	0.094	0.016
Alfalfa	48.8	8.7	42.5	0.134	0.023

- Alfalfa has lower NDF, higher uNDF, but faster K_d than CS.
- Higher rumen turnover rate, less filling, variable DMI response relative to CS.

(Raffrenato and Van Amburgh, 2019)

5

Composition of alfalfa hay and corn silage (% of DM)

	Alfalfa hay	Corn silage
Dry matter	89.3	31.6
Crude protein	21.7	9.0
aNDFom	34.1	37.4
30-h NDF digestibility, % of NDF	39.7	52.0
ADL	6.3	3.0
Starch	3.4	35.8
7-h starch digestibility, % of starch	---	61.3
Sugar (ESC)	8.0	0.7

(Morrison et al., 2022)

6

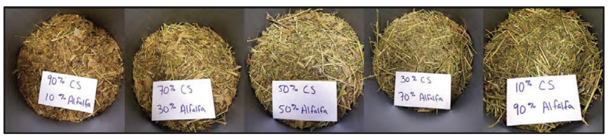
Dietary ingredients
(% of DM)

	Alfalfa-to-corn silage (DM basis)				
	10:90	30:70	50:50	70:30	90:10
Corn silage	56.4	43.5	31.0	18.6	5.7
Alfalfa hay	5.7	18.6	31.0	43.4	56.4
Concentrate	37.9	37.9	38.0	38.0	37.9

✓ All diets were **62% forage** (DM basis).
✓ CNCPS v 6.55 used to formulate for similar predicted MP- and ME-allowable milk.

7

Fiber attributes…DMI?



pef, % ≥4.0 mm	0.62	0.55	0.49	0.42	0.36
uNDF240, % of DM	9.5	10.2	10.1	12.1	12.5
peuNDF240 (pef x uNDF240)	5.7	5.6	5.0	5.1	4.7

8

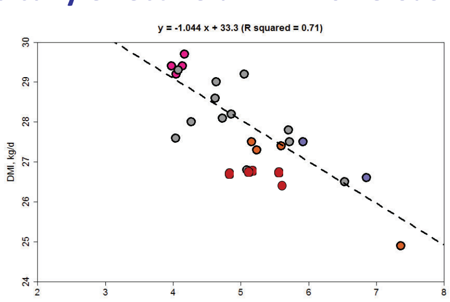
Intake, milk yield, and efficiency

	Alfalfa-to-corn silage ratio (DM basis)				
	10:90	30:70	50:50	70:30	90:10
Dry matter intake, lb/d	57.9	58.6	58.9	59.0	58.2
DMI, % of BW	3.82	3.85	3.86	3.91	3.91
Milk yield, lb/d	97.9	99.0	99.0	96.1	96.8
ECM yield, lb/d	105.6	107.4	106.3	103.6	106.5
ECM/DMI, lb/lb	1.82	1.83	1.81	1.76	1.83

✓ Can maintain high DMI and ECM yield over wide range of ratios.

9

Physically effective uNDF240 versus DMI



(Farricker et al., 2022)

10

Milk components

	Alfalfa-to-corn silage ratio (DM basis)				
	10:90	30:70	50:50	70:30	90:10
Fat, %	4.08	4.06	4.02	4.01	4.22
Fat, lb/d	3.9	4.0	4.0	3.9	4.0
True protein, %	3.01	3.07	3.01	3.02	3.05
True protein, lb/d[a]	2.93	3.02	3.00	2.90	2.92
MUN, mg/dl[b]	9.8	8.5	10.4	11.0	12.0
De novo FA, g/100 g FA[b]	24.76	25.86	25.82	25.22	25.58

[a]Significant cubic effect ($P < 0.05$).
[b]Significant quadratic effect ($P < 0.05$).

➢ **30:70 diet** had least predicted urine N and CH_4 output and greatest N efficiency.

11

With any forage program…think about yield and acreage needed

	Alfalfa-to-corn silage ratio (DM basis)				
	10:90	30:70	50:50	70:30	90:10
Corn silage, tons/cow/yr	18.9	14.8	10.5	6.3	1.9
Corn silage, acres/cow/yr	1.3	1.0	0.7	0.4	0.1
Alfalfa hay, tons/cow/yr	0.7	2.2	3.7	5.2	6.7
Alfalfa hay, acres/cow/yr	0.2	0.6	1.0	1.4	1.9

1.5 versus 2.0 acres/cow/yr

12

What is optimal forage mix for a specific farm?

- Best answer requires **whole-farm modeling** approach…under development but unavailable today
  - Allow **optimization of forages** from **nutritional, agronomic, and economic** perspective
  - **RuFaS, Ruminant Farm Systems**
    - https://rufas.org/
    - Animal, Manure, Crop & Soil, Feed Modules

13

Alfalfa or alfalfa/grass or grass?

- From nutritional perspective: **Focus on ability to maintain dry matter intake**
- Factors **in addition to response to diet** will determine optimal amounts of CS, alfalfa, and grass grown or purchased and fed
  - **Cost of production**
  - **Agronomic considerations** and **water** usage
  - **Variability** in nutrient profile across cuttings
  - Relative **costs of protein** sources and other ration ingredients

14

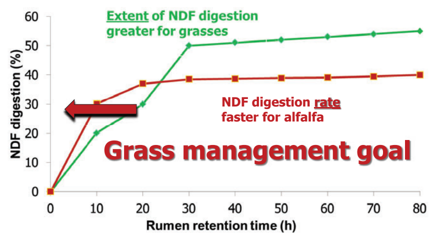
Grass versus legume: different rumen dynamics

- Legumes have more fragile NDF and particle size decreases more rapidly with rumination.
- Grasses increase amount of long particles, contribute to slower passage rate.
  - More selective retention
  - Increases fill and mass of rumen NDF
  - **Can reduce DMI if grass is not high quality!**

15

Take advantage of grass rumen digestion profile

Q: What is average time a forage particle stays in the rumen of a lactating cow?



16

Maturity at harvest MORE IMPORTANT than crop type (Mertens, 2007)

Forage	Maturity	Rate (%/h)	dNDF (% NDF)	Lignin (% DM)
Legume	Average	11.6	51.2	9.6
Grass	Average	9.6	68.7	6.2
L + G	Immature	15.2	72.4	4.6
L + G	Mature	6.0	47.4	11.2

17

Forage quality can change rapidly in the field!

- Alfalfa, Wisconsin data:
  - Crude protein, -0.25 units/day
  - NDF, +0.43
  - NDF digestibility, -0.43
- Cornell data:
  - NDFD decreases by 0.5 to 1.0 unit/d for alfalfa
  - **Grass decline can be even faster!**

18

Targets for forage NDF and NDF digestibility ...

Nutrient	Alfalfa, Mean	Alfalfa, Normal range[1]	Grass, Mean	Grass, Normal range
NDF, % of DM	43.7	38.2 - 49.3	56.7	49.9 - 63.4
Lignin, % of DM	7.4	6.1 - 8.6	5.2	3.5 - 6.8
30-h NDFD, %	51.5	45.4 - 57.6	63.3	56.4 - 70.1

[1]Mean plus/minus one standard deviation.
Source: DairyOne Forage Lab, Ithaca, NY.

Need to target higher NDFD to maximize response to forages!

19

Fiber benchmarks…

- 30-h NDFD
  - >50% for legumes
  - >60% for grasses
  - >60% for corn silage (65% for bmr)
- Some ration "guard rails":
  - uNDF240 > 10% of DM, ↓DMI
    - Consider finer chop length
  - peuNDF240 range: 4 to 6% of DM
  - uNDF240 < 7% of DM, ↓rumen pH and ↑risk of MFD
    - Keep peNDF at least 19-20% of ration DM
  - RFS:uNDF240 > 2.8, ↑risk of MFD
    - When uNDF240 less than 7% of DM, be careful!

20

20

Successfully balancing eating, resting, and ruminating time is critical for precise and efficient feeding of dairy cattle…

"Precision Chewing Management"

21

Optimized chewing behavior

*Forage NDF%, NDFD, uNDF, and particle size
*Feeding environment

22

- Value in integrating forage (un)degradability and particle size to better predict DMI and milk yield
  - Adjust particle size/chop length as forage maturity and moisture change.
    - As forage matures (i.e., NDF digestibility declines) chop finer.
    - Growing season enhances lignin.
    - Corn crop gets too dry.
  - Boost dry matter intake by up to 5 lb/d.

(Grant and Cotanch, 2023. *Applied Animal Science*. 39:146-155.)

23

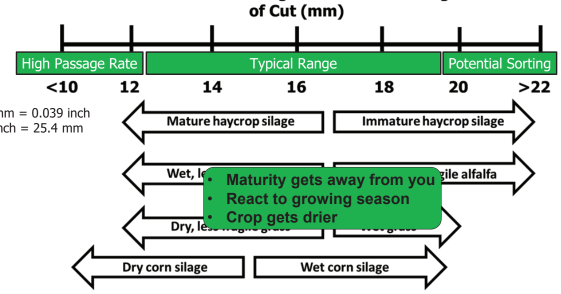
Suggested PSPS targets:
Miner Institute (Cotanch, 2017; rev. 2020)

	Sieve mm	PSPS 2013 %	Miner 2020 %	Comments
Top	19	2-8	2-5	Sortable material, too long, increases time needed for eating; especially if >10%. Length 1-2 inches maximum.
Mid 1	8	30-50	>50	Still long and functional pef, more so than 4 mm material. Maximize amount on this sieve, 50-60%
Mid 2	4	10-20	10-20	Functions as pef sieve, no recommendation for amount to retain here other than total on the top 3 sieves = pef
Pan	---	30-40	25-30	40-50% grain diet results in at least 25-30% in the pan

✓ Keep feed in front of cow
✓ Comfortable stalls
✓**Part of a system**

24

Recommended Range in Theoretical Length of Cut (mm)



1 mm = 0.039 inch
1 inch = 25.4 mm

Figure adapted from Woodley (2022)

25

Take-home messages…

- Sustainable dairy-forage programs could include higher alfalfa-to-corn silage ratios than commonly fed.
  - Nutritional perspective: choice of alfalfa, grass, or mixture is a function of rumen turnover and DMI.
  - Decision depends of nutritional, agronomic, and economic considerations…
- Dynamic approach to forage chop length and quality helps maintain higher DMI and cow response.

26

Carrying on William Miner's vision:
"Science in the Service of Agriculture."

27

Practical Aspects of Reducing the Carbon Footprint of Dairy Farms Through Feeding

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

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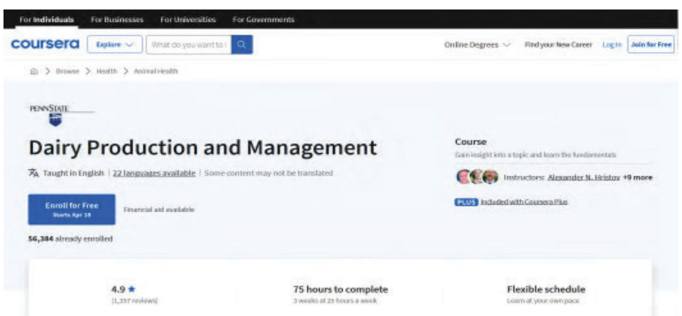
2024 Four-State Dairy Nutrition & Management Conference, June 4-6th, Dubuque, Iowa

1

PennState College of Agricultural Sciences

The world's first Dairy Production and Management MOOO-C: >57,000 enrolled from 155 countries (translated into 7 languages)

https://www.coursera.org/learn/dairy-production/

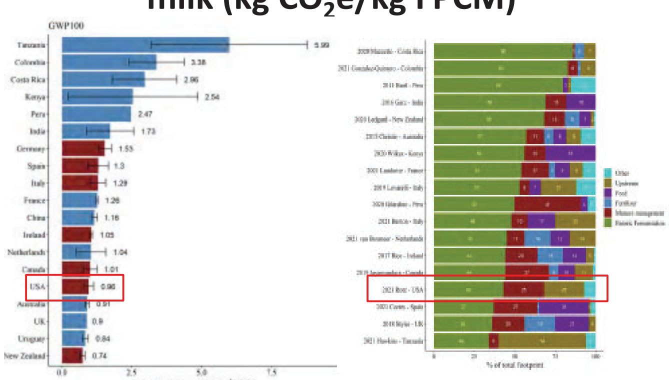


2

PennState College of Agricultural Sciences

Mazzetto et al., 2022

Cradle to farm-gate C-footprint of milk (kg CO_2e/kg FPCM)



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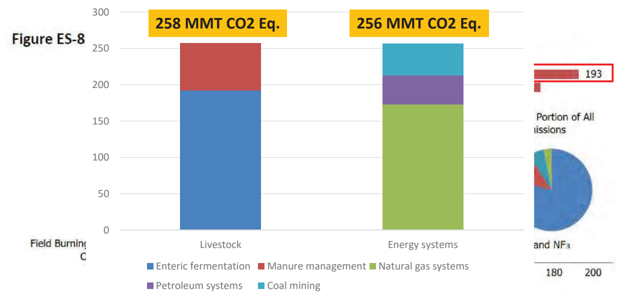
USEPA, 2024

Breakdown of US methane emissions



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Sources of methane in ruminant production systems

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Methane metrics

- Daily methane emission (g/d)
- Methane yield (g/kg DMI)
- Methane intensity (g/kg milk or ECM/FPCM yield)

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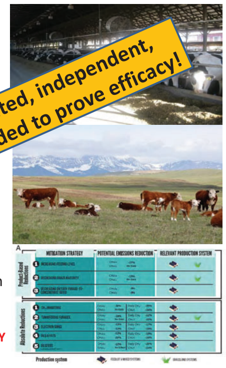
Hristov et al., 2013; Arndt et al., PNAS 2022

What are the enteric methane mitigation strategies available today?

- Nutritional strategies
  - Improving forage quality
  - Feeding concentrates
  - Lipids
  - Nitrates
  - Ionophores
  - Tannins & saponins
  - Methane inhibitors BOVAER
  - Seaweeds
  - Precision feeding
- Management strategies
  - ... methanogens
  - ... of the rumen microbiome
  - ... genetics, selecting for low-methane emission
  - Improving animal health
  - Lifetime productivity
  - IMPROVING ANIMAL PRODUCTIVITY AND FEED EFFICIENCY

With all these, well-designed and executed, independent, long-term research experiments are needed to prove efficacy!



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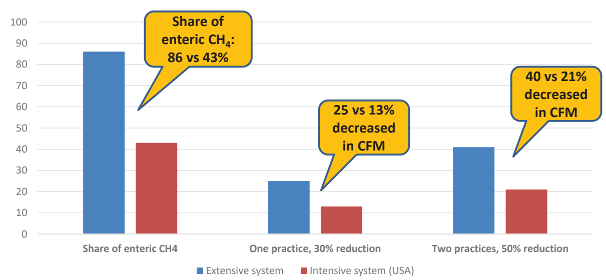
Based on Rotz et al., 2021 and Mazzetto et al., 2022

The impact of enteric CH_4 mitigation practices can be different* depending on the production system



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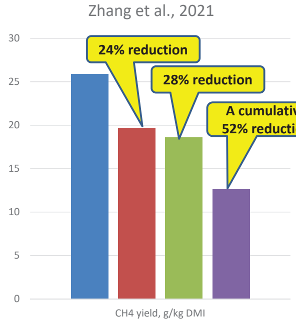
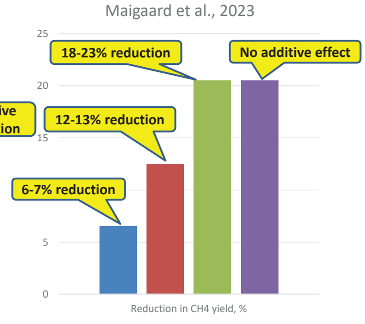
One area that needs more research: additivity of mitigation practices

Zhang et al., 2021



Maigaard et al., 2023



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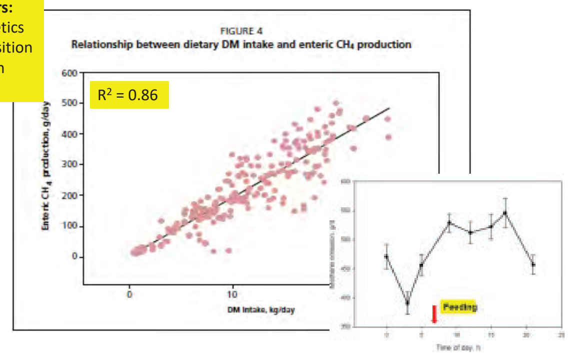
Hristov et al., 2013

Factors affecting enteric methane emission: DMI

Other factors:
Animal genetics
Diet composition
- fiber/starch
- fat



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Forage type, digestibility, starch

- Type of forage
  - Corn silage, legumes, grasses, brassicas, tanniferous forages
  - high-WSC, high-ME grasses
- Forage digestibility
- Concentrate inclusion
- Feeds – we are not going to talk about this

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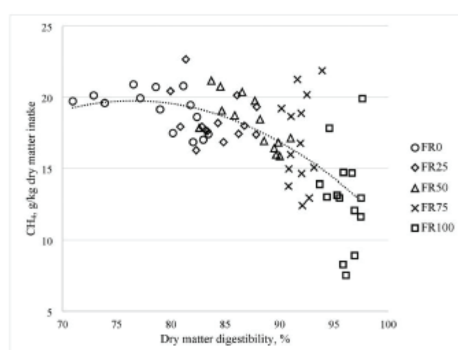
Della Rosa et al., 2022

Methane yield decreases with increasing forage digestibility



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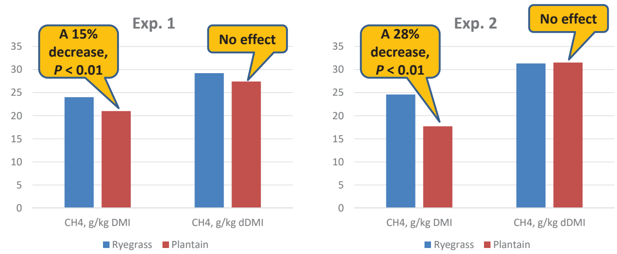
Della Rosa et al., 2022

Digestibility and CH_4, the plantain example (lactating dairy cows)



DMD was: 84 vs 76% and 79 vs 57%

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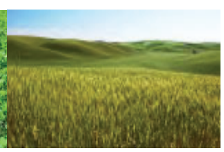
Various sources

Forage type: most studied – corn silage vs alfalfa silage

- Overall, a small decrease (5-15%) in CH_4 yield when CS replaces AS
  - In some cases, CH_4 intensity also decreased due to increased milk production; however, ECM intensity effect is more variable due to decrease in milk fat % with CS
- Corn silage vs grass silage: typically, a small, up to 10%, decrease in CH_4 yield with CS
- Limited studies: BMR corn silage has been shown to decrease CH_4 yield (ECM basis) by about 10%, compared with conventional CS





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Harper et al., 2017, 2018

Alternative forages: triticale, wheat, pearl millet, sorghum, oats silages

- About 10% inclusion in the diet, replacing corn silage (20% replacement)
- With some (sorghum, oats), there was no changes in CH_4 emission
- With some (pearl millet), daily CH_4 emission, yield, and intensity all increased
- With some (triticale, wheat), milk production decreased and CH_4 intensity increased



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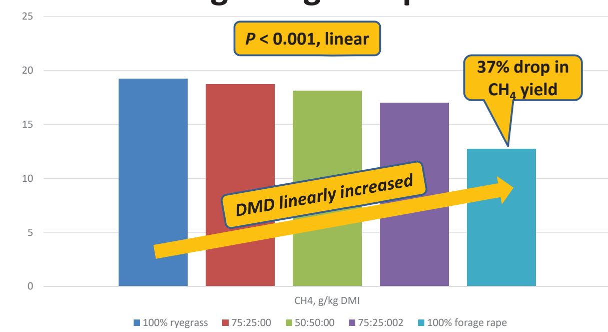
Della Rosa et al., 2022

Forage rape (*Brassica napus*) in grazing sheep



Forage rape has more NFC, less NDF, much more soluble sugars and pectin than ryegrass and is more digestible, which causes lower rumen pH and decreased CH4

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NZ AgResearch

High-WSC forages/High-ME ryegrass

- A 2-yr study; high-WSC & control diploid ryegrass varieties (and a triploid variety)
- WSC concentration varied across seasons but was generally higher for the HWSC RG
- Methane yield was similar for the high-WSC and tetraploid RG (19.4 and 18.4 g/kg DMI, respectively) and both were lower than the diploid control (20.8 g/kg DMI)
- However, methane yield could not be related to WSC concentration
- No difference in emission intensity (LWG/ha)
- Herbage accumulation and average stocking rate did not differ among cultivars in any season
- Overall, no clear advantage of high-WSC in terms of methane
- No animal data with high-ME ryegrass (in vitro data not convincing/promising)

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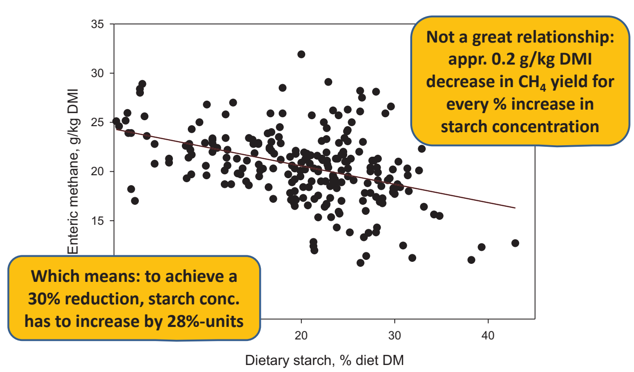
de Ondarza et al., 2023

What is the effect of starch on enteric methane emission?



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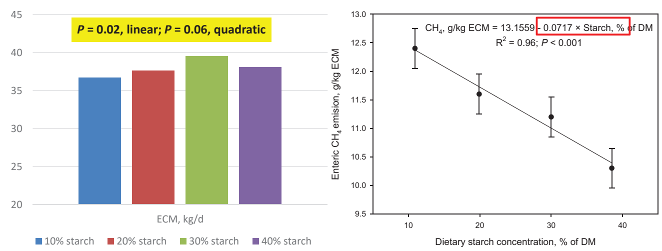
Cueva et al., 2024

A recent experiment with high-starch diets at Penn State

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



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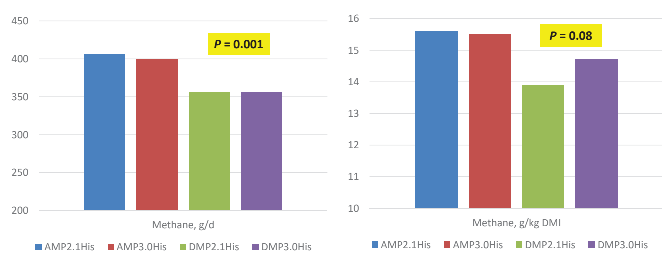
Räisänen et al., 2022

Diet reformulation: Low-protein, high-starch diets

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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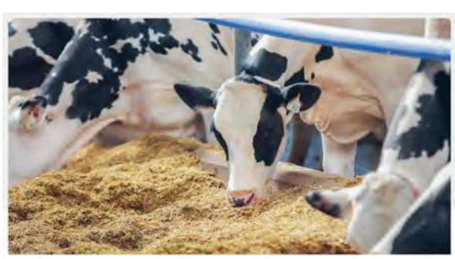
Feed additives: 3-nitrooxypropanol



28 May 2024

Elanco Announces FDA Has Completed Review of Bovaer®, First-in-Class Methane-Reducing Feed Ingredient, for U.S. Dairy Industry

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Martins et al., in review

Dairy cattle-specific meta-analysis

- 12 publications with 25 treatment and control means
- 3-NOP decreased methane emission, yield, and intensity (per kg MY and ECM) by 30.2, 28.8, 29.2, and 32.2%, respectively
- Increase in forage:concentrate ratio in the diet decreased 3-NOP efficacy
- Increased dietary CP also tended to decrease 3-NOP efficacy
- Increased dietary ADF decreased 3-NOP efficacy
- Increased dietary starch increased 3-NOP efficacy

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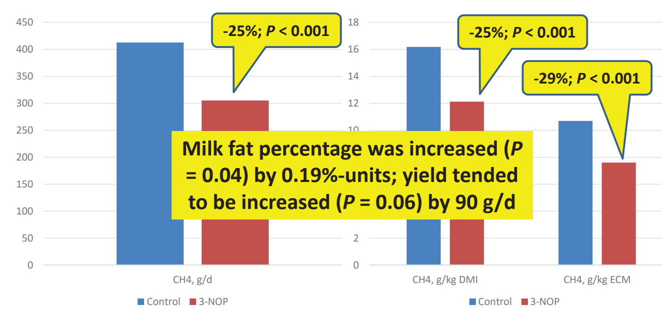
Hristov et al., 2022

Meta-analysis of Penn State's 3-NOP data with dairy cows



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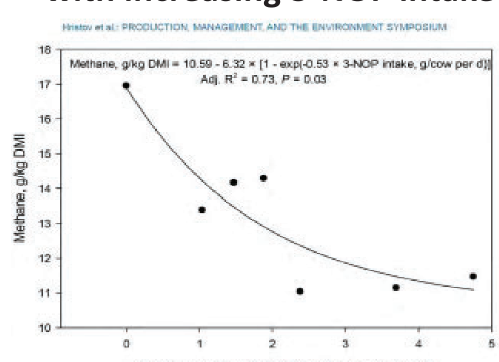
Hristov et al., 2022

Exponential decrease in CH_4 yield with increasing 3-NOP intake



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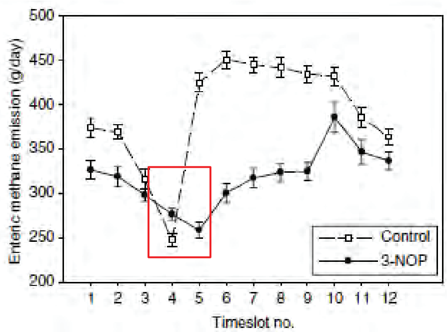
Hristov & Melgar, 2019

Diurnal pattern in the mitigation effect of 3-NOP



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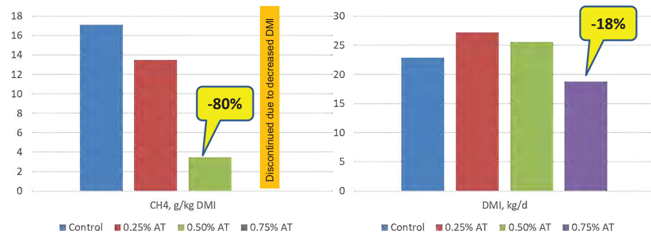
Stefenoni et al., 2021

Large reduction in methane emission with *Asparagopsis taxiformis* in dairy cows


Asparagopsis taxiformis (source: Penn State)



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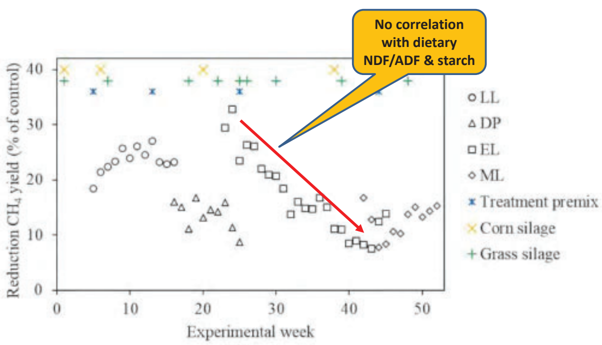
van Gastelen et al., 2024

Long-term effects of 3-NOP



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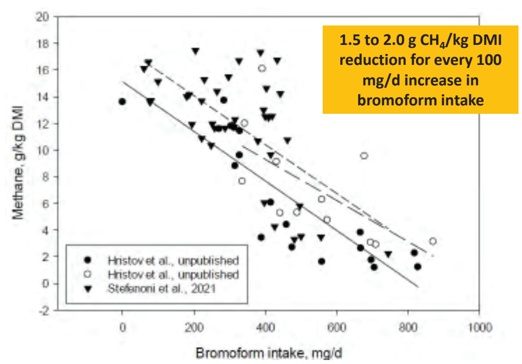
Hristov et al., 2022

Decrease in CH_4 yield was related to bromoform intake



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Hristov et al., 2013

Nitrates – an example of a promising rumen modifier with uncertain side effects..

About 16% reduction in a meta-analysis by Lee et al. (2015)

- Alternative electron sink.....does reduce enteric CH_4 emission
- Persistency of the effect (??)
- Toxicity of intermediate products ... e
  - The rumen ecosystem can adapt ... however, the adaptation can be lost quickly
- Do we need more N ... diet? May be applicable to diets that need NPN
  - If used in ... blocks – access has to be limited
- Nitrate ... the basal diet? NH_3 losses and manure NH_3/N_2O; ... production in the rumen

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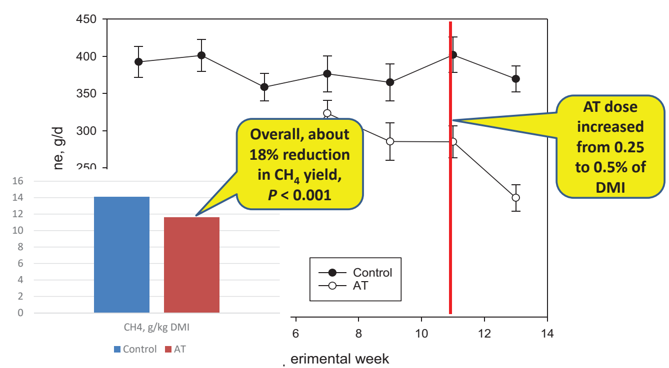
Wasson et al., 2022

Is the mitigation effect of *A. taxiformis* transient?



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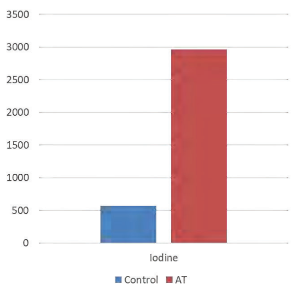
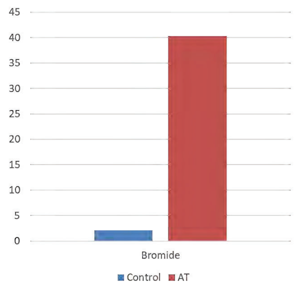
Stefenoni et al., 2021

Milk quality





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Plant extracts

Perhaps 5 to max 10% mitigation; however, more independent, long-term studies are needed to verify claims

- Numerous experiments
- Many in vitro, not followed up by animal trials
- Several commercial/experimental products:
  - **Mootral** (garlic/citrus extract) – one study with beef cattle showed 23% reduction in CH_4 yield at the end of the experiment (12 wks)
  - **Agolin** (a blend of essential oils) – a meta-analysis showed an overall 2% decrease in CH_4 yield and 13% beyond 28 d of treatment
  - **AVT** (capsicum & botanicals) – 5% decrease in CH_4 yield
  - **ADM/Pancosma** plant extracts product – 3% reduction
  - For some of these, adaptation may be needed to show effects

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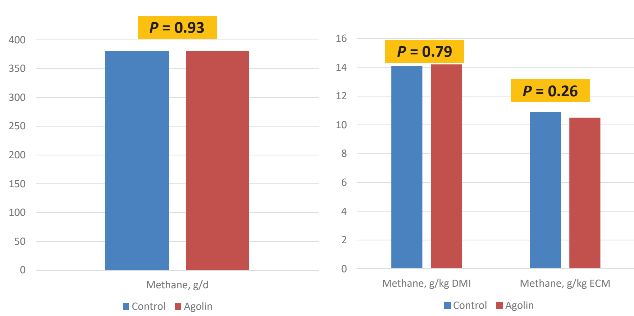
Silvestre et al., 2023

Plant extracts - Agolin



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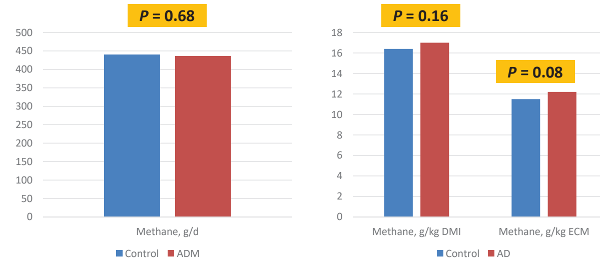
Richards et al., 2024

Another botanical product (ADM)



J. Dairy Sci. 107:857–869
https://doi.org/10.3168/jds.2023-23406
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Effect of a blend of cinnamaldehyde, eugenol, and *Capsicum* oleoresin on methane emission and lactation performance of Holstein-Friesian dairy cows

Sanne van Gastelen,[1]* David Yáñez-Ruiz,[2] Hajer Khelil-Arfa,[3] Alexandra Blanchard,[3] and André Bannink[1]
[1]Wageningen Livestock Research, Wageningen University & Research, 6700 AH Wageningen, the Netherlands
[2]Estación Experimental del Zaidín, CSIC, 18008, Granada, Spain
[3]ADM International Sàrl, CH-1180 Rolle, Switzerland

The same product that in this study decreased methane yield by 3.4%!

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Nutritional mitigation practices: summary

- **Forages**:
  - Corn silage is better than alfalfa and grass silages in terms of methane yield
  - BMR is better than conventional corn silage
  - Other, alternative forages don't seem to compete with corn silage
  - Increased forage digestibility will likely result in decreased methane yield
  - High-WSC grasses – data not convincing, need more research
  - High-ME grasses – no in vivo data, in vitro data are not encouraging
- **Concentrate feeds:**
  - Higher starch will typically result in decreased methane yield; need to watch milk fat and ECM
  - Overall, the benefit of increasing starch (or fat) to decrease methane yield (per ECM) may have limitations in high-producing herds
- **Additives seem to be the only nutritional mitigation option that may deliver a sizeable decrease in methane yield:**
  - Consistent results with 3-NOP; other inhibitors are being developed
  - Seaweeds have a way to go before recommendations can be made
  - Nitrates and tannins are also effective, or conditionally effective, but practicality is questionable
  - Questionable results with plant extracts

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So, what difference could nutrition make on the C-footprint of milk?

