Four-State Dairy Nutrition and Management Conference

June 1 & 2, 2022

Cooperative Extension for:
Iowa State University
University of Illinois
University of Minnesota
University of Wisconsin

2022

Volume 31

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Transition Cows:Update on DCAD and Stumbling Blocks when Trying to Balance Rations Properly

Jesse Goff DVM, PhD
Iowa State University
College of Veterinary Medicine

Transition Cows: Update on DCAD and Stumbling Blocks when Trying to Balance Rations Properly

Jesse Goff DVM, PhD

Professor Emeritus
Iowa State University
College of Veterinary Medicine

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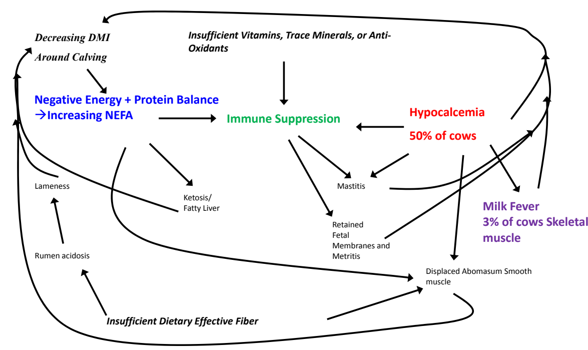

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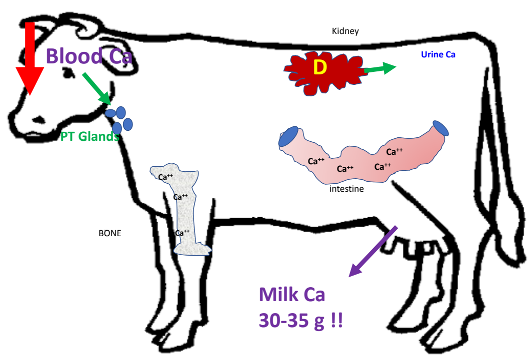

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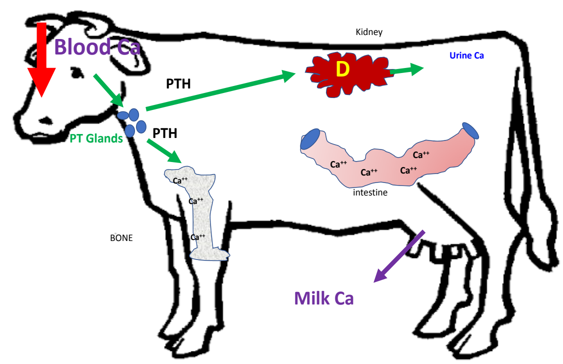

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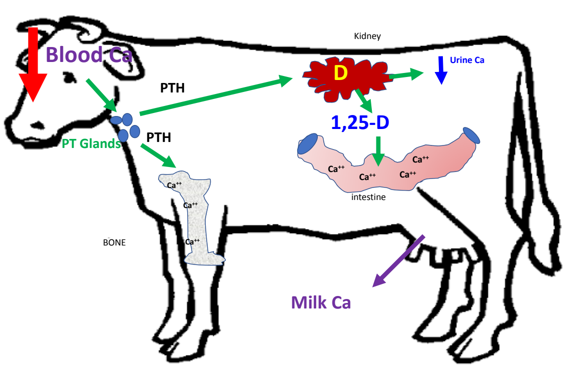

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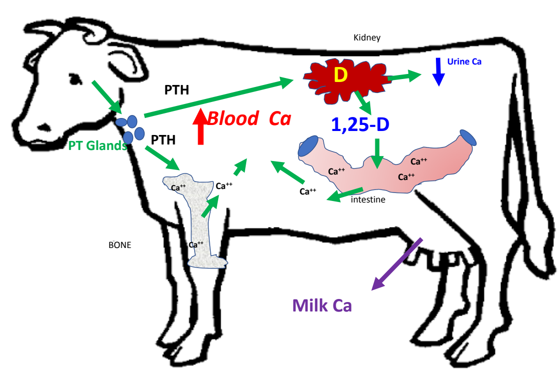

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Why doesn't Ca Homeostasis work in all cows???

Aged cows lose vitamin D receptors in intestine

Aged cows have fewer sites of active bone resorption (fewer osteoclasts) capable of responding to PTH rapidly

BLOOD pH AFFECTS TISSUE RESPONSE TO PTH!

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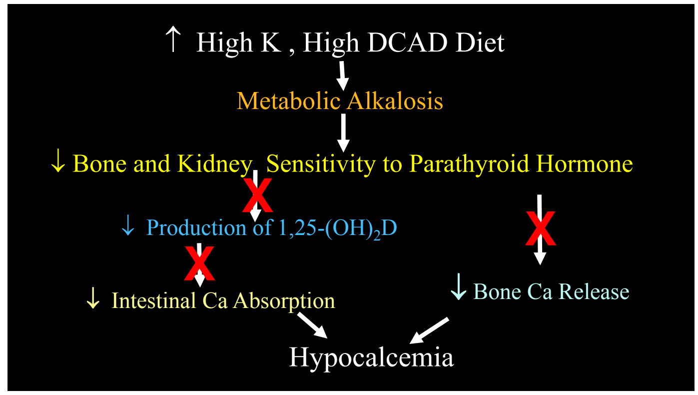

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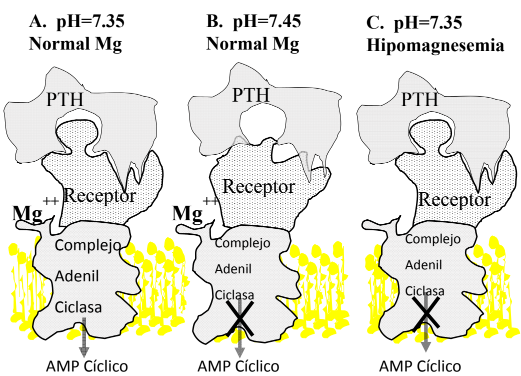

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Blood pH is dependent on Diet Cation –Anion Difference

DCAD = (mEq Na^+ + mEq K^+)- (mEq Cl^- + mEq SO^{-2}_4)

High DCAD diets, where K and Na are in much greater concentration than Cl or SO_4 cause Alkalosis & milk fever

Cations (+) ***absorbed*** from forages and diet cause the blood and urine of the cow to become alkaline

Anions (-) ***absorbed*** from forages and diet cause the blood and urine of the cow to become acidic

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Milk Fever & Hypocalcemia Prevention

1. Avoid very high potassium forages for close-up cows; practiced by most dairies in US.
2. **Add anions (Cl or Sulfate) to diet to reduce blood and urine pH and improve tissue ability to respond to PTH!.**

Choosing the right anion sources

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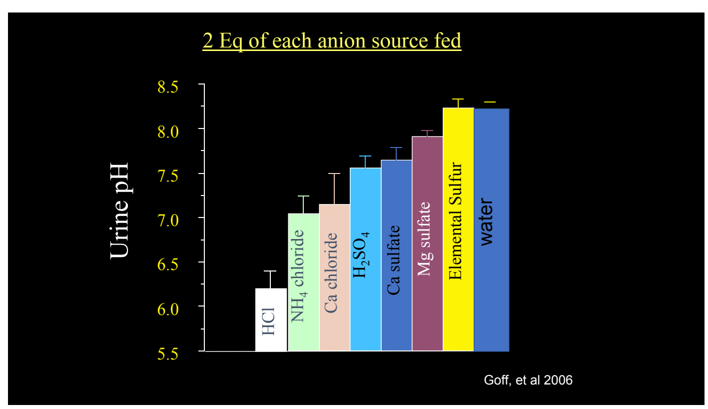

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Milk Fever & Hypocalcemia Prevention

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Choosing the right anion sources

Palatability Issues

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Soychlor

Soychlor usa cloruro como su única Fuente de aniones
- efecto muy predecible en el pH de orina
- **las dietas típicas de Soychlor son eficientes cuando DCAD está entre -75 y -125 mEq/kg DM**
- menor necesidad de medir pH en orina

Soychlor usa HCl como Fuente de cloruro
- NO salado, por lo que mejora palatabilidad

Soychlor aporta Mg en forma muy disponible

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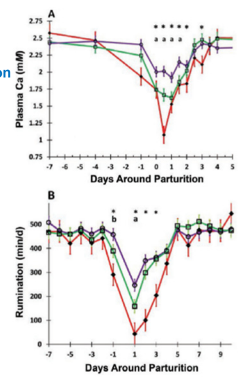
Soychlor Trial, 3rd or 4th lactation cows

Soychlor – 15 Cows = Purple
DCAD = -9 mEq/kg

Control- 15 cows
No milk fever, 11 cows = Green
Milk fever, 4 cows = Rojo



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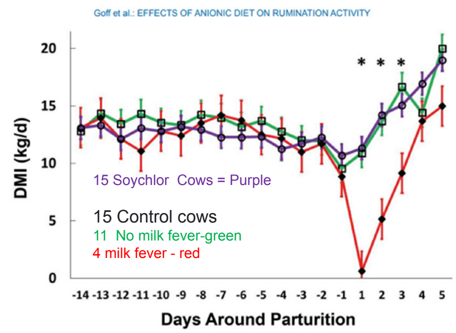

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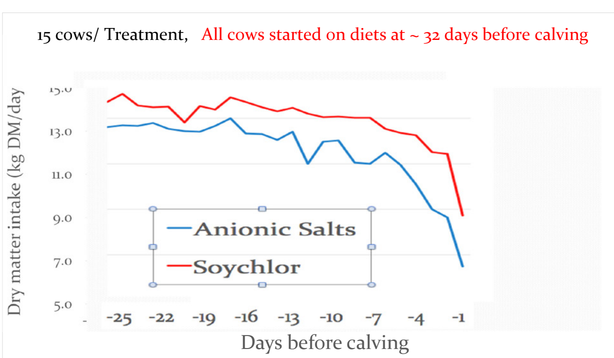

Strydom & Swiegart, 2016 ADSA

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Milk Fever & Hypocalcemia Prevention

1. Avoid very high potassium forages for close-up cows; practiced by most dairies in US.
2. **Add anions (Cl or Sulfate) to diet to reduce blood and urine pH and improve tissue ability to respond to PTH!.**

Choosing the right anion sources

Palatability Issues

Over and under acidification

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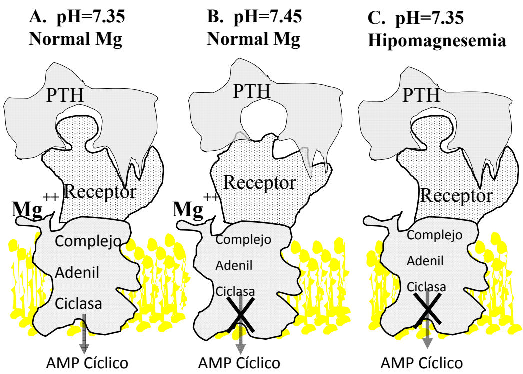

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Blood pH above 7.38 is associated with more problems with calcium metabolism.

With typical diets high in K we see blood pH above 7.4 .

Blood pH is difficult to accurately measure in cows on farms

Urine pH is a good indicator of blood pH and easy to determine

We wish to avoid problems with PTH insensitivity of bone and kidney- which occurs most when urine pH is above 7.25.

Our target is to induce a compensated metabolic acidosis in cows – a urine pH of 6.2-6.5.

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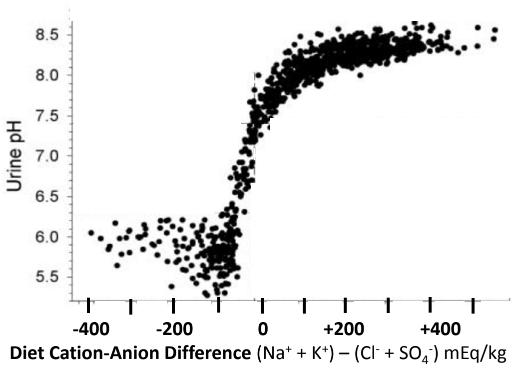

Adapted from Constable et al., 2017; Spanghero, 2004; and Charbonneau et al., 2006

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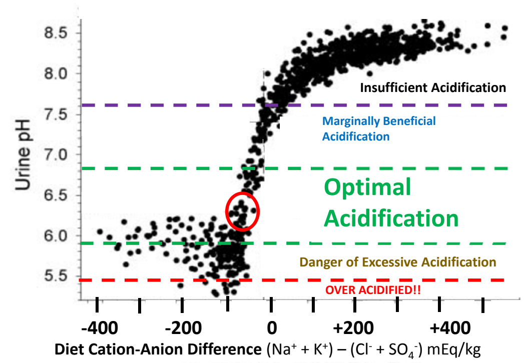

Adapted from Constable et al., 2017; Spanghero, 2004; and Charbonneau et al., 2006

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Hey Goff! How is it that you tell us the sweet spot for urine pH is around 6.3?

Other Anion Products tell us you need to be down between 5.5 and 6.0.

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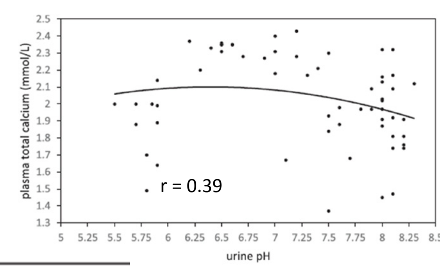

Urine pH	Stillborn %
<6.0 ($n = 22$)	13.6[a] (3/22)
6.0–7.0 ($n = 46$)	8.7[ab] (4/46)
>7.0 ($n = 135$)	4.4[b] (6/135)

Melendez et al., Animal:2021

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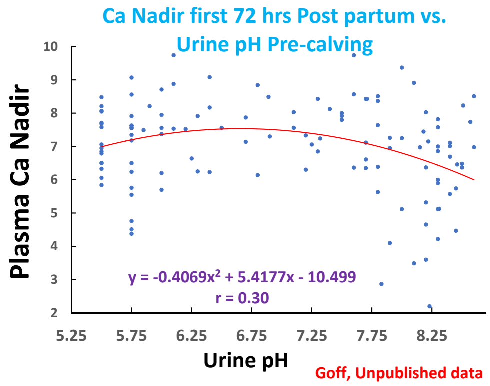

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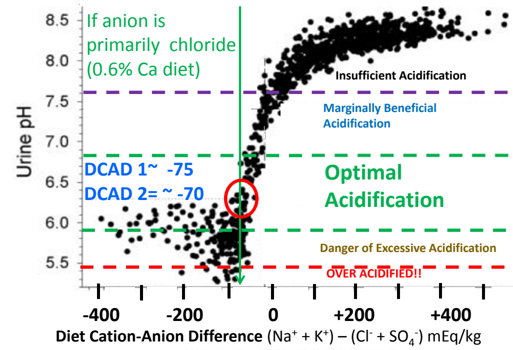

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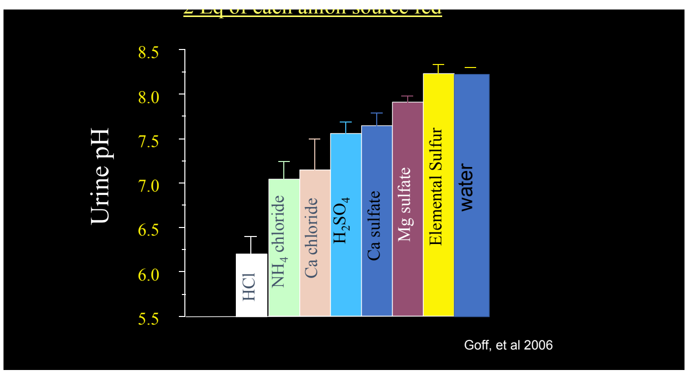

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DCAD Equations

1. Traditional DCAD 1 equation (mEq Na + mEq K) – (mEq Cl + mEq S)

   Does not account for fact S is not as acidifying as Cl

2. DCAD 2 =(Na + K) – (Cl + 0.6 S) may be more biologically correct!!!

   - **which means mathematically if you use DCAD 1 you need to feed a more negative diet when using the sulfate salts to acidify**

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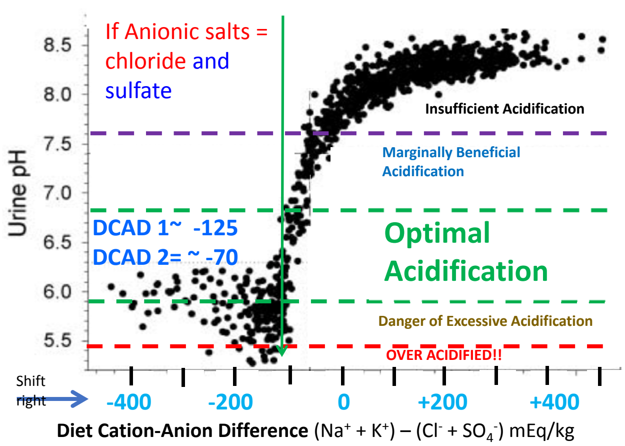

Adapted from Constable et al., 2017; Spanghero, 2004; and Charbonneau et al., 2006

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How much Ca should I feed with a low DCAD diet???