J. Dairy Sci. 106:7336–7340
https://doi.org/10.3168/jds.2023-23461
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***Perspective:* Could dairy cow nutrition meaningfully reduce the carbon footprint of milk production?**

Alexander N. Hristov*
Department of Animal Science, The Pennsylvania State University, University Park, PA 16802

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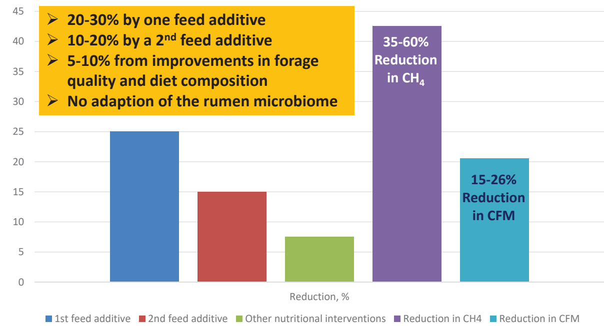
BEST-CASE SCENARIO
(no adaptation of the rumen microbiome; additivity of mitigation practices)



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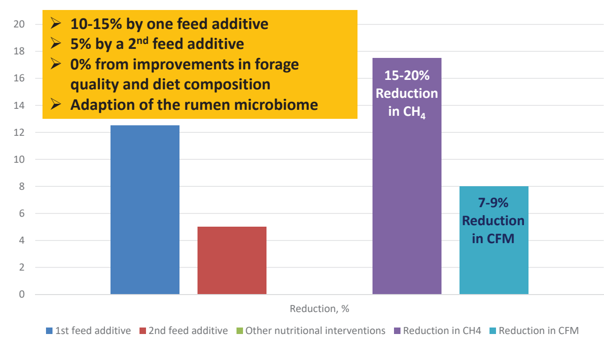
WORST-CASE SCENARIO
(perhaps adaptation of the rumen microbiome; no additivity of mitigation practices)



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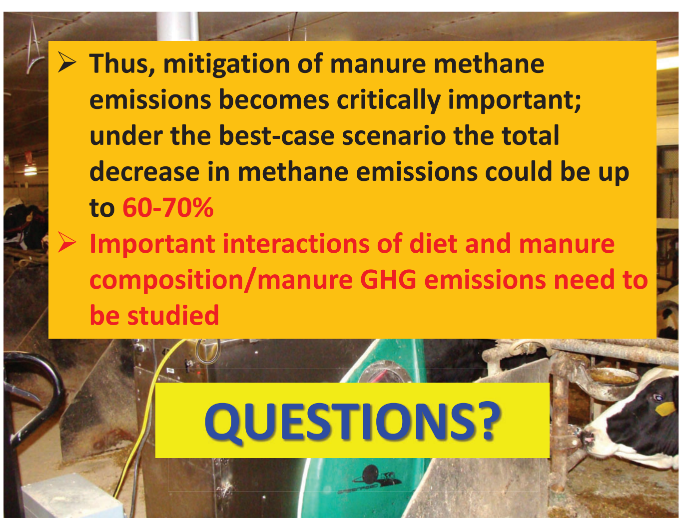

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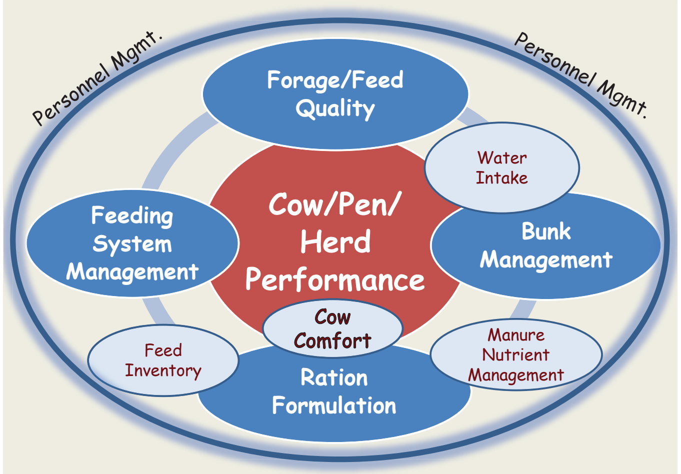
Modulating Cow Performance and Feeding Behavior With High Quality Forages

Luiz F. Ferraretto, PhD, PAS
Assistant Professor & Ruminant Nutrition Extension Specialist
University of Wisconsin, Dept. of Animal & Dairy Sciences

Modulating cow performance and feeding behavior with high quality forages

Luiz F. Ferraretto, Ph.D., PAS
Assistant Professor and Ruminant Nutrition Extension Specialist

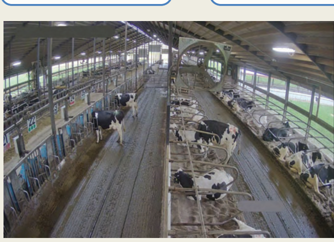
1

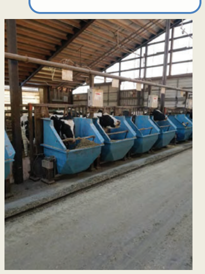


2

UW – NDF source study (summer)

- What are the effects of replacing forage fiber with a non-forage fiber source?
- How this change affects feeding behavior?
- Are there any implications for heat stress?





Pupo et al., 2023; ADSA Abstract

3

UW – NDF source study (summer)

- 64 multiparous Holstein cows (76 DIM and 1625 lb of BW at trial initiation)
- 32 gate feeders (8 gates/trt, cows had access to all gates from their respective treatments)
- 1 week acclimation to gates, 2 weeks covariate, and 8 treatment weeks

Pupo et al., 2023; ADSA Abstract

4

UW – NDF source study (summer)

- High-forage diet
- High-forage diet with 75 ml/cow of *L. plantarum*, *L. buchneri* and *S. cerevisiae*
- Low-forage diet
- Low-forage diet with 75 ml/cow of *L. plantarum*, *L. buchneri* and *S. cerevisiae*

Pupo et al., 2023; ADSA Abstract

5

Ingredient composition

Ingredient, % DM	High	Low
Corn silage	34.9	24.0
Alfalfa haylage	21.8	21.8
High-moisture corn	12.0	16.0
Whole cottonseed	4.5	5.1
Dry Ground Corn	5.8	6.7
Canola Meal	4.0	3.4
Expeller Soybean Meal	5.5	5.8
Soy Hulls	2.2	8.5
Soybean Meal, 46% CP	4.5	3.9
Other	4.8	4.8

Pupo et al., 2023; ADSA Abstract

6

Nutrient composition

Ingredient, % DM	High	Low
DM	50.9	54.7
CP, %DM	18.4	18.5
NDF, %DM	25.0	25.5
Starch, %DM	28.8	28.2
Ether extract, %DM	5.7	5.7
Forage NDF, %DM	19.5	15.7
Penn state particles		
19 mm	3.4	3.2
8 mm	45.2	42.3
1.18 mm	34.6	35.7
Pan	17.1	18.9

Pupo et al., 2023; ADSA Abstract

7

Lactation Performance

Item	High	Low	*P* - Value
DMI, lb/d	67.6	70.5	0.001
Milk, lb/d	121.1	127.5	0.01
ECM, lb/d	118.7	120.5	0.25
Fat, %	3.52	3.34	0.02
Protein, %	2.95	3.01	0.04
MUN, mg/dL	11.9	11.4	0.01
ECM FE, lb/lb DMI	1.76	1.70	0.01

Pupo et al., 2023; ADSA Abstract

8

Feeding behavior

Item	High	Low	*P* - Value
Bunk visits, no./d	30.6	29.2	0.50
Eating time, min/d	195.3	189.1	0.14
Eating rate, lb of DM/min	0.35	0.37	0.89
Meal frequency, no./d	6.16	6.48	0.02
Meal length, min/meal	33.3	30.7	0.001
Largest meal size, kg of DM	9.91	9.02	0.001

Pupo et al., 2023; ADSA Abstract

9

Forage NDF digestibility and cow performance

For every 1 percentage-unit increase in NDF digestibility

- +0.40 lb/d DMI
- +0.55 lb/d 4%FCM
  (Oba and Allen, 1999)

>40% corn silage in diet

- +0.26 lb/d DMI
- +0.31 lb/d 3.5%FCM
  (Jung et al., 2010)

Slide courtesy of Dr. Rick Grant, Miner Institute

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Fiber digestibility and chewing behavior

Study	Intake	Eating time
Grant et al., 1994	88.3	120.7
Aydin et al., 1999 Exp. 1	85.0	117.9
Aydin et al., 1999 Exp. 2	95.6	105.6
Oliver et al., 2004	95.5	114.9

Data presented as percentage of control treatment
(Sorghum silage – Corn silage)

Grant and Ferraretto, 2018; JDS

11

Brown mid-rib mutant hybrids

- BMR mutation reduces forage lignin
- Characteristic brown mid-rib color
- Markedly improved digestibility outweighs lower yields

12

Nutrient composition of corn hybrids

Item	CON	BMR	*P*-value
DM Yield, ton/acre	9.2	8.2	0.001
DM, % as fed	37.7	37.1	045
CP, %DM	7.3	7.7	0.06
NDF, %DM	37.1	36.6	0.47
Starch, %DM	39.5	37.8	0.01
ivNDFD, %NDF[1]	55.6	62.0	0.001
uNDF, %DM	9.8	8.5	0.001

30 h and 240 h of incubation for NDFD and uNDF

Diepersloot et al,.; abstract submitted to ADSA 2024

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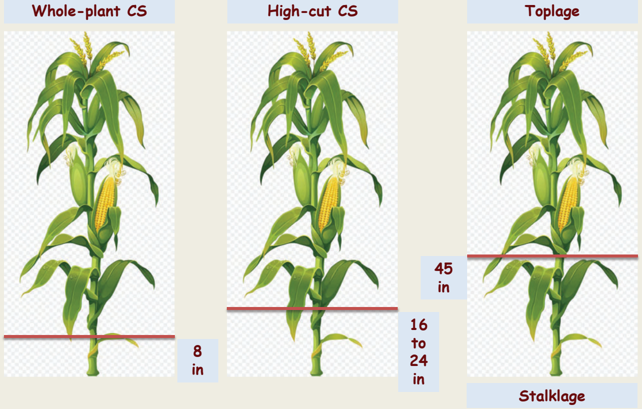
More recent BMR research

Study	DMI, lb/d	Milk, lb/d	ECM, lb/d	Fat, %
Lim et al., 2015	NS	+4.9	+4.6	NS
Cook et al., 2016	NS	+8.6	+6.4	NS
Hassanat et al., 2017	+3.5	+7.1	+6.4	-0.11
Coons et al., 2019*	+2.7	+7.7	+6.9	-0.15
Miller et al., 2020	+1.3	+5.1	+3.1	NS
Miller et al., 2021	+3.3	+6.4	+6.2	-0.07

Data presented as difference to control treatment (BMR – Conventional)

14

Whole-plant material



15

Normal vs. high chop height

Average of 7 studies		
Cutting height, inches	7	21
NDF, %	40	37
ivNDFD, % of NDF	52	56
Starch, %	32	35
Yield, ton of DM/ac	7.7	6.8
Milk, lb/ton	3291	3422
Milk, lb/ac	21407	19917

Ferraretto et al., 2018; JDS

16

Chop height feeding trials

Study	DMI, lb/d	Milk, lb/d	FE	Fat, %
Neylon and Kung, 2003	NS	+3.3	+0.05	NS
Kung et al., 2008	NS	NS	NS	-0.12
Vieira et al., 2023	+2.9	+2.4	NS	NS

Data presented as difference to control treatment (High chop – Low chop)

17

Diet nutrient composition

Nutrient, % DM	11.2% uNDF	10.5% uNDF	9.7% uNDF	9.0% uNDF
DM, % as fed	48.4	49.0	49.4	49.9
CP	17.7	17.8	17.9	18.0
NDF	36.4	36.1	35.8	35.4
Starch	29.1	29.5	30.0	30.4
NDF >8mm	19.8	19.3	19.0	18.9
NDF >19mm	4.8	4.5	4.3	4.2

Vieira et al., 2023; ADSA Abstract

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Performance

Item	11.2% uNDF	10.5% uNDF	9.7% uNDF	9.0% uNDF	L	Q
DMI, lb/d	61.0	62.3	62.5	63.9	0.01	0.97
Milk, lb/d	79.3	81.1	81.5	81.8	0.001	0.23
3.5% FCM, lb/d	84.0	86.0	87.7	87.3	0.07	0.40
Milk fat, %	3.76	3.81	3.87	3.84	0.41	0.63
Milk protein, %	3.19	3.16	3.17	3.18	0.85	0.16
MUN, mg/dL	15.2	15.1	15.4	14.4	0.47	0.53

Vieira et al., 2023; ADSA Abstract

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Other measurements

Item	11.2% uNDF	10.5 % uNDF	9.7% uNDF	9.0% uNDF	L	Q
Eating time, min/d	299	305	306	296	0.62	0.05
Rumination time, min/d	505	502	501	512	0.41	0.22
Diet sorting, %	85.5	91.6	90.2	91.5	0.02	0.12

Vieira et al., 2023; ADSA Abstract

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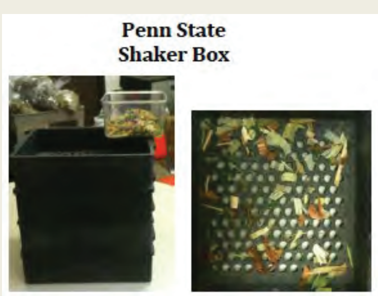
Particle Size



21

UEM CS Particle Size Trial

- Treatments:
  - CON – 17% NDF from CS
  - <8mm – 17% NDF from CS + 9% NDF from CS <8mm
  - 8-19mm – 17% NDF from CS + 9% NDF from CS 8-19mm
  - >19mm – 17% NDF from CS + 9% NDF from CS >19mm

Piran Filho et al., 2023; JDS

22

Diet nutrient composition

Nutrient, % DM	CON	<8mm	8-19mm	>19mm
DM, % as fed	47.1	45.6	46.5	47.5
CP	15.9	15.9	16.1	16.0
NDF	31.9	37.9	38.3	38.8
Starch	31.5	25.9	25.5	24.9
uNDF	6.43	8.49	8.33	8.12
Forage NDF	17.0	25.3	25.2	25.3
NDF >8mm	12.5	12.2	20.3	20.5
NDF >19mm	1.9	2.1	2.1	8.6

Piran Filho et al., 2023; JDS

23

Performance

Item	CON	<8mm	8-19mm	>19mm	P-value
DMI, lb/d	46.0^{b}	47.7^{ab}	49.5^{a}	46.9^{b}	0.05
Milk, lb/d	57.5^{ab}	58.1^{ab}	59.2^{a}	54.8^{b}	0.05
ECM, lb/d	54.6^{b}	57.0^{ab}	59.4^{a}	54.8^{b}	0.04
Milk fat, %	3.18^{b}	3.43^{ab}	3.62^{a}	3.46^{ab}	0.01
Milk protein, %	3.37	3.27	3.28	3.30	0.30
MUN, mg/dL	10.3	11.2	11.5	12.1	0.07

Piran Filho et al., 2023; JDS

24

Other measurements

Item	CON	<8mm	8-19mm	>19mm	P-value
Eating time, min/d	221	235	256	232	0.13
Rumination time, min/d	383^{b}	424^{ab}	462^{a}	425^{ab}	0.04
Diet NDF sorting, %	98.9^{a}	99.0^{a}	97.8^{a}	95.6^{b}	0.01
Rumen pH	5.85^{b}	6.07^{a}	6.12^{a}	6.12^{a}	0.01
Rumen pH <5.8, h/d	11.1^{a}	3.4^{b}	2.5^{b}	3.0^{b}	0.01
Plasma LPS, EU/ml	0.18^{a}	0.17^{a}	0.03^{b}	0.03^{b}	0.01

Piran Filho et al., 2023; JDS

25

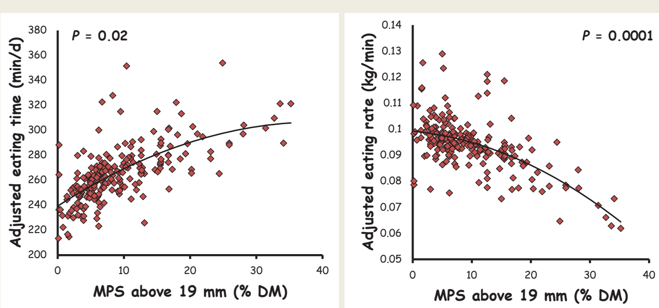
Effect of diet proportion above 19 mm on performance

Parameter[1]	Intercept	Slope	n	*P*-value
DMI (kg/d)	29.1	-0.08	219	0.09
Milk (kg/d)	44.6	-0.13	196	0.07
ECM (kg/d)	47.1	-0.17	196	0.06
Milk fat (%)	-	-	196	0.12
Milk protein (%)	-	-	196	0.55

Pupo et al.; Abstract submitted to ADSA 2024

26

Diet mean particle size above 19 mm and feeding behavior



$y = 236.09 + 3.87x - 0.06x^2$; n = 219

$y = 0.10 + 0.001x - 0.0001x^2$; n= 219

Pupo et al.; Abstract submitted to ADSA 2024

27

Conclusions

- Forage particle size and digestibility drive performance and modulate feeding behavior patterns
- More digestible corn silage increase intake and allow for the establishment of high-forage diets
- Hybrid selection, chop height and maturity impact fiber digestibility, but at the expense of yield

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Questions

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Ferraretto Lab™

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Setting Accurate, Precise, and Inspiring Goals for Milk Fat and Protein

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Setting accurate, precise, and inspiring goals for milk fat and protein

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2024 Four States

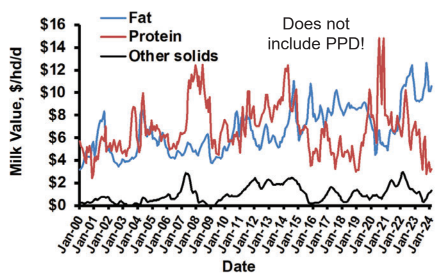
1

What to be thinking about?

- Focus on component yields, but think mechanistically
- The seasonal pattern of milk yield and composition
- Genetic potential of cows and herds
- Milk fat depression

4

Milk fat and protein yield are the drivers of the "income" part of IOFC ($/hd/d @85 lb of 4.0 fat & 3.1 protein)



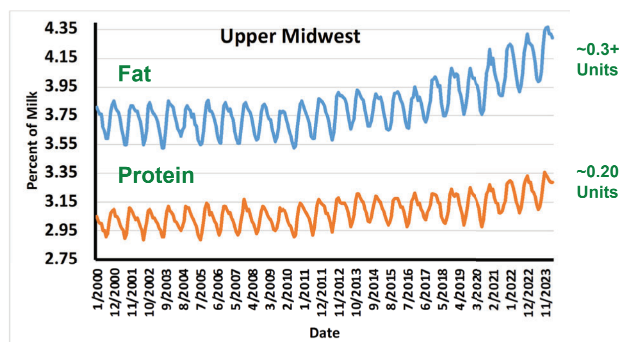
5 year average:
Fat = $2.48/lb
Prot = $2.70/lb
Other Solids = $0.26/lb

Harvatine unpublished based on USDA NASS milk price

- We are going to focus on milk fat today, but remember soybeans are have a large impact on MP that is needed to maximize milk protein yield

2

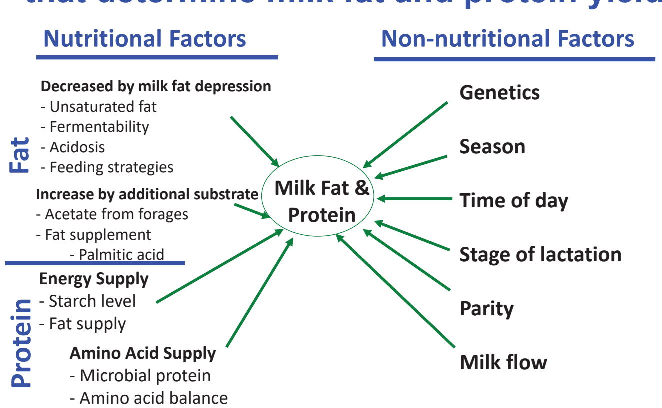
There is a seasonal pattern to milk fat concentration



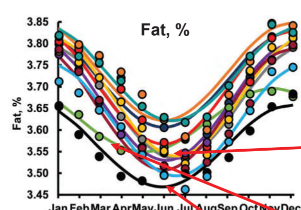
Harvatine unpublished from USDA NASS

5

We have to think about many factors that determine milk fat and protein yield



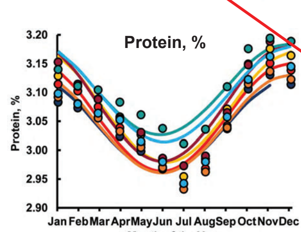
3



Region affected the seasonal rhythms of milk fat and protein %

- Northeast
- Florida
- Southeast
- Central
- Arizona-Las Vegas
- Western
- Appalacian
- Mideast
- Upper MW
- Southwest
- Pacific NW

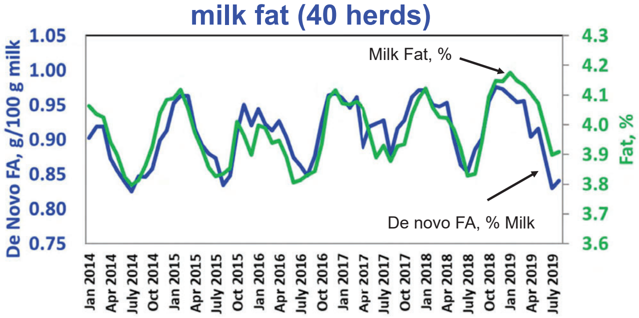
Item	Region	Amp	Acro	*P*-value
Fat, %	Northeast	0.11[b]	Dec 31[a]	< 0.001
	Appalachian	0.13[a]	Jan 17[bc]	< 0.001
	Florida	0.07[d]	Dec 4[d]	< 0.001
	Southeast	0.14[a]	Jan 3[a]	< 0.001
	Upper MW	0.11[b]	Dec 31[a]	< 0.001
	Central	0.14[a]	Jan 19[c]	< 0.001
	Mideast	0.13[a]	Dec 31[a]	< 0.001
	Pacific NW	0.11[b]	Jan 12[b]	< 0.001
	Southwest	0.14[a]	Dec 31[a]	< 0.001
	AZ-LV	0.09[c]	Dec 29[a]	< 0.001
	Western	0.13[a]	Jan 18[bc]	< 0.001
Protein, %	Northeast	0.08[c]	Dec 31	< 0.001
	Upper MW	0.09[bc]	Dec 30	< 0.001
	Central	0.10[ab]	Jan 6	< 0.001
	Mideast	0.09[ab]	Dec 30	< 0.001
	Pacific NW	0.08[c]	Dec 27	< 0.001
	Southwest	0.10[a]	Dec 30	< 0.001
	Western	0.08[abc]	Jan 2	< 0.001



Salfer et al. JDS 2019

6

de novo synthesis (<16 C FA) is the main contributor to the the seasonal variation in milk fat (40 herds)

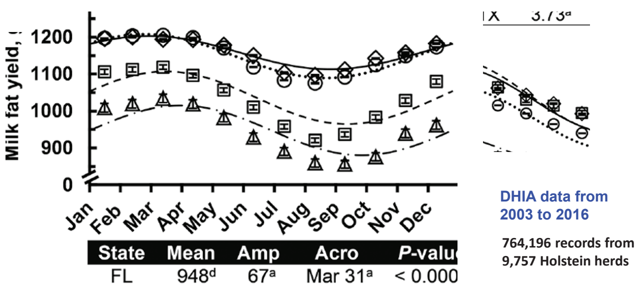


40 St. Albans Coop herds

Dann 2019 PSU Dairy Nutr. Workshop

7

There is also an annual rhythm to milk yield: Data from PA, MN, FL, and TX



State	Mean	Amp	Acro	*P*-valu
FL	948[d]	67[a]	Mar 31[a]	< 0.000
MN	1158[a]	45[c]	Feb 27[b]	< 0.000
PA	1149[b]	59[b]	Feb 23[b]	< 0.000
TX	1035[c]	71[a]	Mar 13[a]	< 0.000

1000

kg kg

Salfer et al. JDS 2020

8

What do I think is going on?

Two seasonal time-keepers:

- Milk composition is driven by lengthening and shortening days and aligns with the solstice
- Milk yield is driven by rate of change in day length and aligns with the equinox

Constant long days appears to be setting physiology of the spring equinox (increased milk yield and no change in composition)

- No data on how to manage out of this, but recommendation is to have long-day lighting with a dark period

9

Pounds of components is the right goal, but it is more complicated than it sounds!

Fat Yield = Milk Yield * Fat %

- You can't give up much yield when seeking to increase milk fat or protein (especially if paid for protein!)

Fat Yield

	Milk Fat, %	
lb	**4.0**	**4.1**
80	3.20	3.28
81.9	3.28	3.36

Protein+Fat Yield

	Fat+Protein, %	
lb	**7.0**	**7.1**
80	5.60	5.68
81.1	5.68	5.76

Harvatine Unpublished

10

I think you want to beat average milk fat percent

- **Shipping, deductions and most quotas are based on pounds of milk**
- **If you are below average percent, you have the opportunity to do better**
  - **Do you have some milk fat depression or fat or acetate limitation?**
  - **Could you be doing better on energy or protein balancing?**

11

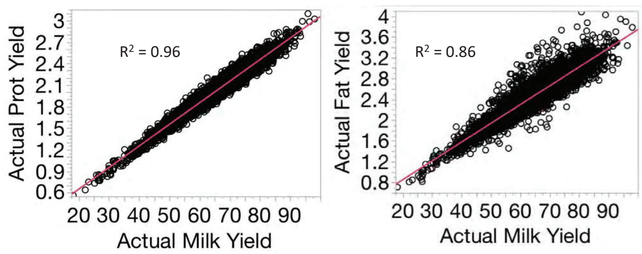
The mammary gland is a milk synthesis "factory" with three assembly lines: Fat, Protein, and Lactose

- **There is coordinated regulation of these three assembly lines**
  …….. and also some differential regulation

12

Milk yield is the biggest driver of fat and protein yield. Why? They are all turned on by the same factors that drive lactation

Not independent X-Y axis, but shown to compare between protein and fat.



(5926 herds)

Harvatine unpublished from DRMS Dataset

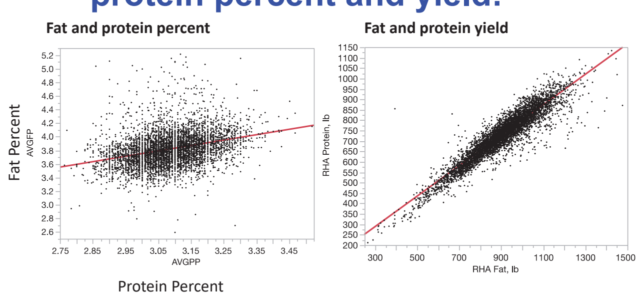
13

Some things drive synthesis of all three pathways and that is OK

- **"A rising tide lifts all boats"**
- **Regulation of lactose and protein are tightly connected**
- **Milk fat has more differential regulation from lactose**
- **Long term- hopefully we can disconnect lactose synthesis from fat and protein synthesis (Jersey's already do this!)**

14

We can have both fat and protein percent and yield!



Fat Per = 1.37 + 0.793 * Prot Per

R^2 = 0.10

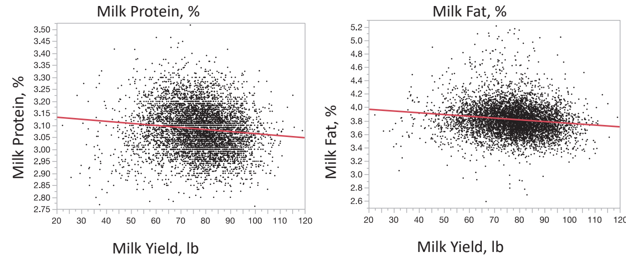
RHA Protein = 69.3 + 0.731 * RHA Fat, lb

R^2 = 0.86

(5926 herds)

15

Milk yield has little effect on protein and fat concentration at the herd level



Prot % = 3.15 - 0.00085 * Milk

R^2 = 0.01

Fat % = 4.0214377 - 0.0026 * Milk

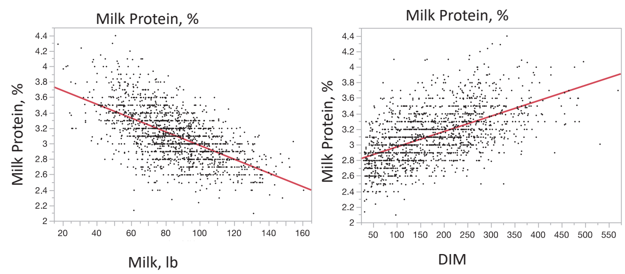
R^2 = 0.02

(5926 herds)

Harvatine unpublished from DRMS Dataset

16

Milk yield and DIM does have an effect on protein concentration at the cow level



Prot % = 3.863 - 0.0089 * Milk

R^2 = 0.36

Prot % = 2.769826 + 0.00198 * DIM

R^2 = 0.31

(~1700 cows)

Harvatine unpublished

17

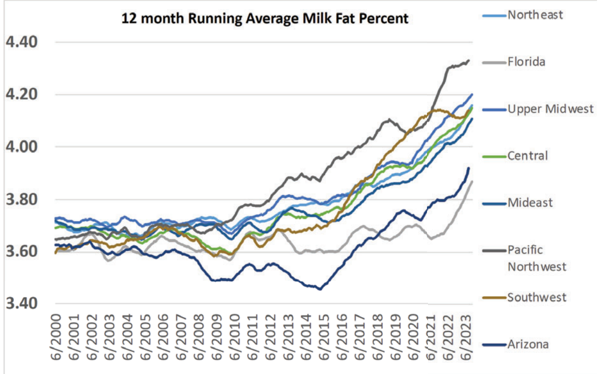
We need to work with the cow to get high yields- Everything good farms do right!

- **Cow comfort**
  - Stalls, beds, handling, heat stress etc
  - Overcrowding
- **Reproduction**
  - Don't get stale
- **Cow longevity**
- **Feed and bunk management**
  - Time without feed, slug feeding etc
- **Milking management and udder health**
- **Forage quality**
- **Good genetics**

There is milk fat and protein yield to be gained through good management!!

18

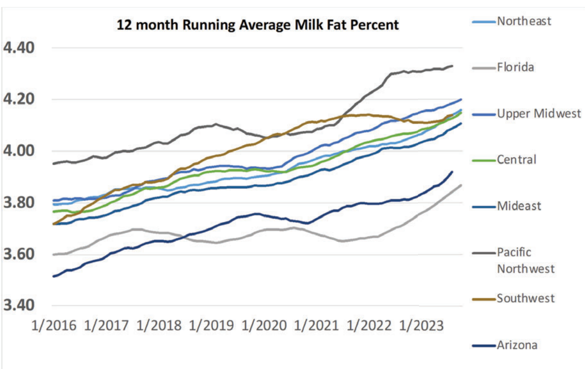
Milk fat has been increasing since 2010 and we need to meet demands to make milk fat



Harvatine unpublished from USDA NASS

19

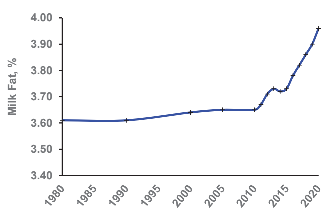
Milk fat has been increasing since 2010 and we need to meet demands to make milk fat



Harvatine unpublished from USDA NASS

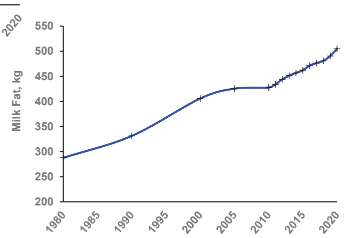
20

Milk fat genetic potential of Holsteins has increased ~0.3 units and 156 lb in 10 years!



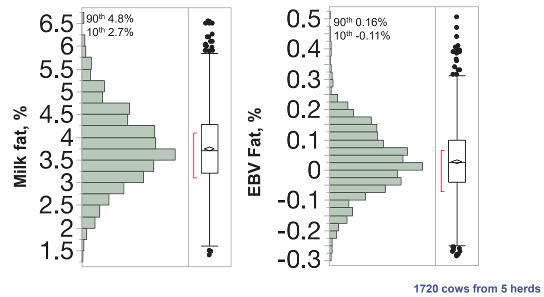
From Center for Dairy Cattle Breeding

- Genetic potential of Jerseys has also increased



21

There is considerable variation in genetic potential (EBV) between cows within a herd, but not nearly as big as the difference in fat percent

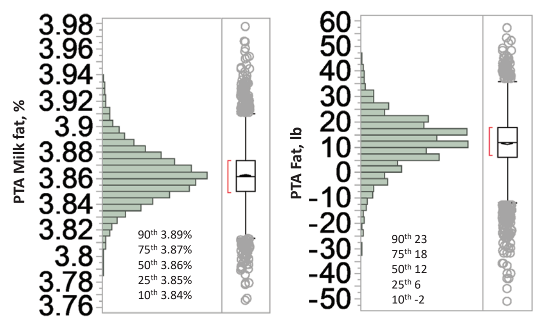


- Differences between cows also influenced by DIM, feeding behavior, sorting, and susceptibility to BH-induced milk fat depression

Harvatine Unpublished

22

But, There is very little difference in genetic potential for milk fat between herds



PTA Milk fat % = [(PTAF + 1006) / (PTAM + 26995)] * 100

(5926 DRMS Herds)

Harvatine Unpublished

23

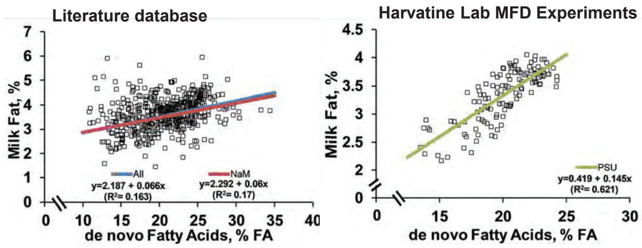
I have been told "*diet-induced MFD is not a problem anymore*"! Is this true?