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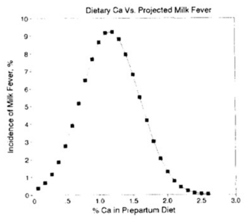

Figure 4. Sample relationship of dietary Ca to the incidence of milk fever using the final regression model. Points plotted were calculated using the mixed breed intercept, lactation number = 5, Na = .20%, and S = .35%.

Oetzel, 2006

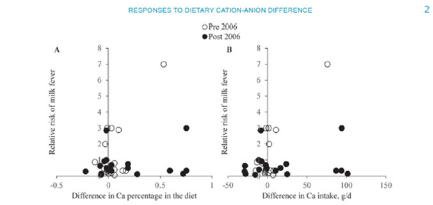

Figure 9. Difference in Ca percentage in the diet (A) and difference in Ca intake g/d (B) by experiments before 2006 and after 2006.

Lean et al 2018

Santos et al., 2019

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DCAD Equations

1. Traditional equation (Na + K) – (Cl + S)

Does not account for fact S is not as acidifying as Cl

2. (Na + K) – (Cl + 0.6 S)

Does not account for alkalinizing effect of diet Ca^{++} coming from Calcium carbonate/ Limestone

3. (Na + K + 0.15 Ca + 0.15 Mg) – (Cl + 0.6 S + 0.5 P)

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You heard low DCAD diets need to be high in Ca and you bring diet Ca to 1.7% from a baseline diet of 0.8%. You will add **9 g Ca/kg** X 13 kg = 117 g Ca from limestone.

$CaCO_3$ is alkalinizing! Ca^{++} is a cation!!! DCAD Eq 4 NRC 2001.

(Na + K + 0.15 Ca + 0.15 Mg) – (Cl + 0.6 S + 0.5 P)

117 g Ca / 20 g Ca/Eq = 5.85 Eq X 0.15 abs = 0.878 Eq = adding +878 mEq /day

If abs coeff is just 0.10!!

5.85 Eq X 0.10 abs = 0.585 Eq = +585 mEq / day

ADD LIMESTONE, BUY MORE ANION!!!!

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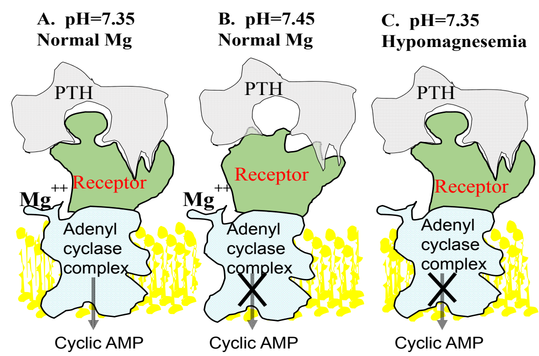

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Milk Fever & Hypocalcemia Prevention

1. Avoid very high potassium forages for close-up cows; practiced by most dairies in US.
2. Add anions (Cl or Sulfate) to diet to reduce blood and urine pH; various forms practiced.
3. **Close-up and Fresh cow Diet Mg ~ 0.4%**

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Magnesium sources

Pre-calving

- using $MgSO_4$ or $MgCl_2$ as "anions" also supplies readily available, soluble Mg.

-The better anion supplements on the market include Mg in this form to remove Mg worries pre-calving.

Post-calving is the bigger issue!!!!!!
Magnesium Oxide – supplies Mg and acts as rumen alkalinizer.

MgO must be available for absorption by rumen wall!!!!

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Milk Fever & Hypocalcemia Prevention

1. Avoid very high potassium forages for close-up cows; practiced by most dairies in US.
2. Add anions (Cl or Sulfate) to diet to reduce blood and urine pH; various forms practiced.
3. **Close-up and Fresh cow Diet Mg ~ 0.4%**
4. **Diet P < 0.35%, better below 0.25%**

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AVOID HIGH PHOSPHORUS DIETS

In addition to stimulating intestinal Ca transport 1,25-$(OH)_2$Vitamin D also stimulates transport of phosphate!!!

Now we know there is a phosphate homeostasis mechanism relying on a bone hormone called FGF23.

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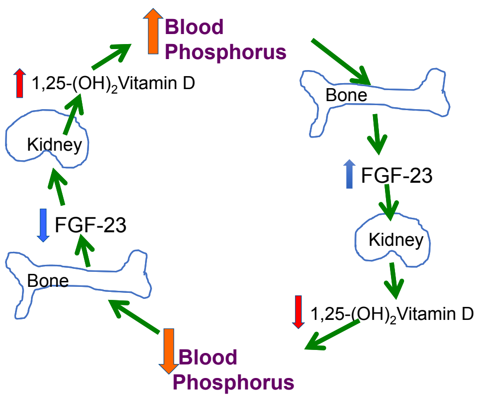

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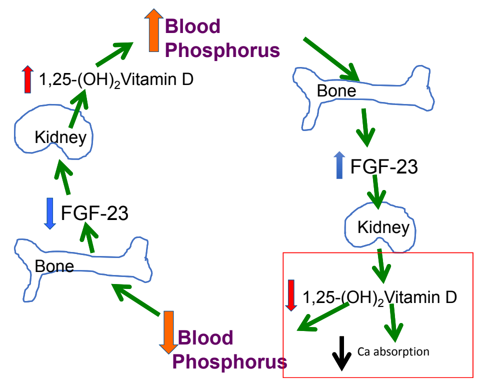

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Impact of Reducing DCAD on health and milk production

Lean et al., 2019. Meta-analysis indicates significant beneficial effects (P<0.02) on:
Milk Fever, Blood Ca (the day of calving and "postpartum"), Retained Placenta, Metritis, and risk of Multiple Health Events
But not Mastitis (P=0.63) and LDA (P= 0.73)

Milk Production – Multiparous → + 1.1 kg/day
Nulliparous → - 1.28 kg/day

Santos et al., 2019 reducing DCAD from +200 to -100 mEq/kg
Multiparous → 1.7 kg **more** milk / day (+1 kg DMI/d)
Nulliparous → 1.4 kg **less** milk / day

Zimpel et al. 2021 (a,b) - negative effects on heifers not observed if "moderately low DCAD" was fed with urine pH 6.67 vs 5.41

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DCAD During Lactation

Heavy corn silage diets can be low in potassium
- milk has 1.5 g K / Liter and 1.05 g Ca / Liter!

Acids are produced during metabolism
- mostly organic acids which are largely but not entirely metabolized within liver and other tissues

Raising DCAD can promote better control of blood pH during lactation

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DCAD Balancing is also important to Milk production

Beyond + 500 mEq/kg diet – milk production begins to fall.

Cows are too alkaline and they must decrease DMI to keep from dying of metabolic alkalosis

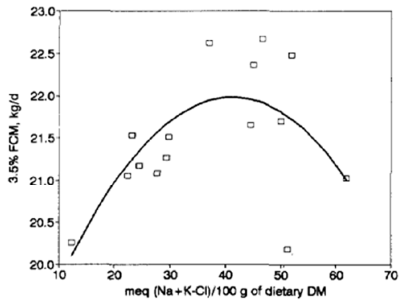

Figure 4. Yield of 3.5% FCM with varying cation-anion difference.

Sanchez and Beede, 1991

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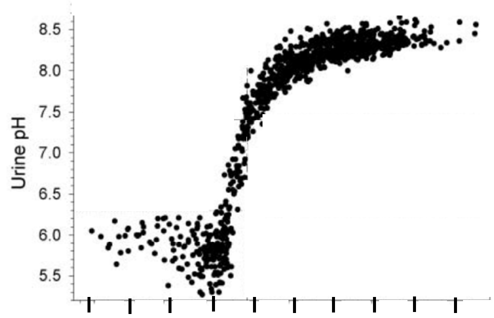

Diet Cation-Anion Difference ($Na^+ + K^+$) – ($Cl^- + SO_4^-$) mEq/kg

Adapted from Constable et al., 2017; Spanghero, 2004; and Charbonneau et al., 2006

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Heat Stress

Loss of potassium via drool can increase requirement for K.

Need potassium in addition to Na to help cow .

Counteract loss of potassium cations

Counteract effect of slug feeding of diets that occurs when it cools off at night

45

Develop your Business by Developing your People

Jay Joy, CEO Milk Money, LLC
moneycfo.com
785-275-2772

MILK MONEY
IDENTIFY. INVEST. SUCCEED.

Develop your BUSINESS by Developing your PEOPLE

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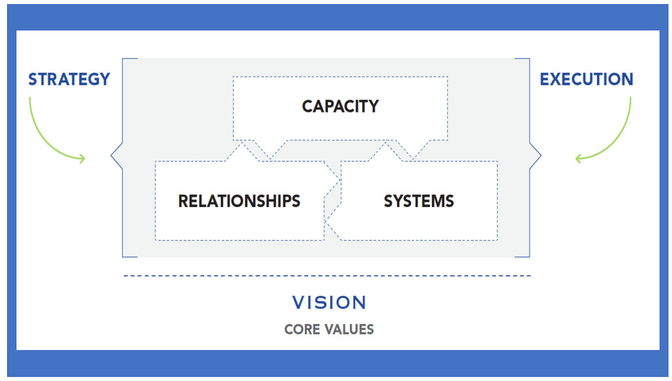

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What is Strategy?

PLAN your Plan, Organize Action

Define "What"……
- Product/Service we are offering
- Is our Target Market
- Does our "Ideal" Customer look like
- **CAPACITIES** do we need to serve our customers and employees
- **RELATIONSHIPS** do we need to serve our customers and employees
- **SYSTEMS** do we need to serve our customers and employees

3

What is Execution?

DO your Plan, Take Action

How do we……
- Provide the Product/Service are we offering
- Engage with our Target Market
- Influence our "Ideal" Customer
- Develop the **CAPACITY** we need to serve the customer
- Develop the **RELATIONSHIPS** we need to serve the customer
- Develop the **SYSTEMS** we need to have in place to execute for the customer

4

Capacity

"The ability or power to do, experience, or understand something"

- Physical
- Mental
- Emotional
- Financial
- Social
- Spiritual

5

Relationships

"The way in which two or more concepts, objects, or people are connected; or the way they behave toward each other"

- Trusted
- Collaborative
- Transactional
- Co-Existence
- Avoidance
- Dysfunctional

6

Systems

"A set of principles or procedures according to which something is done; an organized framework or method"

- Sales & Marketing
- Operational
- Financial
- Administrative
- People Development

7

VISION

"A mental image of what the future will or could be like"

- New or Unique Product or Service
- A specific "Way of Being"
- Size or Geographic Characteristics

8

Core Values

"An organization's fundamental beliefs and standards of behavior; judgment of what is most important"

- Behavioral
- Visible through Actions
- Present without Definition

9

Leadership Q&A

1. How do I serve customers and employees if I don't understand (or know) their personal VISION and Core Values?
2. How do I expect employees to "buy in" emotionally if I haven't defined our VISION and Core Values?
3. What happens if the VISION and Core Values of customers and employees don't align with the organization's?

10

Other Thoughts?

1. What **capacities** do our people need to serve our customers that they currently don't have?
2. What **relationships** do our people need to serve our customers that they currently don't have
3. What **systems** do our people need to serve our customers that they currently don't have?
4. **HOW DO WE HELP THEM GET THEM???**

11

MILK MONEY
IDENTIFY. INVEST. SUCCEED.

Jay Joy
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785-275-2772

12

Protein and Amino Acid Requirement System

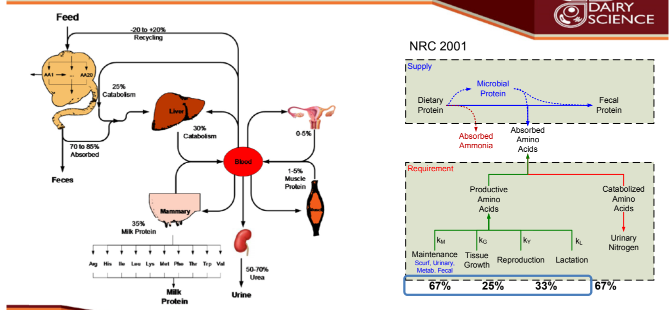
Mark D. Hanigan, Virginia Tech
Jeff Firkins, Ohio State
Helene Lapierre, Ag Canada

Protein and Amino Acid Requirement System

Mark D. Hanigan, Virginia Tech
Jeff Firkins, Ohio State
Helene Lapierre, Ag Canada

1

Reality vs the 2001 Representation



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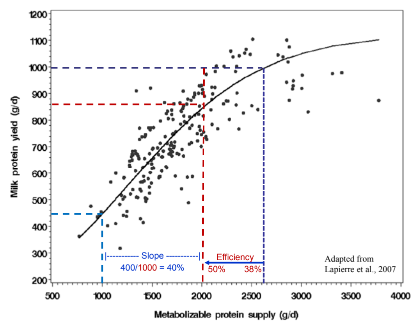
Milk Protein vs Metabolizable Protein



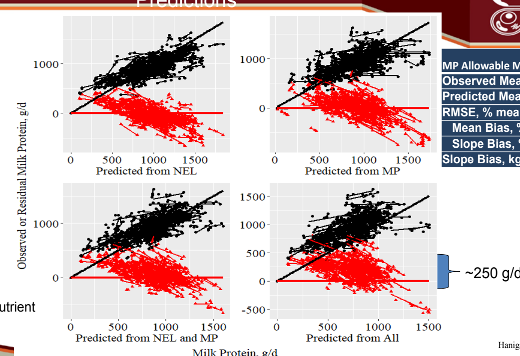
VirginiaTech
Invent the Future

3

NRC 2001 Based Predictions using NRC 2021 Supply Predictions

Independent Predictions

1st Limiting Nutrient

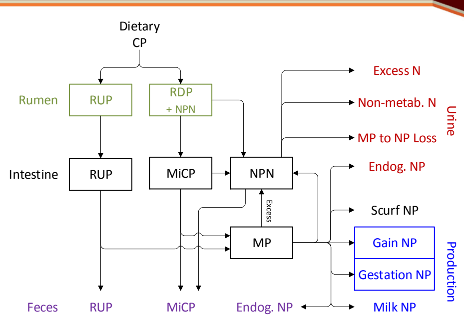


MP Allowable Milk Prt	Stat
Observed Mean, g	918
Predicted Mean, g	890
RMSE, % mean	24.9
Mean Bias, % MSE	1
Slope Bias, % MSE	32
Slope Bias, kg/kg	-0.44

Hanigan et al. in preparation

4

NASEM 2021 Protein and AA System Derivation

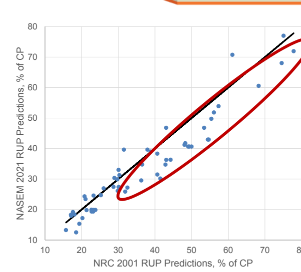


- Track protein and AA through the system
- Add more detail
- Improve accuracy and precision
  - Re-evaluate each component
  - Derive new or revised equations where needed
- Thoroughly test the revised system

5

RUP Predictions

- NRC 2001
  - RMSE = 42% with mean and slope bias
  - Over-predicted RUP!!!
  - Kp/Kd system has value, but …
    - particulate likely not reflective of protein Kp
    - in situ Kd is an under-estimate
- 2021 Patch!
  - Retain Kd's
  - 6.4% passage of A fraction vs 0 from NRC 2001
  - Kp Conc: fixed 5.28%/h vs mean of ~6.7%/h for 2001
  - Kp Forage: static value of 4.87%/h vs 3 classes at ~4.85%/h for 2001
  - RMSE = 40.9% with less slope bias
  - RUP of Conc declined



Hanigan et al. 2021

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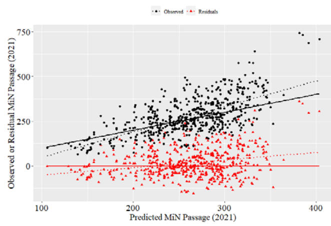
MiN Predictions

- 2001: TDN and RDP based
  - 1st limiting concept; life isn't so fragile
  - RMSE = 29.2%
  - very minor bias
- 2021
  - Integrated RDCHO and RDP
    - RDP response is linear!
    - CHO response has a plateau
    - General target ranges but no "requirements" for either
  - Starch/Fiber affects DMI predictions
  - RDP/CP effects on DMI not captured
  - < 14% CP often ⇒ ↓ DMI for lactating cows

2021:
RMSE = 29.7%

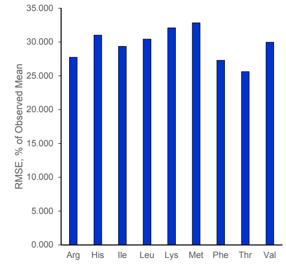
$$MiN = \frac{Int + K_{RDP} \times RDP}{1 + \frac{K_{NDF}}{RDNDF} + \frac{K_{St}}{RDSt}}$$



7

AA Composition of Protein

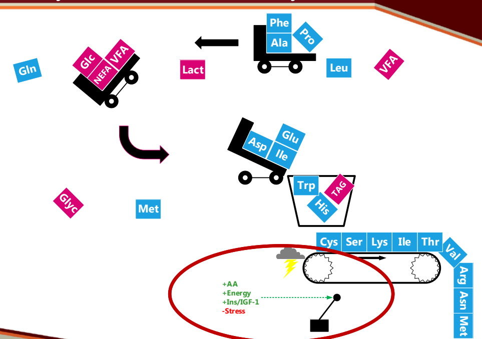
- All proteins have updated AA values
  - Feed, microbes, body protein, milk, gestation
  - Evonik feed library used for feed
  - New composition data for microbes
  - Correctly accounting for mass of hydration
- RUP AA still assumed equal to Feed AA
  - lack of data
- Absorbed AA still assumed equal to protein
  - Clearly not true, but lack of data
  - Estes et al, and Huang et al.