- **Risk factors have decreased?**
  - Lower fat DDGS
  - Better forages and feed management?
  - Higher forage diets and less high moisture corn?
  - Feed management has improved?
- **Maybe we all learned and it is solved?**
- **We have selected for cows more resistant to MFD?**
- **Are we missing diet-induced MFD because we have not adequately adjusted to the new genetic potential?**

I don't know, but don't stop increasing your goals/expectations!

24

Diagnosing MFD: There is a relationship between milk fat and de novo FA (<16 C), but it is not specific for MFD



- <16 C FA can be predicted by MIR at some DHIA and payment labs
- Helpful data, but don't over-interpret!
- Best used to compare within herd over time or between herds with similar diets

Matamoros et al. JDS 2020

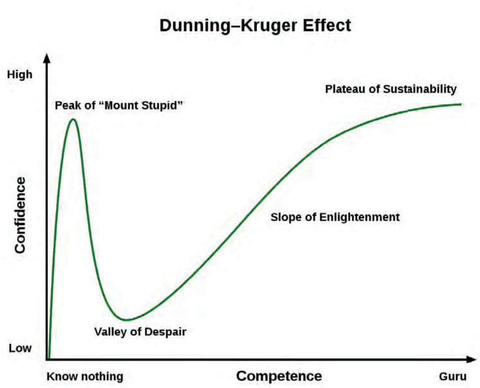
25

How would I use <16 C FA from DHIA/payment analysis?

1. **Monitor same farm over time**
   - If changes and you have not changed the diet, go looking for what is happening
   - Remember seasonal pattern
2. **Compare between farms in same region with similar dietary fat concentration and profile**
   - De novo will decrease with increasing dietary fat
   - Decreased by 18 C FA more than 16 C
3. **I prefer as a % of FA**
   - As a percent of milk is inflated by changes in milk fat concentration

26

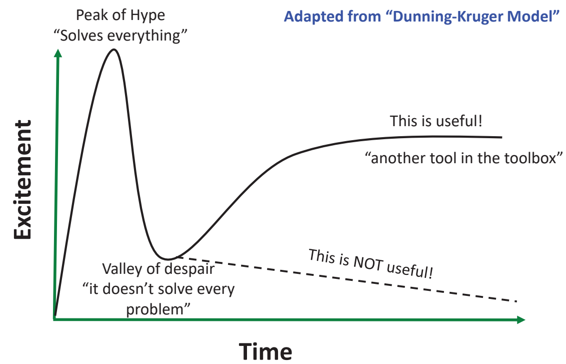
What can we learn from the "Dunning-Kruger Model" in the evolution of thinking in managing?



https://commons.wikimedia.org/wiki/File:Dunning%E2%80%93Kruger_Effect_01.svg

27

We have many tools at our disposal, consider where each opportunity is at on the "innovation & adoption cycle"



28

Let's review

- **Set goals based on the seasonal rhythm**
- **Adjust goals based on the potential of modern genetics and management**
- **Focus on fat and protein pounds, but try to beat average percent**
- **Steer clear of MFD that likely is still present in some cows**

Constant "Experiment in Progress"

29

Lab Members:, Alanna Staffin, Abiel Berhane, Sarah Bennett, Yusuf Adeniji, Muhammad Husnain, Muhammad Arif, and Mahmoud Ibrahim

Previous Lab Members: Dr. Cesar Matamoros, Beckie Bomberger. Dr. Ahmed Elzennary. Reilly Pierce, Dr. Rachel Walker, Dr. Chengmin Li, Elle Andreen, Dr. Isaac Salfer, Dr. Daniel Rico, Dr. Michel Baldin, L. Whitney Rottman, Dr. Mutian Niu, Dr. Natalie Urrutia, Richie Shepardson, Andrew Clark, Dr. Liying Ma, Elaine Brown, and Jackie Ying

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- Harvatine has consulted for Cotton Inc, Micronutrients, Milk Specialties Global, Axiota, and Nutriquest as a member of their science advisory boards and United Soybean Board, ELANCO, and Novus on special projects.
- Harvatine is the founder and owner of Hardscrabble Innovations LLC, an independent consulting LLC.
- Harvatine has also received speaking honorariums from Elanco Animal Health, Cargill, Virtus Nutrition, NDS, Nutreco, Mycogen, Holtz-Nelson Consulting, Renaissance Nutrition, Progressive Dairy Solutions, Intermountain Farmers Association, Diamond V, Purina, Pioneer, Adessio, Standard Nutrition, Hubbard, VitaPlus, and Milk Specialties Global.

Thank You!

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Overcrowding and Response to the Formulated Ration

Rick Grant, Trustee and Retired President
William H. Miner Agricultural Research Institute
Chazy, NY

1

Today's focus…

2

Something for nutritionists to ruminate on…

We often focus on economics…

…but don't neglect cow welfare and social license to produce milk…

3

Essentials for low-stress feeding management

- Management that enhances rest and rumination
- Time outside pen <3.5 h/d
- Feed available on demand, 24/7
- Bunk stocking density ≤100% (≥24 in/cow)
- Consistent feed quality/quantity/delivery time at bunk
- TMR fed 2x/day (?)
- Push-ups focused on 2 hr post-feeding; keep feed in front of cow
- ~3% feed refusal target
- Bunk empty no more than 3 h/d (ideally never)
- Deep bedding

(modified from Grant, 2013; ADSA Discover Conference)

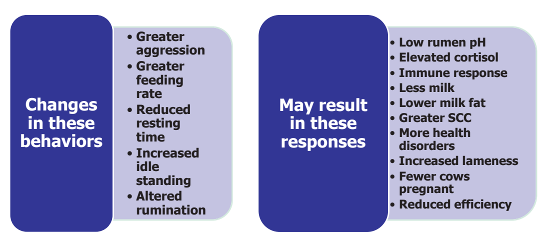
4

Stocking density from the *cow's perspective*

…20 years ago, overcrowding was already becoming a management challenge…

5

Overcrowding consequences: Why the variation among farms?



(Krawczel et al., 2012; Grant, 2017)

6

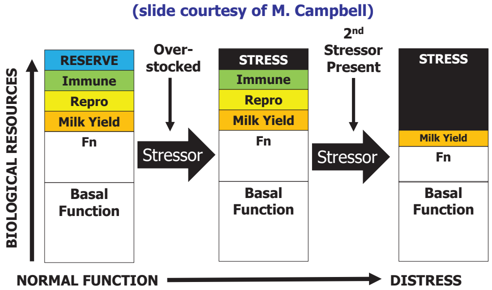
Sub-clinical stressors
(Moberg, 2000)

- For the dairy cow, we can consider overcrowding as a ***sub-clinical stressor***…

…***depletes biological resources*** of an animal without ***creating a detectable change*** in function (milk yield, reproduction…) and leaves animal ***unable to successfully respond*** to additional stressors.

7

Sub-clinical stress of overstocking
(slide courtesy of M. Campbell)



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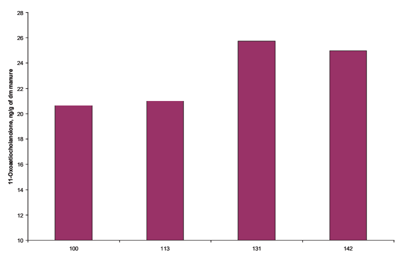
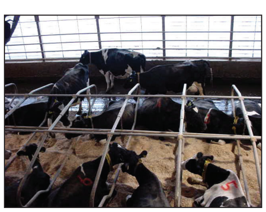
Fecal cortisol metabolites and stocking density
(Krawczel et al., 2010)



9

- <u>**Secondary stressors**</u> abound on dairy farms:
  - Poor feeding management
  - Improperly formulated ration
  - Heat stress
  - Uncomfortable stalls
  - Diseases
  - Inadequate ventilation
  - Mixed parity groups
  - Inadequate water
  - *List goes on and on and on…*



10

From the cow's perspective: Primi- versus multiparous and lame versus sound cows (Hill et al., 2006; 2009)

	100%	113%	131%	142%
Multi - primi				
Milk, lb/d	+5.7	+13.9	+21.1	+8.4
Sound - lame				
Milk, lb/d	-9.5	+2.0	+16.7	+13.9

- Responses in milk yield track with changes in resting and recumbent ruminating behaviors.
  - **Total rumination time not always affected by stocking density, but <u>*%rumination while lying down is*</u>.**

11

Management from the Cow's Perspective!

Do cows have preferred locations in a pen?

Hefter et al., 2023:
- ✓ Cows spent more time at feed bunk nearest pen exit from ~6 am to 9 pm – no difference at night.
- ✓ Lame cows spent more time in stalls nearest pen exit.


(photo courtesy of Sarah Morrison)

12

Cow personality and response to competition (Schwanke et al., 2024)

- Consistent traits with advancing DIM and feed bin competition
  - Fearful, Active-Explorative
- When competition at a feed bin increased from 1:1 to 2:3 (bins:cow) with greater DIM
  - A-E cows naturally encountered unoccupied bins more often and maintained DMI versus lower A-E cows
  - Fearful cows increased feed bin visits and maintained DMI
    - Slower rate at less crowded times
  - Less fearful cows increased feeding rate without changing time of eating

13

High stocking density…Ruminations

- Managing overcrowded herds
  - Greater injuries
  - More accidents
  - Higher employee stress (as well as cows)
- More likely to see agonistic interactions at intermediate levels of overcrowding??
- Response to overcrowding a function of:
  - Time outside pen
  - Group size and "edge effect" - % cows on periphery
  - Location of resources and facility design
  - Individual cow ability to cope

14

What is optimal stocking density?

Close-up and fresh cows:
- ≤80% of bunk space (30 in/cow)
- At least one stall per cow

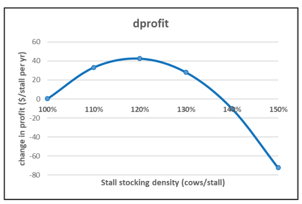
Lactating cows
- 4-row barn: don't exceed 115-120% of stalls
  - Mixed heifer & older cows: 100%
- 6-row barn: 100% of stalls

Ensure access to feed, water, stalls

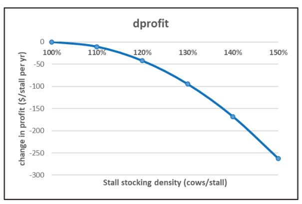
15

Economics of overstocking…

(De Vries et al., 2016. J. Dairy Sci. 99:3848-3857)



Scenario with higher milk price, lower feed costs



Scenario with lower milk price, higher feed costs

Economics change, but on-farm stocking density doesn't!

16

Essential factors for managing overcrowded pens – would you add others?

1) Time outside pen, away from resources
2) Every stall comfortable
3) Feed available 24/7
4) Grouping by parity
5) Water not limiting
6) Effective heat abatement
7) Formulate for more peNDF, less RFS
8) 50-60% of TMR retained on 8-mm sieve of PSPS

(Grant, 2023)

17

In search of Milk Fat and Protein

Realizing the ***potential*** of your formulated ration…

Manage to reduce stressors and enhance rumen environment…

18

Rumen pH and milk fat + protein

- Sub-acute rumen acidosis and lower rumen pH:
  - reduce milk fat (Allen, 1997)
  - reduce de novo fatty acids (Fukumori et al., 2020; Martel et al., 2011)
    - DNFA associated with greater fat and protein output (Barbano, 2014)
  - reduce milk protein (variable response; Stone, 2004)

19

How will these cows respond to the ration? Rumen pH? Components?

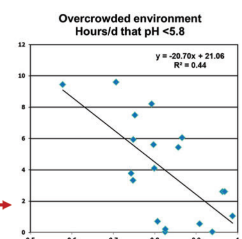
(Campbell and Grant, 2017)

20

Perfect recipe for low rumen pH…

(and lower NDF fermentation, milk components)

- Highly fermentable diet
- Overcrowding feed bunk and stalls
  - Slug feeding
  - Impairs rumination in stalls
    - Recumbent rumination related to less SARA
- Empty bunk



(Campbell and Grant, 2016; 2017)

21

Recumbent rumination boosts intake and milk components

- Cows with greater ruminating while lying down:
  - Have higher rumen pH
  - Consume more DM
  - Produce milk with greater fat, protein %
- Miner study (2023, unpublished):
  - Holsteins, 3.2 to 6.4% milk fat
  - Of all behaviors, strongest positive correlation was between rumination while lying and milk fat

(Campbell and Grant, 2017; McWilliams et al., 2021)

22

Top-5 factors that boost fat + protein…
(and rumen pH, fiber fermentation)

- Dietary fat (≤3.5% of DM)
- Dietary peNDF (≥21% of DM)

- **Stocking density of feed bunk and stalls**
- **Feeding frequency**
- **Feed push-up**

(Woolpert et al., 2016; 2017)

23

Bunk Space and Milk Components

- Higher de novo milk fatty acid synthesis (Woolpert, 2016)
  - –65% of variation explained by bunk space
  - –De novo, relative % = 20.12 + 0.09 x bunk space, cm; *P* < 0.002
- Greater bunk space (Sova et al., 2013)
  - Increased milk yield and fat%
    - +0.06% greater milk fat per 4-in increase in bunk space

24

Regardless of housing system, same basic factors rise to the top

- Management and automated milking systems (Castro et al., 2022; Matson et al., 2022)
- 124 farms in ON and QC
- Milk yield positively associated with ***robotic feed pusher*** (+4.6 lb/d) and ***deep bedding*** (+5.7 lb/d)
- Greater milk yield and less lameness with ***greater bunk space***, ***feed push-up frequency***, and ***deep sand bedding***

  Less time searching for feed, more efficient feed consumption

  + More time spent lying down

  = **Positive effect on milk yield and lameness!**

25

"Cows that ***aren't rushed while eating,***
have ***freedom to lie down and ruminate,***
and can strike proper ***balance between eating and recumbent rumination,*** will have
optimal rumen conditions for fiber digestion
and healthy production of ***more milk components***."

26

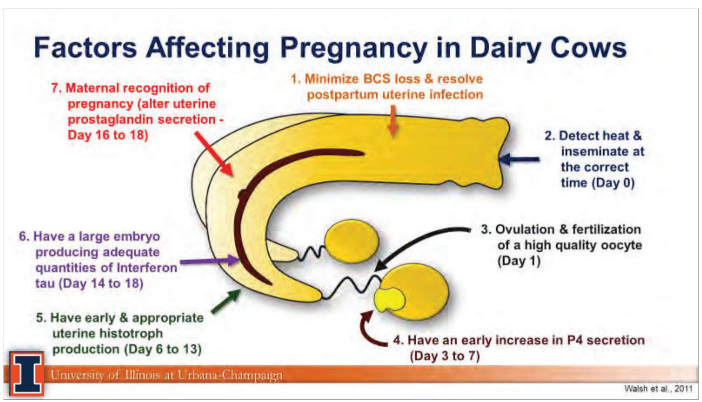
Carrying on William Miner's Vision:
"Science in the Service of Agriculture."

27

Impact of Dry Matter Intake During the Transition Period to Optimize Uterine Health and Fertility

Phil Cardodo, DMV, MS, PhD
Associate Professor
University of Illinois

1



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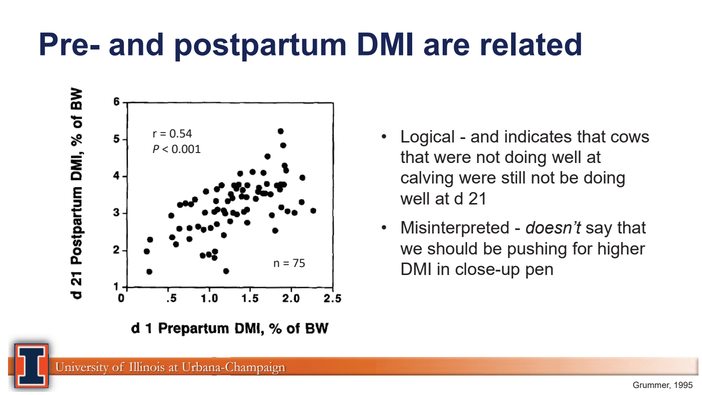

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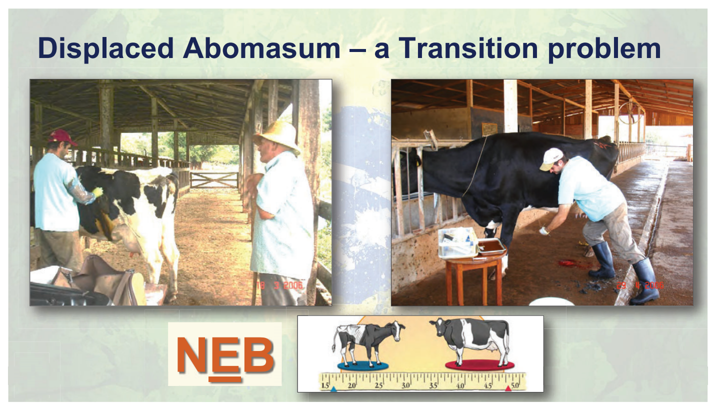

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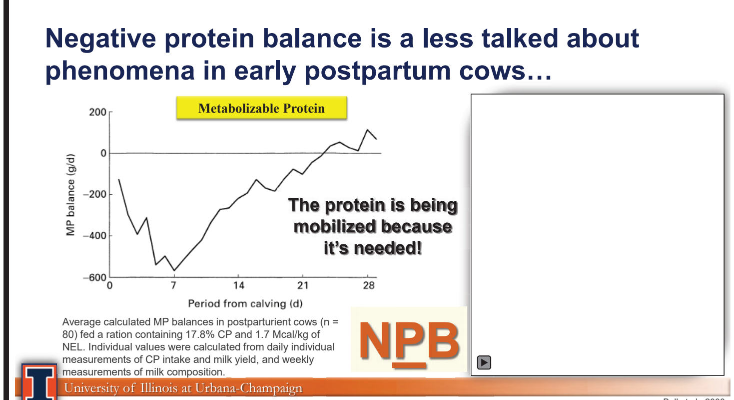

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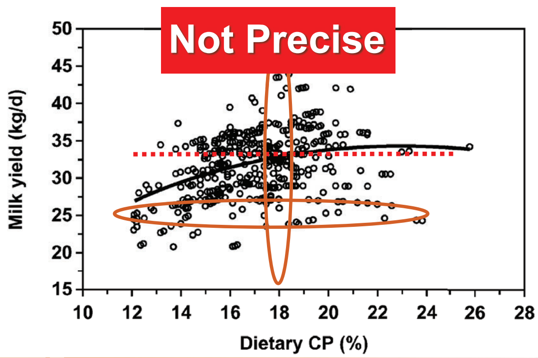
7

Relationship between milk yield and dietary CP (%) for lactating dairy cows



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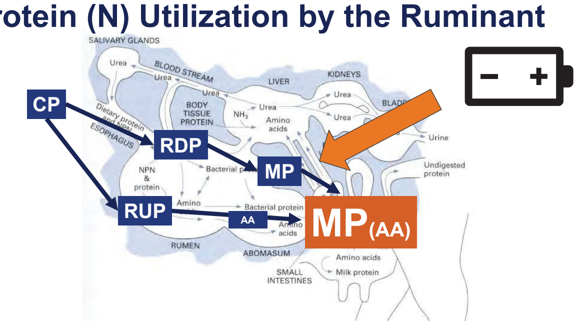
Ipharraguerre and Clark, 2005

8

Protein (N) Utilization by the Ruminant



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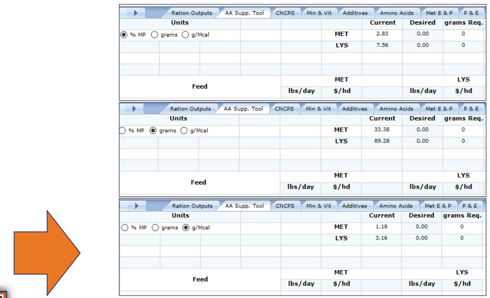
J. Bryant and B. R. Moss, Montana State University

9

Diet Formulation – Precision Feeding

AMTS



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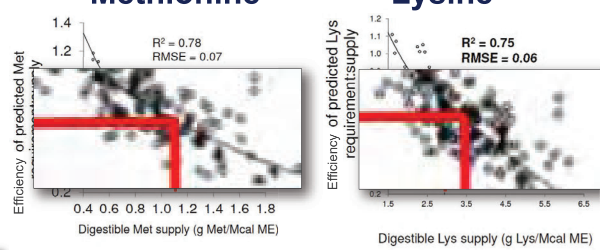
Fehlberg et al., 2020

10

Diet Formulation – Precision Feeding



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Adapted from Van Amburgh, 2019

11

Effects of Precision Essential Amino Acid Formulation on a Metabolizable Energy Basis for Lactating Dairy Cows

- One hundred and forty-four (n = 144) Holstein cows [26 primiparous and 118 multiparous; 2.9 ± 1.4 lactations; 92 ± 24 DIM at enrollment] were enrolled in a 114 day longitudinal study.
- Cattle were blocked into 16 cow pens (free stall) and balanced for parity, DIM, previous lactation performance, and current body weight.
- Each pen was fed TMR once daily at approximately 0600 h and pens were targeted for 5% refusal rate. All nine pens were fed the POS diet during a 14 day covariate period and randomly assigned to one of three diets described above for the remaining 100 d.

	-1 SD		+1 SD
Item	Negative	Neutral	Positive
CP, % of DM	14.04	14.75	15.95
Soluble fiber, % of DM	6.01	5.55	5.05
ADF, % of DM	20.79	19.96	19.77
NDF, % of DM	32.39	31.03	31.39
uNDF240, % of NDF	25.5	29.09	28.73
Lignin, % of NDF	8.06	9.65	8.73
Starch, % of DM	29.82	29.31	29.30
Sugar. % of DM	3.95	4.06	3.9
Ether extract, % of DM	3.49	3.61	3.78
Ash, % of DM	6.60	6.92	6.57
Metabolizable Energy, Mcal/kg of DM	2.58	2.60	2.61
Methionine, g	71.44	78.30	92.67
Methionine, g AA/Mcal ME[1]	1.01	1.09	1.29
Lysine, g	201.70	222.12	250.07
Lysine, g AA/Mcal ME[1]	2.84	3.00	3.49
Histidine, g	62.78	70.42	83.81
Histidine, g AA/Mcal ME[1]	0.88	0.98	1.17

[1] formulated

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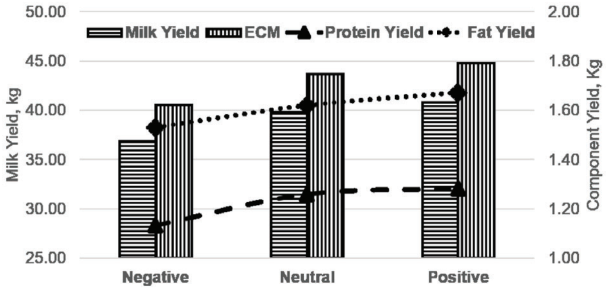
LaPierre et al., 2019

12

Cows fed *Neutral* produced similar levels of energy corrected milk and yield similar production of fat components when compared to cows fed the *Positive* treatment



No difference in dry matter intake (~28 kg/d)

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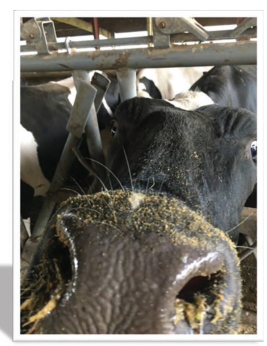
LaPierre et al., 2019

13

How about dry cows?



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Dietary Recommendations for Dry Cows

- **NEL:** Control energy intake at 18 to 20 Mcal daily [diet ~ 1.43 Mcal/kg (0.65 Mcal/lb) DM] for mature cows
- **Metabolizable protein (MP):** > 1,200 g/d → Met Lys
- **Starch content:** 12 to 15% of DM (NFC < 26%)
- **NDF from forage:** 40 to 50% of total DM or 4.5 to 6 kg per head daily (~0.7 – 0.8% of BW). Target the high end of the range if more higher-energy fiber sources (like grass hay or low-quality alfalfa) are used, and the low end of the range if straw is used (2-5 kg)
- **Total ration DM content:** <50% (add water if necessary)
- **Minerals and vitamins:** follow guidelines (For close-ups, target values are 0.40% magnesium (minimum), 0.35 – 0.40% sulfur, potassium as low as possible (Mg:K = 1:4), a DCAD of near zero or negative, calcium without anionic supplementation: 0.9 to 1.2% (~125g) calcium with full anion supplementation: 1.5 to 2.0% (~200g), 0.35 – 0.42% phosphorus, at least 1,500 IU of vitamin E, and 25,000 – 30,000 IU of Vitamin D (cholecalciferol)

CNCPS v6.55 — Lactation
1.17 g Met / Mcal of ME (1.05 – 1.10)
2.7:1 Lys:Met
2.9 – 3.20 g Lys / Mcal of ME

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CNCPS v6.55 — Dry
~ 35g Met
2.65:1 Lys:Met (92g Lys)

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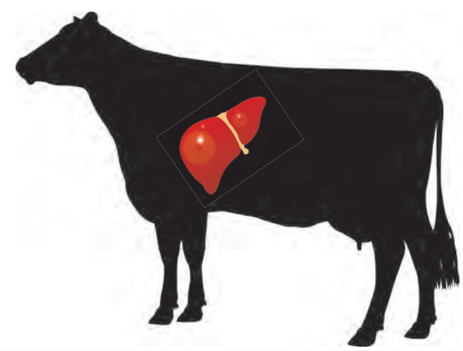

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17

Liver Functionality Index: LFI

Uses changes in plasma concentrations of several blood biomarkers (i.e., albumin, cholesterol, and bilirubin)

- <u>Low</u> LFI (**LLFI**) is indicative of a pronounced inflammatory response and less favorable circulating AA profile, which together suggest a more difficult transition from gestation to lactation
- <u>High</u> LFI (**HLFI**) is suggestive of a smooth transition

A tendency (P = 0.06) for a greater number of Met-supplemented cows in the HLFI was observed

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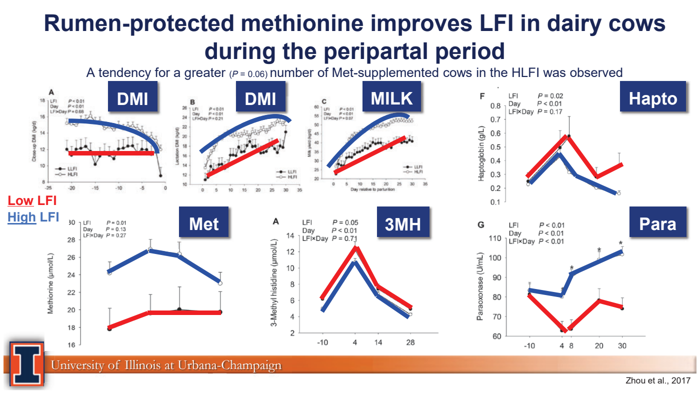
Trevisi et al., 2012; Zhou et al., 2017

18



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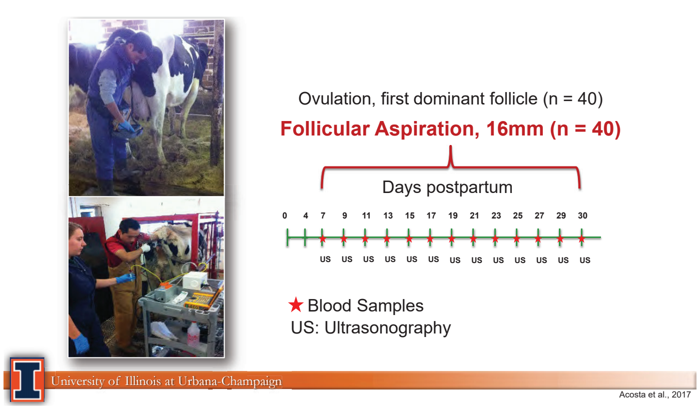

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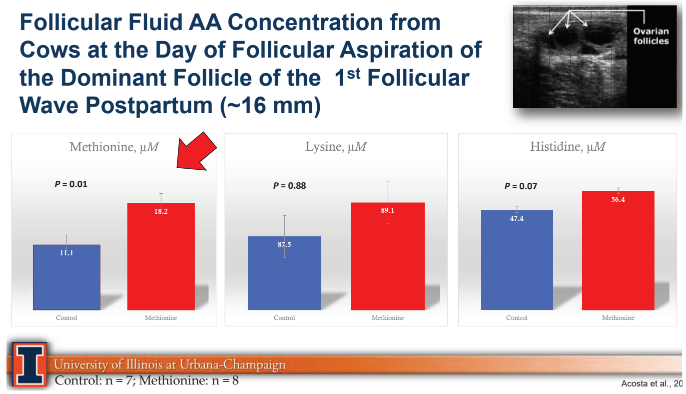

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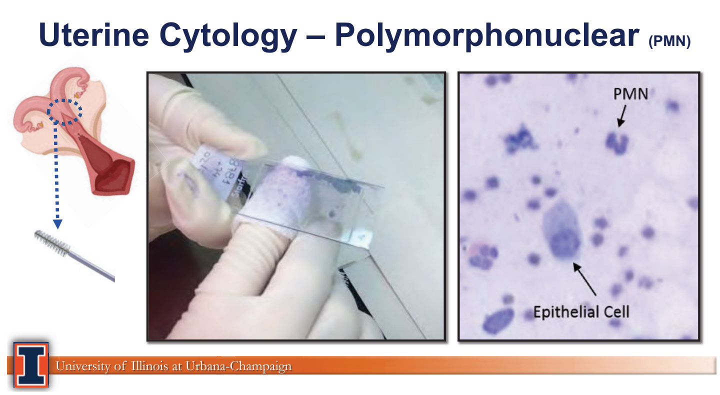

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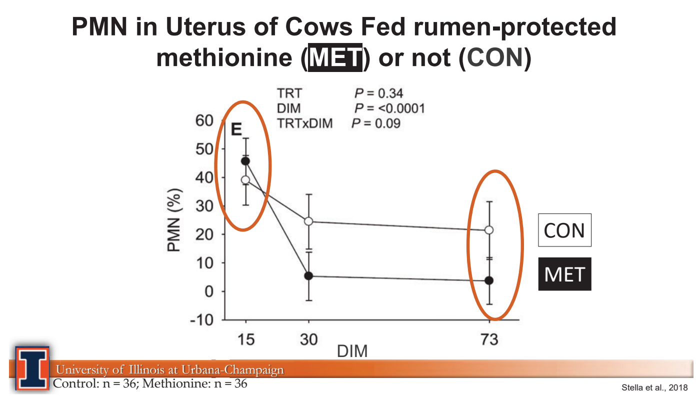
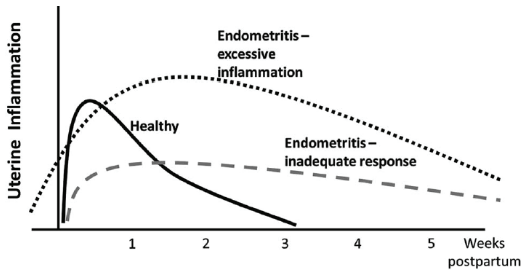


24

Schematic Representation of Concepts of the Patterns of Immune and Inflammatory Response in Dairy Cows in the Postpartum Period



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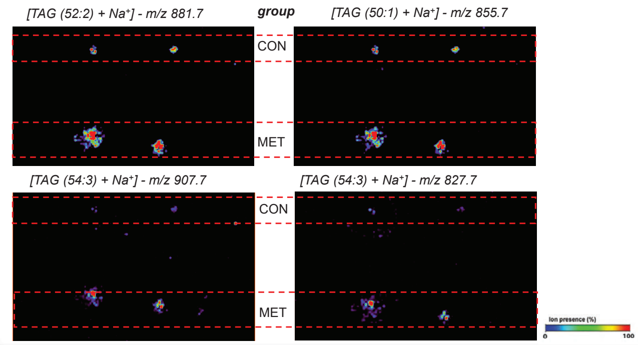
LeBlanc, 2014

25



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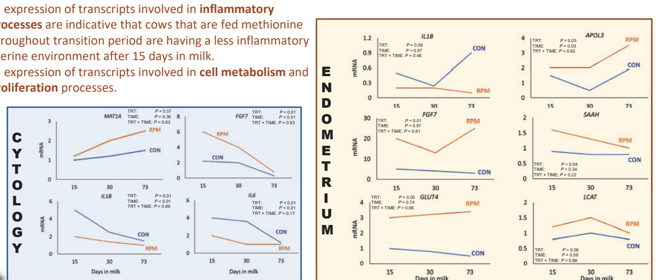
Stella et al., 2023

28

Feeding methionine improved uterine resilience mechanisms and capacity to prevent uterine diseases

↓ expression of transcripts involved in **inflammatory processes** are indicative that cows that are fed methionine throughout transition period are having a less inflammatory uterine environment after 15 days in milk.

↑ expression of transcripts involved in **cell metabolism** and **proliferation** processes.



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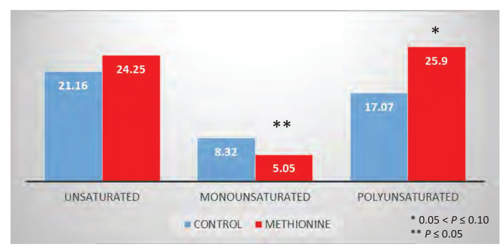
Guadagnin et al., 2021

26

Embryo samples analyzed by (MALDI-MSI)



Units: intensity ion counts multiplied by 1,000

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Stella et al., 2023

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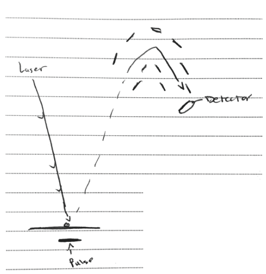
Matrix-assisted laser desorption/ionization mass spectrometry imaging (MALDI-MSI)



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Stella et al., 2023

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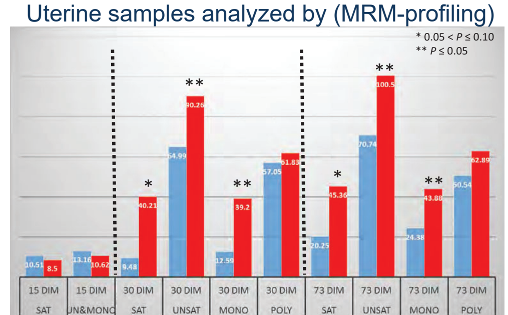
Uterine samples analyzed by (MRM-profiling)



Units: intensity ion counts multiplied by 1,000

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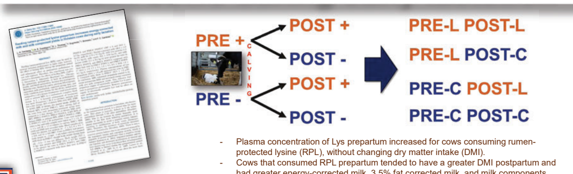
Stella et al., 2023

30

How about Lysine?

31

Feeding rumen-protected lysine prepratum increases energy corrected milk and milk component yields in Holstein cows during early lactation



- Plasma concentration of Lys prepartum increased for cows consuming rumen-protected lysine (RPL), without changing dry matter intake (DMI).
- Cows that consumed RPL prepartum tended to have a greater DMI postpartum and had greater energy-corrected milk, 3.5% fat corrected milk, and milk components.

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Fehlberg et al., 2020

32

TMR

Ingredient, % of DM	Prepartum	Postpartum
Corn silage	31.06	39.38
Canola meal	1.45	5.36
Alfalfa hay	-	20.95
Wheat midds	4.10	-
Corn gluten feed	6.69	-
Soybean meal, 48% CP	2.19	-
Wheat straw	40.25	-
Ground corn	0.16	15.26
Rumen-protected methionine	0.12	0.09
Rumen-protected fat	-	1.93
Soybean meal expeller	5.74	6.66
Anionic salt	3.85	-
Urea 46%	0.23	0.30
Mg oxide	-	0.09
Mg sulfate	0.25	-
Dicalcium phosphate	-	0.33
Molasses	-	4.43
Ca carbonate	2.08	-
Vitamin and mineral prepartum	1.31	-
Vitamin and mineral postpartum	-	4.73

Chemical composition

Item	Prepartum	Postpartum
DM, %	43.43 ± 1.42	45.71 ± 1.64
CP, % of DM	**14.22 ± 0.68**	**16.75 ± 1.06**
ADF, % of DM	28.41 ± 2.80	20.94 ± 1.77
NDF, % of DM	44.82 ± 2.75	31.25 ± 3.29
Lignin, % of DM	4.44 ± 0.74	3.80 ± 0.49
Starch, % of DM	**13.99 ± 1.69**	**24.39 ± 2.62**
Ehter extract, % of DM	3.03 ± 0.21	4.95 ± 0.51
Ash, % of DM	10.34 ± 1.34	9.16 ± 0.74
NE_L, Mcal/kg of DM	1.44 ± 0.03	1.67 ± 0.05
Ca, % of DM	1.46 ± 0.35	1.12 ± 0.21
P, % of DM	0.37 ± 0.04	0.41 ± 0.04
Mg, % of DM	0.50 ± 0.07	0.38 ± 0.03
K, % of DM	1.12 ± 0.11	1.75 ± 0.17
Mn, ppm	91.9 ± 17.5	99.3 ± 13.7
Mo, ppm	1.20 ± 0.30	1.32 ± 0.30

Rumen-protected Lysine top-dressed
0.54% of DMI prepartum
0.40% of DMI postpartum

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Amino acid supply

	Prepartum[2]		Postpartum[3]	
Composition of MP[1]	PRE-L	PRE-C	POST-L	POST-C
Metabolizable protein, g/d	1190	1170	2220	2280
Lys, % of MP	8.24	6.86	7.15	6.27
Met, % of MP	2.94	2.98	2.55	2.54
Lys:Met	2.80	2.30	2.80	2.46
Lys, g/d	98	80	159	143
Met, g/d	35	35	57	57
Lys, g/Mcal	3.55	2.95	3.11	2.73
Met, g/Mcal	1.27	1.19	1.11	1.11

[1]Metabolizable protein and AA predicted by AMTS
[2]Formulated for a dry cow at 1527 lb BW and 28.6 lb/d
[3]Formulated for a cow at 14 days in milk, 1612 lb BW, producing 86 lb/d of milk

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Fehlberg et al., 2020

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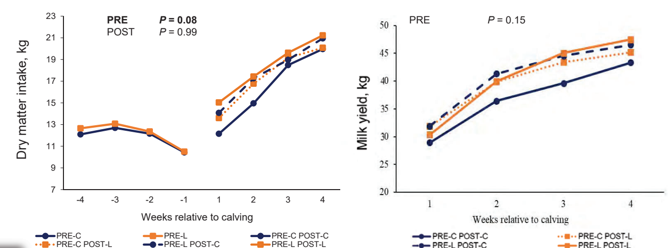
RPL provided prepartum tended to increase DMI postpartum

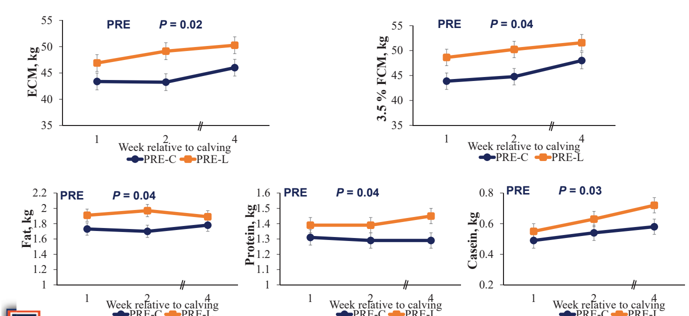


University of Illinois at Urbana-Champaign

Fehlberg et al., 2020

35

RPL prepartum increased ECM, FCM, and milk composition yields postpartum



University of Illinois at Urbana-Champaign

Fehlberg et al., 2020

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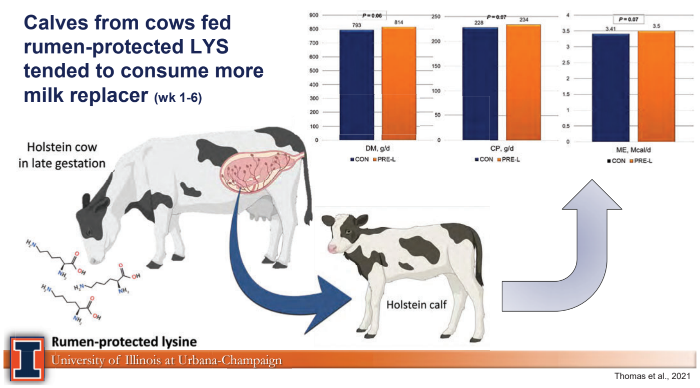

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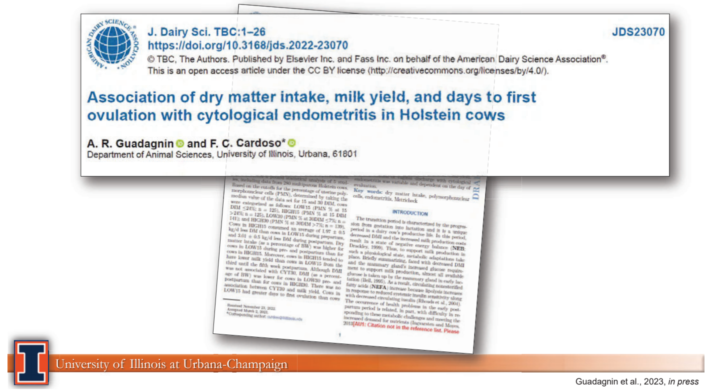

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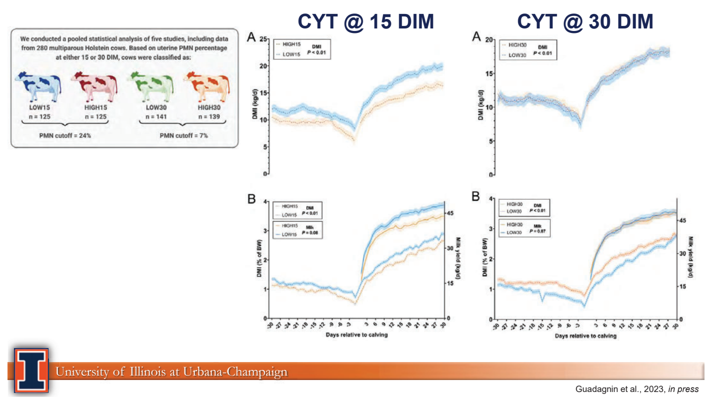

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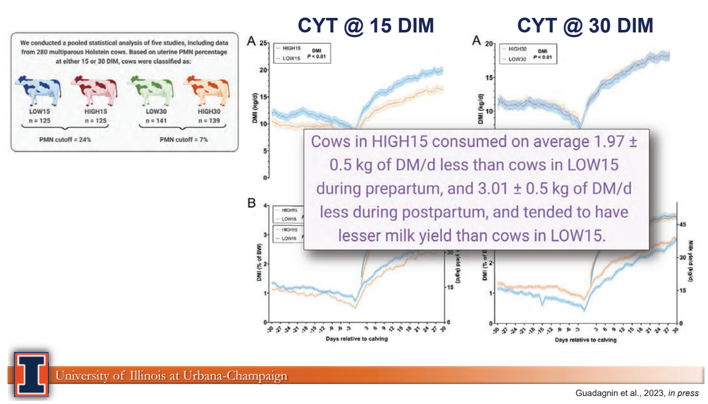

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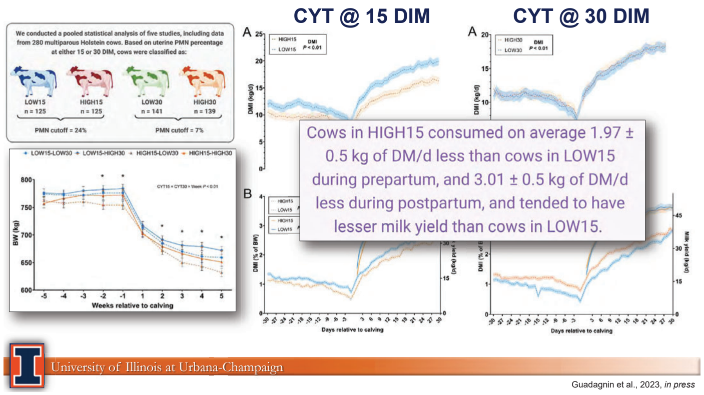

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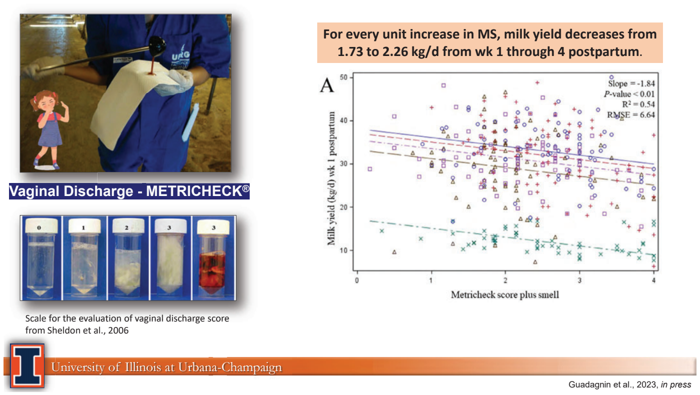

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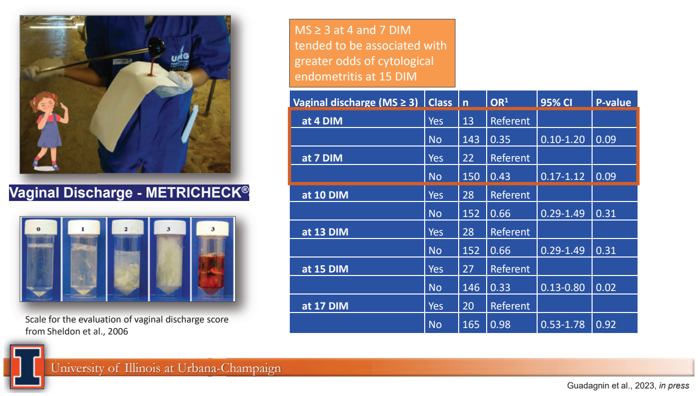
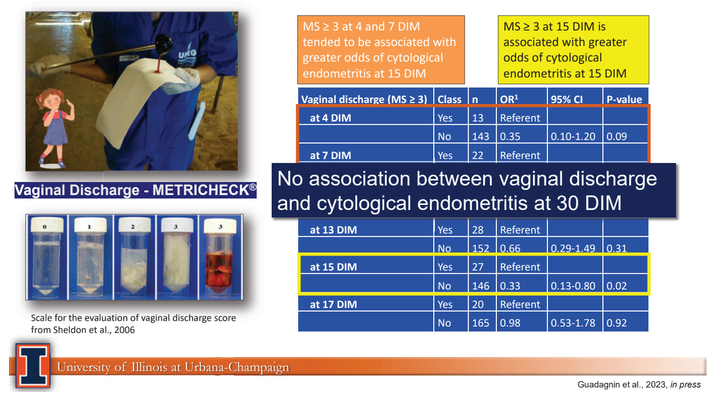


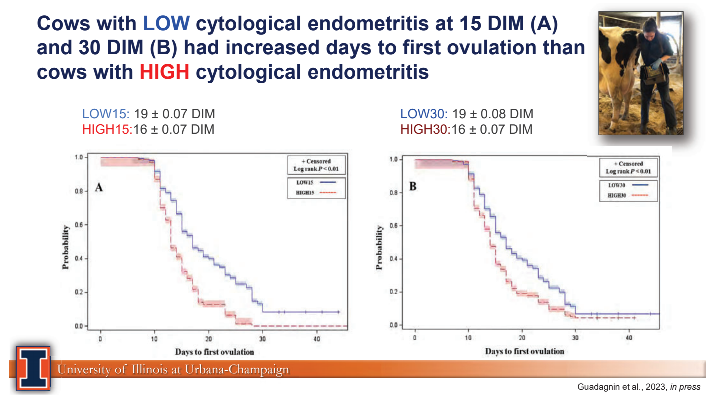
Vaginal discharge (MS ≥ 3)	Class	n	OR[1]	95% CI	P-value
at 4 DIM	Yes	13	Referent		
	No	143	0.35	0.10-1.20	0.09
at 7 DIM	Yes	22	Referent		
	No	150	0.43	0.17-1.12	0.09
at 10 DIM	Yes	28	Referent		
	No	152	0.66	0.29-1.49	0.31
at 13 DIM	Yes	28	Referent		
	No	152	0.66	0.29-1.49	0.31
at 15 DIM	Yes	27	Referent		
	No	146	0.33	0.13-0.80	0.02
at 17 DIM	Yes	20	Referent		
	No	165	0.98	0.53-1.78	0.92

45



Vaginal discharge (MS ≥ 3)	Class	n	OR[1]	95% CI	P-value
at 4 DIM	Yes	13	Referent		
	No	143	0.35	0.10-1.20	0.09
at 7 DIM	Yes	22	Referent		
at 13 DIM	Yes	28	Referent		
	No	152	0.66	0.29-1.49	0.31
at 15 DIM	Yes	27	Referent		
	No	146	0.33	0.13-0.80	0.02
at 17 DIM	Yes	20	Referent		
	No	165	0.98	0.53-1.78	0.92

46



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Herd Dynamics

DairyCOMP 305

Not my farm

DairyComp 305 — Page 1
Command : BREDSUM\E
32504509 University of Illinois-DCTEACH 1 Instructor 08/01/23

Date	Br Elig	Bred	Pct	Pg Elig	Preg	Pct	Aborts	
7/19/22	1313	674	51	1294	193	15	30	
8/09/22	1451	769	53	1430	252	18	38	
8/30/22	1538	830	54	1518	275	18	33	
9/20/22	1580	861	54	1562	270	17	38	
10/11/22	1605	957	60	1589	387	24	50	
11/01/22	1469	840	57	1454	338	23	34	
11/22/22	1422	722	51	1407	288	20	37	
12/13/22	1421	768	54	1404	298	21	28	
1/03/23	1387	755	54	1372	278	20	23	
1/24/23	1423	784	55	1402	309	22	34	
2/14/23	1424	798	56	1412	303	21	36	
3/07/23	1402	789	56	1385	314	23	28	
3/28/23	1291	736	57	1281	299	23	25	
4/18/23	1208	733	61	1199	310	26	19	
5/09/23	1105	618	56	1095	270	25	14	
5/30/23	1119	557	50	1109	242	22	2	
6/20/23	1145	578	50	0	0	0	0	???? Preg Stat
7/11/23	1137	689	61	0	0	0	0	???? Preg Stat
Total	22158	12191	55	21913	4626	21	469	

Wait Period 50

University of Illinois at Urbana-Champaign

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Herd Dynamics

DairyCOMP 305

Not my farm

DairyComp 305 — Page 1
Command : BREDSUM\E
32504509 University of Illinois-DCTEACH 1 Instructor 08/01/23

Date	Br Elig	Bred	Pct	Pg Elig	Preg	Pct	Aborts	
7/19/22	1313	674	51	1294	193	15	30	
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6/20/23	1145	578	50	0	0	0	0	???? Preg Stat
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Total	22158	12191	55	21913	4626	21	469	

Wait Period 50

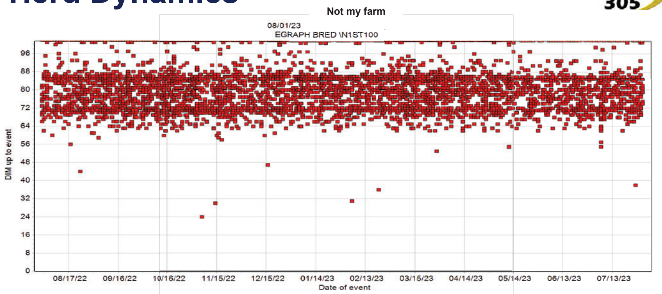
University of Illinois at Urbana-Champaign

50

Herd Dynamics

DairyCOMP 305

Not my farm



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Herd Dynamics

DairyCOMP 305

Not my farm

DairyComp 305 — Page 1
Command : BREDSUM\EV
32504509 University of Illinois-DCTEACH 1 Instructor 08/01/23

Date	Br Elig	Bred	Pct	Pg Elig	Preg	Pct	Aborts	
7/19/22	1077	658	61	1058	188	18	29	
8/09/22	1179	749	64	1158	244	21	38	
8/30/22	1267	805	64	1247	267	21	32	
9/20/22	1314	835	64	1298	262	20	38	
10/11/22	1368	934	68	1352	376	28	48	
11/01/22	1222	811	66	1208	327	27	33	
11/22/22	1171	703	60	1156	279	24	36	
12/13/22	1191	748	63	1174	288	25	28	
1/03/23	1137	743	65	1122	274	24	23	
1/24/23	1163	762	66	1142	297	26	34	
2/14/23	1165	771	66	1153	291	25	35	
3/07/23	1174	767	65	1157	309	27	27	
3/28/23	1093	714	65	1085	289	27	22	
4/18/23	1010	712	70	1001	306	31	18	
5/09/23	934	604	65	924	266	29	14	
5/30/23	884	545	62	875	239	27	2	
6/20/23	936	554	59	0	0	0	0	???? Preg Stat
7/11/23	895	665	74	0	0	0	0	???? Preg Stat
Total	18349	11861	65	18110	4502	25	457	

Wait Period 65

University of Illinois at Urbana-Champaign

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Herd Dynamics

DairyCOMP 305

65 to 75%
11,861 to 13,761

Not my farm

DairyComp 305 — Page 1
Command : BREDSUM\EV
32504509 University of Illinois-DCTEACH 1 Instructor 08/01/23

Date	Br Elig	Bred	Pct	Pg Elig	Preg	Pct	Aborts	
7/19/22	1077	658	61	1058	188	18	29	
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5/09/23	934	604	65	924	266	29	14	
5/30/23	884	545	62	875	239	27	2	
6/20/23	936	554	59	0	0	0	0	???? Preg Stat
7/11/23	895	665	74	0	0	0	0	???? Preg Stat
Total	18349	11861	65	18110	4502	25	457	

Wait Period 65

University of Illinois at Urbana-Champaign

53

Herd Dynamics

DairyCOMP 305

65 to 75%
11,861 to 13,761

18,110 to 20,826
@ 25%
4,502 to 5,206

Not my farm

DairyComp 305 — Page 1
Command : BREDSUM\EV
32504509 University of Illinois-DCTEACH 1 Instructor 08/01/23

Date	Br Elig	Bred	Pct	Pg Elig	Preg	Pct	Aborts	
7/19/22	1077	658	61	1058	188	18	29	
8/09/22	1179	749	64	1158	244	21	38	
8/30/22	1267	805	64	1247	267	21	32	
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5/30/23	884	545	62	875	239	27	2	
6/20/23	936	554	59	0	0	0	0	???? Preg Stat
7/11/23	895	665	74	0	0	0	0	???? Preg Stat
Total	18349	11861	65	18110	4502	25	457	

Wait Period 65

University of Illinois at Urbana-Champaign

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Herd Dynamics

DairyCOMP 305

65 to 75%
11,861 to 13,761

18,110 to 20,826
@ 25%
4,502 to 5,206

10 to 7%
457 to 315

DairyComp 305 | Not my farm | Page 1
Command : BREDSUM\EV

32504509 University of Illinois-DCTEACH 1 Instructor 08/01/23

Date	Br Elig	Bred	Pct	Pg Elig	Preg	Pct	Aborts	
7/19/22	1077	658	61	1058	188	18	29	
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5/30/23	884	545	62	875	239	27	2	
6/20/23	936	554	59	0	0	0	0	???? Preg Stat
7/11/23	895	665	74	0	0	0	0	???? Preg Stat
Total	18349	11861	65	18110	4502	25	457	

Wait Period 65

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Herd Dynamics

DairyCOMP 305

65 to 75%
11,861 to 13,761

18,110 to 20,826
@ 25%
4,502 to 5,206

10 to 7%
457 to 315

+ 846 @ $200
$169,200

DairyComp 305 | Not my farm | Page 1
Command : BREDSUM\EV

32504509 University of Illinois-DCTEACH 1 Instructor 08/01/23

Date	Br Elig	Bred	Pct	Pg Elig	Preg	Pct	Aborts	
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8/09/22	1179	749	64	1158	244	21	38	
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5/30/23	884	545	62	875	239	27	2	
6/20/23	936	554	59	0	0	0	0	???? Preg Stat
7/11/23	895	665	74	0	0	0	0	???? Preg Stat
Total	18349	11861	65	18110	4502	25	457	

Wait Period 65

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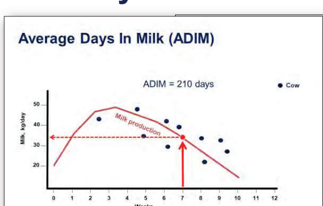
Herd Dynamics

DairyCOMP 305



+ 846 @ $200
$169,200

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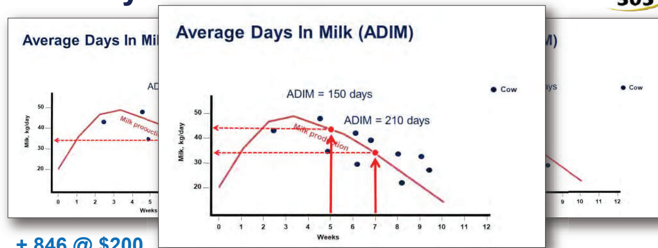
Herd Dynamics

DairyCOMP 305



+ 846 @ $200
$169,200

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Summary

- Amino acid balancing (methionine and lysine) during the transition period seems to improve the uterine environment of dairy cows by:
  - Increased metabolism and cell proliferation
  - Reduced oxidative stress
- Cytological endometritis at 15 DIM was associated with lower DMI and milk yield
  - Cytological endometritis at 30 DIM is not associated with milk yield
- Vaginal discharge is negatively associated with milk yield
  - Association with cytological endometritis is variable and dependent on the day of the vaginal discharge evaluation (4, 7, and 15 DIM)
  - No association between vaginal discharge and cytological endometritis at 30 DIM
- Small increments in reproductive indicators add up to big results.

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COLLEGE OF AGRICULTURAL, CONSUMER & ENVIRONMENTAL SCIENCES
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cardoso2@Illinois.edu
www.dairyfocus.Illinois.edu
Dairy Focus Lab

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Optimizing IVF Embryo Transfer in Dairy Herds

Paul M. Fricke
Professor of Dairy Science
University of Wisconsin

Optimizing IVF Embryo Transfer in Dairy Herds

Paul M. Fricke

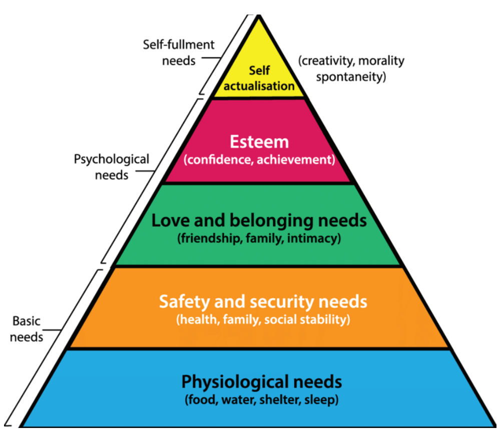
Professor of Dairy Science

Department of Animal & Dairy Sciences
UNIVERSITY OF WISCONSIN–MADISON

Extension
UNIVERSITY OF WISCONSIN–MADISON

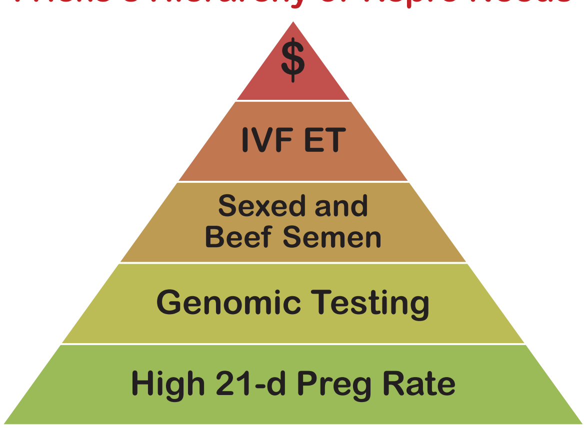
1

Maslow's Hierarchy of Needs



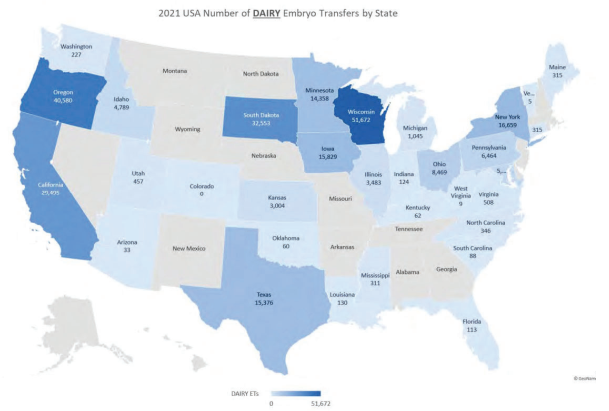
2

Fricke's Hierarchy of Repro Needs



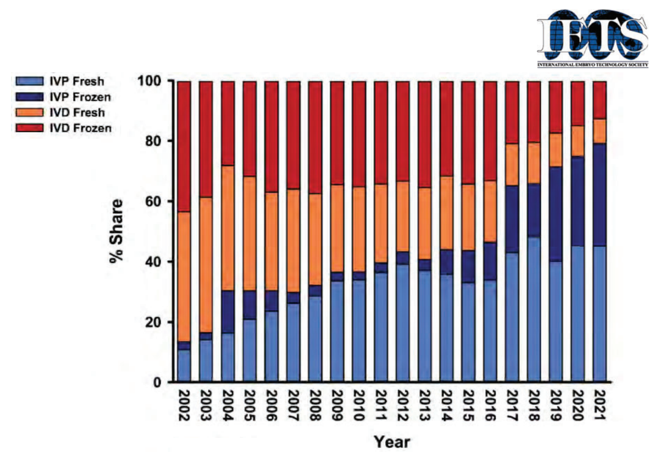
3

2022 Annual Report of the AETA Statistical Information Committee



Wisconsin is the leader in Dairy embryo transfers

4

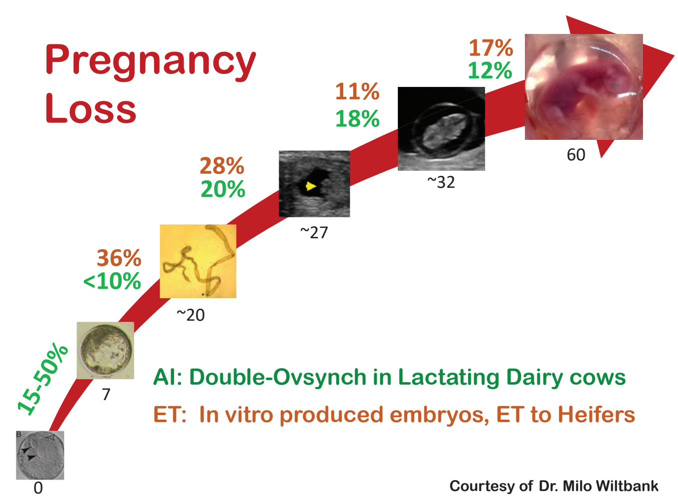


Flourishing business in the world

IETS, 31st annual report, 2022 ET activities during 2021.