Fleming et al, 2019
Study effects excluded

8

Protein Synthesis is an Assembly Line



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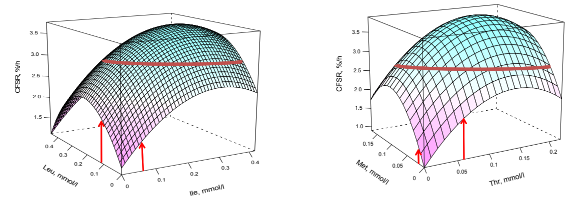
AA Effects on αS1-Casein Synthesis



Arrows indicate high cow in vivo concentrations (Swanepoel et al., 2016 and Yoder, 2019)

Arriola, 2014

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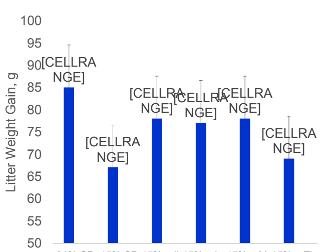
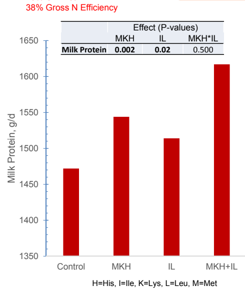
Additive Responses to EAA in Mice and Cows

Liu et al., 2017



Yoder et al., 2020
15% CP Diet
38% Gross N Efficiency



H=His, I=Ile, K=Lys, L=Leu, M=Met

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Integrated Milk Protein Predictions using NASEM 2021 Nutrient Supply

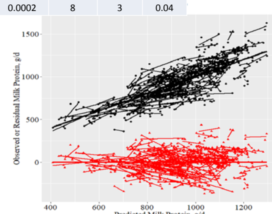
$$mPrt = Int + \alpha Arg + \beta His + \chi Ile + \delta Leu + \varepsilon Lys + \phi Met + \psi Phe + \varphi Thr + \mu Trp + \theta Val + \lambda OthAA + \varpi \sum EAA^2 + \kappa DEInp + \eta dNDF + \gamma dSt + \pi dFA + \mu BW$$

Predictors	Intercept	His	Ile	Leu	Lys	Met	OthAA	$\sum(EAA^2)$	DEInp	dNDFIn	BW
	g/d	---- g/g ----							Mcal/d	% DM	kg
Estimates	-97	1.68	0.89	0.47	1.15	1.84	0.077	-0.0024	10.8	-4.06	-0.42
SE	45	0.50	0.27	0.16	0.17	0.19	0.055	0.0002	8	3	0.04

Cross Evaluation Results – 500 Iterations

Variable	NRC 2001	NRC 2021	SE
Observed Mean, g/d	918	921	17
Predicted Mean, g/d	890	923	12
RMSE	228	131	7
RMSE, % mean	**24.9**	**14.3**	**0.8**
Mean Bias, % MSE	2	0.7	1.0
Slope Bias, % MSE	32	4	3
CCC	0.65	0.75	0.03

- Arg, Thr, & NEAA trends
- Trp, Phe, and Val → inadequate data



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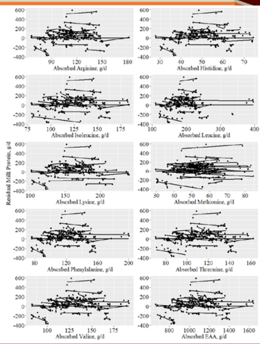
Residuals from Eqn. 9.7 versus Absorbed EAA for Studies Feeding RPAA



without study effects

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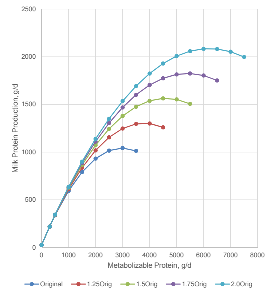
Scaling Maximum using 305d RHA Milk Protein



- Squared term highly significant
- Plateau at 3000 g MP
  - 1250 g Milk Protein
  - 42 kg Milk/d
- Algebraically scale the quadratic and slope
  - reflects genetics, management, environment
  - based on 305 d RHA Milk TP (kg/305 d)
  - should be actual, not genetic merit
  - Check "Pred Milk NP to Quad Max", Tbl 6.2
    - should be 0.8 or less based on current data
    - Must adjust 305d RHA for high production herds

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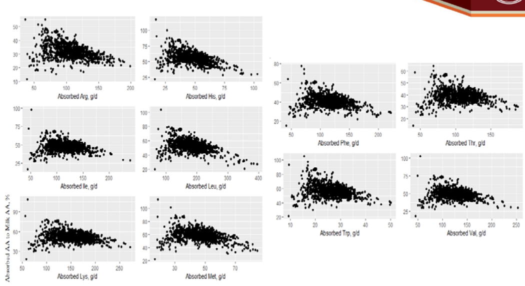
Efficiency of Absorbed EAA Conversion to Milk EAA



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Report 6. Target Amino Acid Supply and Efficiency

6.3 Predicted and Target Supply of Metabolizable Protein and Amino Acids

Item	Target Milk Protein g/d	Target Metab AA Efficiency	Target Supply g/d	Predicted Supply Mcal or g/d	Predicted Metab AA Efficiency	Milk Protein Regr Coeff	Predicted Milk Protein g/d
Intercept + BW effects + dNDF							-122
DE Non-Protein				68		10.79	739
Arg	58			159	0.45	0.00	0
His	45	0.75	78	67	0.77	1.64	110
Ile	95	0.71	161	161	0.63	0.87	140
Leu	163	0.73	269	253	0.68	0.46	116
Lys	136	0.72	228	203	0.71	1.13	230
Met	47	0.73	73	60	0.78	1.81	108
Phe	81	0.60	167	158	0.56	0.00	0
Thr	71	0.64	152	143	0.61	0.00	0
Trp	25	0.86	37	35	0.79	0.00	0
Val	106	0.74	178	168	0.69	0.00	0
EAA	827		1343	1407	0.64	0.00	-190
Other AA				2439		0.08	189
Nutrient Allowable (1)	1540				0.65	N/A	1318
Pred Milk NP / 305d Max (2)	N/A	N/A	N/A	N/A	N/A	N/A	0.57

(1) Manipulate digested NDF, absorbed DE, and absorbed EAA (His, Ile, Leu, Lys, and Met) to match Target and Predicted efficiencies and NP production.
(2) Pred Milk NP / 305d Max reflects the ratio of the Nutrient Allowable Milk NP to the user entered 305d herd production. This ratio should not be greater than 0.80 under normal feeding conditions.

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Using (Abs – Maint Efficiency) as a Guide: Table 6.3 Example

Example Diet 1: 35 kg milk , 24.9 kg DM/d, 17.5% CP

MP Supply: 2383 g, Target MP: 2301 g
NE Allow Milk: 40.4 kg

	Trg Milk NP	Trg Effic	Trg Suppl	Pred Suppl	Pred Effic	Regr Coeff	Milk NP
Int_BW_NDF							-125
DEInp				59		10.79	638
Arg	41			137	0.45	0	0
His	32	0.75	60	57	0.77	1.675	95
Ile	67	0.71	121	142	0.59	0.885	125
Leu	115	0.73	205	214	0.68	0.466	100
Lys	96	0.72	174	182	0.66	1.153	210
Met	33	0.73	55	52	0.75	1.839	95
Phe	57	0.60	127	138	0.54	0	0
Thr	50	0.64	118	126	0.58	0	0
Trp	18	0.86	28	31	0.75	0	0
Val	75	0.74	135	147	0.66	0	0
AA_other				2095		0.0773	162
EAA^2	582		1025	1224	0.62	-0.00215	-225
Nutr_Allow	1085				0.65	NA	1075
Milk, kg/d							34.7

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Using Total AA Efficiency as a Guide: Table 6.3

Example Diet 3: 35 kg milk , 24.9 kg DM/d, 14.7% CP

MP Supply: 2117 g, Target MP: 2320 g
NE Allow Milk: 40.9 kg

	Trg Milk NP	Trg Effic	Trg Suppl	Pred Suppl	Pred Effic	Regr Coeff	Milk NP
Int_BW_NDF							-115
DEInp				62		10.79	665
Arg	41			130	0.47	0	0
His	32	0.75	60	54	0.81	1.675	91
Ile	67	0.71	121	133	0.64	0.885	117
Leu	115	0.73	204	205	0.71	0.466	96
Lys	96	0.72	174	170	0.72	1.153	196
Met	33	0.73	55	49	0.80	1.839	91
Phe	57	0.60	127	130	0.57	0	0
Thr	50	0.64	118	118	0.62	0	0
Trp	18	0.86	28	29	0.82	0	0
Val	75	0.74	135	138	0.71	0	0
AA_other				1976		0.0773	153
EAA2	582		1021	1156	0.66	-0.00215	-202
Nutr_Allow	1085				0.69	NA	1092
Milk, kg/d							33.5

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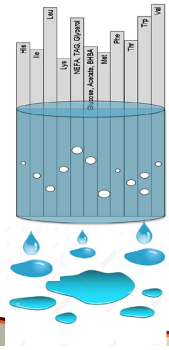
Milk Protein Summary



- Milk Protein
  - Responds Additively to:
    - Individual EAA supplies
    - Energy supply
    - Hormonal signals
  - Has some nonlinearity
  - New equations representing those are far superior
- Implications
  - substrate available
  - barrel is leaking not spilling over
  - no such thing as first-limiting nutrient for protein
  - no unique requirements for protein synth substrates
  - infinite substrate combinations yield similar output

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Protein System Summary

- Removed bias in RUP; RDP will be greater and RUP less for concentrates
- More mechanistic representation of MiN (RDCHO and RDP)
- Improved AA supply from MiN and dRUP; no longer empirically adjusted
- Endogenous N removed from supply
- Post-absorptive use more closely follows biology
- Updated maintenance representations
- MAJOR conceptual change in milk protein and export protein efficiency
- Considers all 10 EAA, but Arg is semi-essential and Trp data are very, very thin.

20

Field Application via CNCPS

- CNCPS predictions of AA supply appear to be accurate (Martineau et al. in preparation)
- Milk protein equation thus directly applicable given EAA supplies
  - Milk Prt = fn(AA supply)!!!
  - DON'T subtract maintenance or anything else first
  - CAN'T use most limiting AA approach, thus many report changes required
- Efficiency calcs are more complicated
  - Milk EAA / (EAA Supply – Maintenance – Gestation)
  - new maintenance equations
  - corrected for hydration mass changes between AA and protein
  - endogenous urinary is only AA, not protein and at 100% efficiency
- CNCPS application certainly possible, just quite a bit of work
  - Helene has been working with Mike to incorporate

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Acknowledgements

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- Alvaro Morales
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22

Transition Cows:Update on DCAD and Stumbling Blocks when Trying to Balance Rations Properly

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Department of Animal Science
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Feeding the fresh group for better health and lactation performance

Thomas R. Overton, Ph.D.
Professor and Chair

1

Transition cow nutrition

- The vast majority of controlled research during the past 25 years on transition cow nutrition has focused on the ***dry*** cow
- Most lactating cow nutrition studies did not start until three to four weeks after calving
- Several studies published over the past 5 to 7 years focused specifically on feeding the fresh cow

2

Fresh cow diets – common themes

- Frequently based upon high cow diet
- Some common "tweaks"
  - Lower starch
  - Higher physically effective fiber
    - Usually less than 0.5 kg/d of chopped straw/hay
  - Additional RUP/AA
  - Additional fat
  - Strategic addition of other nutrients (e.g., RP-choline)
- Success usually gauged by farm-level outcomes

3

Fresh diets – a few key questions

- How fermentable should fresh cow diets be?
  - do we need to feed lower starch diets to fresh cows?
  - what about starch fermentability?
- How important is physically effective NDF in fresh cow diets?
- MP supply to the postcalving cow

4

To starch, or not to starch?

5

Several experiments conducted by groups at University of Alberta, Miner Institute, Cornell, and Michigan State University

- Starch level in fresh diet
  - Dann and Nelson, 2011 Cornell Nutrition Conference
  - Sun and Oba. 2014. J. Dairy Sci. 97:1594-1602.
  - McCarthy et al., 2015. J. Dairy Sci. 98:3335-3350.
  - Williams et al., 2015 ADSA-ASAS Joint Annual Meeting
  - Haisan et al., 2021. J. Dairy Sci. 104:4362-4374.
- Starch source in fresh diet
  - Rockwell and Allen. 2016. J. Dairy Sci. 99:4453-4463.
- Starch source and level in fresh diet
  - Dyck et al., 2011. J. Dairy Sci. 94:4636-4646.
  - Albornoz and Allen. 2018. J. Dairy Sci. 101:8902-8915.

6

Dann and Nelson, 2011 Cornell Nutrition Conference

- 72 Holstein cows (2nd and greater lactation)
- Fed high straw controlled energy diet for 40-d dry period
- At calving, one of three starch regimens
  - Low starch (~ 21%) for first 91 DIM
  - Medium starch (~23%) for first 21 d followed by high starch (~25.5%) until 91 DIM
  - High starch (~25.5%) for first 91 DIM

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Table 1. Ingredient and analyzed chemical composition (mean ± standard error) of low, medium, and high starch diets fed to early lactation Holstein cows.

Item	Low	Medium	High
Ingredients, % of DM			
Corn silage	34.6 ± 0.1	34.6 ± 0.1	34.6 ± 0.1
Haylage	11.4 ± 0.4	11.7 ± 0.3	11.4 ± 0.4
Wheat straw	4.1	4.1	4.1
Corn meal	6.9 ± 0.4	11.1 ± 0.1	16.7 ± 0.4
Soybean meal	11.4 ± 0.1	11.9 ± 0.1	11.9 ± 0.1
Soybean hulls	9.7	6.5 ± 0.2	3.2
Wheat middlings	6.1	3.9 ± 0.1	1.8 ± 0.1
Canola meal	3.1	6.1	6.1
AminoPlus	2.5	-	-
Other	10.2 ± 0.3	10.1 ± 0.3	10.2 ± 0.2
Chemical composition			
DM, %	49.5 ± 0.7	50.1 ± 0.9	49.6 ± 0.7
CP, %	17.3 ± 0.1	17.0 ± 0.2	16.7 ± 0.2
NDF, %	35.7 ± 0.3	33.9 ± 0.4	31.9 ± 0.3
Sugar, %	6.1 ± 0.1	5.8 ± 0.1	5.9 ± 0.1
Starch, %	21.0 ± 0.3	23.2 ± 0.3	25.5 ± 0.3
Rumen fermentable starch, %	16.8 ± 0.5	18.9 ± 0.6	20.2 ± 0.5
Digestibility			
24-h NDF, % NDF	58.4 ± 0.6	57.3 ± 0.5	54.0 ± 0.8
7-h starch, % starch	76.5 ± 1.4	76.7 ± 1.2	74.5 ± 1.2

Dann and Nelson, 2011 CNC

8

DMI and milk during first 13 wk of lactation for cows fed varying levels of starch in early lactation

Item	Low-low	Medium-High	High-High	SEM	P, Trt	P, Trt x wk
DMI, kg/d	25.2^{x}	24.9^{xy}	23.7^{y}	0.5	0.06	0.09
Milk, kg/d	47.9^{ab}	49.9^{a}	44.2^{b}	1.6	0.04	0.75
SCM, kg/d	47.4	47.9	43.5	1.5	0.09	0.39
NEFA, uEq/L (wk 1-3)	452^{aby}	577^{ax}	431^{by}	43	0.03	0.11
BHBA, mg/dL (wk 1-3)	9.3	8.8	7.8	1.1	0.15	0.97

^{ab} Least squares means within a row without a common superscript differ ($P \le 0.05$).
^{xy} Least squares means within a row without a common superscript differ ($P \le 0.10$).