5

Pregnancy Loss



AI: Double-Ovsynch in Lactating Dairy cows

ET: In vitro produced embryos, ET to Heifers

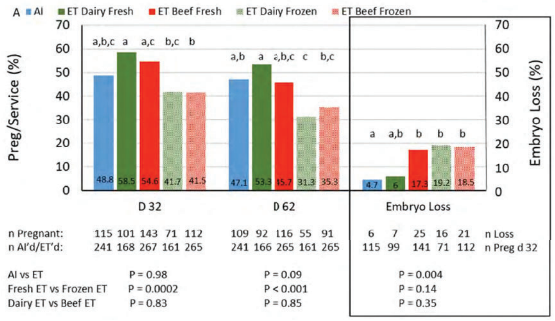
Courtesy of Dr. Milo Wiltbank

6

J. Dairy Sci. TBC
https://doi.org/10.3168/jds.2023-23520

Fertility in seasonal-calving pasture-based lactating dairy cows following timed artificial insemination or timed embryo transfer with fresh or frozen in vitro produced embryos

A. D. Crowe,12 J. M. Sánchez,23 S. G. Moore,[1] M. McDonald,[2] R. Rodrigues,[4] M. F. Morales,[4] L. Orsi de Freitas,[4] F. Randi,[5] J. Furlong,[6] J. A. Browne,[2] M. B. Rabaglino,[2] P. Lonergan,[2] and S. T. Butler[1]*



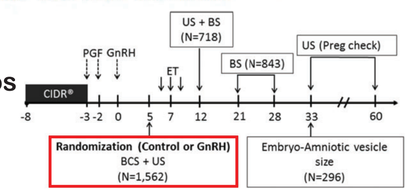
7

Postovulatory treatment with GnRH on day 5 reduces pregnancy loss in recipients receiving an in vitro produced expanded blastocyst

Theriogenology 141 (2020) 202–210

Alvaro García-Guerra [1], Rodrigo V Sala [2], Luciana Carrenho-Sala [2], Giovanni M Baez [3], Jéssica C L Motta [4], Meliton Fosado [2], Juan F Moreno [5], Milo C Wiltbank [6]

Holstein
IVP fresh embryos
(n = 1,562 +/- GnRH)



Accessory CL	Preg Loss (%)	P-value
No	28[a]	0.004
Yes	12[b]	

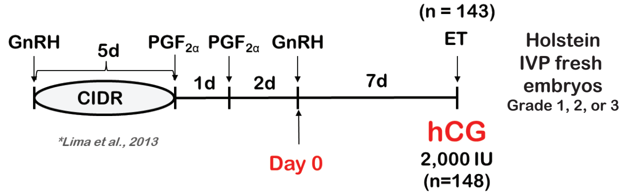
8

J. Dairy Sci. 102:2593–2606
https://doi.org/10.3168/jds.2018-15588

Effect of treatment with human chorionic gonadotropin 7 days after artificial insemination or at the time of embryo transfer on reproductive outcomes in nulliparous Holstein heifers

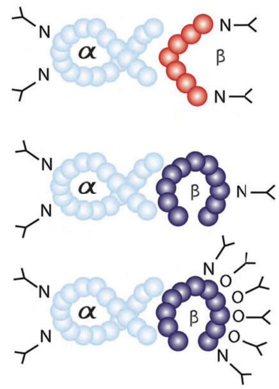
A. M. Niles, H. P. Fricke, P. D. Carvalho, M. C. Wiltbank, L. L. Hernandez, and P. M. Fricke*
Department of Dairy Science, University of Wisconsin-Madison, Madison 53706

ET after synchronization of ovulation



9

Glycoprotein Hormones



Pituitary gonadotropins

The amino acid sequence homology between hCG and bovine LH is ~80%.
(Pierce and Parsons, 1981)

10

Hypothalamic – Pituitary – Gonadal Axis

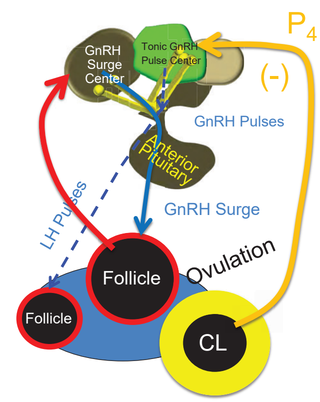
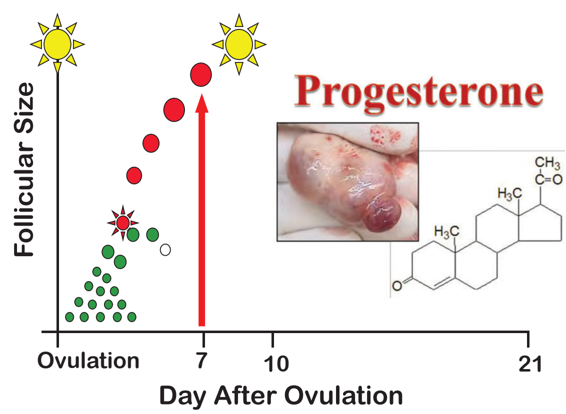


Diagram compliments of M.C. Wiltbank

Hypothalamus
GnRH
Anterior Pituitary
Gonadotropins
LH & FSH
Ovary
Steroid Hormones
Estrogen & Progesterone

11

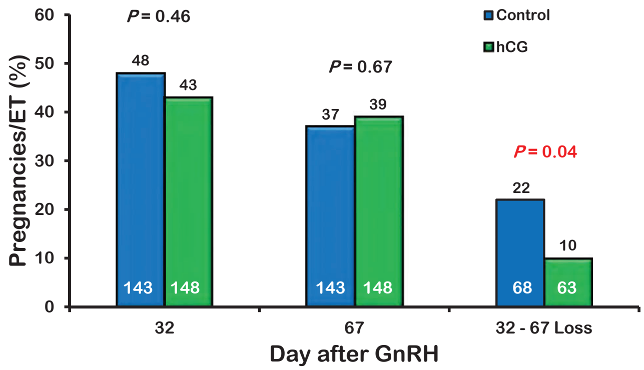
Induction of an accessory CL



12

Experiment 2 – ET

Effect of treatment on pregnancy outcomes and pregnancy loss



13

Preliminary Experiment

Evaluation of the effect of hCG on pregnancy outcomes in lactating Jersey cows receiving IVP beef embryos after a synchronized estrus versus a synchronized ovulation

J. Dairy Sci. 2023 (Abstract #1723W)

ANIMAL & DAIRY SCIENCES
University of Wisconsin-Madison

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Commercial Angus IVF Embryos

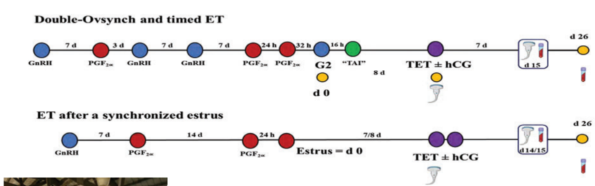
Simplot ANIMAL SCIENCES

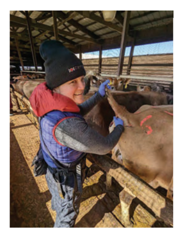
- Commercial Angus oocytes
- IVF with 1 of 3 Angus sires
  Selected for calving ease
- Grade 1 Stage 7 embryos
- Frozen for direct transfer

SimVitro HERDFLEX™ SELECT SIRES

14

Experimental Design





2,500 IU hCG

Protocol	Control	hCG
DO n = 157/169	78	79
ED n = 90/180	44	46

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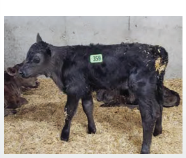
Why Angus embryos in Jerseys?

$10 Jersey Bull

$200 Jersey x Beef



$400 Angus IVF Calf

Beef Embryos in Dairy Cows can be Profitable for Dairies

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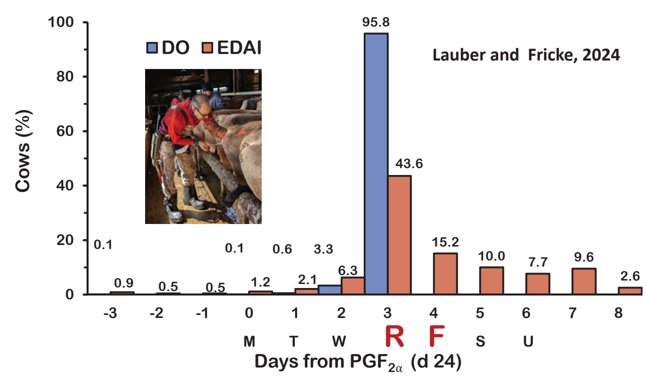
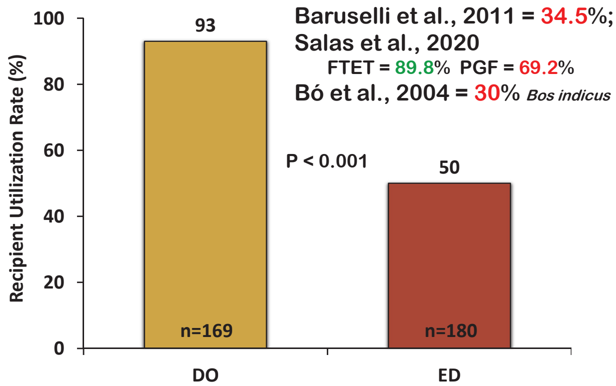
Days of the Week for ET



18

Recipient Utilization Rate



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Partial Budget

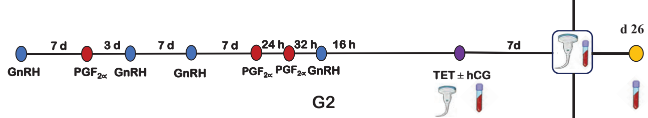
Based on recipient utilization

	Protocol	
Cost per pregnancy US$	Double Ovsynch	Synchronized Estrus
Cows enrolled (n)	169	180
Recipient utilization (%)	93	50
Hormonal Treatments, $	10.80	6.84
Detection of estrus, $	-	1.94
Unutilized recipients, $	3.80	47.41
Embryo, $	50.00	50.00
Transfer, $	40.00	40.00
Nonpregnant recipients, $	197.28	305.81
Pregnancy diagnosis, $	9.50	9.50
Total cost per pregnancy, $	311.38	461.5

20

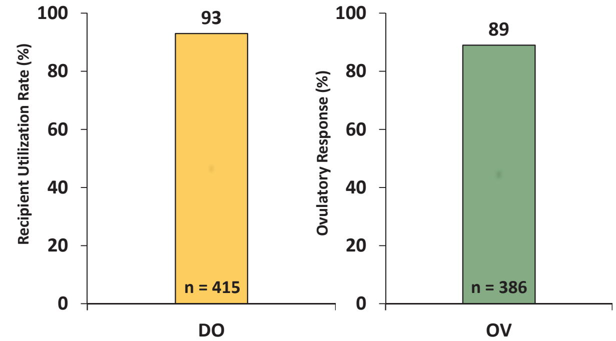
Experiment 2

Double-Ovsynch and timed ET



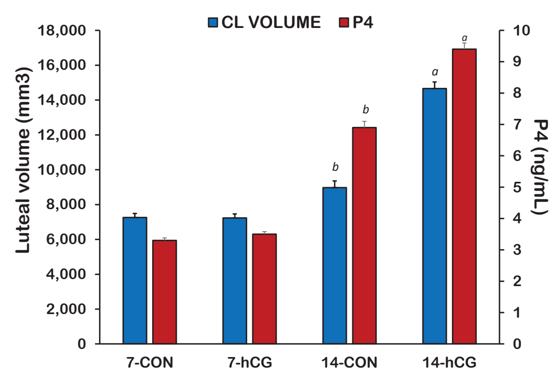
21

Recipient Utilization Rate and Ovulatory Response



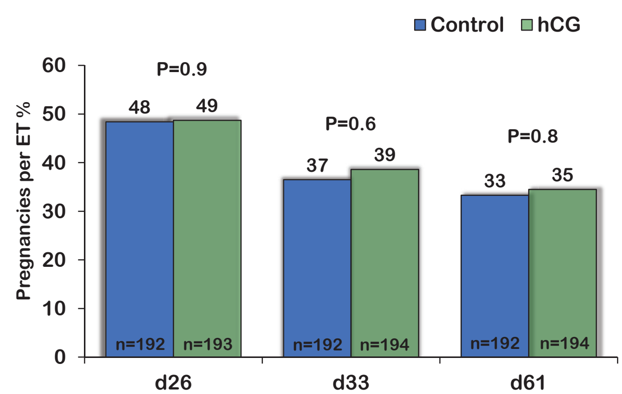
22

Effect of hCG on P4 and CL at 7 and 14 d



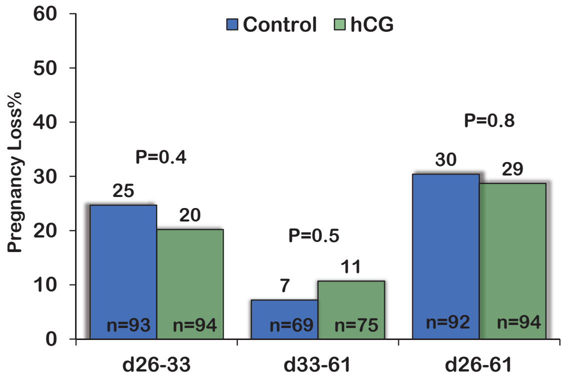
23

Effect of hCG on Pregnancies per ET



24

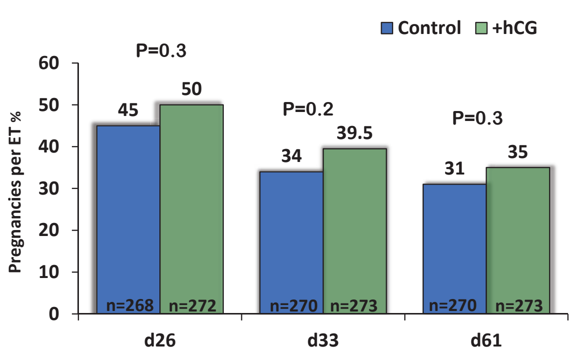
Effect of hCG on Pregnancy Loss



25

Effect of hCG on Pregnancies per ET

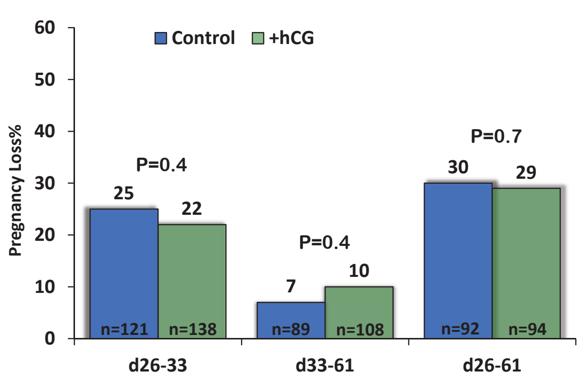
Combined data



26

Effect of hCG on Pregnancy Loss

Combined data



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What we have learned thus far…

- Pregnancies per ET is less than P/AI
  - ~50% with beef semen after Timed AI
  - ~30% with IVP Timed ET
- Estrus treatment is not sustainable
  - Recipient utilization is low
  - Multiple days of the week for transfers
  - Need more trained ET technicians

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Challenging Dogma with New Research: Fatty Acid Supplementation Strategies for Early Lactation Cows

Adam L. Lock & Jair Esteban Parales-Giron
Department of Animal Sciences
Michigan State University

MICHIGAN STATE UNIVERSITY | Extension

CHALLENGING DOGMA WITH NEW RESEARCH:

FATTY ACID SUPPLEMENTATION STRATEGIES FOR EARLY LACTATION COWS

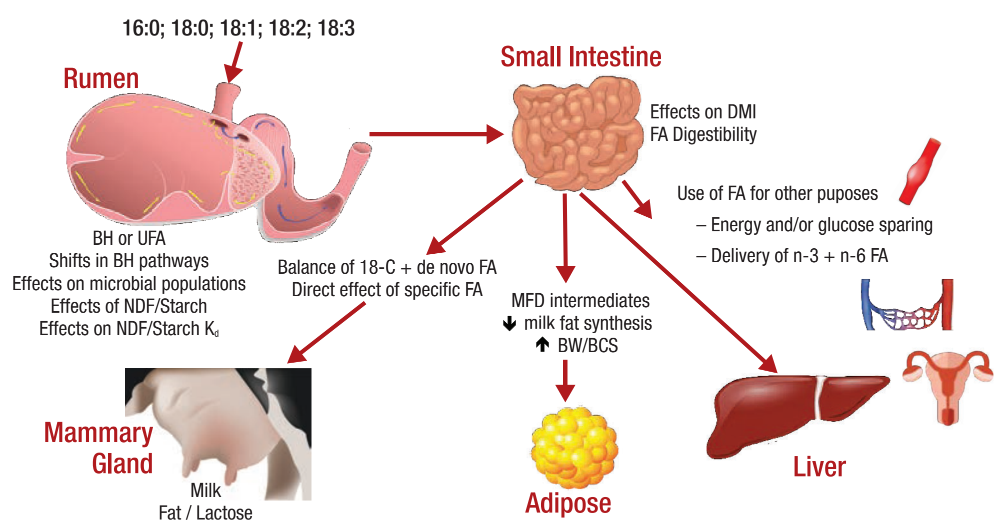
Adam L. Lock & Jair Esteban Parales-Girón

Department of Animal Science
Michigan State University

Four-State Dairy Nutrition and Management Conference
Dubuque, IA
June 5-6, 2024

1

Impact of Dietary Fatty Acids on Digestion, Metabolism, and Nutrient Use in Lactating Dairy Cows



2

Fatty Acid Supplementation to Early Lactation Cows?

dogma

dog·ma [dawg-muh, dog-]

noun, plural **dog·mas**

Prescribed doctrine proclaimed as unquestionably true by a particular group.

- Should not feed supplemental FA to cows in negative energy balance
- Already too much circulating FA

Feeding Strategies for Supplemental Fat

- When Should Fat Feeding Begin?
  - Ideally, fat probably should be left out of the diet immediately postpartum
  - Numerous trials have indicated that there was little benefit from feeding fat during the first 5 to 7 wk postpartum
  - The lack of early lactation response seems to be related to depression in feed intake which offsets any advantage that may be gained by increasing energy density of the diet

- ~ 2.8 to 5.0% DM inclusion into fresh cow diets of prilled fat, tallow, soybean oil

3

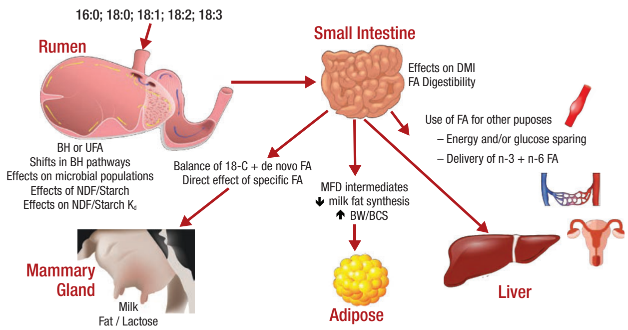
Negative Nutrient Balance

- The high metabolic demand of lactation and reduced DMI during the immediate postpartum period result in a state of negative energy and nutrient balance
- Approaches to increase energy intake of postpartum cows include increasing dietary starch content and supplementing FA to increase the energy density of the diet
  - Feeding high starch diets that promote greater ruminal propionate production during early lactation could be hypophagic and therefore further reduce DMI and increase the risk of ruminal acidosis and displaced abomasum
  - Some authors suggest that caution should be exercised when using supplemental FA to increase the caloric density of diets in early lactation dairy cows, since a high lipid load may affect the endocrine system, feed intake, and increase the risk for metabolic disorders

➢ **We are increasing our understanding on the effects of different FA on metabolism and animal responses**

➢ **Caloric vs. non-caloric effects**

4



Fatty Acid Supplementation to Early Lactation Cows?

- Mixed SFA prills
- Palmitic acid-enriched prills
- Palmitic and oleic acid blends
- Oilseeds
- Interactions with other nutrients

5

Fatty Acid Supplements and Oilseeds

Fatty acid profile of dietary FA sources.

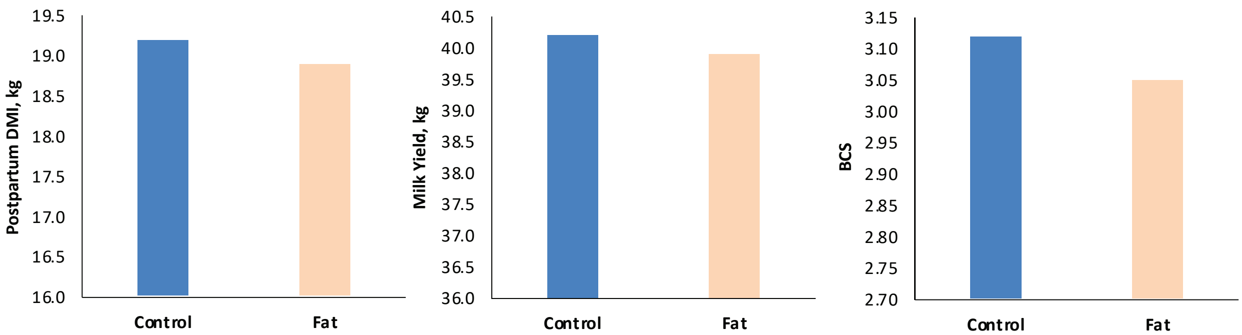
	Fat Supplements[1]			Oilseeds[1]		
Fatty Acid, g/100 g	**Mixed SFA prill**	**C16:0-enriched prill**	**Ca-salt of palm fat**	**WCS**	**Conventional soybean**	**High C18:1 soybean**
C14:0	2.70	1.60	1.01	0.61	0.60	0.90
C16:0	32.8	89.7	47.7	24.6	10.2	5.80
C18:0	51.4	1.00	3.90	2.00	4.10	3.50
C18:1 (n-9)	5.80	5.90	37.3	14.8	25.2	73.9
C18:2 (n-6)	0.80	1.30	8.25	56.5	48.2	6.10

[1]Determined by GLC analysis in the Lock Lab.

6

Effect of a Mixed C16:0 + C18:0 Supplement Pre & Post Calving

- Prilled C16:0 and C18:0 supplement provided from -21d to +10-d of lactation (250 g/d pre- and 1% DM post-partum)
- No effect of supplementation on DMI, milk yield, or BCS



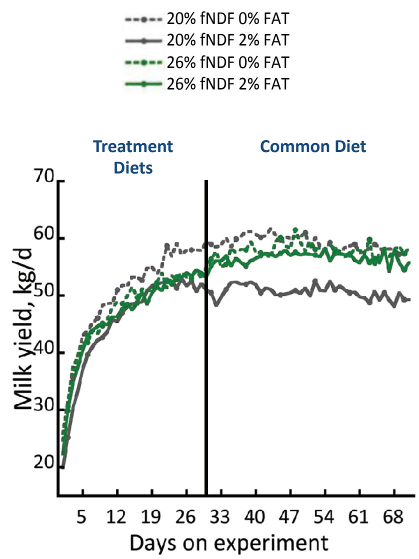
Ballou et al. 2009. J. Dairy Sci. 92:657–669

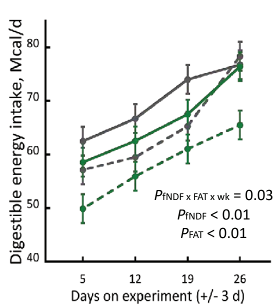
7

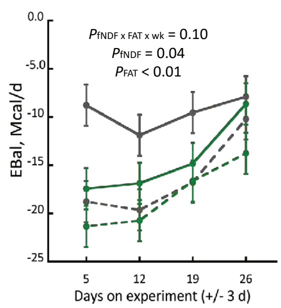
Effect of a Mixed C16:0 + C18:0 Supplement in Early Lactation

- Treatments fed during fresh period
- Common diet fed during peak period
- fNDF fed at 20 or 26% DM and SFA prill fed @ 0 or 2% DM

- 2% vs. 0% FA during PP: increased DMI and tended to decrease milk yield, increasing BCS
- 2% vs. 0% FA supplement during carryover: Decreased milk yield and cumulative milk yield, but did not affect DMI, increasing BCS







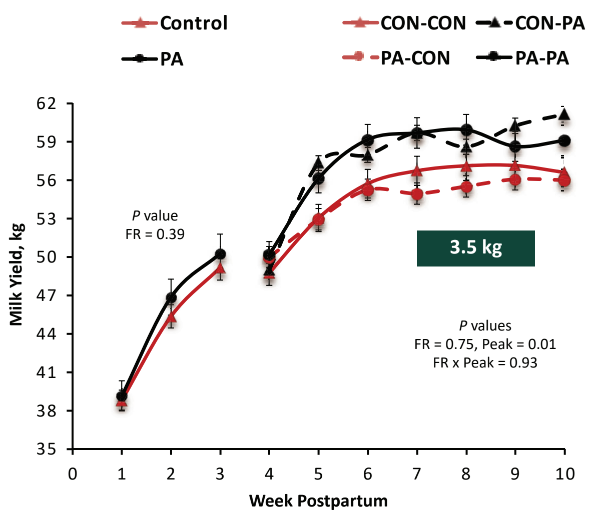
Piantoni et al. 2015. J Dairy Sci. 98:3309–3322
Piantoni et al. 2015. J Dairy Sci. 98:3323–3334

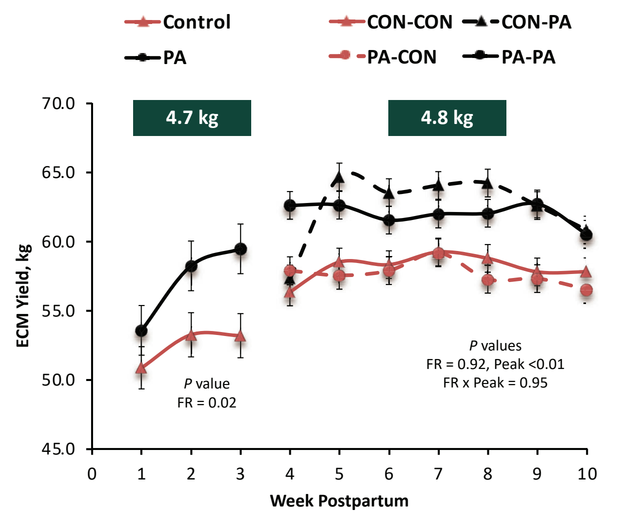
8

Effect of Supplemental C16:0 on Milk Yield and ECM

C16:0-enriched supplement fed during fresh and peak periods (1.5% DM)

No main effects or interactions for DMI



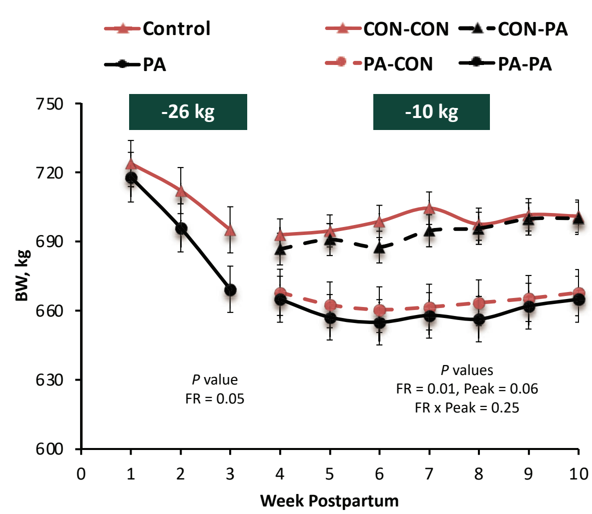


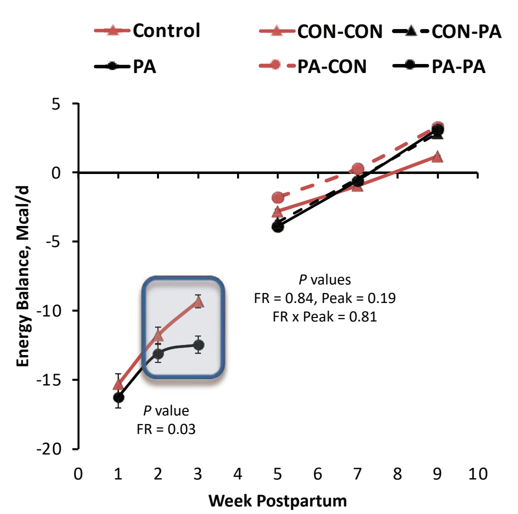
de Souza & Lock. 2019. J. Dairy Sci. 102:260-273
de Souza et al. 2019. J. Dairy Sci. 102:274-287

9

Effect of Supplemental C16:0 on Body Weight and ECM

C16:0-enriched supplement fed during fresh and peak periods (1.5% DM)





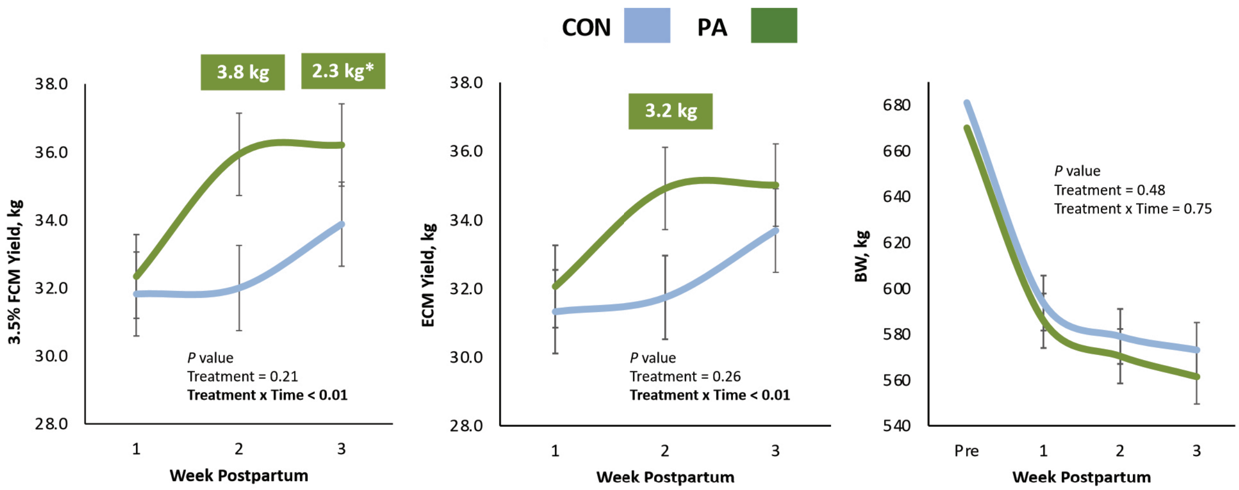
de Souza & Lock. 2019. J. Dairy Sci. 102:260-273
de Souza et al. 2019. J. Dairy Sci. 102:274-287

10

Effect of C16:0 Supplementation to Heifers

C16:0-enriched supplement fed during fresh period (1.5% DM)
Study stopped 2/3 through due to COVID protocols

No effect of treatment on DMI



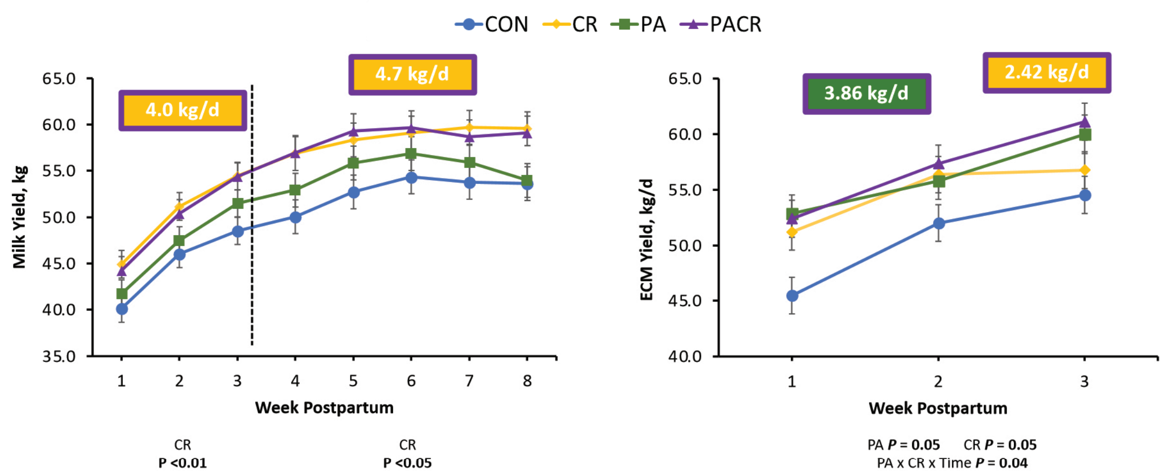
Parales et al. (ADSA Abstract 2022)

11

Effect of Palmitic Acid and Cr Supplementation

- Treatments fed during fresh period
- Common diet fed during peak period
- C16:0 fed @ 1.5% DM and Cr fed at 0.45 ppm/kg DM

No main effects or interactions for DMI



Parales et al. (ADSA Abstract 2021)

12

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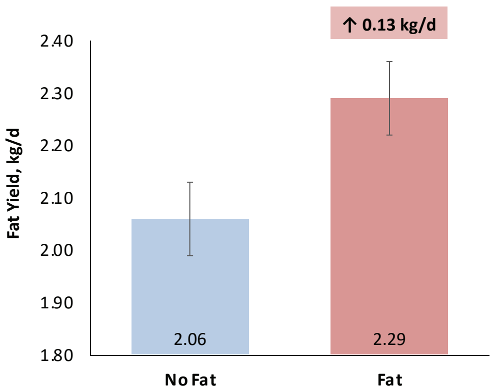
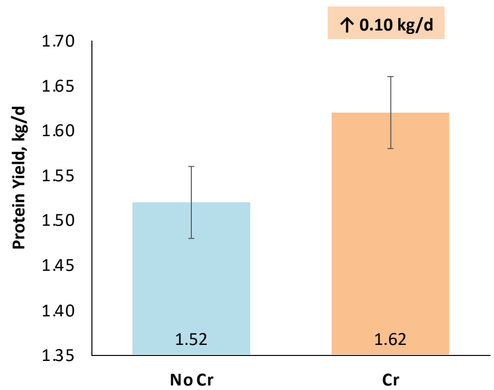


PA P **< 0.01** Cr P = 0.59
PA x Cr x Time P **= 0.04**

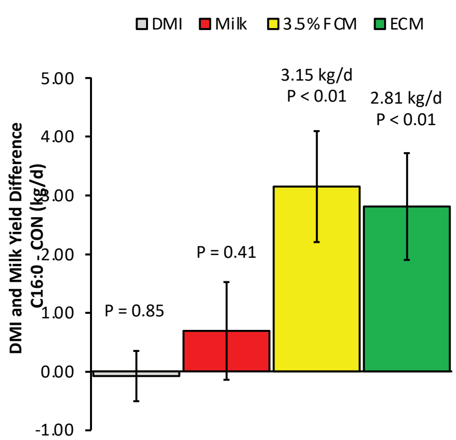


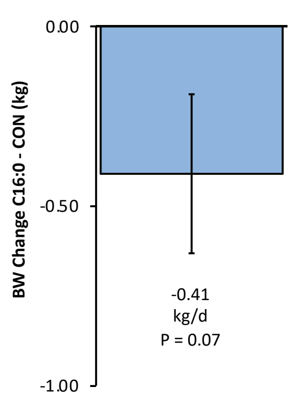
PA P = 0.99 Cr P **= 0.01**
PA x Cr x Time P **= 0.44**

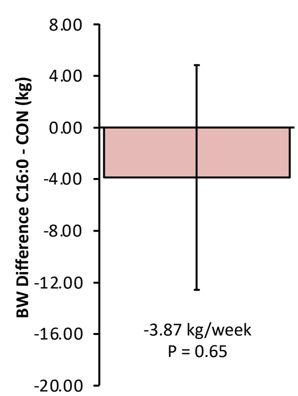
Parales et al. (ADSA Abstract 2021)

13

Meta-Analysis: Supplemental C16:0 During the Fresh Period





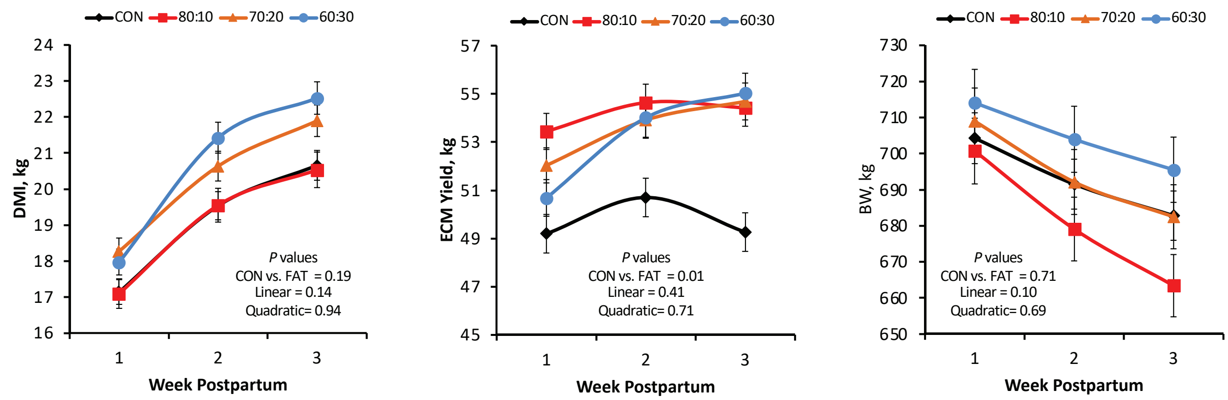


dos Santos Neto and Lock (ADSA Abstract 2024)

14

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

- Treatments fed during fresh period and common diet fed during peak period (1.5% DM)
- FA blends fed @ 1.5% DM using different proportions of a Ca-salt of palm oil and a C16:0-enriched prill



de Souza et al. 2021. J Dairy Sci 104:2896–2909
de Souza et al. 2021. J Dairy Sci 104:2910–2923

17

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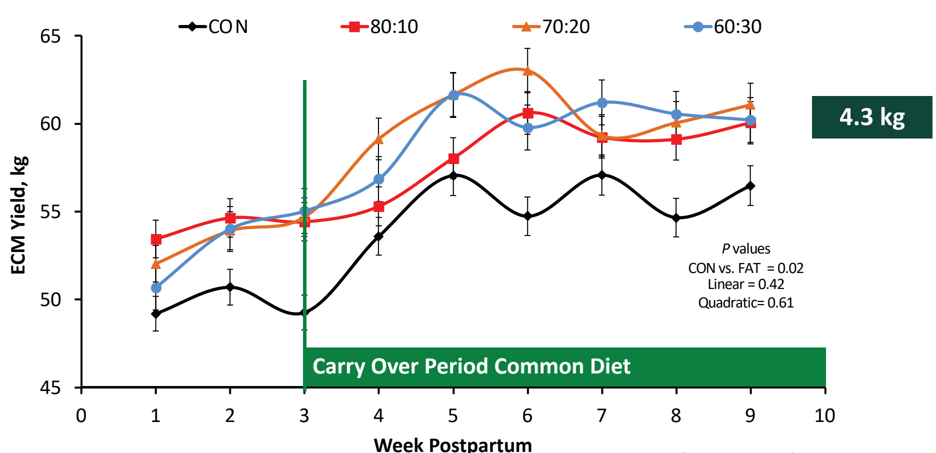


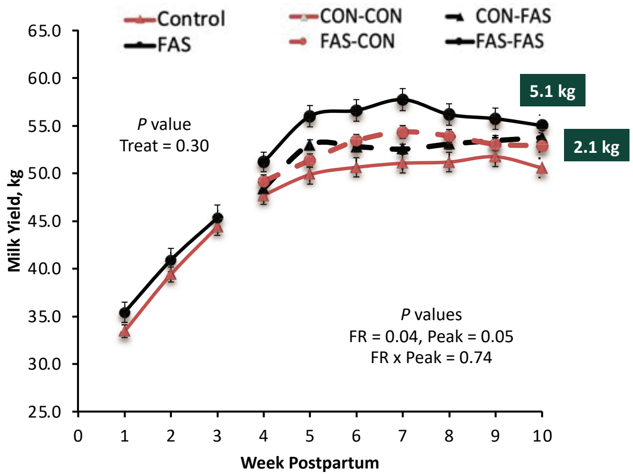
de Souza et al. 2021. J Dairy Sci 104:2896–2909
de Souza et al. 2021. J Dairy Sci 104:2910–2923

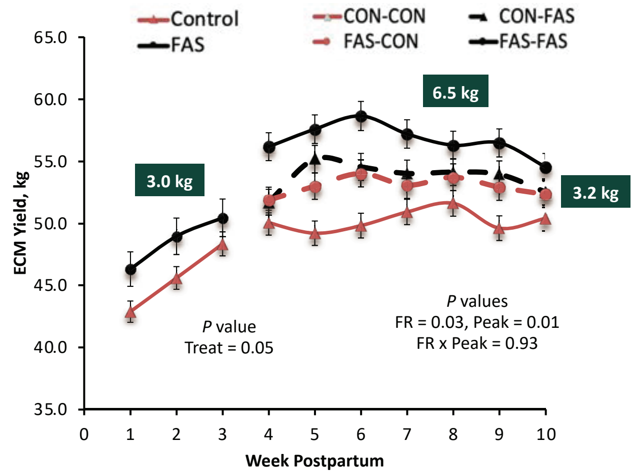
18

Effect of Timing of a Ca-Salt of Palmitic and Oleic Acid to Fresh and Peak Lactation Cows

Ca-salt (60/30 palmitic and oleic acids) fed (1.5% DM) during fresh and peak periods

No main effects or interactions for DMI or BW





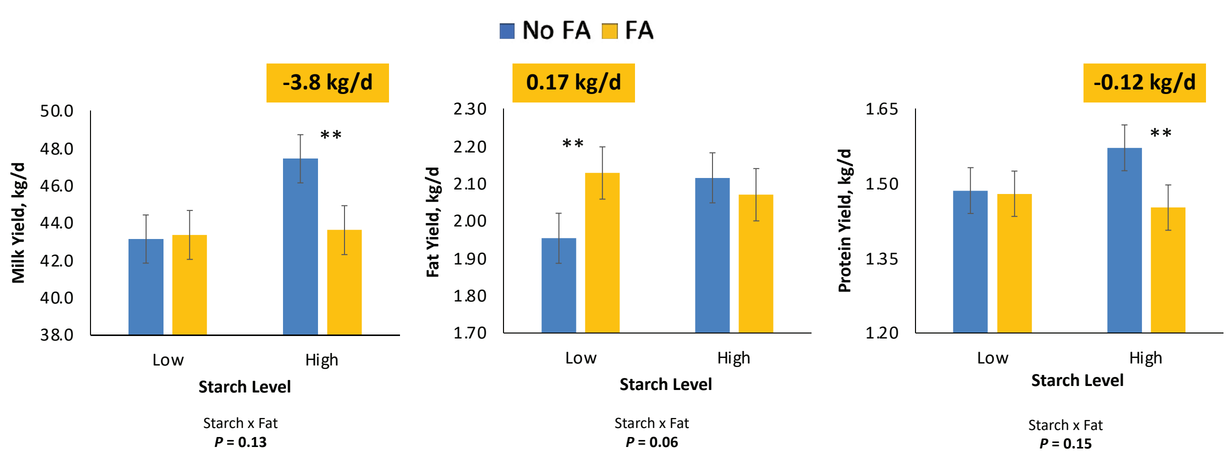
Pineda, de Souza, & Lock (ADSA 2020)

19

Effect of Dietary Starch and FA Supplementation

- Treatments fed during fresh period and common diet fed during peak period
- Dietary starch fed at 22 vs. 28% DM (dry ground corn) and 70/20 PA/OA Ca salt fed @ 2% DM

FA treatments reduced DMI 1.2 kg/d *(response more consistent in HS diets)*



Parales et al. (ADSA Abstract 2023)

20

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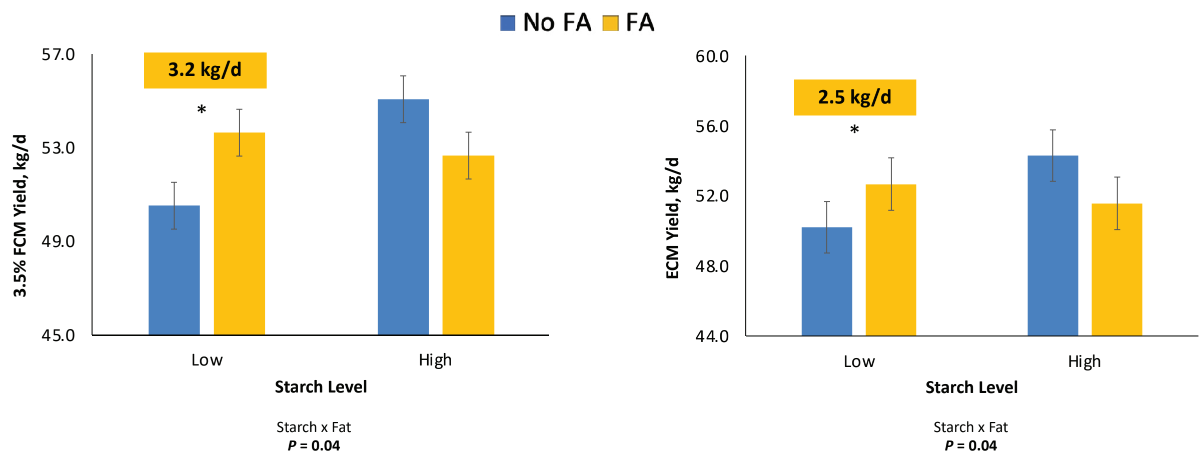
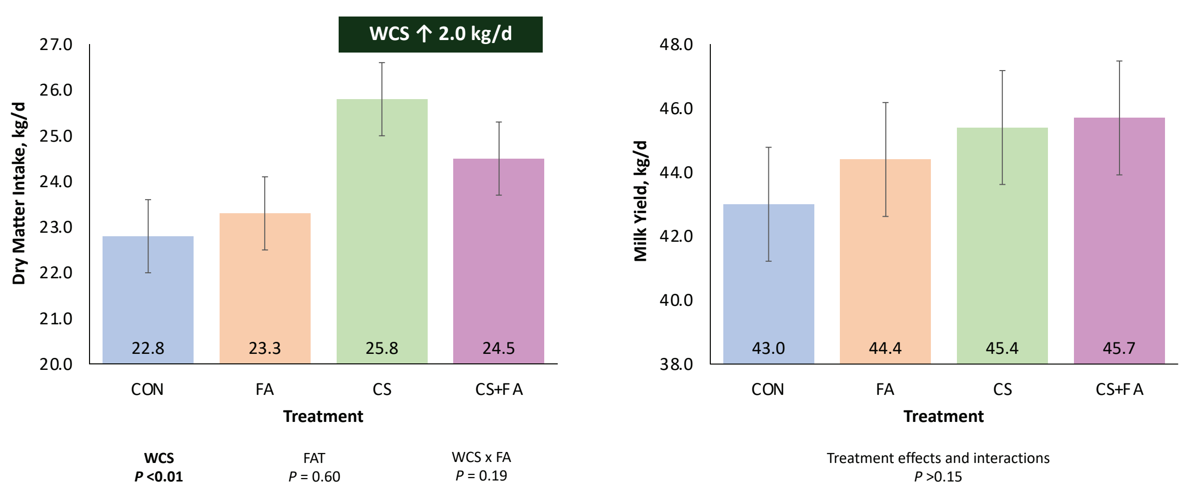


Parales et al. (ADSA Abstract 2023)

21

FA Supplementation and WCS Improve Production Responses During the Immediate Postpartum

- Treatments fed during fresh period (WCS @ 10% DM and Ca salt of PA/OA [60/30] @ 1.5% DM)
- Common diet fed during peak period



Parales et al. (ADSA Abstract 2024)

22

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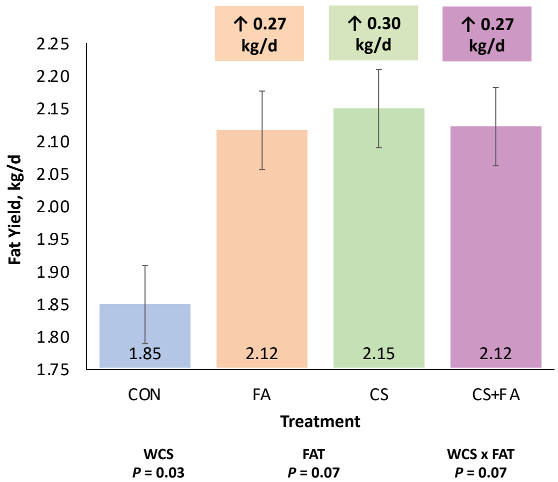

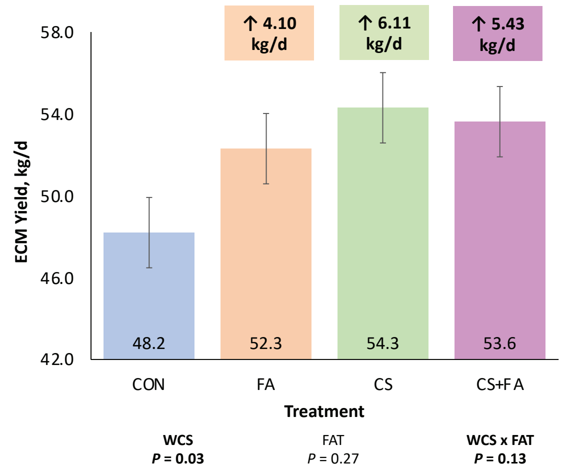

Parales et al. (ADSA Abstract 2024)

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Implications

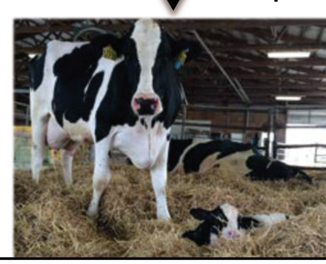
- Feeding fat in the fresh period could be beneficial, but the FA profile is key
- Using different FA in the fresh cow diet can allow nutritionists to fine-tune based on BCS, management style, etc.
- Carryover effects show that it is possible to program the cow during the fresh period for future success
- We have no data that supports the use of C18:0-enriched supplements vs. C16:0-enriched or C16:0/C18:1 supplements (better ways to increase C18:0 absorption)

Palmitic acid (C16:0)

After the fresh period
Post-peak
Cows producing ~100lbs

Oleic acid (C18:1)

Early lactation
BW gain
Cows producing ~130lbs



24

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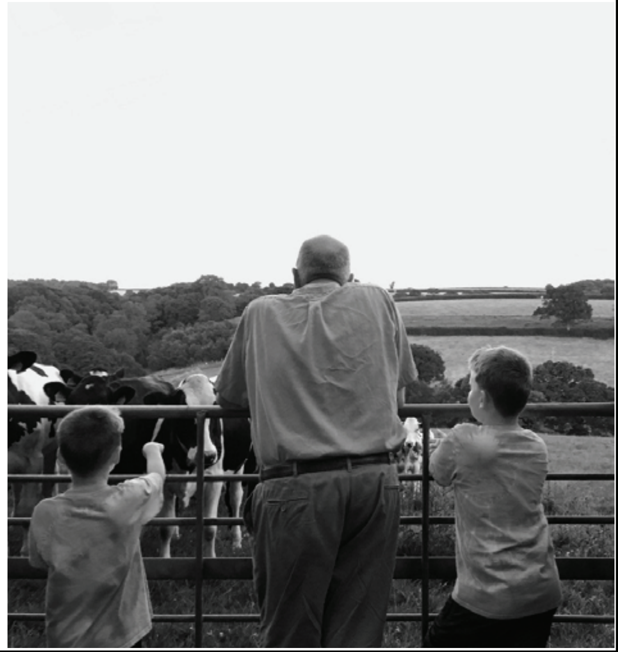
MSUDairyNutritionProgram



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25

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26

Strategies to Improve Heifer Reproductive Performance and Reduce Heifer Rearing Costs

JP Martins, DVM, MS, PhD
Assistant Professor in Bovine Reproduction
Department of Medical Sciences
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School of Veterinary Medicine
UNIVERSITY OF WISCONSIN–MADISON

Strategies to Improve Heifer Reproductive Performance and Reduce Heifer Rearing Costs

JP Martins, DVM, MS, PhD

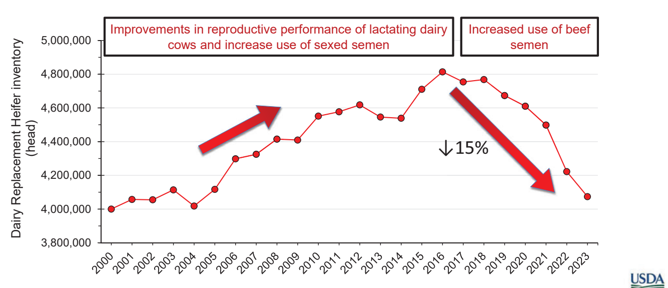
Assistant Professor in Bovine Reproduction
Department of Medical Sciences

1

Why is important to optimize reproductive performance in dairy heifers?

2

US Dairy Replacement Heifer Inventory is Decreasing

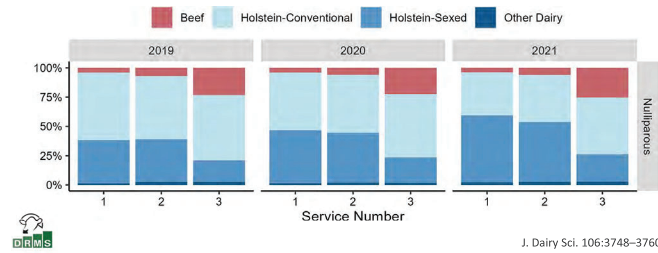


USDA – NASS, 2024

3

Increased Use of Sexed Semen in Dairy Heifers

1,106,806 Holstein heifers from 9,196 herds

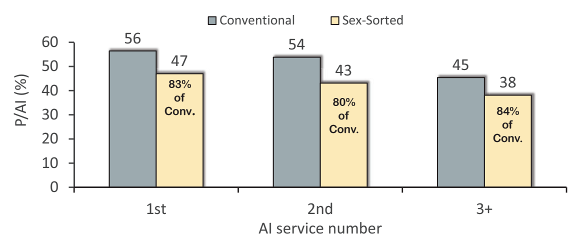


J. Dairy Sci. 106:3748–3760

4

Sexed Semen Results in fewer Pregnancies per AI than Conventional Semen

49 herds from Jan 2005 to Jan 2008; 41,398 sexed semen AI services.
Sexed semen resulted in ~45% CR and ~90% female calves in Holstein heifers.



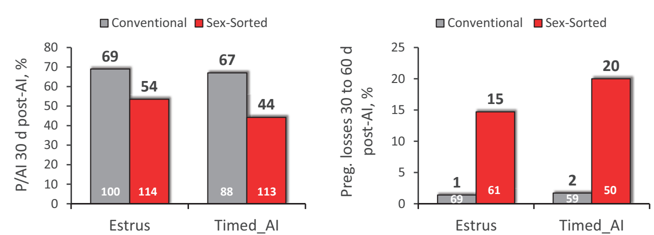
DeJarnette et al., J. Dairy Sci. 91:459; 2008 (Abstr.)

5

Sexed Semen Results in fewer Pregnancies per AI and more Embryo Losses than Conventional Semen

P-value:
Sync: 0.24; Semen: <0.001; Sync x Semen: 0.45

P-value:
Sync: 0.44; Semen: <0.001; Sync x Semen: 0.48



Guner et al., Repro Dom. Anim.56:1254-60; 2021

6

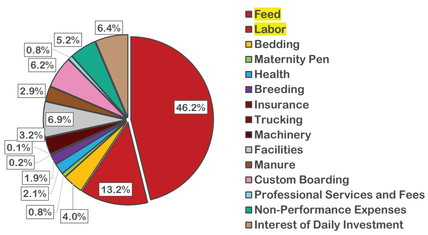
Heifer Rearing is Costly

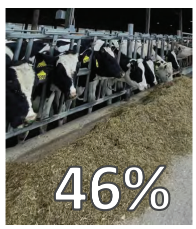
$ 2,355

Karszes and Hills (2020)

7

The highest heifer-raising cost is feed

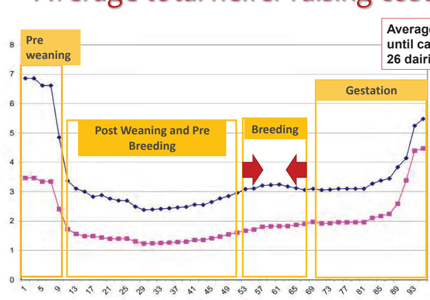




Adapted from Karzes and Hill, 2020

8

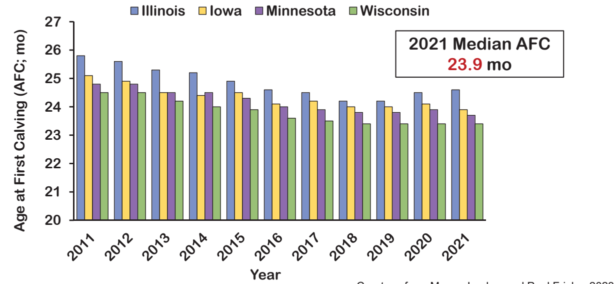
Average total heifer raising costs



Slide adapted from J. Giordano
Karzsez, 2014 (https://ecommons.cornell.edu/bitstream/handle/1813/36889/DairyReplaceCost12-3.pdf?sequence=1&isAllowed=y)

9

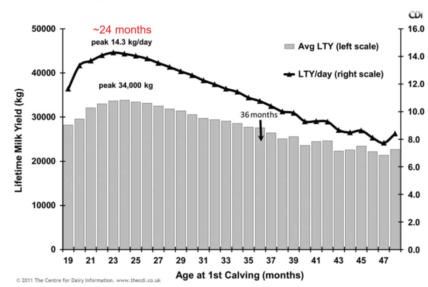
Decreased Median Age at First Calving (AFC)
Holstein cows



Courtesy from Megan Lauber and Paul Fricke, 2023

10

Relationship between Age at First Calving (AFC) and overall lifetime yield (LTY) in UK Holstein heifers



169,443 heifers entering the UK milking herd between 1996 and 1998

Richardson, 2011 in Wathes et al., Animal 8:91-104; 2014

11

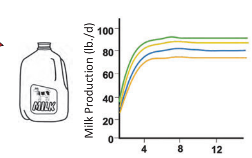
JDS Communications®
2023; 4

https://doi.org/10.3168/jdsc.2023-0372
Short Communication
Physiology

The association between insemination eligibility and reproductive performance of nulliparous heifers on subsequent body weight and milk production of primiparous Holstein cows

M. R. Lauber and P. M. Fricke*

- Pregnancies per AI (P/AI) 1st AI
- Predicted transmitting ability (PTA)



~7,000-lactating Holstein cow commercial dairy in NW IA
Weights at 30 DIM of the first lactation
Selection criteria:
-1st AI with sexed semen after estrus after 380 d of age
-Gestation lengths: > 250 and < 300 d
N= 1,849
Ranked in quartiles based on body weight (BW)

12

Body Weight (BW), Mature BW (MBW), and Age at First Calving (AFC) by Quartiles

	Body Weight (BW) Quartile			
	Q1 Lightest	Q2 Light Moderate	Q3 Moderate	Q4 Heaviest
Items	n = 462	n = 456	n = 472	n = 459
BW at 30 DIM (lb.)	1,127.3^{a} ± 1.78	1,215.7^{b} ± 1.80	1,283.3^{c} ± 1.76	1,387.5^{d} ± 1.78
MBW[1] (%)	74.7^{a} ± 0.001	80.5^{b} ± 0.001	85.0^{c} ± 0.001	91.9^{d} ± 0.001
AFC (d)	674.6^{a} ± 1.25	681.8^{b} ± 1.25	688.2^{c} ± 1.24	694.6^{d} ± 1.25

$^{a\text{-}d}$Within a row, means with different lowercase superscripts differ (P ≤ 0.05).

[1]Percent mature body weight (MBW;%) was calculated as the recorded weight of primiparous cows at 30 DIM divided by the MBW of the herd of 1,510 lb. determined by the mean weight of a random sample of 3rd and 4th lactation cows (n = 75) at 30 to 40 DIM.

13

Predicted Transmitting Abilities (PTA) by Quartiles

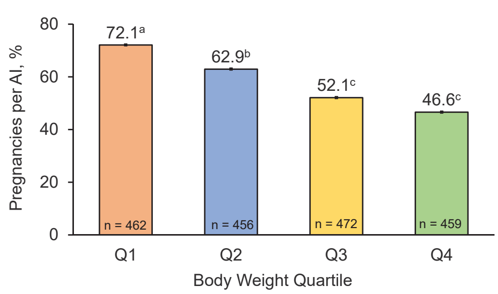
	Body Weight (BW) Quartile			
	Q1	Q2	Q3	Q4
Predicted Transmitting Abilities (PTA)	n = 462	n = 456	n = 472	n = 459
Milk (lb.)	**380.8^{b} ± 21.45**	**414.9^{ab} ± 21.63**	**394.2^{b} ± 21.27**	**473.0^{a} ± 21.54**
Fat (lb.)	28.2^{b} ± 0.59	29.3^{b} ± 0.59	28.8^{b} ± 0.57	31.7^{a} ± 0.59
Protein (lb.)	16.9^{b} ± 0.53	17.4^{b} ± 0.53	17.4^{b} ± 0.53	20.0^{a} ± 0.53
Stature	**-0.56^{c} ± 0.03**	**-0.52^{bc} ± 0.03**	**-0.46^{b} ± 0.03**	**-0.29^{a} ± 0.03**
Feed Saved (lb.)	**70.2^{a} ± 4.4**	**54.1^{b} ± 4.4**	**29.5^{c} ± 4.4**	**12.5^{d} ± 4.4**
Net Merit $ (NM$)	274.7^{A} ± 3.2	272.7^{AB} ± 3.2	263.4^{B} ± 3.1	270.4^{AB} ± 3.2
Productive Life (PL)	2.4^{a} ± 0.04	2.2^{bA} ± 0.04	2.1^{bcB} ± 0.04	1.9^{d} ± 0.04
Daughter Pregnancy Rate (DPR)	**0.37^{a} ± 0.05**	**0.27^{abA} ± 0.05**	**0.26^{ab} ± 0.05**	**0.11^{bB} ± 0.05**
Heifer Conception Rate (HCR)	**0.03^{a} ± 0.04**	**0.0^{a} ± 0.04**	**-0.08^{ab} ± 0.04**	**-0.16^{b} ± 0.04**

$^{a\text{-}d}$Within a row, means with different lowercase superscripts differ (P ≤ 0.05).

$^{A\text{-}B}$Within a row, means with different uppercase superscripts tended to differ (0.05 < P ≤ 0.10).

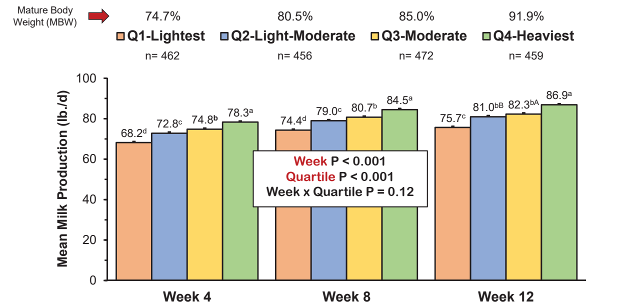
14

Pregnancies per AI for 1st AI after estrus as Heifers



15

Daily Milk Production in weeks 4, 8 and 12 in the first lactation



16

Take-Home Message

- Insemination eligibility of heifers should be defined not only by age but also by % of mature body weight to maximize genetic potential for future milk production
- Future first lactation performance should be evaluated after adopting management change

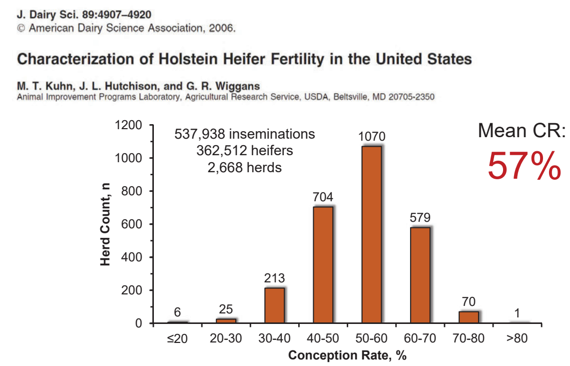
	Mature Body Size Benchmarks*	
	Weight (%)	Height (%)
At 1st Insemination	**55**	**90**
Pre-calving	**94**	**95**
Post-calving	**85**	**95**

*Van Amburgh and Meyer, 2005[2]; Van Amburgh et al., 1998[2]; Heinrichs and Hargrove, 1987[2]

17

How to reduce time to pregnancy and decrease their rearing period and associated costs?

18



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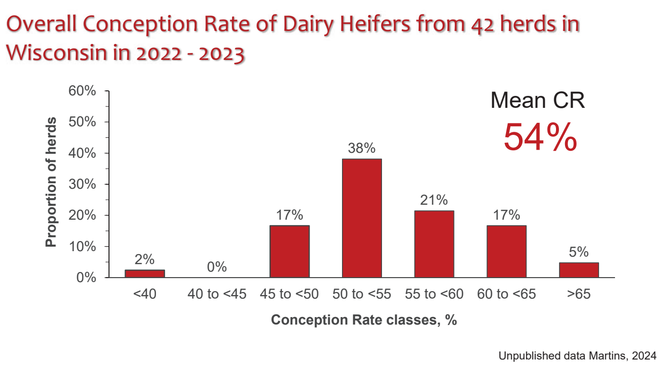

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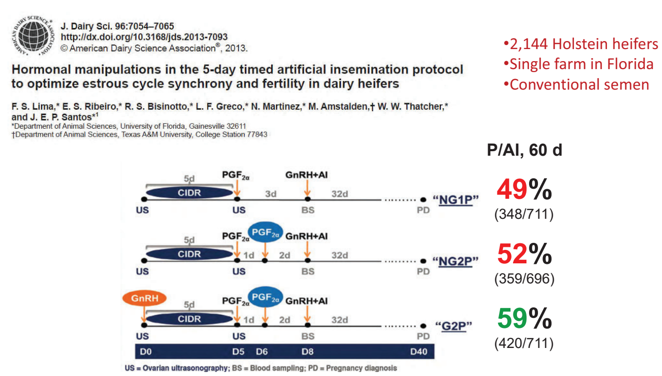

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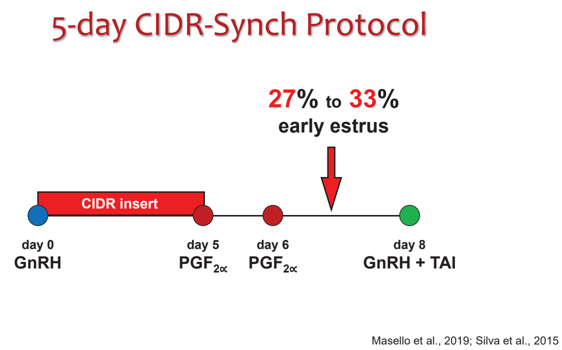

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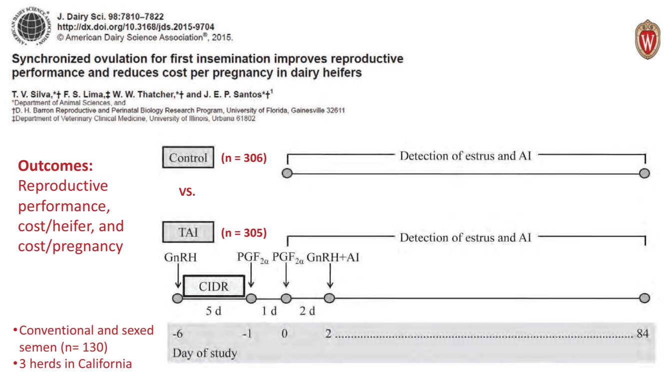

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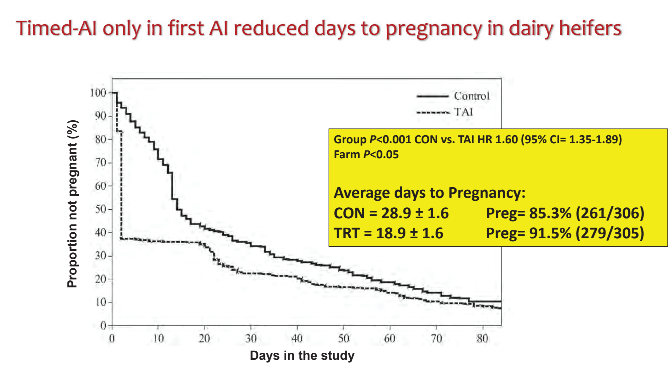

24

Timed-AI only in first AI reduced cost per heifer

	CON	TAI	Difference	P-value
Costs per heifer, US$				
Hormonal treatment	1.31	12.87	-11.56	<0.01
Detection of estrus	4.57	3.92	0.65	<0.01
Semen and AI	13.28	14.50	-1.22	0.03
Pregnancy diagnosis	3.68	3.86	-0.18	<0.01
Extra feed	62.11	40.43	21.68	<0.01
Total cost	**85.00**	**75.57**	**9.43**	**0.08**

Timed-AI decreased cost by ~ $10/heifer

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Timed-AI only in first AI reduced cost per pregnancy

	CON	TAI	Difference	P-value
Costs per pregnancy, US$				
Hormonal treatment	1.54	14.07	-12.53	<0.01
Detection of estrus	5.37	4.28	1.09	<0.01
Semen and AI	15.56	15.83	-0.27	0.68
Pregnancy diagnosis	4.31	4.22	0.09	0.22
Extra feed	72.82	44.17	28.65	<0.01
Total cost	**99.59**	**82.59**	**17.00**	**<0.01**

Timed-AI decreased cost by $17/pregnancy

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Take home message

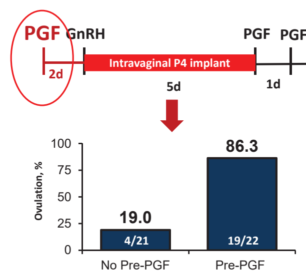
- Conception rates in Holstein heifers inseminated using conventional semen should be ~60%
- Heifers inseminated with conventional semen after 5-d CIDR-Synch protocol have similar P/AI than heifers receiving AI after estrus
- Submission of heifers to a 5-d CIDR-Synch protocol for first TAI decreased total days on feed compared with heifers detected in estrus for first AI.