Dann and Nelson, 2011 CNC

9

J. Dairy Sci. 97:1594–1602
http://dx.doi.org/10.3168/jds.2013-7068
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Effects of feeding a high-fiber byproduct feedstuff as a substitute for barley grain on rumen fermentation and productivity of dairy cows in early lactation

Y. Sun and M. Oba[1]
Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, T6G 2P5 Canada

- 61 Holstein cows (22 PP and 39 MP)
- Treatments fed from calving through 12 wk postpartum
  - Control (high starch; 29.2% of DM)
  - DDGS (low starch; 19.1% of DM)

% of DM	Control	DDGS
Barley silage	43.0	43.1
Corn grain, rolled	21.6	21.6
Barley grain, rolled	17.3	---
Wheat DDGS	---	17.2
Corn gluten meal	8.3	---
Beet pulp	3.2	12.3
Balance	6.6	5.8
CP, %	17.3	19.4
NDF, %	27.2	30.5
Starch, %	29.2	19.1

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Results

Item	Control		DDGS		SE	P value	
Milk, kg/d	35.3		34.9		1.03	0.83	
Fat, kg/d	1.33		1.31		0.05	0.85	
CP, kg/d	0.97		0.97		0.03	1.00	
ECM, kg/d	35.6		35.4		1.03	0.88	
	PP	MP	PP	MP		TRT	TRT*PAR
DMI, kg/d	14.7	21.3	16.2	20.1	0.45	0.62	<0.001
Rumen pH, mean	6.33		6.30		0.07	0.78	
pH < 5.8, min/d	126		108		49.4	0.80	
Area, pH x min/d	28.8		16.6		11.3	0.53	

Sun and Oba, 2014

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J. Dairy Sci. 98:3335–3350
http://dx.doi.org/10.3168/jds.2014-8820
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Performance of early-lactation dairy cows as affected by dietary starch and monensin supplementation

M. M. McCarthy,* T. Yasui,* C. M. Ryan,* G. D. Mechor,† and T. R. Overton*[1]
*Department of Animal Science, Cornell University, Ithaca, NY, 14853
†Elanco Animal Health, Greenfield, IN, 46140

- 70 Holstein cows (21 PP and 49 MP)
- Fed high straw, moderate energy diet during close-up
- At calving, fed one of two rations
  - Low starch (~ 20.9% starch; 35.9% NDF)
  - Higher starch (~ 25.5% starch; 33.6% NDF)
  - Beginning at 22 DIM, all cows fed higher starch ration
- Also fed either 0 mg/d monensin or 400 mg/d prepartum/450 mg/d postpartum via topdress pellet

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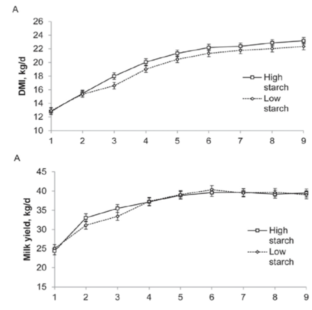
Diet Composition, % of DM

Item	Prepartum	Postpartum	
		High Starch	Low Starch
Corn Silage	39.5	—	—
BMR Corn Silage	—	37.0	37.0
Haylage	—	9.3	9.3
Wheat Straw	20.5	11.1	11.1
Corn meal, finely ground	3.9	20.2	9.9
Corn Germ Meal	—	2.4	5.4
Citrus Pulp	6.6	0.9	6.7
Soy Hulls	6.6	—	3.4
Soybean Meal	5.0	5.5	3.7
Canola Meal	4.3	2.6	2.0
Blood Meal	1.0	1.9	1.9
Supplements	6.6	5.3	5.9
Topdress	6.1	4.2	4.2

McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

13



DMI and milk yield for cows fed low vs. high starch postpartum.

From McCarthy et al. 2015

	DMI	Milk yield
	P, starch x wk	P, starch x wk
Wk 1 to 3	0.04	0.002
Wk 1 to 9	0.32	<0.001

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J. Dairy Sci. 99:4453–4463
http://dx.doi.org/10.3168/jds.2015-10344

Chromium propionate supplementation during the peripartum period interacts with starch source fed postpartum: Production responses during the immediate postpartum and carryover periods

R. J. Rockwell and M. S. Allen[1]
Department of Animal Science, Michigan State University, East Lansing 48824

- 48 Holstein cows entering 2+ lactation
- 2 x 2 factorial
  - control vs. Cr-prop peripartum
  - Dry ground vs. High Moisture corn postpartum through d 28

% of DM	Dry corn	HM corn
Corn silage	25.0	25.0
Alfalfa silage	19.2	19.2
Alfalfa hay	11.8	11.8
Dry ground corn	23.3	---
High-moisture corn	---	23.3
Soybean meal	12.9	12.9
Vitamin-mineral mix	7.8	7.8
CP, %	16.2	16.2
NDF, %	31.4	31.1
Starch, %	26.4	26.5

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Results (d 1 to 28 postpartum)

Item	Dry corn	HM corn	SE	P value
Milk, kg/d	38.5	41.4	1.65	0.02
Fat, kg/d	1.95	1.99	0.13	0.33
TP, kg/d	1.27	1.32	0.06	0.28
ECM, kg/d	47.9	49.5	2.61	0.18
DMI, kg/d	18.1	18.6	0.7	0.53
Cumulative DMI, kg	507	521	20	0.51

Rockwell and Allen, 2016

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J. Dairy Sci. 94:4636–4646
doi:10.3168/jds.2010-4056

Starch source and content in postpartum dairy cow diets: Effects on plasma metabolites and reproductive processes

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- 40 Holstein cows (16 PP and 24 MP)
- Three dietary treatments from calving until 70 DIM

% of DM	Alfalfa silage	Barley silage	Barley silage + starch
Alfalfa silage	44.7	---	---
Barley silage	---	44.6	40.6
Alfalfa hay	10.0	10.0	10.1
Corn starch	---	---	4.0
Corn	25.4	20.3	4.8
Barley	10.2	4.8	4.8
Balance of mix	10.4	20.3	20.3
CP, %	17.1	18.8	18.4
NDF, %	25.8	30.9	28.8
Starch, %	25.2	23.3	26.7

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Results (d 1 to 70 postpartum)

Item	AS	BS	BS+S	SE	P value	
					Source	Level
DMI, kg/d	19.5	18.4	19.1	0.6	0.31	0.43
Milk, kg/d	35.7	35.8	38.3	1.7	0.49	0.29
Fat, kg/d	1.30	1.34	1.36	0.57	0.44	0.82
TP, kg/d	1.04	1.08	1.14	0.44	0.21	0.28

Source: AS vs (BS + BS+S)
Level: BS vs BS+S

Dyck et al., 2011

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J. Dairy Sci. 101:8902–8915
https://doi.org/10.3168/jds.2018-14843

Highly fermentable starch at different diet starch concentrations decreased feed intake and milk yield of cows in the early postpartum period

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- 52 Holstein cows entering 2+ lactation
- 2 x 2 factorial arrangement of treatments (calving to 23 DIM)
  - Low (22%) starch vs high (28%) starch
  - Dry ground corn vs high-moisture corn

	Low starch		High starch	
% of DM	Dry corn	HM corn	Dry corn	HM corn
Alfalfa silage	37.0	37.1	37.7	37.0
Grass hay	8.25	8.35	8.35	8.21
Dry ground corn	27.5	---	35.4	---
High-moisture corn	---	28.1	---	36.2
Soyhulls	11.0	11.0	1.87	2.18
Soybean meal	11.7	11.1	12.2	12.4
Balance of mix	4.5	4.5	4.5	4.5
CP, %	17.2	16.7	17.3	16.9
NDF, %	33.0	33.0	28.3	27.6
Starch, %	21.4	21.9	27.1	27.8

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Results (d 1 to 23 postpartum)

	Low starch		High starch			P value		
Item	Dry	HM	Dry	HM	SE	L	S	L x S
DMI, kg/d	18.6	17.7	20.2	16.3	0.8	0.96	< 0.01	0.07
Cumulative DMI, kg	415	385	445	370	12	0.69	<0.01	0.20
Milk, kg/d	40.6	37.0	41.5	36.6	1.8	0.88	0.02	0.66
Fat, kg/d	1.81	1.70	1.84	1.58	0.10	0.59	0.03	0.40
TP, kg/d	1.24	1.14	1.35	1.09	0.07	0.64	0.01	0.21
ECM, kg/d	45.1	41.9	46.7	40.0	2.2	0.94	0.01	0.37

L = effect of starch level
S = effect of starch source

Albornoz and Allen, 2018

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Studies that had favorable responses to higher starch levels or increased starch fermentability generally had higher forage or forage NDF levels

- Favorable responses
  - McCarthy et al., 2015 (28.2% of DM as F-NDF)
  - Rockwell et al., 2016 (27.4% of DM as F-NDF)
- Neutral or negative responses
  - Albornoz and Allen., 2018 (~22.5% of DM as F-NDF)
  - Sun and Oba, 2014 (Diet was 39.9% forage)
  - Dann and Nelson, 2011 (Diet was ~ 50% forage)
  - Haisan et al., 2021 (~18% of DM as F-NDF)

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Adequate forage NDF; physically effective NDF; $uNDF_{240}$; $peuNDF_{240}$ in rations is probably very important in fresh cows

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A case study

- Cornell study evaluating high or low starch diets for fresh cows
- Controlled energy/high straw dry cow approach starting 28 to 35 days before calving
- At calving, one of two fresh diets until 21 DIM
- First cows that calved onto either ration developed significant health problems; diets adjusted and study re-started

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Table 3. Ingredient and chemical composition of diets (± SD[1]) before and after postpartum ration changes (DM basis)

		Postpartum[2]			
Item	Prepartum	HSLF	LSLF	HSHF	LSHF
Ingredient (% of DM)					
Corn silage, conv.	42.1	---	---	---	---
BMR corn silage	---	46.1	46.1	38.5	38.5
Wheat straw	21.2	3.84	3.84	11.5	11.5
Legume silage	---	9.62	9.62	9.62	9.62
Corn meal, fine	4.28	21.0	10.3	21.0	10.3
Citrus pulp	7.23	1.01	7.15	1.01	7.15
Corn germ meal	---	2.52	5.56	2.52	5.56
Soybean hulls	7.08	---	3.58	---	3.58
Soybean meal	5.27	5.87	3.86	5.87	3.86
Canola meal	4.63	2.73	2.08	2.73	2.08
Blood meal	1.05	1.94	1.93	1.94	1.93
Expeller soy	1.78	1.70	2.34	1.70	2.34
Bypass fat	---	0.77	0.96	0.77	0.96
Anionic suppl.	1.33	---	---	---	---
Sodium bicarbonate	---	0.86	0.85	0.86	0.85
Minerals/vitamins	3.35	1.99	1.72	1.99	1.72
Chemical					
CP, %	13.0 ± 0.8	16.5	15.3	15.5 ± 1.2	15.4 ± 0.8
ADF, %	28.2 ± 1.2	17.7	22.3	22.7 ± 1.2	25.2 ± 1.2
NDF, %	42.9 ± 2.0	26.4	31.5	34.3 ± 1.5	36.9 ± 1.5
Sugar, %	4.9 ± 0.8	3.1	3.9	3.5 ± 0.6	4.5 ± 0.4
Starch, %	17.4 ± 1.2	28.3	22.0	26.2 ± 1.2	21.5 ± 1.0
Fat, %	2.6 ± 0.2	3.2	3.1	4.0 ± 0.2	2.2 ± 0.6
$uNDF_{240}$,[3] % of DM	14.9	7.7	8.9	10.5	10.9

[1] Chemcial composition was analyzed on 4-wk composite samples (n = 1 for HSLF, n = 1 for LSLF, n = 7 for HSHF, and n = 6 for LSHF).
[2] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).
[3] Determined using wet chemistry methods on a single composite sample from each diet (Cumberland Valley Analytical Services, Hagerstown, MD)

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Table 2. Health events for cows fed either high or low starch diets for the first 3 wk postpartum before and after postpartum ration changes.

	Postpartum ration[1]				Parity		P-values[2]		
Item[3]	HSLF	LSLF	HSHF	LSHF	Primi	Multi	S	F	P
Multiparous, n	3	8	27	28					
Primiparous, n	4	2	11	11					
Clinical ketosis[3]	4	1	4	6	6	9	0.23	0.05	0.14
DA[4]	4	2	0	0	4	2	0.22	<0.001	0.06
RP[5]	1	2	2	1	3	3	0.32	0.05	0.20
Total disorders	9	5	6	7					

[1] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).
[2] S = effect of starch; F = effect of fiber; P = effect of parity.
[3] Clinical ketosis defined as rapidly decreased milk production and DMI and blood BHBA ≥ 2.6 mmol/L using Precision Xtra, displaced abomasum by auscultation
[4] Displaced abomasum diagnosed by auscultation.
[5] Placenta retained for ≥ 24 h postcalving.

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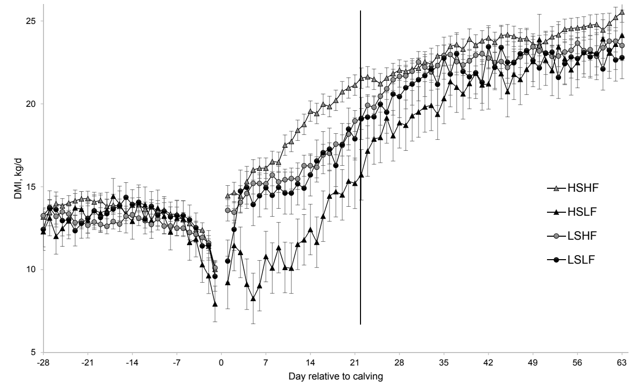

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Plasma metabolites and haptoglobin

	Low fiber		High fiber			P value		
Item	High starch	Low starch	High starch	Low starch	SE	Fiber	Starch	F x S
NEFA, uEq/L	646	528	406	493	54	0.001	0.67	0.009
BHB, mg/dL	12.31	8.88	9.27	10.70	1.34	0.53	0.30	0.01
Haptoglobin, g/L	1.44	0.94	1.06	0.86	0.18	0.07	0.008	0.25

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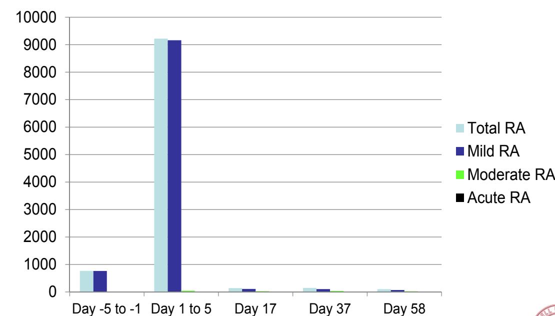
Severity of ruminal acidosis during the transition period (RA total area – pH x min)



Penner et al., 2007

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Fresh cow starch levels and acute phase response (Miner Institute and Zennoh)

- Randomized design with 16 multiparous Holstein cows
- 55-d dry period and fed close-up diet fed starting 21 d before expected calving
- Treatments from calving to 21 DIM
  - Lower starch diet (21% starch, 37% NDF)
  - Higher starch diet (27% starch, 32% NDF)

Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

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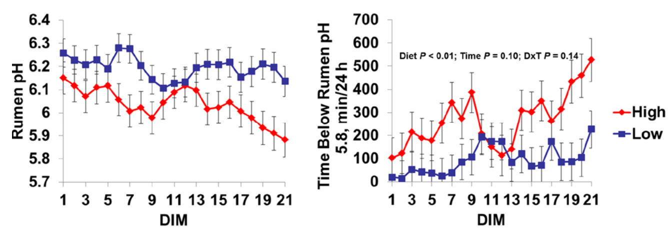
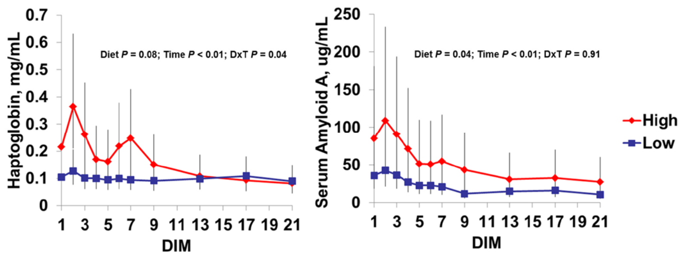
Rumen pH and time below pH 5.8 for cows fed high and low starch fresh diets



Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

30

Acute phase proteins in cows fed high and low starch fresh diets



Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

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Other studies reporting inflammatory markers with starch level or fermentability

- McCarthy et al. 2015b
  - Cows fed higher starch had higher circulating haptoglobin
- Albornoz et al., 2020
  - Cows fed high starch had higher haptoglobin, LBP, and TNF-alpha with HM corn but results were opposite at lower starch level
- Haisan et al., 2021
  - Cows fed high starch (32.8% of DM) had lower haptoglobin and serum amyloid A than cows fed lower starch (25.1% of DM)

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Can you go too far with higher peNDF/uNDF$_{240}$/peuNDF$_{240}$ in fresh cow rations?

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Ingredient and nutrient composition of experimental diets (LaCount et al., 2017)

	Diet		
Item	Prepartum	Low Fiber (LF)	High Fiber (HF)
Ingredients, % of ration DM			
Conventional corn silage	45.21	42.31	38.46
Alfalfa hay	-	10.58	10.58
Straw	20.84	1.15	8.65
Corn meal	2.43	17.64	20.15
Soybean meal	-	6.03	4.73
Wheat middlings	-	4.82	1.58
Amino Plus	5.9	4.34	5.31
Canola meal	3.47	1.61	3.88
Corn gluten feed	1.74	1.61	0.47
Blood meal	2.43	0.95	1.09
Soybean hulls	6.95	2.41	-
Citrus pulp	4.52	-	0.79
Energy Booster	-	1.29	1.58
Rumensin, mg/d[1]	439	365	334
Other	6.4	2.3	2.3
Analyses, % of ration DM			
aNDFom	43.1 ± 0.3	32.8 ± 1.4	35.3 ± 2.3
ADF	29.0 ± 0.5	21.3 ± 1.1	22.9 ± 2.1
Starch	15.6 ± 0.3	24.8 ± 1.7	24.6 ± 2.3
Sugar	3.5 ± 0.4	5.0 ± 0.7	3.9 ± 0.1
Fat	2.3 ± 0.2	3.3 ± 0.2	3.2 ± 0.2
uNDF$_{240}$	12.8 ± 0.5	9.5 ± 0.4	12.2 ± 1.6
peNDF	33.3	21.6	23.2
MP, g/kg DM[1]	89.0	112.1	108.0

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Dry matter intake, milk yield, and milk composition for cows fed low fiber (LF) or high fiber (HF) diets from d 1 to 28 postcalving. LaCount et al., 2017

				P-Value	
Item	LF	HF	SEM	Trt	Trt×Time
Prepartum DMI, kg/d	15.5			-	-
Postpartum DMI, kg/d	21.1	19.4	0.4	<0.01	<0.01
uNDF intake, %BW	0.27	0.32	0.01	<0.01	0.06
Milk yield, kg/d	46.2	44.7	1.0	0.26	0.001
Fat, %	3.89	4.06	1.1	0.55	0.10
Protein, %	3.27	3.20	0.06	0.31	0.41
Lactose, %	4.73	4.69	0.04	0.49	0.39
Total solids, %	12.9	13.0	0.2	0.50	0.57
ECM, kg/d	47.2	46.0	1.1	0.55	0.10
Rumination, min/d	544	543	8	0.56	0.14

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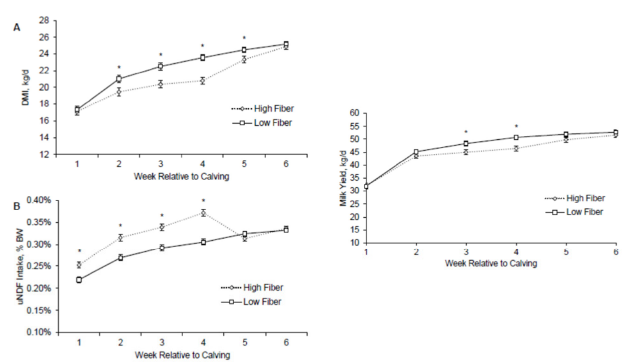

DMI, uNDF240 intake, and milk yield for cows fed High Fiber or Low Fiber diets from d 1 to 28 postpartum. From LaCount et al., 2017.

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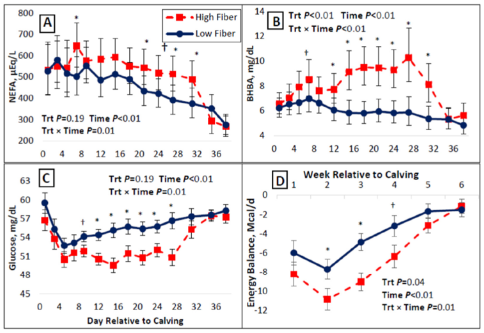

Figure 1. Plasma NEFA (A), BHBA (B), glucose (C), and energy balance (D) by time relative to calving, NEFA and BHBA reported as geometric means with back transformed 95% confidence intervals. Significant differences indicted with an asterisk (*), trends with a cross (†). Energy balance was calculated according to NRC (2001).

LaCount et al., 2017

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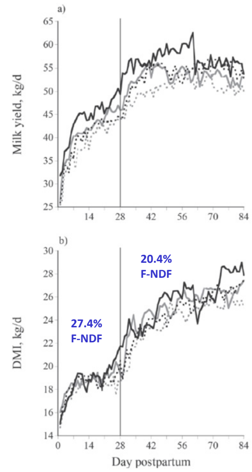

Effects of chromium propionate (CrPr) and corn grain source on (a) milk yield (kg/d) and (b) DMI (kg/d) over time during the treatment (1 to 28 d postpartum) and carryover (29 to 84 d postpartum) periods.

From Rockwell and Allen, 2016

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MP and AA in the fresh cow

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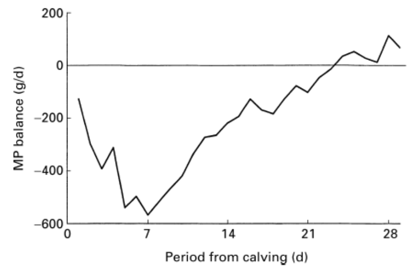

Fig. 1. Calculated metabolizable protein (MP) balance in post-parturient cows (*n* 80) fed on a ration containing (/kg DM) 178 g crude protein (nitrogen × 6·25) and 7·0 MJ net energy for lactation. Individual values were calculated from daily individual measurements of crude protein intake and milk yield, and weekly measurements of milk composition.

Bell et al., 2000

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Increasing MP supply postpartum?

- 8 Holstein cows entering second lactation
- Received either water (control) or casein infused into the abomasum to meet approximate calculated deficit in MP
- Casein was supplied at 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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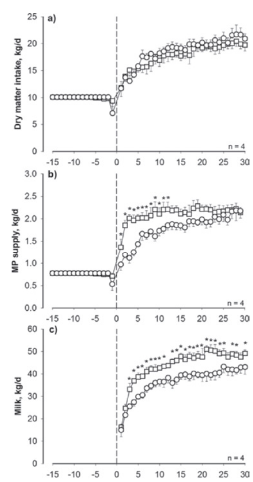

Milk yield was increased (~ 7.2 kg/d) in cows receiving additional MP by casein infusion postpartum

From Larsen et al., 2014. J. Dairy Sci. 97:5608–5622

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J. Dairy Sci. 104:5583–5600
https://doi.org/10.3168/jds.2020-19663

Concurrent and carryover effects of feeding blends of protein and amino acids in high-protein diets with different concentrations of forage fiber to fresh cows. 1. Production and blood metabolites

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Department of Animal Sciences, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster 44691

- 80 Holstein cows (40 PP and 40 MP)
- Four dietary treatments from calving though 25 DIM

% of DM	Deficient MP	Adequate MP	Blend	Blend –fNDF
Corn silage	40.0	39.8	40.1	30.7
Alfalfa silage	12.3	12.6	12.1	9.6
Alfalfa hay	6.8	6.8	6.8	6.6
Corn grain ground	12.2	10.4	10.3	15.4
Soybean meal	17.7	15.0	12.7	12.8
Lignosulfonate SBM	--	11.4	---	---
Protein and AA blend	--	---	13.9	13.8
Soy hulls	4.01	---	---	4.02
Beet pulp	2.99	---	---	2.99
RP-Met	0.10	0.10	0.10	0.10
Mineral/vitamin mix	3.55	3.55	3.55	3.55
CP, %	16.9	20.2	19.9	19.7
NDFom, %	30.2	27.7	28.7	28.3
F-NDF, %	24.3	24.4	24.3	19.6
Starch, %	23.7	22.8	23.7	25.4

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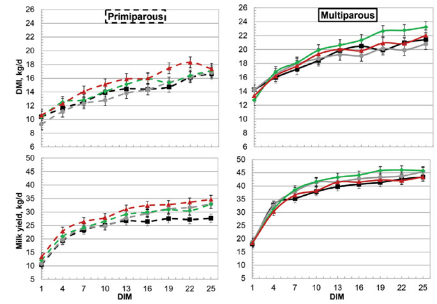

Black squares = Def MP
Gray circles = ADQ MP
Green Diamonds = Blend
Red triangles = Blend-fNDF

Parity by treatment interactions (P < 0.10) for DMI and milk yield; Tebbe and Weiss, 2021

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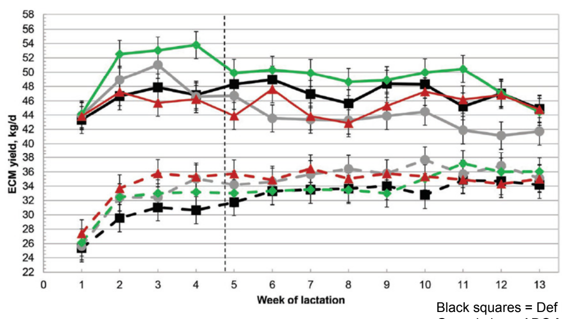

Black squares = Def MP
Gray circles = ADQ MP
Green Diamonds = Blend
Red triangles = Blend-fNDF

Parity by treatment interactions (P < 0.10) for milk yield; Tebbe and Weiss, 2021

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Other areas of opportunity in feeding the fresh cow

- Strategic use of nutrients and feed additives to modulate metabolism, health, and performance
  - RP-choline, RP-Met and RP-Lys, Cr, biotin, improved trace mineral sources
  - Monensin, yeast culture/yeast products, rumen buffers, mycotoxin mitigators
- Sugars in fresh cow diets
- Fatty acid nutrition
  - Essential FA and anti-inflammatory FA
- Macromineral nutrition
  - Ca and Mg

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Summary and implications

- Evolution in fresh cow feeding strategies over next few years – more than just tweaks of the high cow diet
- Starch level, source/fermentability, and NDF fractions all need to be considered when formulating fresh cow diets
  - Higher starch, higher peNDF/uNDF$_{240}$ diets may lead to best outcomes, but can easily limit intake by the second week postcalving if too high in peNDF/ uNDF$_{240}$
  - Heifers may benefit from replacing forage NDF with nonforage fiber sources in fresh diets
- Additional MP with AA balanced appears to improve performance and modulate protein metabolism
- Much opportunity to continue to improve our understanding of how nutritional strategies can improve fresh cow health and performance.

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Transition Cows:Update on DCAD and Stumbling Blocks when Trying to Balance Rations Properly

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Feeding the fresh group for better health and lactation performance

Thomas R. Overton, Ph.D.
Professor and Chair

1

Transition cow nutrition

- The vast majority of controlled research during the past 25 years on transition cow nutrition has focused on the ***dry*** cow
- Most lactating cow nutrition studies did not start until three to four weeks after calving
- Several studies published over the past 5 to 7 years focused specifically on feeding the fresh cow

2

Fresh cow diets – common themes

- Frequently based upon high cow diet
- Some common "tweaks"
  - Lower starch
  - Higher physically effective fiber
    - Usually less than 0.5 kg/d of chopped straw/hay
  - Additional RUP/AA
  - Additional fat
  - Strategic addition of other nutrients (e.g., RP-choline)
- Success usually gauged by farm-level outcomes

3

Fresh diets – a few key questions

- How fermentable should fresh cow diets be?
  - do we need to feed lower starch diets to fresh cows?
  - what about starch fermentability?
- How important is physically effective NDF in fresh cow diets?
- MP supply to the postcalving cow

4

To starch, or not to starch?

5

Several experiments conducted by groups at University of Alberta, Miner Institute, Cornell, and Michigan State University

- Starch level in fresh diet
  - Dann and Nelson, 2011 Cornell Nutrition Conference
  - Sun and Oba. 2014. J. Dairy Sci. 97:1594-1602.
  - McCarthy et al., 2015. J. Dairy Sci. 98:3335-3350.
  - Williams et al., 2015 ADSA-ASAS Joint Annual Meeting
  - Haisan et al., 2021. J. Dairy Sci. 104:4362-4374.
- Starch source in fresh diet
  - Rockwell and Allen. 2016. J. Dairy Sci. 99:4453-4463.
- Starch source and level in fresh diet
  - Dyck et al., 2011. J. Dairy Sci. 94:4636-4646.
  - Albornoz and Allen. 2018. J. Dairy Sci. 101:8902-8915.

6

Dann and Nelson, 2011 Cornell Nutrition Conference

- 72 Holstein cows (2nd and greater lactation)
- Fed high straw controlled energy diet for 40-d dry period
- At calving, one of three starch regimens
  - Low starch (~ 21%) for first 91 DIM
  - Medium starch (~23%) for first 21 d followed by high starch (~25.5%) until 91 DIM
  - High starch (~25.5%) for first 91 DIM

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Table 1. Ingredient and analyzed chemical composition (mean ± standard error) of low, medium, and high starch diets fed to early lactation Holstein cows.

Item	Low	Medium	High
Ingredients, % of DM			
Corn silage	34.6 ± 0.1	34.6 ± 0.1	34.6 ± 0.1
Haylage	11.4 ± 0.4	11.7 ± 0.3	11.4 ± 0.4
Wheat straw	4.1	4.1	4.1
Corn meal	6.9 ± 0.4	11.1 ± 0.1	16.7 ± 0.4
Soybean meal	11.4 ± 0.1	11.9 ± 0.1	11.9 ± 0.1
Soybean hulls	9.7	6.5 ± 0.2	3.2
Wheat middlings	6.1	3.9 ± 0.1	1.8 ± 0.1
Canola meal	3.1	6.1	6.1
AminoPlus	2.5	-	-
Other	10.2 ± 0.3	10.1 ± 0.3	10.2 ± 0.2
Chemical composition			
DM, %	49.5 ± 0.7	50.1 ± 0.9	49.6 ± 0.7
CP, %	17.3 ± 0.1	17.0 ± 0.2	16.7 ± 0.2
NDF, %	35.7 ± 0.3	33.9 ± 0.4	31.9 ± 0.3
Sugar, %	6.1 ± 0.1	5.8 ± 0.1	5.9 ± 0.1
Starch, %	21.0 ± 0.3	23.2 ± 0.3	25.5 ± 0.3
Rumen fermentable starch, %	16.8 ± 0.5	18.9 ± 0.6	20.2 ± 0.5
Digestibility			
24-h NDF, % NDF	58.4 ± 0.6	57.3 ± 0.5	54.0 ± 0.8
7-h starch, % starch	76.5 ± 1.4	76.7 ± 1.2	74.5 ± 1.2

Dann and Nelson, 2011 CNC

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DMI and milk during first 13 wk of lactation for cows fed varying levels of starch in early lactation

Item	Low-low	Medium-High	High-High	SEM	P, Trt	P, Trt x wk
DMI, kg/d	25.2[x]	24.9[xy]	23.7[y]	0.5	0.06	0.09
Milk, kg/d	47.9[ab]	49.9[a]	44.2[b]	1.6	0.04	0.75
SCM, kg/d	47.4	47.9	43.5	1.5	0.09	0.39
NEFA, uEq/L (wk 1-3)	452[aby]	577[ax]	431[by]	43	0.03	0.11
BHBA, mg/dL (wk 1-3)	9.3	8.8	7.8	1.1	0.15	0.97

[ab] Least squares means within a row without a common superscript differ ($P \leq 0.05$).
[xy] Least squares means within a row without a common superscript differ ($P \leq 0.10$).