27

Is there any reliable timed-AI program without a P4 implant available for dairy heifers?

28

Effect of a Pre-PGF on ovulatory response of the first GnRH of the 5-d CIDR Synch program

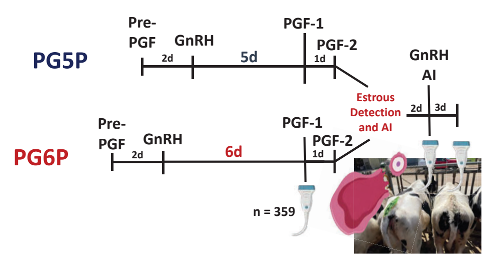


Karakaya-Bilen et al. (2019)

29

Abstracts of the
2023 American Dairy Science Association®
Annual Meeting

2749 Effect of inducing luteolysis 5 or 6 d after the first GnRH on estrous expression and fertility in a modified timed-AI program for dairy heifers. I. M. R. Leão*, F. P. J. da Silva Junior, M. I. Mancheno-Valarezo, T. Valdes-Arciniega, and J. P. N. Martins, *University of Wisconsin–Madison, Madison, WI.*



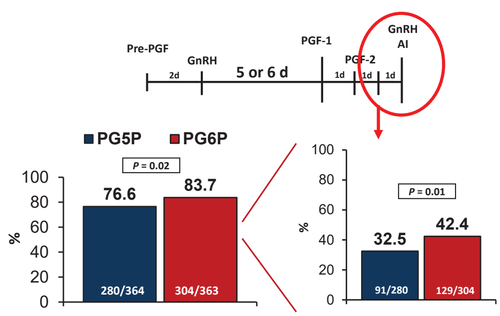
30

Materials & Methods

- Conducted on a commercial dairy farm in WI
- n = 833 first-service Holstein heifers enrolled
- Average age at enrollment ± SD: **388.5** ± 2.5 d old (from 384 to 393 d old)
- $PGF_{2\alpha}$: 0.5 mg cloprostenol
- GnRH: 100 µg gonadorelin diacetate tetrahydrate
- Estrous detection records of n=727 heifers
- Inseminations using sexed semen
- Pregnancy diagnosis was performed 34 and 62 d after AI by the farm veterinarian using ultrasound

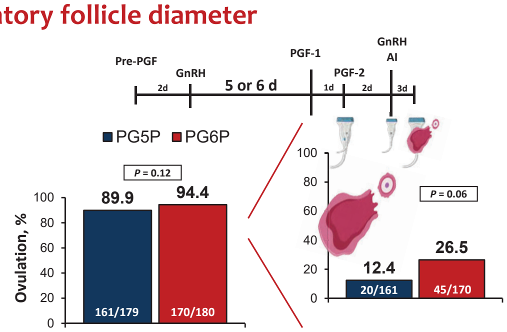
31

Effect of treatment on **proportion of heifers detected in estrus and time of estrous detection**



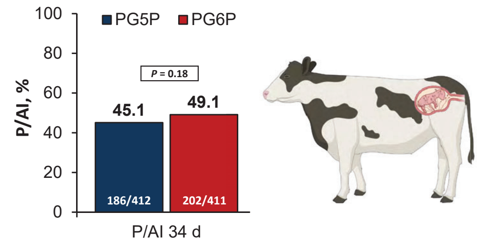
32

Effect of treatment on **ovulatory response and pre-ovulatory follicle diameter**



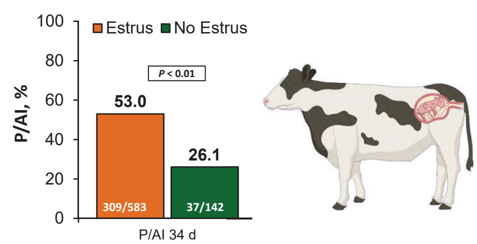
33

Effect of treatment on **pregnancy per AI on d 34 and 62 post-AI**



34

Effect of estrus expression on **pregnancy per AI on d 34 and 62 post-AI**



35

Summary

- ✓ Delaying the induction of luteolysis in one day increased the proportion of heifers detected in estrus
- A greater proportion of heifers in the PG6P group were detected in estrus before the d of GnRH
- ✓ Heifers detected in estrus had a greater P/AI 34 and 62 d post AI and a greater pre-ovulatory follicle diameter
- ✓ The PG6G program seem to be a good alternative program for producers that do not want to use P4-implants in dairy heifers

36

Must-Do for Heifer Management

1. Quality over quantity
   - How many heifers are needed?
   - Genomic Selection
2. Determining MBW and programs that optimize growth and health of young heifers
   - Measuring growth of heifers to determine ADG
   - Reduce the incidence of disease
     - Scours and pneumonia
3. Aggressive reproductive management
   - Inseminate heifers quickly after desired weight and age (VWP)
     - E.g., 5-d CIDR-Synch protocol
     - $17 less per pregnancy than once-daily detection of estrus (Lauber et al., 2021)

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School of Veterinary Medicine
UNIVERSITY OF WISCONSIN–MADISON

Thank you!

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https://jpmartinslab.wiscweb.wisc.edu/

Team members:

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- ***Teresita Valdes-Arciniega***
- ***Florentino da Silva Junior***
- ***Martina Mancheno-Valarezo***
- ***Madeline Zutz***
- ***Lindsey Wichman***

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School of
Veterinary Medicine
UNIVERSITY OF WISCONSIN–MADISON

40

Driving Milk Fat Synthesis: The importance of de novo fatty acids

Dr. Kevin J. Harvatine
Professor of Nutritional Physiology
Department of Animal Science
Penn State University

PennState College of Agricultural Sciences

Driving Milk Fat Synthesis: The importance of de novo fatty acids

Dr. Kevin J. Harvatine
Professor of Nutritional Physiology
Department of Animal Science
Penn State University

2024 Four State Post-Conference

1

Where do the fatty acids in milk come from?

~25% entirely from de novo synthesis in the mammary gland (<16 carbon)

~39% are mixed source (16 carbon)
(~50% de novo)

~35% are preformed from plasma (>16 carbon)

Together

~45% are de novo
Made from acetate, butyrate, and glucose (NADPH)

~55% Preformed FA
85% of this directly from absorption

2

How do we know how much of each we have? FTIR in payment and DHIA labs can "predict"

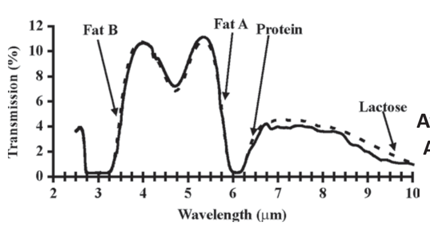


Figure 1. Mid-infrared transmission spectra of water (dashed line) and milk (solid line) with approximate wavelengths of the fat B, fat A, protein, and lactose measurements indicated.

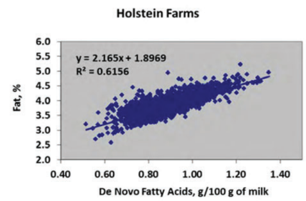
Kaylegian et al. 2009

Prediction of:
FA < 16 C
16C
FA > 16 C
Average double bonds
Average chain length

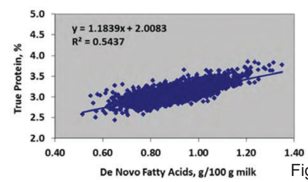
**My first question with a change in milk fat is which category changed!

3

good things in the Miner/Cornell work



This one is autocorrelated!!

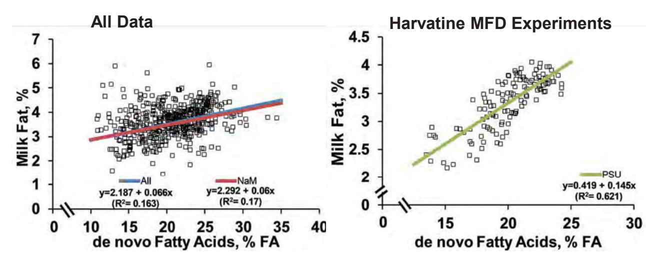


But, be careful in interpreting because de novo FA are impacted by many things!!!

Figures from Barbano, Dann et al.

4

Relationship of milk fat and de novo FA in the literature is more variable because it is impacted by many factors



Matamoros et al. 2022

5

What does the "7 lb Fat+Prot" cow need to make the de novo FA in milk fat?

If 45% is made in the mammary gland..

- **4 lb of milk fat x 45% de novo = 1.8 lb**
- **1.8 lb of fat = 1.67 lb of FA**
  - **Acetate (C and NADPH)**
  - **BHBA**
  - **Glucose (NADPH)**
  - **These come from rumen digestible starch, fiber, and sugar**

6

Why do we care about de novo FA?

- If we decrease synthesis and do not make up with preformed FA, we will lose fat yield
- De novo FA are likely more profitable than many preformed FA

Challenge-
- The cow may hit maximal capacity for de novo synthesis.
  - This will limit total milk fat yield
- Feeding fat can decrease de novo synthesis as the mammary gland is “smart” to be “lazy” and use preformed FA

7

What determines de novo FA yield?

- Enzyme capacity of the mammary gland
  - The enzyme are regulated and can be decreased (ex. MFD)
- Amount of substrate for the mammary gland to make milk fat
  - Can’t make from thin air!
  - Acetate uptake driven by plasma concentration

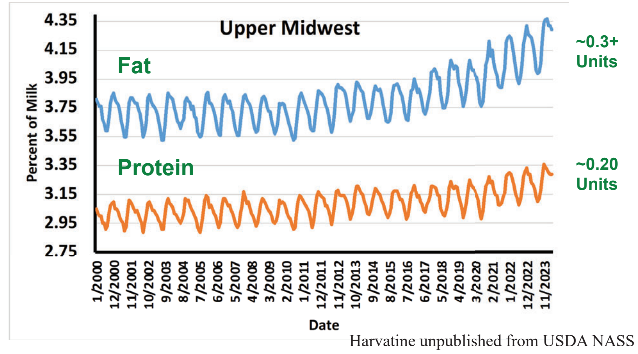
8

In the real world, what impacts amount of de novo FA?

- Season of the year
- “BH-Induced” milk fat depression
  - The old “diet-induced MFD”
- Acetate supply
- Amount of absorbed FA

9

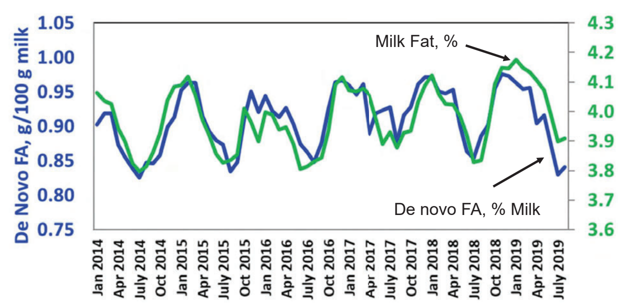
There is a seasonal pattern to milk fat concentration (and yield)



Harvatine unpublished from USDA NASS

10

There is also a seasonal pattern to de novo synthesized FA (<16 C FA)

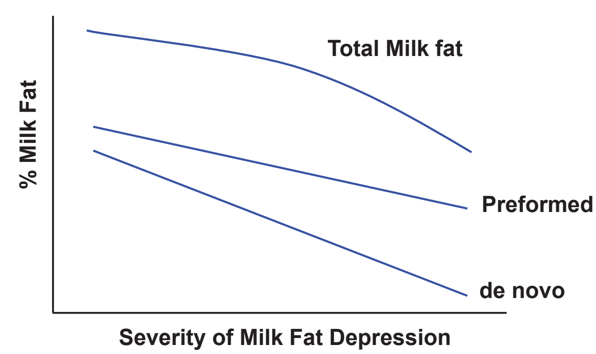


40 St. Albans Coop herds

Dann 2019 PSU Dairy Nutr. Workshop

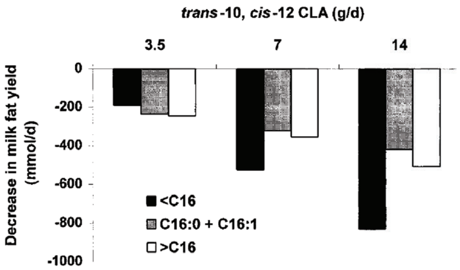
11

“Biohydrogenation-Induced” MFD decreases de novo more than preformed FA



12

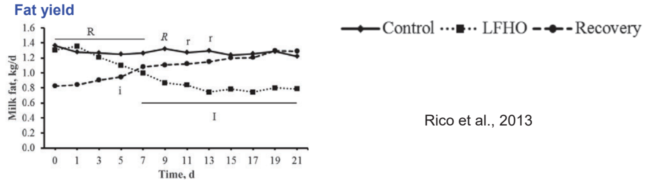
The decrease in de novo FA is greater with more severe MFD



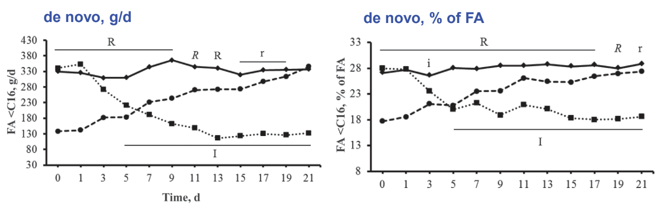
Baumgard et al., 2001

13

de novo FA are progressively changed during induction and recovery of MFD

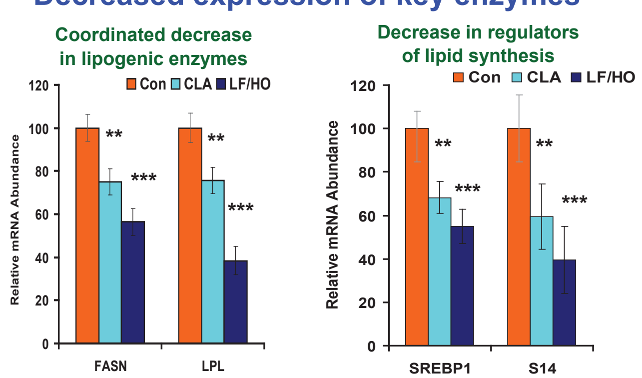


Rico et al., 2013



14

How is de novo synthesis decreased? Decreased expression of key enzymes



Harvatine and Bauman, 2006

15

But.. "we don't see *diet-induced MFD on farms anymore*?" Is this true?

- Risk factors have decreased?
  - Lower fat DDGS
  - Better forages and feed management?
  - Higher forage diets and less high moisture corn?
  - Feed management has improved?
- Maybe we all learned and it is solved?
- We have selected for cows more resistant to MFD?
- Are we missing diet-induced MFD because we have not adequately adjusted to the new genetic potential?

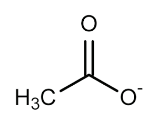
I don't know, but don't stop increasing your goals/expectations!

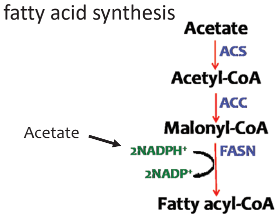
16

PennState

Acetate is a main energy and carbon substrate for milk fat synthesis in the cow

- VFA's are ~70% of total energy supply
  - 45% of this is from acetate (~30% of total energy)
- Mammary uptake is proportional to plasma concentration
- Most important substrate for de novo fatty acid synthesis





Bauman et al, 1970; Palmquist et al, 1969, Miller et al, 1991

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Acetate deficiency does not cause diet-induced milk fat depression

	Normal Diet	HG/LF Diet
Milk yield	**No change**	
Milk fat, g/d	**683**	**363**
Rumen Production, moles/d		
Acetate	29.4	28.1[a]
Propionate	13.3	31.0[b]
B-hydroxybutyrate	7.0	9.1[c]

From Davis et al. 1967 and Bauman et al. 1971.

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But, Acetate infusion can increase milk fat under normal conditions by increasing de novo and 16 C FA

	Acetate (g/d)					*P*-value	
	0	300	600	900	SE	Linear	Quad.
Milk, lbs	38.6	39.2	40.4	38.9	2.8	-	-
Milk Fat							
g/d	1382	1468	1582	1577	59	<0.001	-
%	3.64	3.87	4.03	4.10	0.20	<0.001	-
FA by Source, g/d							
<C16	307	340	364	352	14.0	<0.001	<0.01
C16	343	390	430	443	20.3	<0.001	-
>C16	559	542	588	594	20.0	0.04	-

- 600 g/d of acetate increased milk fat by 200 g/d

Urrutia et al. J Nutr. 2017

19

PennState

How much acetate is made in the rumen per day?

- Observed in very few studies as requires labeling approaches

- Literature ranges from **90 to 498** g/kg digestible dry matter (**DDM**) in lactating cows, but old data with low intakes (Sutton 1985).

- Best guess, we would expect modern cows with an intake of 25 kg/d to produce approximately 6500 g/d of acetate.

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PennState

Feeding dietary acetate increased milk fat, but butyrate did not

	Treatment			SE	*P-value*		
	NaHCO	NaAc	CaBu		trt	time	t*t
Milk fat, kg/d	1.50[b]	1.59[a]	1.44[c]	0.05	0.00	0.08	0.22
Milk fat, %	3.65[b]	3.77[a]	3.63[b]	0.09	0.03	0.01	0.05

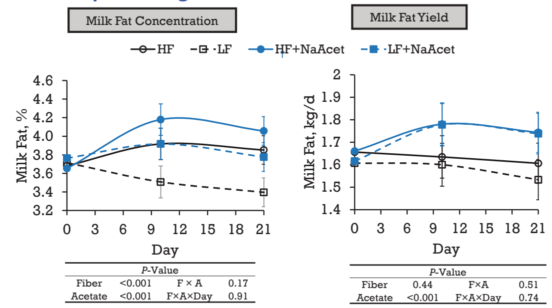
- 6% and 3% increase in milk fat yield and % with acetate supply.
- 4% decrease in milk fat yield with dietary butyrate.
- 15% net transfer of dietary acetate to milk fat

Urrutia et al. JDS 2019

21

Feeding acetate increased milk fat regardless of forage:concentrate ratio

2.5 percentage units of NDF substituted for starch



Acetate supplementation increased milk fat synthesis, regardless of dietary fiber level

Matamoros et al. JDS 2022

22

Feeding acetate increased milk fat regardless of fiber digestibility

Replacement of 7 percentage units of corn silage for soyhulls and citrus pulp

	Treatment					P-values		
	L Dig	LD +Acet	H Dig	HD + Acet	SEM	Dig	Acet	DxA
Milk, kg	42.7	44.6	43.7	44.0	1.91	0.82	0.22	0.36
Milk Fat								
%	**3.40**	**3.54**	**3.33**	**3.51**	0.22	0.57	**0.08**	0.79
kg	**1.45**	**1.60**	**1.48**	**1.54**	0.11	0.69	**0.02**	0.36
Milk FA								
<16 C, g	**357**	**408**	**370**	**383**	32.4	0.61	**0.01**	0.14
16 C, g	**363**	**448**	**372**	**419**	34.0	0.51	**<0.01**	0.23
> 16 C, g	561	553	553	561	46.0	0.99	0.99	0.67

Acetate supplementation increased milk fat synthesis, regardless of digestible fiber

Husnain et al. Unpublished

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Feeding acetate increased milk fat regardless of dietary unsaturated FA

1.5 percentage units of soybean oil

Variable	Treatment				SEM	P-value		
	Con	Acet	UFA	UFA+Acet		Fat	Acetate	F×A
Milk, kg	45.1	45.9	47.4	48.2	2.66	0.002	0.26	0.94
Milk Fat								
%	**3.40**	**3.92**	**3.54**	**3.69**	0.20	0.61	**<0.001**	**0.03**
kg	**1.55**	**1.81**	**1.71**	**1.79**	0.14	0.11	**0.001**	**0.06**
Milk FA								
<16 C, g	**443**	**474**	**398**	**430**	35.8	<0.001	0.002	0.99
16 C, g	**418**	**486**	**369**	**425**	**34.5**	**<0.001**	**<0.001**	**0.55**
> 16 C, g	**569**	**605**	**704**	**731**	45.3	<0.001	0.03	0.73

Acetate supplementation increased milk fat synthesis slightly more in the absence of unsaturated fatty acids

Staffin et al. Unpublished

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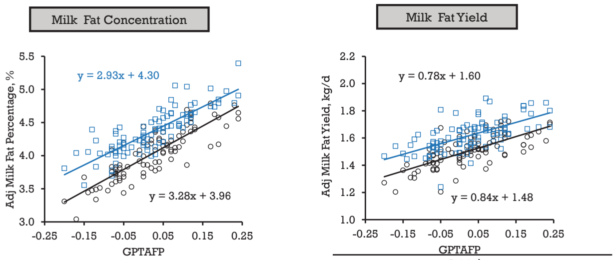
Acetate also increased milk fat yield regardless of genetic potential (GPTA) for milk fat



	P-Value		
Treatment	<0.001	GPTAFP	<0.001
Parity	0.72	T×G	0.39
T×P	0.03	T×G×P	0.45

	P-Value		
Treatment	<0.001	GPTAFP	0.002
Parity	<0.001	T×G	0.73
T×P	0.34	T×G×P	0.83

Matamoros et al. JDS 2023

Acetate increased milk fat yield regardless of GPTAFP or parity.

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Overall, increasing acetate consistently increased milk fat yield

How do we use this information?

- **Sodium acetate is not currently available as an ingredient**
- **Feed highly digestible fiber and maintain optimal rumen function to get optimal microbial protein and VFA synthesis**

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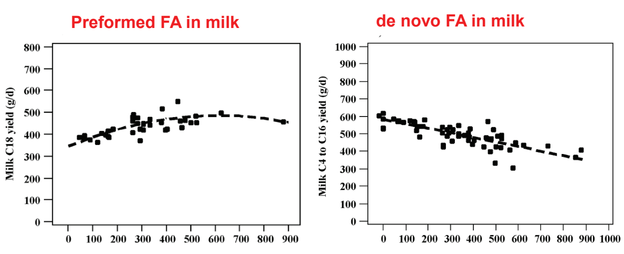
Feeding fat increases milk preformed FA to a point, but decreases de novo FA



C18milk (g/d) = Δ_{exp} + 345 (±7) + 0.46 (±0.08) × ΔC18duo (g/d) − 0.00038 (±0.00013) × $\Delta C18duo^2$ (Nexp = 26, Ntrt = 77, R^2 = 0.92, RMSE = 40.3 g/d).

C4 to C16milk (g/d) = Δ_{exp} + 583 (±8) − 0.26 (±0.03) × ΔC18duo (g/d) (Nexp = 29, Ntrt = 90, R^2 = 0.94, RMSE = 52 g/d). [4]

- Mammary gland is "lazy"- why make if I can take up from blood?

Glasser et al. 2008 JDS 91:2771-2785

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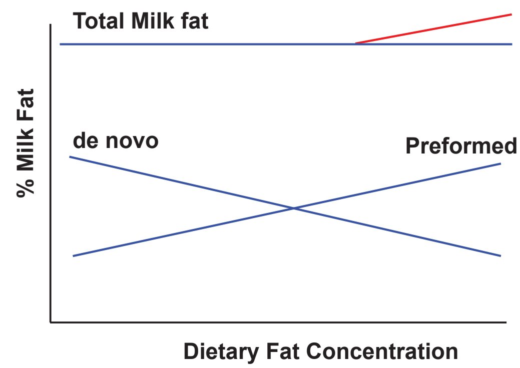
Often dietary acids are decreased milk fat yield does not change because de novo makes up the difference



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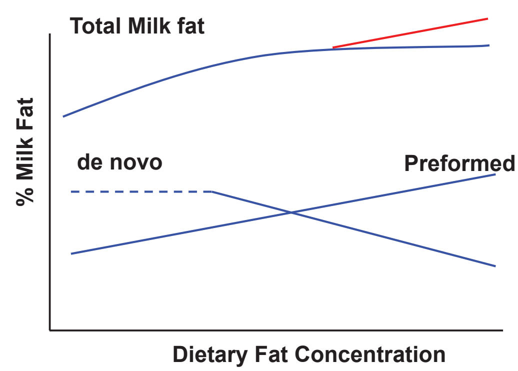
However, if de novo synthesis hits its maximum capacity, we will then lose milk fat yield



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An example, increasing high oleic roasted beans had no effect on milk fat in primiparous and tended to increase milk fat in multiparous cows

	High Oleic Soybean					*P*-Values		
	0%	5%	10%	15%	SEM	TxP	L	Q
Milk								
Fat, %	4.02	4.02	4.06	4.16	0.29	0.97	0.17	0.47
Prim.	4.07	4.08	4.15	4.24	0.11		0.44	0.75
Multi.	3.97	3.96	3.96	4.09	0.11		0.24	0.48
Fat, kg	1.62	1.63	1.67	1.71	0.16	0.19	0.10	0.80
Prim.	1.44	1.47	1.56	1.46	0.06		0.60	0.29
Multi.	1.80	1.79	1.79	1.96	0.06		0.07	0.16

Prim. = primiparous; Multi. = multiparous; Trt = treatment; TxP = the interaction effect of treatment and parity

30

Increasing roasted HO soybeans linearly decreased de novo FA (<16C) and quadratically increased preformed FA (>16 C)

	High Oleic Soybean						*P*-Values	
	0%	5%	10%	15%	SEM	TxP	L	Q
∑<16 C ⬇	271	254	249	238	17.8	0.66	<0.001	0.52
∑ >16 C ⬆	328	363	383	404	29.6	0.13	<0.001	0.36
Trans-10, C18:1	0.43	0.44	0.45	0.46	0.05	0.26	0.06	0.70

Prim. = primiparous; Multi. = multiparous; Trt = treatment; TxP = the interaction effect of treatment and parity

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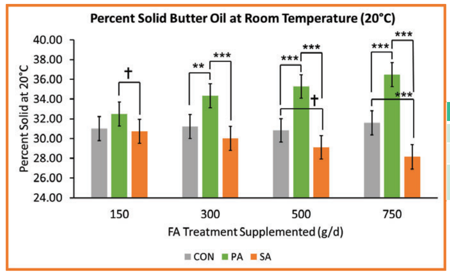
These changes have implications for milk fat melting properties

- Increasing shorter chain and 18:1 FA decreases melting temperature while increasing 16:0 increases



At the highest dose, **PA** was 36.5% solid at 20° C while **CON** was 31.6% solid and **SA** was 28.2% solid

	CON	750g PA	750g SA
16:0%	30.1	36.8	26.9
18:0%	9.37	8.06	11.8
cis-9 18:1%	17.2	16.7	20.2

† = $P \leq 0.10$
* = $P \leq 0.05$
** = $P \leq 0.01$
*** = $P \leq 0.001$

Staffin et al. Unpublished

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Increasing roasted soybeans from 5 to 10% increased milk fat in a different study with lower milk fat

	Treatment Means[1]							
	Conv. Soybean		High 18:1 Soybean			*P*-Values[2]		
Item	5%	10%	5%	10%	SEM	Type	Level	Type* Level
Milk, kg/d	43.8	43.7	43.4	44.8	1.28	0.69	0.28	0.18
Milk Fat								
%	3.28	3.46	3.42	3.66	0.12	<0.05	0.01	0.69
g/d	1393	1464	1461	1574	108	0.08	0.01	0.55
Milk Fatty acids, % FA								
>16C[5]	37.4	41.5	37.8	41.5	0.70	0.42	<0.001	0.57
*t*10 C18:1	0.79	0.89	0.62	0.63	0.13	0.01	0.96	0.67
OBCFA	3.88	3.37	4.13*	3.66*	0.09	<0.001	<0.001	0.76

But, we have not been successful in titrating this effect with soybeans or cottonseed

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Overall, our challenge is to balance rumen fermentation and fat supply

- **Consider the seasonal rhythm when monitoring de novo FA and setting goals**
- **Steer clear of BH-induced MFD**
- **Feed highly digestible forages and maintain great rumen function to get optimal acetate supply**
- **Find the optimal level of dietary FA to support milk fat yield and energy intake**

35

The challenges of fat supplementation

- **Some fats cause MFD or decreases fiber digestion**
  - This will decrease de novo synthesis and fat yield
- **If feeding lower fat need more acetate to make up for the preformed FA**
- **Theoretically, there is an optimum that maintains high levels of inexpensive de novo FA while not limiting milk fat yield or shorting the cow on energy**

33

Lab Members:, **Alanna Staffin, Abiel Berhane, Sarah Bennett, Yusuf Adeniji, Muhammad Husnain, Muhammad Arif, and Mahmoud Ibrahim**

Previous Lab Members: **Dr. Cesar Matamoros, Beckie Bomberger. Dr. Ahmed Elzennary. Reilly Pierce, Dr. Rachel Walker, Dr. Chengmin Li, Elle Andreen, Dr. Isaac Salfer, Dr. Daniel Rico, Dr. Michel Baldin, L. Whitney Rottman, Dr. Mutian Niu, Dr. Natalie Urrutia, Richie Shepardson, Andrew Clark, Dr. Liying Ma, Elaine Brown, and Jackie Ying**

Disclosures

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- Harvatine has consulted for Cotton Inc, Micronutrients, Milk Specialties Global, Axiota, and Nutriquest as a member of their science advisory boards and United Soybean Board, ELANCO, and Novus on special projects.
- Harvatine is the founder and owner of Hardscrabble Innovations LLC, an independent consulting LLC.
- Harvatine has also received speaking honorariums from Elanco Animal Health, Cargill, Virtus Nutrition, NDS, Nutreco, Mycogen, Holtz-Nelson Consulting, Renaissance Nutrition, Progressive Dairy Solutions, Intermountain Farmers Association, Diamond V, Purina, Pioneer, Adessio, Standard Nutrition, Hubbard, VitaPlus, and Milk Specialties Global.

Thank You!