Dann and Nelson, 2011 CNC

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J. Dairy Sci. 97:1594–1602
http://dx.doi.org/10.3168/jds.2013-7068

Effects of feeding a high-fiber byproduct feedstuff as a substitute for barley grain on rumen fermentation and productivity of dairy cows in early lactation

Y. Sun and M. Oba[1]
Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, T6G 2P5 Canada

- 61 Holstein cows (22 PP and 39 MP)
- Treatments fed from calving through 12 wk postpartum
  - Control (high starch; 29.2% of DM)
  - DDGS (low starch; 19.1% of DM)

% of DM	Control	DDGS
Barley silage	43.0	43.1
Corn grain, rolled	21.6	21.6
Barley grain, rolled	17.3	---
Wheat DDGS	---	17.2
Corn gluten meal	8.3	---
Beet pulp	3.2	12.3
Balance	6.6	5.8
CP, %	17.3	19.4
NDF, %	27.2	30.5
Starch, %	29.2	19.1

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Results

Item	Control		DDGS		SE	P value	
Milk, kg/d	35.3		34.9		1.03	0.83	
Fat, kg/d	1.33		1.31		0.05	0.85	
CP, kg/d	0.97		0.97		0.03	1.00	
ECM, kg/d	35.6		35.4		1.03	0.88	
	PP	MP	PP	MP		TRT	TRT*PAR
DMI, kg/d	14.7	21.3	16.2	20.1	0.45	0.62	<0.001
Rumen pH, mean	6.33		6.30		0.07	0.78	
pH < 5.8, min/d	126		108		49.4	0.80	
Area, pH x min/d	28.8		16.6		11.3	0.53	

Sun and Oba, 2014

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J. Dairy Sci. 98:3335–3350
http://dx.doi.org/10.3168/jds.2014-8820

Performance of early-lactation dairy cows as affected by dietary starch and monensin supplementation

M. M. McCarthy,* T. Yasui,* C. M. Ryan,* G. D. Mechor,† and T. R. Overton*[1]
*Department of Animal Science, Cornell University, Ithaca, NY, 14853
†Elanco Animal Health, Greenfield, IN, 46140

- 70 Holstein cows (21 PP and 49 MP)
- Fed high straw, moderate energy diet during close-up
- At calving, fed one of two rations
  - Low starch (~ 20.9% starch; 35.9% NDF)
  - Higher starch (~ 25.5% starch; 33.6% NDF)
  - Beginning at 22 DIM, all cows fed higher starch ration
- Also fed either 0 mg/d monensin or 400 mg/d prepartum/450 mg/d postpartum via topdress pellet

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Diet Composition, % of DM

Item	Prepartum	Postpartum	
		High Starch	Low Starch
Corn Silage	39.5	—	—
BMR Corn Silage	—	37.0	37.0
Haylage	—	9.3	9.3
Wheat Straw	20.5	11.1	11.1
Corn meal, finely ground	3.9	20.2	9.9
Corn Germ Meal	—	2.4	5.4
Citrus Pulp	6.6	0.9	6.7
Soy Hulls	6.6	—	3.4
Soybean Meal	5.0	5.5	3.7
Canola Meal	4.3	2.6	2.0
Blood Meal	1.0	1.9	1.9
Supplements	6.6	5.3	5.9
Topdress	6.1	4.2	4.2

McCarthy et al., 2015a; *J. Dairy Sci.* 98:3335-3350

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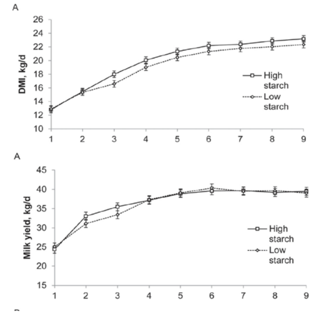

DMI and milk yield for cows fed low vs. high starch postpartum.

From McCarthy et al. 2015

	DMI	Milk yield
	P, starch x wk	P, starch x wk
Wk 1 to 3	0.04	0.002
Wk 1 to 9	0.32	<0.001

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J. Dairy Sci. 99:4453–4463
http://dx.doi.org/10.3168/jds.2015-10344
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Chromium propionate supplementation during the peripartum period interacts with starch source fed postpartum: Production responses during the immediate postpartum and carryover periods

R. J. Rockwell and M. S. Allen[1]
Department of Animal Science, Michigan State University, East Lansing 48824

- 48 Holstein cows entering 2+ lactation
- 2 x 2 factorial
  - control vs. Cr-prop peripartum
  - Dry ground vs. High Moisture corn postpartum through d 28

% of DM	Dry corn	HM corn
Corn silage	25.0	25.0
Alfalfa silage	19.2	19.2
Alfalfa hay	11.8	11.8
Dry ground corn	23.3	---
High-moisture corn	---	23.3
Soybean meal	12.9	12.9
Vitamin-mineral mix	7.8	7.8
CP, %	16.2	16.2
NDF, %	31.4	31.1
Starch, %	26.4	26.5

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Results (d 1 to 28 postpartum)

Item	Dry corn	HM corn	SE	P value
Milk, kg/d	38.5	41.4	1.65	0.02
Fat, kg/d	1.95	1.99	0.13	0.33
TP, kg/d	1.27	1.32	0.06	0.28
ECM, kg/d	47.9	49.5	2.61	0.18
DMI, kg/d	18.1	18.6	0.7	0.53
Cumulative DMI, kg	507	521	20	0.51

Rockwell and Allen, 2016

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J. Dairy Sci. 94:4636–4646
doi:10.3168/jds.2010-4056
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Starch source and content in postpartum dairy cow diets: Effects on plasma metabolites and reproductive processes

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- 40 Holstein cows (16 PP and 24 MP)
- Three dietary treatments from calving until 70 DIM

% of DM	Alfalfa silage	Barley silage	Barley silage + starch
Alfalfa silage	44.7	---	---
Barley silage	---	44.6	40.6
Alfalfa hay	10.0	10.0	10.1
Corn starch	---	---	4.0
Corn	25.4	20.3	4.8
Barley	10.2	4.8	4.8
Balance of mix	10.4	20.3	20.3
CP, %	17.1	18.8	18.4
NDF, %	25.8	30.9	28.8
Starch, %	25.2	23.3	26.7

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Results (d 1 to 70 postpartum)

Item	AS	BS	BS+S	SE	P value	
					Source	Level
DMI, kg/d	19.5	18.4	19.1	0.6	0.31	0.43
Milk, kg/d	35.7	35.8	38.3	1.7	0.49	0.29
Fat, kg/d	1.30	1.34	1.36	0.57	0.44	0.82
TP, kg/d	1.04	1.08	1.14	0.44	0.21	0.28

Source: AS vs (BS + BS+S)
Level: BS vs BS+S

Dyck et al., 2011

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J. Dairy Sci. 101:8902–8915
https://doi.org/10.3168/jds.2018-14843

Highly fermentable starch at different diet starch concentrations decreased feed intake and milk yield of cows in the early postpartum period

Rodrigo I. Albornoz and Michael S. Allen[1]
Department of Animal Science, Michigan State University, East Lansing 48824

- 52 Holstein cows entering 2+ lactation
- 2 x 2 factorial arrangement of treatments (calving to 23 DIM)
  - Low (22%) starch vs high (28%) starch
  - Dry ground corn vs high-moisture corn

	Low starch		High starch	
% of DM	Dry corn	HM corn	Dry corn	HM corn
Alfalfa silage	37.0	37.1	37.7	37.0
Grass hay	8.25	8.35	8.35	8.21
Dry ground corn	27.5	---	35.4	---
High-moisture corn	---	28.1	---	36.2
Soyhulls	11.0	11.0	1.87	2.18
Soybean meal	11.7	11.1	12.2	12.4
Balance of mix	4.5	4.5	4.5	4.5
CP, %	17.2	16.7	17.3	16.9
NDF, %	33.0	33.0	28.3	27.6
Starch, %	21.4	21.9	27.1	27.8

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Results (d 1 to 23 postpartum)

	Low starch		High starch			P value		
Item	Dry	HM	Dry	HM	SE	L	S	L x S
DMI, kg/d	18.6	17.7	20.2	16.3	0.8	0.96	< 0.01	0.07
Cumulative DMI, kg	415	385	445	370	12	0.69	<0.01	0.20
Milk, kg/d	40.6	37.0	41.5	36.6	1.8	0.88	0.02	0.66
Fat, kg/d	1.81	1.70	1.84	1.58	0.10	0.59	0.03	0.40
TP, kg/d	1.24	1.14	1.35	1.09	0.07	0.64	0.01	0.21
ECM, kg/d	45.1	41.9	46.7	40.0	2.2	0.94	0.01	0.37

L = effect of starch level
S = effect of starch source

Albornoz and Allen, 2018

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Studies that had favorable responses to higher starch levels or increased starch fermentability generally had higher forage or forage NDF levels

- Favorable responses
  - McCarthy et al., 2015 (28.2% of DM as F-NDF)
  - Rockwell et al., 2016 (27.4% of DM as F-NDF)
- Neutral or negative responses
  - Albornoz and Allen., 2018 (~22.5% of DM as F-NDF)
  - Sun and Oba, 2014 (Diet was 39.9% forage)
  - Dann and Nelson, 2011 (Diet was ~ 50% forage)
  - Haisan et al., 2021 (~18% of DM as F-NDF)

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Adequate forage NDF; physically effective NDF; $uNDF_{240}$; $peuNDF_{240}$ in rations is probably very important in fresh cows

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A case study

- Cornell study evaluating high or low starch diets for fresh cows
- Controlled energy/high straw dry cow approach starting 28 to 35 days before calving
- At calving, one of two fresh diets until 21 DIM
- First cows that calved onto either ration developed significant health problems; diets adjusted and study re-started

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Table 3. Ingredient and chemical composition of diets (± SD[1]) before and after postpartum ration changes (DM basis)

		Postpartum[2]			
Item	Prepartum	HSLF	LSLF	HSHF	LSHF
Ingredient (% of DM)					
Corn silage, conv.	42.1	---	---	---	---
BMR corn silage	---	46.1	46.1	38.5	38.5
Wheat straw	21.2	3.84	3.84	11.5	11.5
Legume silage	---	9.62	9.62	9.62	9.62
Corn meal, fine	4.28	21.0	10.3	21.0	10.3
Citrus pulp	7.23	1.01	7.15	1.01	7.15
Corn germ meal	---	2.52	5.56	2.52	5.56
Soybean hulls	7.08	---	3.58	---	3.58
Soybean meal	5.27	5.87	3.86	5.87	3.86
Canola meal	4.63	2.73	2.08	2.73	2.08
Blood meal	1.05	1.94	1.93	1.94	1.93
Expeller soy	1.78	1.70	2.34	1.70	2.34
Bypass fat	---	0.77	0.96	0.77	0.96
Anionic suppl.	1.33	---	---	---	---
Sodium bicarbonate	---	0.86	0.85	0.86	0.85
Minerals/vitamins	3.35	1.99	1.72	1.99	1.72
Chemical					
CP, %	13.0 ± 0.8	16.5	15.3	15.5 ± 1.2	15.4 ± 0.8
ADF, %	28.2 ± 1.2	17.7	22.3	22.7 ± 1.2	25.2 ± 1.2
NDF, %	42.9 ± 2.0	26.4	31.5	34.3 ± 1.5	36.9 ± 1.5
Sugar, %	4.9 ± 0.8	3.1	3.9	3.5 ± 0.6	4.5 ± 0.4
Starch, %	17.4 ± 1.2	28.3	22.0	26.2 ± 1.2	21.5 ± 1.0
Fat, %	2.6 ± 0.2	3.2	3.1	4.0 ± 0.2	2.2 ± 0.6
$uNDF_{240}$,[3] % of DM	14.9	7.7	8.9	10.5	10.9

[1] Chemcial composition was analyzed on 4-wk composite samples (n = 1 for HSLF, n = 1 for LSLF, n = 7 for HSHF, and n = 6 for LSHF).
[2] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).
[3] Determined using wet chemistry methods on a single composite sample from each diet (Cumberland Valley Analytical Services, Hagerstown, MD)

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Table 2. Health events for cows fed either high or low starch diets for the first 3 wk postpartum before and after postpartum ration changes.

Item[3]	Postpartum ration[1] HSLF	LSLF	HSHF	LSHF	Parity Primi	Multi	P-values[2] S	F	P
Multiparous, n	3	8	27	28					
Primiparous, n	4	2	11	11					
Clinical ketosis[3]	4	1	4	6	6	9	0.23	0.05	0.14
DA[4]	4	2	0	0	4	2	0.22	<0.001	0.06
RP[5]	1	2	2	1	3	3	0.32	0.05	0.20
Total disorders	9	5	6	7					

[1] HSLF = high starch, low fiber (pre-change); LSLF = low starch, low fiber (post-change); HSHF = high starch, high fiber (post change); LSHF = low starch, high fiber (post-change).
[2] S = effect of starch; F = effect of fiber; P = effect of parity.
[3] Clinical ketosis defined as rapidly decreased milk production and DMI and blood BHBA ≥ 2.6 mmol/L using Precision Xtra, displaced abomasum by auscultation
[4] Displaced abomasum diagnosed by auscultation.
[5] Placenta retained for ≥ 24 h postcalving.

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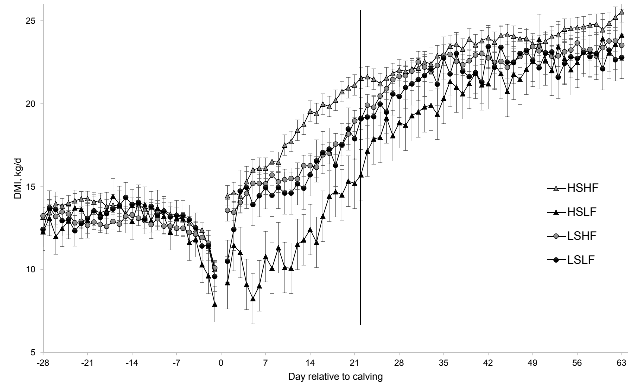

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Plasma metabolites and haptoglobin

Item	Low fiber High starch	Low fiber Low starch	High fiber High starch	High fiber Low starch	SE	P value Fiber	Starch	F x S
NEFA, uEq/L	646	528	406	493	54	0.001	0.67	0.009
BHB, mg/dL	12.31	8.88	9.27	10.70	1.34	0.53	0.30	0.01
Haptoglobin, g/L	1.44	0.94	1.06	0.86	0.18	0.07	0.008	0.25

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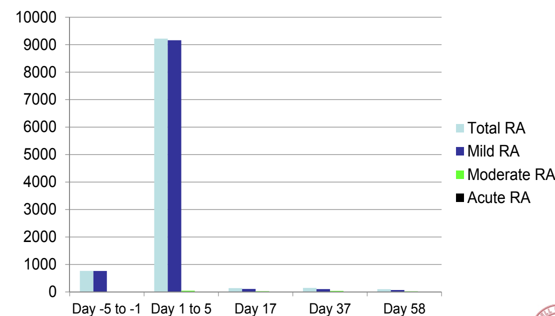
Severity of ruminal acidosis during the transition period (RA total area – pH x min)



Penner et al., 2007

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Fresh cow starch levels and acute phase response (Miner Institute and Zennoh)

- Randomized design with 16 multiparous Holstein cows
- 55-d dry period and fed close-up diet fed starting 21 d before expected calving
- Treatments from calving to 21 DIM
  - Lower starch diet (21% starch, 37% NDF)
  - Higher starch diet (27% starch, 32% NDF)

Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

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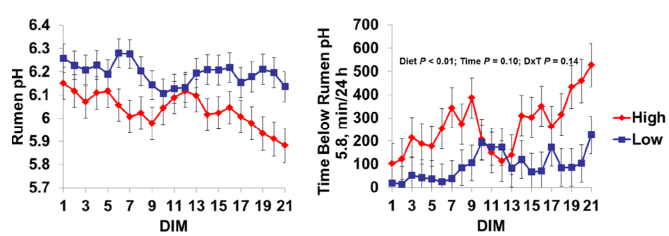
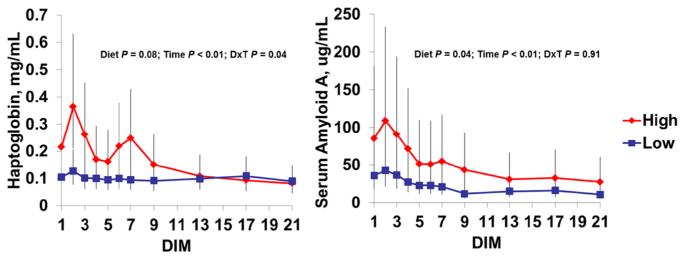
Rumen pH and time below pH 5.8 for cows fed high and low starch fresh diets



Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

30

Acute phase proteins in cows fed high and low starch fresh diets



Williams et al., 2015. J. Dairy Sci. 98(Suppl. 1):741-742.

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Other studies reporting inflammatory markers with starch level or fermentability

- McCarthy et al. 2015b
  - Cows fed higher starch had higher circulating haptoglobin
- Albornoz et al., 2020
  - Cows fed high starch had higher haptoglobin, LBP, and TNF-alpha with HM corn but results were opposite at lower starch level
- Haisan et al., 2021
  - Cows fed high starch (32.8% of DM) had lower haptoglobin and serum amyloid A than cows fed lower starch (25.1% of DM)

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Can you go too far with higher peNDF/uNDF$_{240}$/peuNDF$_{240}$ in fresh cow rations?