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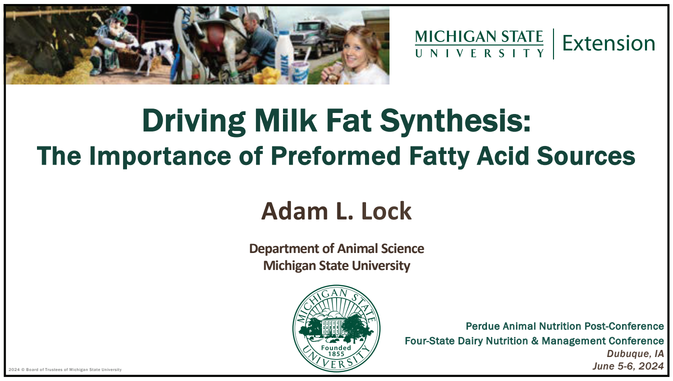
Driving Milk Fat Synthesis:
The Importance of Preformed Fatty Acid Sources

Adam L. Lock. PhD
Department of Animal Science
Michigan State University



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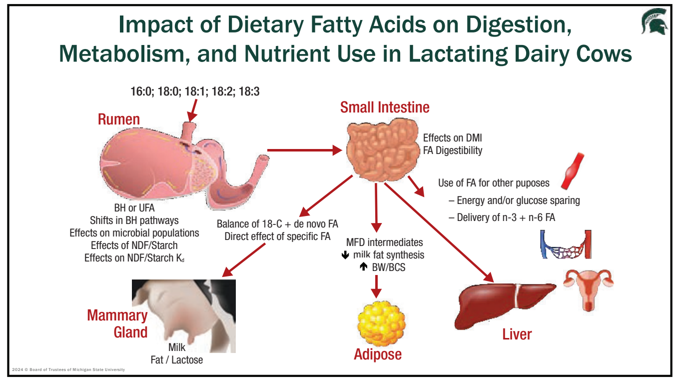

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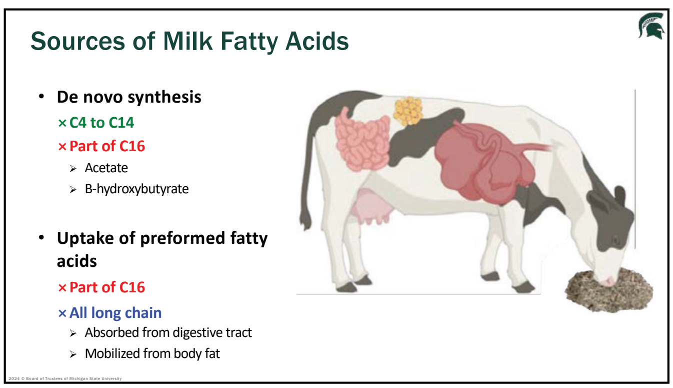

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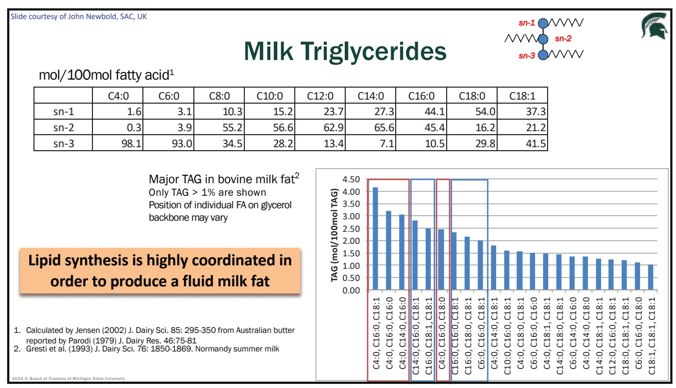
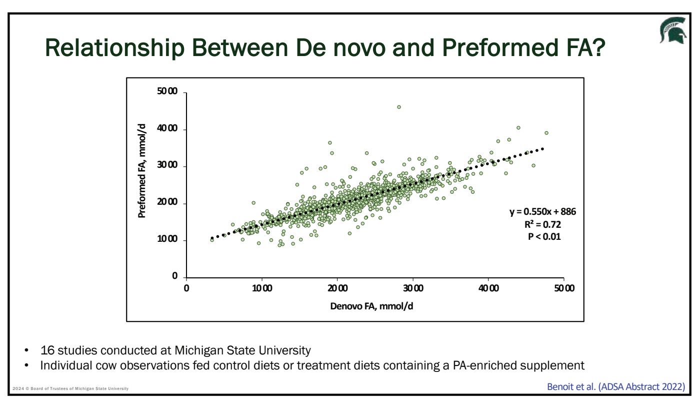


	C4:0	C6:0	C8:0	C10:0	C12:0	C14:0	C16:0	C18:0	C18:1
sn-1	1.6	3.1	10.3	15.2	23.7	27.3	44.1	54.0	37.3
sn-2	0.3	3.9	55.2	56.6	62.9	65.6	45.4	16.2	21.2
sn-3	98.1	93.0	34.5	28.2	13.4	7.1	10.5	29.8	41.5

4

5



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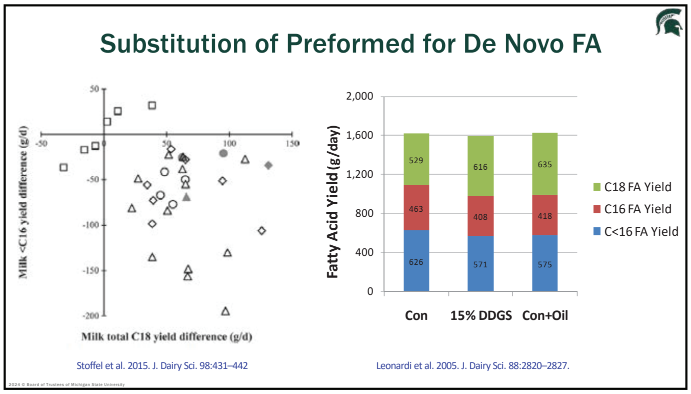
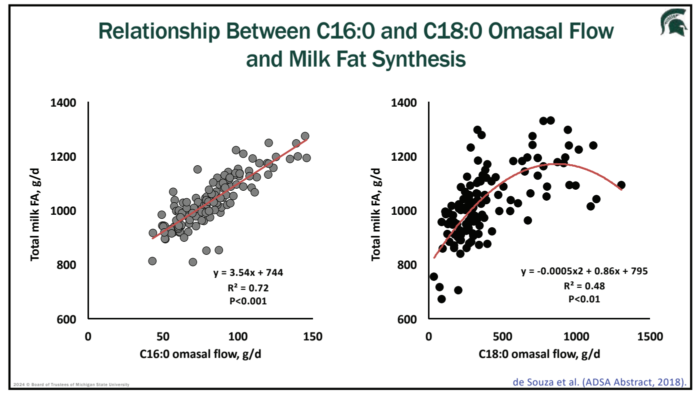
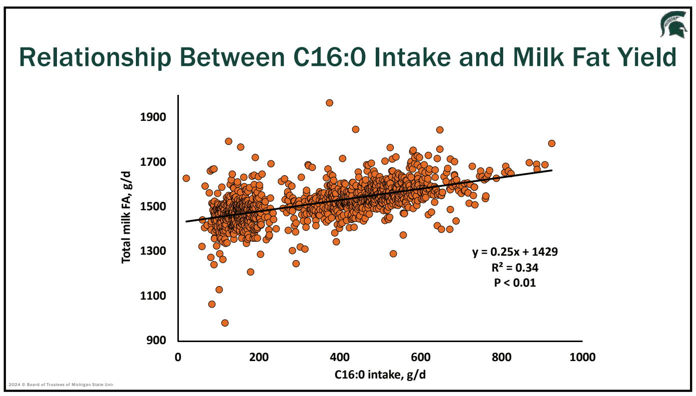

Substitution of Preformed for De Novo FA
Milk <C16 yield difference (g/d)
Milk total C18 yield difference (g/d)
Fatty Acid Yield (g/day)
Con
15% DDGS
Con+Oil
C18 FA Yield
C16 FA Yield
C<16 FA Yield
529
616
635
463
408
418
626
571
575
Stoffel et al. 2015. J. Dairy Sci. 98:431–442
Leonardi et al. 2005. J. Dairy Sci. 88:2820–2827.

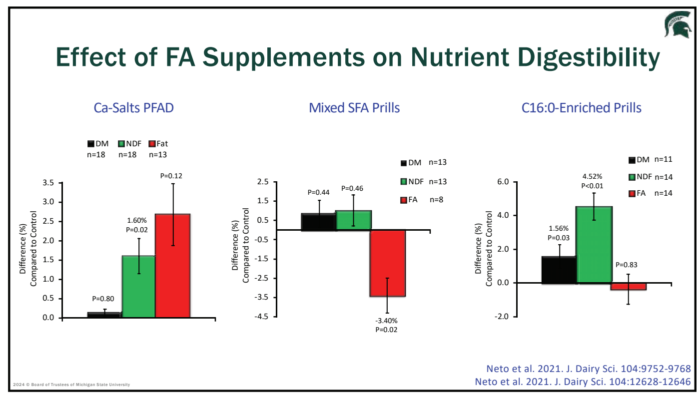
7


Relationship Between C16:0 and C18:0 Omasal Flow and Milk Fat Synthesis
Total milk FA, g/d
C16:0 omasal flow, g/d
y = 3.54x + 744
R² = 0.72
P<0.001
C18:0 omasal flow, g/d
y = -0.0005x2 + 0.86x + 795
R² = 0.48
P<0.01
de Souza et al. (ADSA Abstract, 2018).

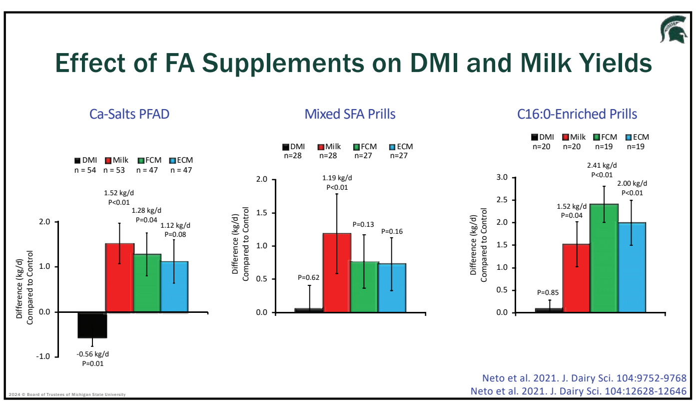
8


Relationship Between C16:0 Intake and Milk Fat Yield
Total milk FA, g/d
C16:0 intake, g/d
y = 0.25x + 1429
R² = 0.34
P < 0.01

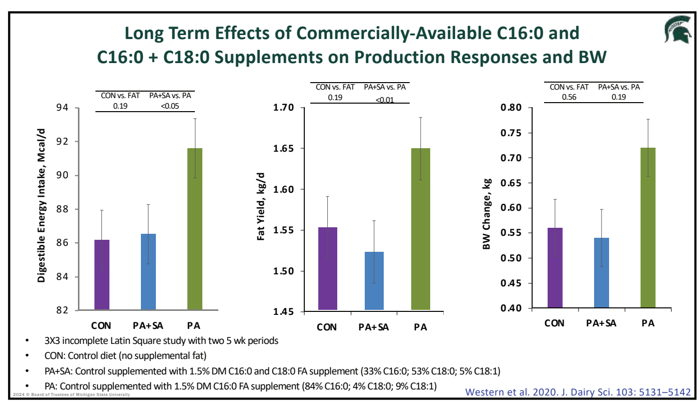
9


Effect of FA Supplements on Nutrient Digestibility
Ca-Salts PFAD
Mixed SFA Prills
C16:0-Enriched Prills
Difference (%) Compared to Control
Neto et al. 2021. J. Dairy Sci. 104:9752-9768
Neto et al. 2021. J. Dairy Sci. 104:12628-12646

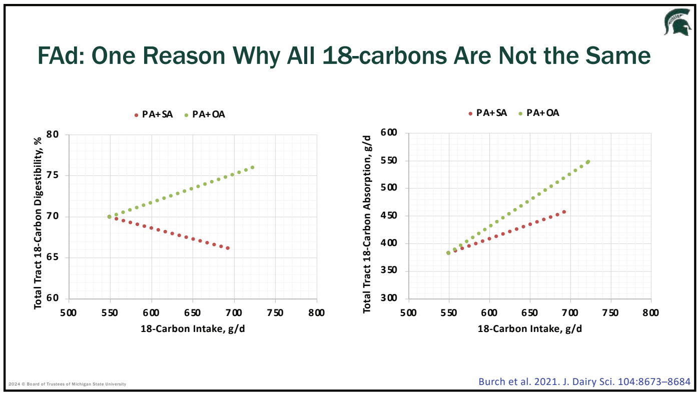
10


Effect of FA Supplements on DMI and Milk Yields
Ca-Salts PFAD
Mixed SFA Prills
C16:0-Enriched Prills
Difference (kg/d) Compared to Control
Neto et al. 2021. J. Dairy Sci. 104:9752-9768
Neto et al. 2021. J. Dairy Sci. 104:12628-12646

11


Long Term Effects of Commercially-Available C16:0 and C16:0 + C18:0 Supplements on Production Responses and BW
Digestible Energy Intake, Mcal/d
Fat Yield, kg/d
BW Change, kg
CON
PA+SA
PA
3X3 incomplete Latin Square study with two 5 wk periods
CON: Control diet (no supplemental fat)
PA+SA: Control supplemented with 1.5% DM C16:0 and C18:0 FA supplement (33% C16:0; 53% C18:0; 5% C18:1)
PA: Control supplemented with 1.5% DM C16:0 FA supplement (84% C16:0; 4% C18:0; 9% C18:1)
Western et al. 2020. J. Dairy Sci. 103: 5131–5142

12



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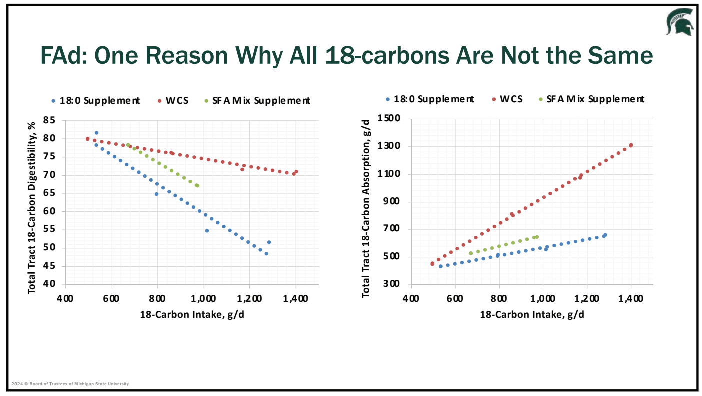

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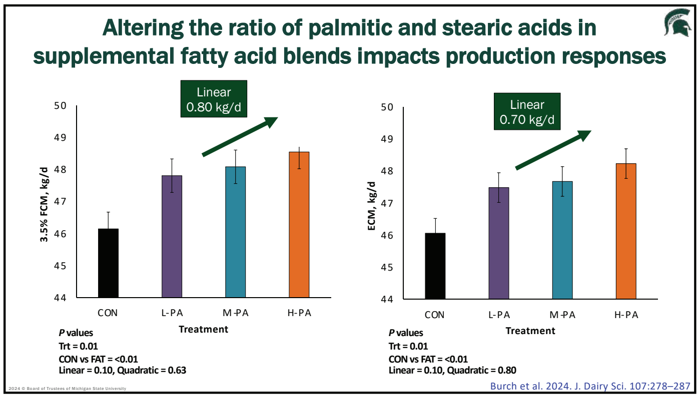

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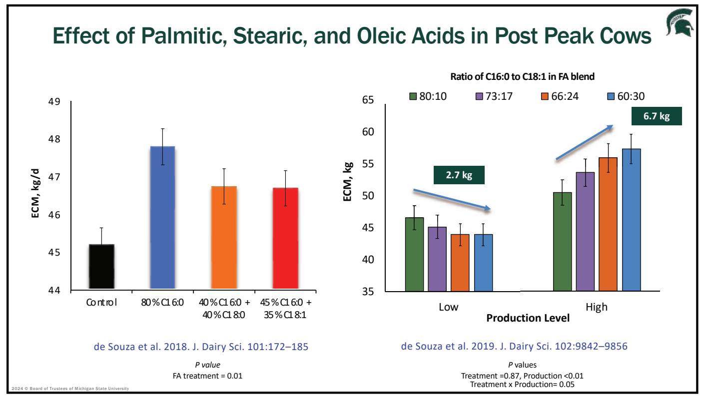

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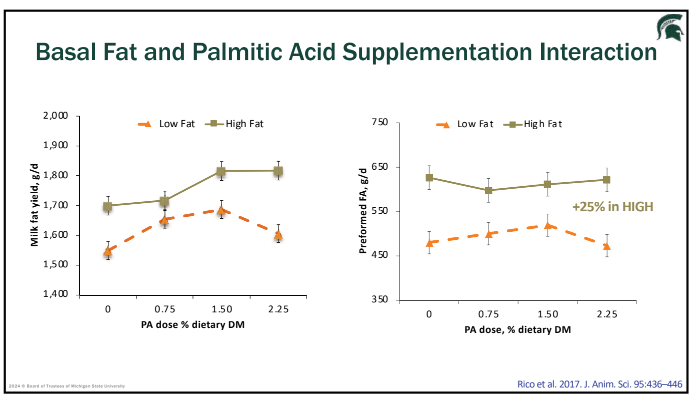

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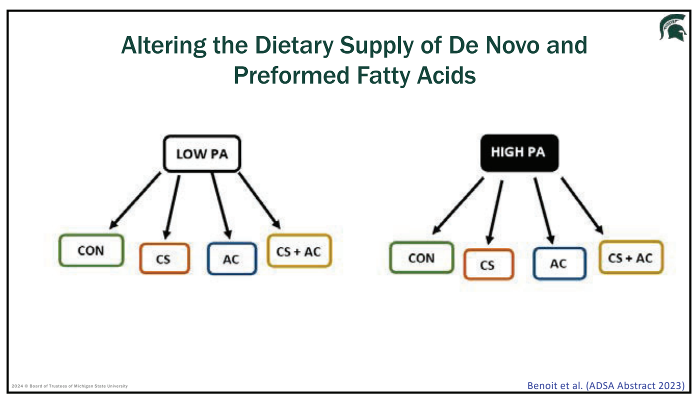
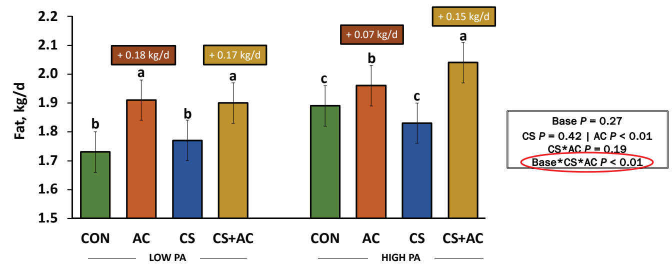


18

Altering the Dietary Supply of De Novo and Preformed Fatty Acids



Benoit et al. (ADSA Abstract 2023)

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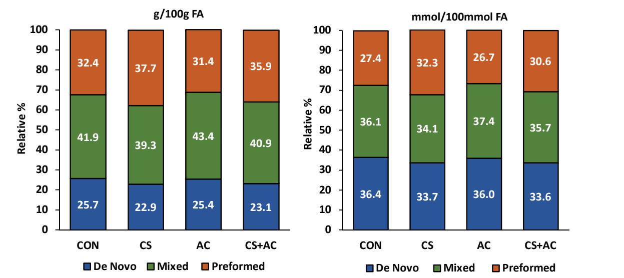
Contribution of Sources to Milk Fat Yield



Benoit et al. (ADSA Abstract 2023)

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Fatty Acid Supplements and Oilseeds

Fatty acid profile of dietary FA sources.

Fatty Acid, g/100 g	Fat Supplements[1] Mix FA prill	C16:0-enriched prill	Ca-salt of palm fat	Oilseeds[1] WCS	Conventional soybean	High C18:1 soybean
C14:0	2.70	1.60	1.01	0.61	0.60	0.90
C16:0	32.8	89.7	47.7	24.6	10.2	5.80
C18:0	51.4	1.00	3.90	2.00	4.10	3.50
C18:1 (n-9)	5.80	5.90	37.3	14.8	25.2	73.9
C18:2 (n-6)	0.80	1.30	8.25	56.5	48.2	6.10

[1]Determined by GLC analysis in the Lock Lab.

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Recent Studies with Oilseeds

WCS

- 24 multiparous cows in a 4 x 4 Latin Square design
  - 52.7 ± 2.6 kg/day milk yield
  - 104 ± 22 DIM

WCS doses: 0% | 8% | 16% | 24%

HOSB

- 24 multiparous cows in a 4 x 4 Latin Square design
  - 50.7 ± 4.4 kg/day milk yield
  - 122 ± 57 DIM

HOSB doses: 0% | 8% | 16% | 24%

Four, 21- day periods with 5 sampling days at the end of each period

Both studies now available line

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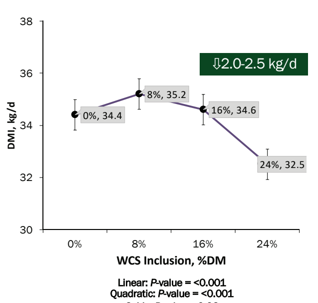
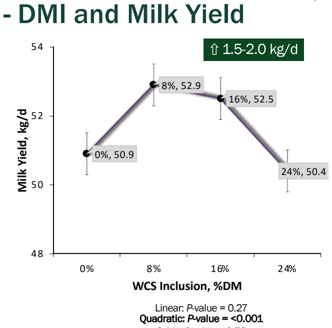
Whole Cotton Seed - DMI and Milk Yield





Burch et al. 2024. J. Dairy Sci. (in press)

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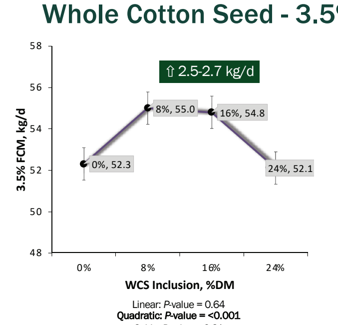
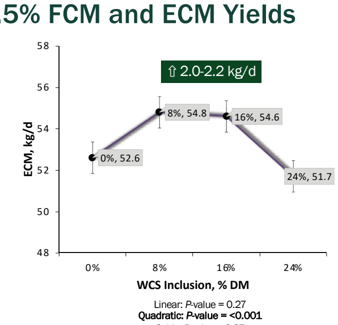
Whole Cotton Seed - 3.5% FCM and ECM Yields





Burch et al. 2024. J. Dairy Sci. (in press)

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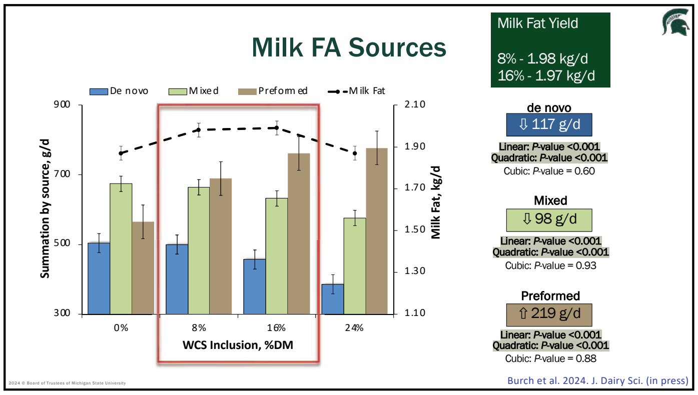

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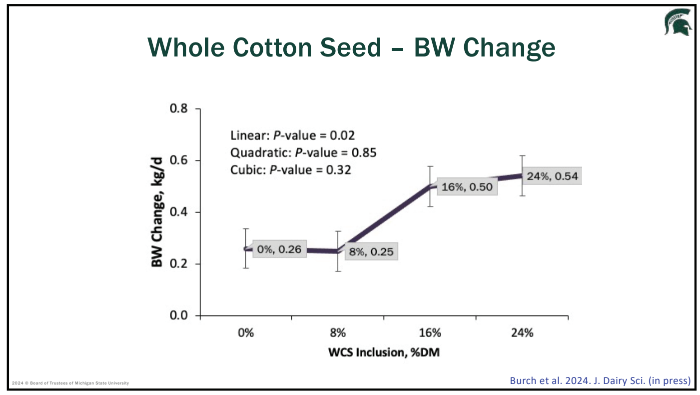

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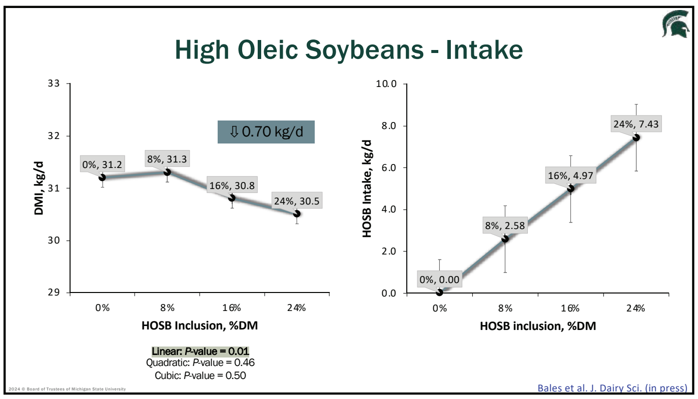

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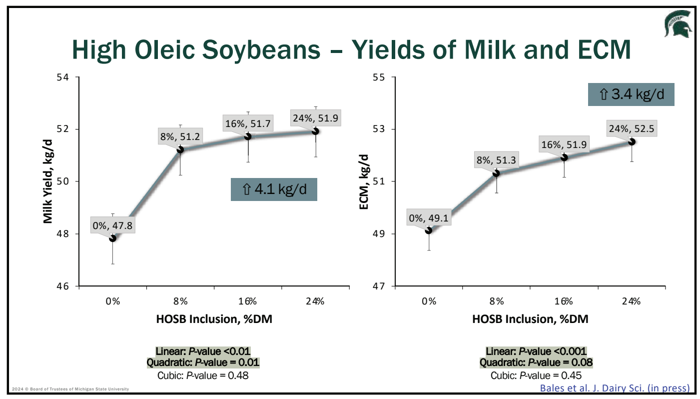

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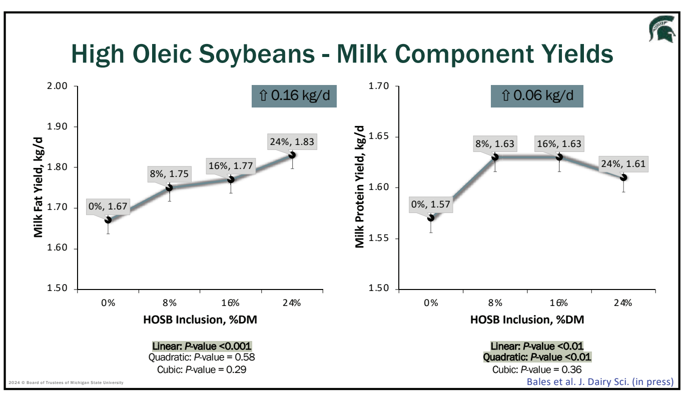

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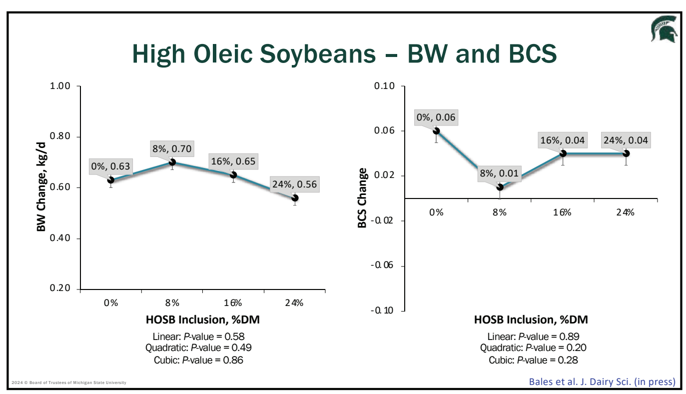

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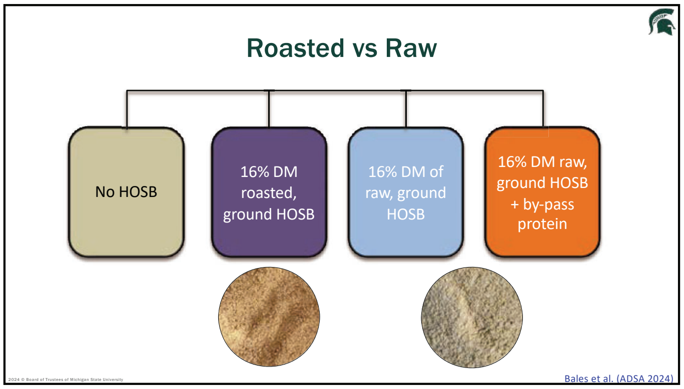

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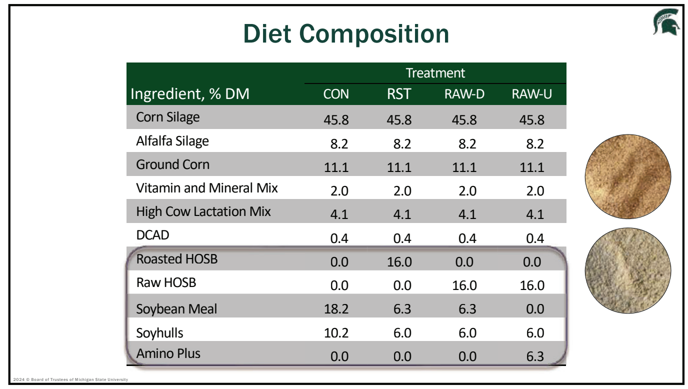

	Treatment			
Ingredient, % DM	CON	RST	RAW-D	RAW-U
Corn Silage	45.8	45.8	45.8	45.8
Alfalfa Silage	8.2	8.2	8.2	8.2
Ground Corn	11.1	11.1	11.1	11.1
Vitamin and Mineral Mix	2.0	2.0	2.0	2.0
High Cow Lactation Mix	4.1	4.1	4.1	4.1
DCAD	0.4	0.4	0.4	0.4
Roasted HOSB	0.0	16.0	0.0	0.0
Raw HOSB	0.0	0.0	16.0	16.0
Soybean Meal	18.2	6.3	6.3	0.0
Soyhulls	10.2	6.0	6.0	6.0
Amino Plus	0.0	0.0	0.0	6.3

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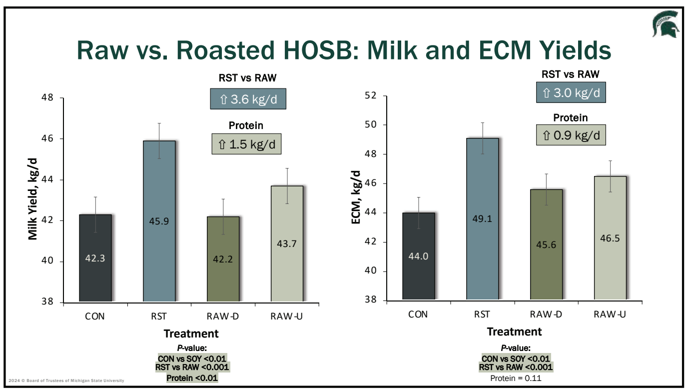

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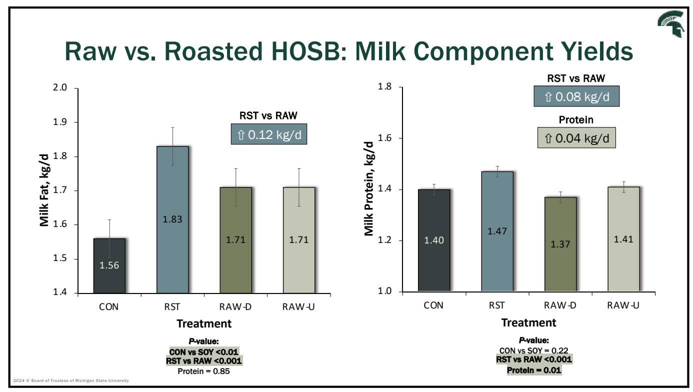

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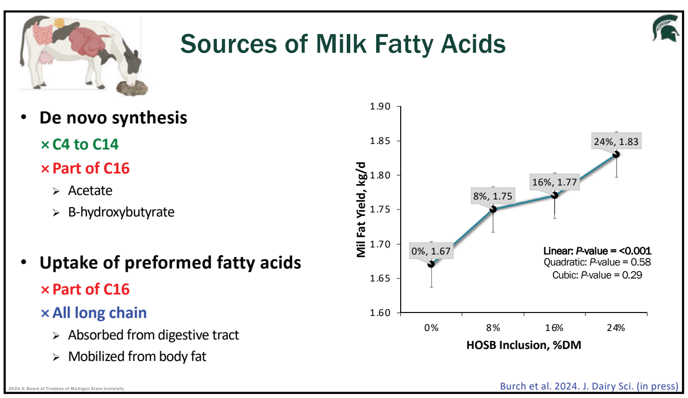

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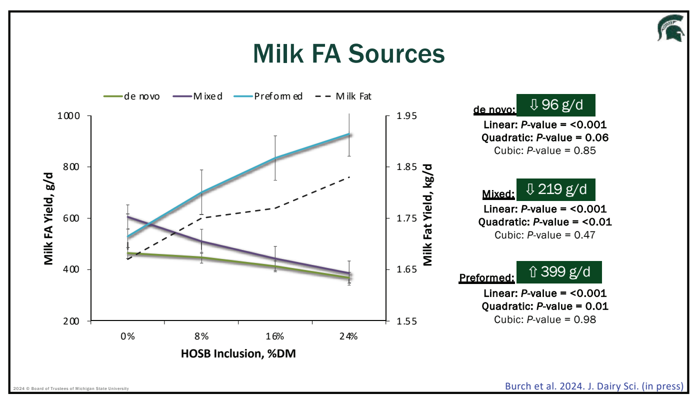

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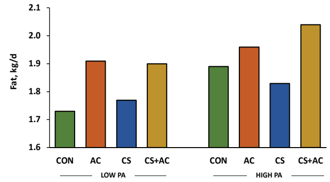
Interdependence of FA Sources

- MG lipid synthesis is highly coordinated
  - Must make fluid milk fat (triglycerides)
- Many different ways to drive milk fat
- Substitution of FA sources in milk fat represents a lost opportunity
- Interdependence of different sources is key
- In order to maximize milk fat gains we need to focus on driving all 3 sources
  - Acetate
  - Palmitic acid
  - Long chain/18-carbon FA (different FA will have different responses)



Benoit et al. (ADSA Abstract 2023)

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Take Home Messages

- Milk fat synthesis is highly coordinated to produce a fluid milk fat
  - Many ways to drive milk fat; substitution of FA sources a lost opportunity
  - To maximize milk fat gains, need to focus on driving all 3 sources: acetate, palmitic acid, and 18-carbon FA (different FA will have different responses)
- Profile of supplemental FA key in determining production responses and energy partitioning
  - C16:0 drives increases in milk fat yield and ECM
  - C16:0 and C18:1 drive increases in milk yield and ECM, especially in early and high producing cows
  - Exciting data around effects of C18:1 on digestion and metabolism
  - We have no data that supports the use of C18:0-enriched supplements vs. C16:0-enriched or C16:0/C18:1 supplements (better ways to increase C18:0 absorption)
- Oilseeds can increase yields of milk and milk components, but depends on oilseed type
  - WCS ⇧ Yields of milk and milk components up to 16% DM
  - HOSB ⇧ Yields of milk and milk components up to 24% DM
  - Heat-treatment of HOSB an important consideration
  - Nutritional strategies that minimize reductions in de novo milk FA will further improve responses

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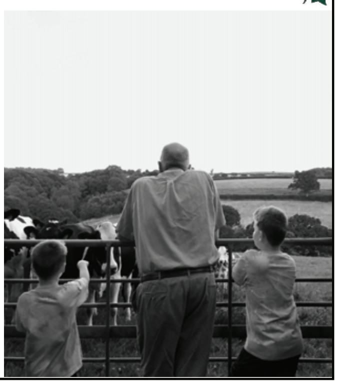

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