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Ingredient and nutrient composition of experimental diets (LaCount et al., 2017)

	Diet		
Item	Prepartum	Low Fiber (LF)	High Fiber (HF)
Ingredients, % of ration DM			
Conventional corn silage	45.21	42.31	38.46
Alfalfa hay	-	10.58	10.58
Straw	20.84	1.15	8.65
Corn meal	2.43	17.64	20.15
Soybean meal	-	6.03	4.73
Wheat middlings	-	4.82	1.58
Amino Plus	5.9	4.34	5.31
Canola meal	3.47	1.61	3.88
Corn gluten feed	1.74	1.61	0.47
Blood meal	2.43	0.95	1.09
Soybean hulls	6.95	2.41	-
Citrus pulp	4.52	-	0.79
Energy Booster	-	1.29	1.58
Rumensin, mg/d[1]	439	365	334
Other	6.4	2.3	2.3
Analyses, % of ration DM			
aNDFom	43.1 ± 0.3	32.8 ± 1.4	35.3 ± 2.3
ADF	29.0 ± 0.5	21.3 ± 1.1	22.9 ± 2.1
Starch	15.6 ± 0.3	24.8 ± 1.7	24.6 ± 2.3
Sugar	3.5 ± 0.4	5.0 ± 0.7	3.9 ± 0.1
Fat	2.3 ± 0.2	3.3 ± 0.2	3.2 ± 0.2
uNDF$_{240}$	12.8 ± 0.5	9.5 ± 0.4	12.2 ± 1.6
peNDF	33.3	21.6	23.2
MP, g/kg DM[1]	89.0	112.1	108.0

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Dry matter intake, milk yield, and milk composition for cows fed low fiber (LF) or high fiber (HF) diets from d 1 to 28 postcalving. LaCount et al., 2017

				P-Value	
Item	LF	HF	SEM	Trt	Trt×Time
Prepartum DMI, kg/d	15.5			-	-
Postpartum DMI, kg/d	21.1	19.4	0.4	<0.01	<0.01
uNDF intake, %BW	0.27	0.32	0.01	<0.01	0.06
Milk yield, kg/d	46.2	44.7	1.0	0.26	0.001
Fat, %	3.89	4.06	1.1	0.55	0.10
Protein, %	3.27	3.20	0.06	0.31	0.41
Lactose, %	4.73	4.69	0.04	0.49	0.39
Total solids, %	12.9	13.0	0.2	0.50	0.57
ECM, kg/d	47.2	46.0	1.1	0.55	0.10
Rumination, min/d	544	543	8	0.56	0.14

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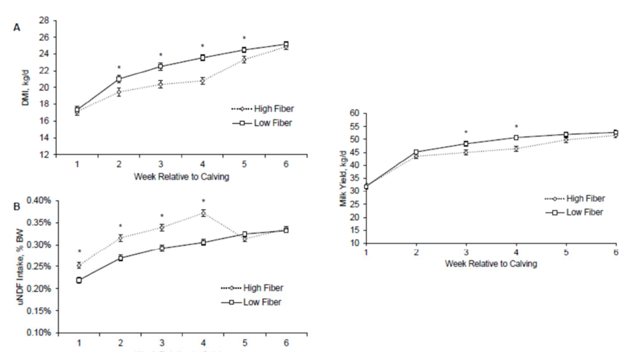

DMI, uNDF240 intake, and milk yield for cows fed High Fiber or Low Fiber diets from d 1 to 28 postpartum. From LaCount et al., 2017.

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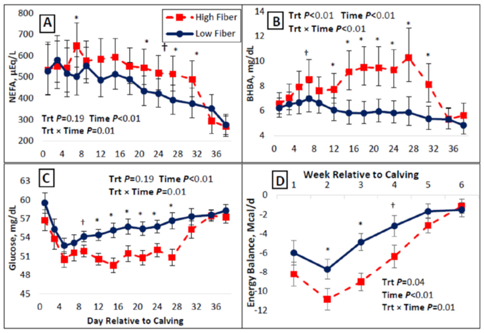

Figure 1. Plasma NEFA (A), BHBA (B), glucose (C), and energy balance (D) by time relative to calving, NEFA and BHBA reported as geometric means with back transformed 95% confidence intervals. Significant differences indicted with an asterisk (*), trends with a cross (†). Energy balance was calculated according to NRC (2001).

LaCount et al., 2017

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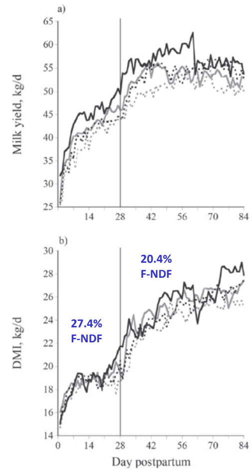

Effects of chromium propionate (CrPr) and corn grain source on (a) milk yield (kg/d) and (b) DMI (kg/d) over time during the treatment (1 to 28 d postpartum) and carryover (29 to 84 d postpartum) periods.

From Rockwell and Allen, 2016

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MP and AA in the fresh cow

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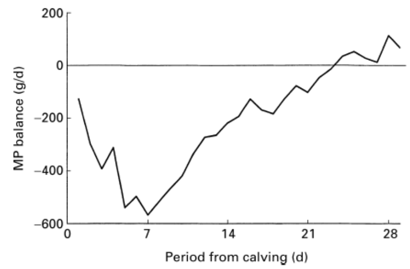

Fig. 1. Calculated metabolizable protein (MP) balance in post-parturient cows (*n* 80) fed on a ration containing (/kg DM) 178 g crude protein (nitrogen × 6·25) and 7·0 MJ net energy for lactation. Individual values were calculated from daily individual measurements of crude protein intake and milk yield, and weekly measurements of milk composition.

Bell et al., 2000

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Increasing MP supply postpartum?

- 8 Holstein cows entering second lactation
- Received either water (control) or casein infused into the abomasum to meet approximate calculated deficit in MP
- Casein was supplied at 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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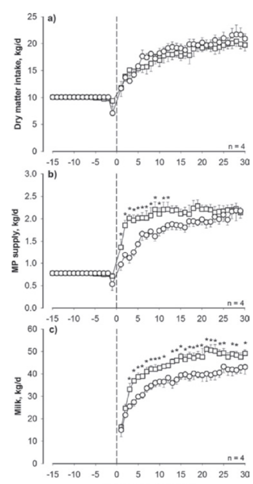

Milk yield was increased (~ 7.2 kg/d) in cows receiving additional MP by casein infusion postpartum

From Larsen et al., 2014. J. Dairy Sci. 97:5608–5622

42

J. Dairy Sci. 104:5583–5600
https://doi.org/10.3168/jds.2020-19663

Concurrent and carryover effects of feeding blends of protein and amino acids in high-protein diets with different concentrations of forage fiber to fresh cows. 1. Production and blood metabolites

A. W. Tebbe* and W. P. Weiss†
Department of Animal Sciences, Ohio Agricultural Research and Development Center, The Ohio State University, Wooster 44691

- 80 Holstein cows (40 PP and 40 MP)
- Four dietary treatments from calving though 25 DIM

% of DM	Deficient MP	Adequate MP	Blend	Blend –fNDF
Corn silage	40.0	39.8	40.1	30.7
Alfalfa silage	12.3	12.6	12.1	9.6
Alfalfa hay	6.8	6.8	6.8	6.6
Corn grain ground	12.2	10.4	10.3	15.4
Soybean meal	17.7	15.0	12.7	12.8
Lignosulfonate SBM	--	11.4	---	---
Protein and AA blend	--	---	13.9	13.8
Soy hulls	4.01	---	---	4.02
Beet pulp	2.99	---	---	2.99
RP-Met	0.10	0.10	0.10	0.10
Mineral/vitamin mix	3.55	3.55	3.55	3.55
CP, %	16.9	20.2	19.9	19.7
NDFom, %	30.2	27.7	28.7	28.3
F-NDF, %	24.3	24.4	24.3	19.6
Starch, %	23.7	22.8	23.7	25.4

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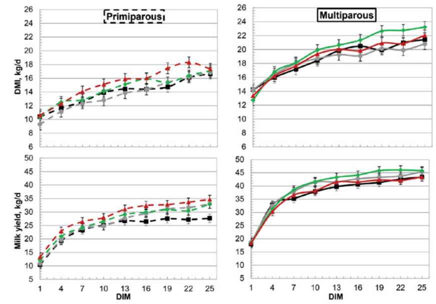
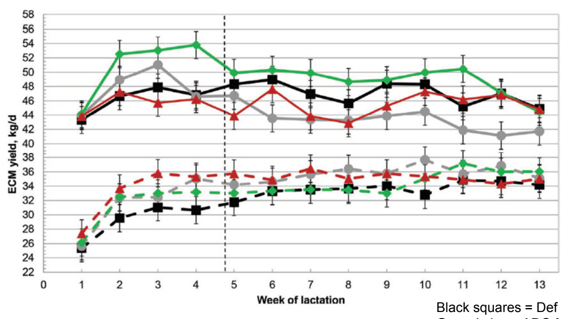


Black squares = Def MP
Gray circles = ADQ MP
Green Diamonds = Blend
Red triangles = Blend-fNDF

Parity by treatment interactions (P < 0.10) for DMI and milk yield; Tebbe and Weiss, 2021

44



Black squares = Def MP
Gray circles = ADQ MP
Green Diamonds = Blend
Red triangles = Blend-fNDF

Parity by treatment interactions (P < 0.10) for milk yield; Tebbe and Weiss, 2021

45

Other areas of opportunity in feeding the fresh cow

- Strategic use of nutrients and feed additives to modulate metabolism, health, and performance
  - RP-choline, RP-Met and RP-Lys, Cr, biotin, improved trace mineral sources
  - Monensin, yeast culture/yeast products, rumen buffers, mycotoxin mitigators
- Sugars in fresh cow diets
- Fatty acid nutrition
  - Essential FA and anti-inflammatory FA
- Macromineral nutrition
  - Ca and Mg

46

Summary and implications

- Evolution in fresh cow feeding strategies over next few years – more than just tweaks of the high cow diet
- Starch level, source/fermentability, and NDF fractions all need to be considered when formulating fresh cow diets
  - Higher starch, higher peNDF/uNDF$_{240}$ diets may lead to best outcomes, but can easily limit intake by the second week postcalving if too high in peNDF/ uNDF$_{240}$
  - Heifers may benefit from replacing forage NDF with nonforage fiber sources in fresh diets
- Additional MP with AA balanced appears to improve performance and modulate protein metabolism
- Much opportunity to continue to improve our understanding of how nutritional strategies can improve fresh cow health and performance.

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The Transition Period: Rethinking an Old Problem
NASEM Nutrient Requirements

Dr. James K. Drackley
University of Illinois Urbana-Champaign

The Transition Period: Rethinking an Old Problem
NASEM Nutrient Requirements

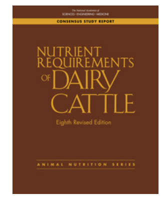
James K. Drackley, Ph.D.

Professor of Animal Sciences
University of Illinois Urbana-Champaign

1

Nutrient Requirements of Dairy Cattle (8th rev. ed.) National Academies of Sciences, Engineering and Medicine (NASEM), 2021

- Replaces "NRC", 2001
- 21 chapters, over 500 pages
- $149.95 (nap.edu)
- New computer model (similar interface), expanded outputs (free download)
- New material as well as extensively revised material from NRC 2001



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Chapter 12
Dry and Transition Cows

3

Changes from NRC 2001

- Updated literature review
- New DMI equations
- Gestation requirement model structure
- Energy requirements and dietary energy concentrations
- Mineral requirements
- Vitamin E requirements

4

Estimated DMI by NASEM 2021

- Equations include parity, diet NDF, and week prepartum
  - Week used because of uncertainty of calving date
- Insufficient data for true meta-analysis
- Insufficient data to evaluate interactions among parity, diet, and time prepartum
- Data from 2001 and all newer data available were used
- Almost all experiments used high forage diets; diets with byproduct NDF sources not represented

5

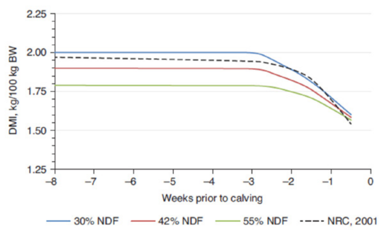
Estimating DMI using NASEM 2021

- **Cows (% of BW):**
  $= 1.47 - [(0.365 - 0.0028 \times NDF)\ week] - 0.035 \times week^2$
  where week = week from calving (i.e., it is negative)
  If cow > 3 wk from parturition, week = -3

- **Heifers:** Cow equation × 0.88
  Insufficient new data, therefore average parity effect from 2001 was retained

6

Estimated DMI by cows using NASEM 2021



7

New DMI equations

For far-off dry cows (>3 wk prepartum)

- DMI will be between 1.8 and 2% of BW
- Negatively correlated with dietary NDF

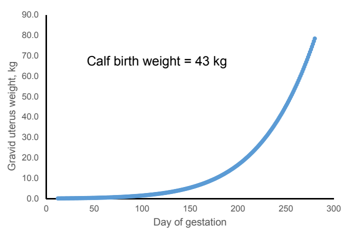
For close-up dry cows (<3 wk prepartum)

- DMI starts decreasing ~2.5 wk prepartum
- Rate of decline negatively correlated with dietary NDF
- At about wk 1 prepartum DMI about the same for all NDF (1.65% of BW)

8

Calculation of gestation requirements

- Mass model for conceptus starts at d 12 of gestation (compared with d 190 in NRC 2001)
- Function of maternal BW (heifer has smaller calf)
- Energy = 0.88 Mcal/kg
- CP = 125 g/kg



9

Gestation energy and protein requirements

	Gestation NEL, Mcal/d		Gestation MP, g/d	
Day of gestation	NRC 2001	NASEM 2021	NRC 2001	NASEM 2021
50	0	0.04	0	3
100	0	0.1	0	13
150	0	0.5	0	43
200	2.7	1.4	199	125
220	3.0	2.0	245	185
250	3.4	3.5	306	320
275	3.8	5.4	357	489

10

Close-up starch, fiber, and energy

- Almost impossible to separate these effects (e.g., as NDF goes up starch and NEL usually go down)
- Increasing prefresh energy (more starch, less NDF):
  - ➢Increases prepartum DMI
  - ➢Generally little effect on postpartum DMI
  - ➢Most studies show no effect on milk yield

11

Use of pre-fresh diet to adapt rumen

- To "help rumen deal with higher starch postpartum diet"

"Based on available data, benefits of feeding a diet of moderate starch and fiber to transition ruminal cells and rumen tissue morphology from a high-forage diet to a higher-starch lactation diet are not evident."

12

NEL concentration of diets: dry cows

Ingredient	% of DM
Corn silage	40.0
Wheat straw	40.8
Corn gluten feed	8.05
Soybean meal	5.9
Canola meal	3.0
Urea	0.30
Minerals and vitamins	1.95

1790 lb, 240 DCC, 30.8 lb/d DMI

- NEL NRC 2001:
  0.63 Mcal/lb
  (19.5 Mcal/d)
- NEL NASEM 2021:
  0.71 Mcal/lb
  (21.8 Mcal/d)

Requirements also increase!

13

Comparison of energy requirements – dry cows

Ingredient	NRC, 2001	NASEM, 2021
NEL maintenance, Mcal/d	11.4	15.2
NEL pregnancy, Mcal/d	3.6	3.1
Total NEL required, Mcal/d	15.0	18.3

1790 lb, 240 DCC, 30.8 lb/d DMI

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Comparison of nutrient balances – dry cows

Ingredient	NRC, 2001	NASEM, 2021
ME balance, Mcal/d	6.3	5.4
NEL balance, Mcal/d	4.5	3.6
MP balance, g/d	219	373

1790 lb, 240 DCC, 30.8 lb/d DMI

Both dietary energy prediction and energy requirements are higher with NASEM 2021.

Must use dietary NEL calculated by NASEM to be accurate!

15

NEL concentration of diets: close-up cows

Ingredient	% of DM
Corn silage	32.1
Wheat straw	36.3
Corn gluten feed	8.2
Soy hulls	6.6
Wheat midds	6.2
Soybean meal	5.8
Canola meal	2.6
Urea	0.25
Minerals and vitamins	1.95

1790 lb, 270 DCC, 28.6 lb/d DMI

- NEL NRC 2001:
  0.65 Mcal/lb
  (18.6 Mcal/d)
- NEL NASEM 2021:
  0.73 Mcal/kg
  (20.9 Mcal/d)

Requirements also increase!

16

Comparison of energy requirements – close-up cows

Ingredient	NRC, 2001	NASEM, 2021
NEL maintenance, Mcal/d	11.4	15.2
NEL pregnancy, Mcal/d	3.6	5.2
Total NEL required, Mcal/d	15.0	20.4

1790 lb, 270 DCC, 28.6 lb/d DMI

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Comparison of nutrient balances – close-up cows

Ingredient	NRC, 2001	NASEM, 2021
ME balance, Mcal/d	5.0	0.5
NEL balance, Mcal/d	3.6	0.3
MP balance, g/d	240	-113

1790 lb, 270 DCC, 28.6 lb/d DMI

Both dietary energy prediction and energy requirements are higher with NASEM 2021.

Must use dietary NEL calculated by NASEM to be accurate!

18

NEL concentration of diets: fresh cows

Ingredient	% of DM
Corn silage	30.0
Wheat straw	1.0
Alfalfa silage	15.0
Corn gluten feed	17.0
Corn grain	25.05
Soybean meal	3.0
Soybean meal, expellers	2.0
Blood meal	2.5
Tallow	2.0
Rumen protected Lys Met	0.2
Minerals and vitamins	2.25

1375 lb, 15 DIM, 46.2 lb/d DMI, 88 lb/d milk

- NEL NRC 2001:
  0.76 Mcal/kg
  (35.1 Mcal/d)
- NEL NASEM 2021:
  0.84 Mcal/kg
  (38.8 Mcal/d)

Requirements also increase!

19

Comparison of energy requirements – fresh cows

Ingredient	NRC, 2001	NASEM, 2021
NEL maintenance, Mcal/d	10.0	12.5
NEL milk, Mcal/d	29.0	29.0
Total NEL required, Mcal/d	39.0	41.5
NEL balance, Mcal/d	-3.9	-3.4

1375 lb, 15 DIM, 46.2 lb/d DMI, 88 lb/d milk

Both dietary energy prediction and energy requirements are higher with NASEM 2021.

Must use dietary NEL calculated by NASEM to be accurate!

20

Summary – diet energy concentrations (Mcal/lb DM)

Cow class	NRC, 2001	NASEM, 2021
Far-off dry cows	0.63	0.71
Close-up dry cows	0.65	0.73
Fresh cows	0.76	0.84

Don't mix systems!

Overall changes in energy balance are small.

21

Summary - Energy

- Energy requirements for NASEM 2021 are about 17-18 Mcal/d NEL for dry cows and about 19-20 Mcal/d NEL for transition cows (mature Holstein).
- Diets will be higher in calculated energy with NASEM 2021 than with NRC 2001.
- Balances will be lower with NASEM 2021 than with NRC 2001 – closer to what is observed in field.

22

Dry cow dietary protein and milk production

- For NRC (2001) most studies fed treatments during entire dry period, not just pre-fresh
- Milk and milk composition during first 3 wk to 17 wk were the primary outcome variables
- In a few studies, diets were as low as 10% CP without effect on milk production (cows)
  - Diet with 10% CP prepartum remained in protein balance at d -10 (Putnam and Varga, 1998)

23

Dry cow dietary CP and milk production

Meta-analysis (Lean et al., 2013)

12 studies, 26 treatment comparisons

Control diets: 9.7 to 14.1% CP (avg. = 12.3)

Treatment diets: 11.7 to 23.4% CP (avg. = 15.9%)

Milk yield first 28 d to 120 d (avg = 65 DIM)

Average increase in milk = 0.1 kg/d (-0.6 to +1.2 kg/d)

24

Dry cow dietary MP and milk production

Meta-analysis (Husnain and Santos, 2019)
27 comparisons for heifers
97 comparisons for cows
Mostly prefresh treatment comparisons
Diets: 9 to 21% CP (avg. = 14.0%)
6 to 10% MP (avg. 9.3% for cows; 6 to 13%)
MP calculated according to NRC 2001

25

Dry cow dietary CP and milk production

- No difference in milk yield for cows
  - Milk protein increased 60 g/1000 g MP intake in cows producing >36 kg/d milk
- Increased milk and milk protein in first lactation cows

(Husnain and Santos, 2019)

26

Protein - NASEM 2001 model

Far-off dry cow and heifer

- ~11% CP (6.5% MP) will ~meet requirement
- 12% CP (7.2% MP) recommended because of limited data and potentially inadequate RDP
- Translates to 864 g/d (DMI 12 kg/d) to 1008 g/d (DMI 14 kg/d)

27

Protein - NASEM 2001 model

Close-up cow and heifer

- ~13% CP (7.8% MP) will meet requirement
- Translates to 936 g/d (DMI 12 kg/d) to 1014 g/d (DMI 13 kg/d)
- Might not be optimum for heifers
- Model ignores MP for colostrum and immune function

28

Amino acid supply – close-up cows

Item	Predicted Supply Mcal or g/d
DE Non-Protein	28
Arg	57
His	27
Ile	66
Leu	96
Lys	86
Met	25
Phe	62
Thr	60
Trp	14
Val	70

Lys:Met = 3.44

Targets (not NASEM):
Lys = 90 g/d
Met = 31 g/d
Lys:Met = 2.9:1

Would likely benefit from rumen-protected Met supplementation

29

Specific minerals/vitamins for transition cows

- Negative DCAD, Ca, P, Mg for hypocalcemia
- Higher vitamin E based on preventing mastitis, RP, and metritis
  - 1000 IU/d for dry cows and 2000 IU/d for prefresh cows (Holsteins)
- No other specific requirements

30

Dietary concentrations (% of DM) required to meet the known requirements for macrominerals

Mineral	NRC, 2001	NASEM, 2021	Recommended[1]
Ca	0.45	0.37	1.5 – 2.0
P	0.23	0.21	0.35
Mg	0.12	0.13	0.40
K	0.52	0.65	1.0
Na	0.10	0.16	0.16
Cl	0.15	0.13	0.7 – 0.9
S	0.20	0.20	0.20 – 0.35

[1] J. K. Drackley recommendation

31

Dietary concentrations (mg/kg of DM) required to meet the known requirements for trace minerals

Mineral	NRC, 2001	NASEM, 2021	Recommended[1]
Co	0.11	0.20	0.20
Cu	13	19	19
I	0.4	0.54	0.54
Fe	13	14	14
Mn	18	41	60
Se	0.3	0.3	0.3
Zn	22	30	60

[1] J. K. Drackley recommendation

32

Dietary supply (IU/d) required to meet the known requirements for vitamins

Vitamin	NRC, 2001	NASEM, 2021	Recommended[1]
A	82,610	81,500	100,000
D	22,530	22,000	25,000
E	1202	2000	2000

[1] J. K. Drackley recommendation

33

No requirement established

- Cr
  - Essentiality recognized but insufficient data to establish an adequate intake
  - Analytical challenges
- Choline
  - Committee acknowledges response to supplementation during transition but declined to establish a requirement
    - Endogenous synthesis
    - Variable results during lactation

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Transition Cow Choline Supplementation: Harnessing Long-term Benefits from Short-term Supplementation

Dr. Heather White
Associate Professor, Department of Animal & Dairy Sciences
University of Wisconsin-Madison

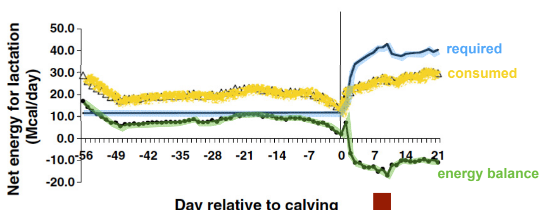
1

Transition Cow Choline Supplementation:
harnessing long-term benefits from short-term supplementation

Dr. Heather White
Associate Professor, Department of Animal & Dairy Sciences
University of Wisconsin-Madison

2

Peripartum Challenges and Opportunities



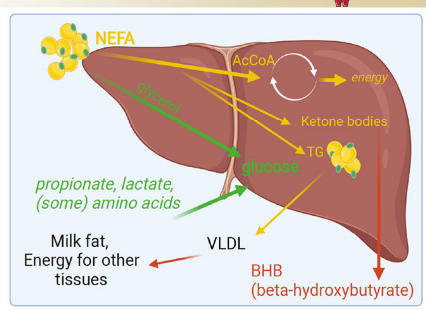
Negative **Energy** Balance
Negative **Macronutrient** balance
Negative **Micronutrient** balance

Grummer, 2008

3

Peripartum Challenges and Opportunities

Nutrients that modulate these pathways can b e beneficial.



Negative **Energy** Balance
Negative **Macronutrient** balance
Negative **Micronutrient** balance

4

Nutrition Can Propagate our Impact

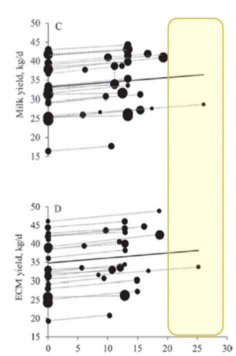
- Impact of RP Choline supplementation on lactation performance
- Mechanism of action to support production
- Impact of supplementing cows with RP Choline on offspring growth and health

5

Choline as a Nutritional Intervention

Choline meta-analysis of
23 transition cow studies;
74 treatment means; 1,938 cows

- Energy-corrected milk: Increased 1.61 kg/day
- Milk fat yield: Increased 0.08 kg/day
- Milk protein yield: Increased 0.06 kg/day
- DMI: Increased pre- and postpartum 0.28 and 0.47 kg/d



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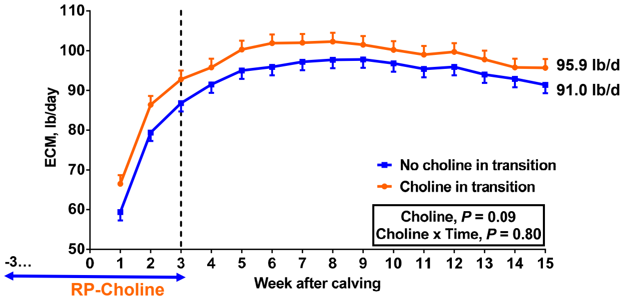
Long-Lasting Benefits of Peripartum Supplementation



7

Effects of Prepartum RPC Dose on Postpartum Performance

- Multiparous cows (n=116) enrolled 21 days prior to calving and fed in electronic feeding gates
- Treatment additives were balanced for non-choline nutrients and amount, and mixed into the TMR

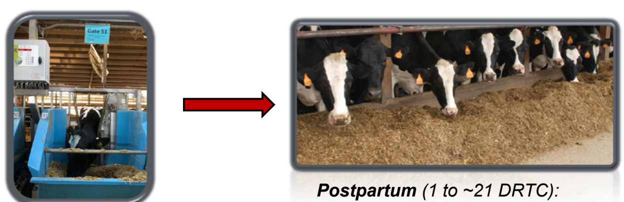
Prepartum:
Individual Cow DMI
Increasing prepartum RPC

- Control: no RPC
- $RPC1_{RD}$: recommended dose (15 g choline ion; ReaShure, Balchem, Corp)
- $RPC2_{RD}$: recommended dose (15 g choline ion; concentrated RPC prototype, Balchem, Corp)
- $RPC2_{HD}$: high dose (22 g choline ion; concentrated RPC prototype, Balchem, Corp)

8

Effects of Rumen Protected Choline Supplementation on Cow and Calf Performance

- Multiparous cows (n=116) enrolled 21 days prior to calving and fed in electronic feeding gates
- Treatments mixed into the TMR

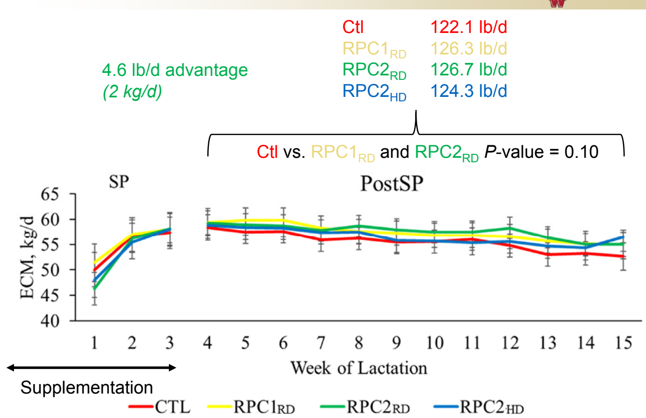


Prepartum:
Individual Cow DMI
Increasing prepartum RPC

Postpartum *(1 to ~21 DRTC):*
Pens of 8, RD of treatments maintained
Lactating *(~21 DRTC to 100 DRTC):*
Mixed pens of 16, common diet

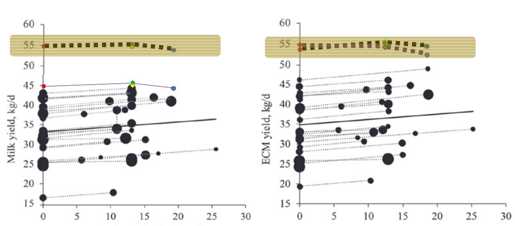
9

Effect of RPC Supplementation on Milk Yield



10

Milk Production compared with Meta Analysis



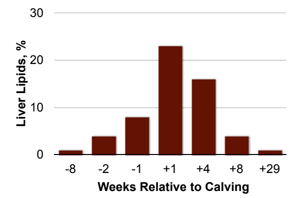
Overall Production Perspective:
During and after supplementation,
Milk yield and ECM were ~30 - 37% greater than Meta-Analysis average

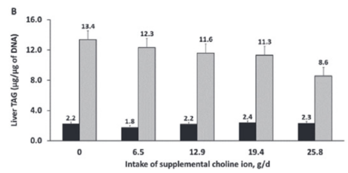
11

What is the mechanism of choline's effects during, and AFTER, supplementation of RP choline??

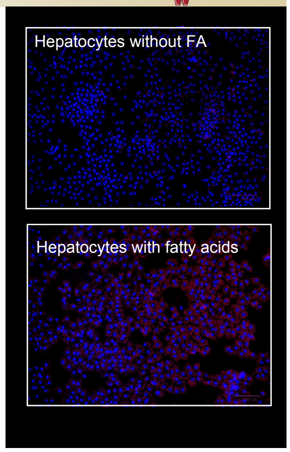
12

Fatty Liver and Cellular Lipids

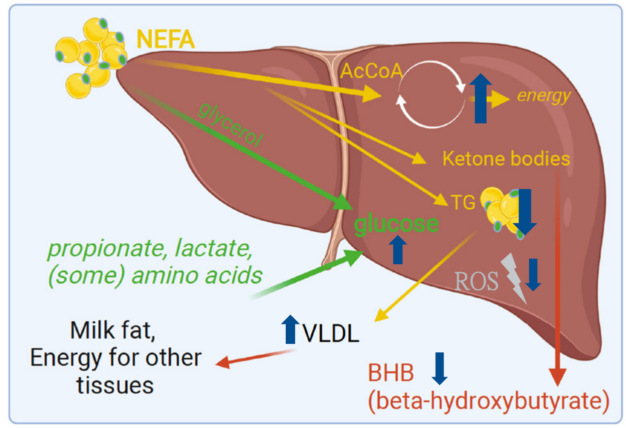




Zenobi et al, 2018

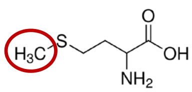


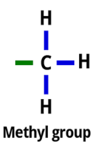
Choline Shifts Pathways in Liver Cells



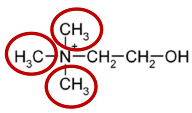
Methyl Group Metabolism

- Methyl groups come from methyl donors
  - methionine (1)

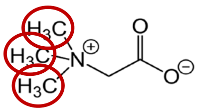




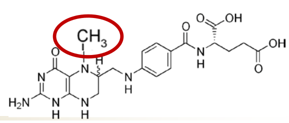
  - choline (3)



  - betaine (3)



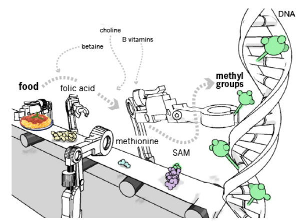
  - folate (5-methyltetrahydrofolate; 1)



Lack of methyl donors across species

=

increased liver inflammation,
decreased liver oxidation,
and
decreased methylation of DNA



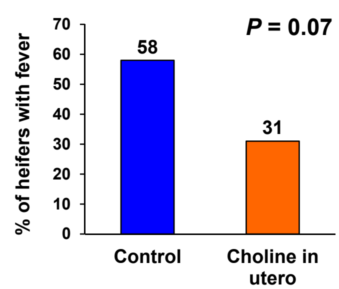
http://learn.genetics.utah.edu/content/epigenetics/nutrition/

What does this mean to the calf in utero?

Calves born to Cows fed RP Choline have increased average daily gain (ADG)

Birth to ~50 weeks of age by heifers		Birth to 5 weeks of age by bulls (given LPS)
2015	2017	2017
0.80 vs. 0.85 kg/d	0.77 vs. 0.82 kg/d	0.44 vs. 0.56 kg/d
P = 0.06	*P* = 0.09	*P* = 0.06
n = 35	n = 46	n = 38

Performance of Choline Calves



↑ Immune Maturation & Function

↑ Lung Development & Maturation

Rectal temperatures measured daily.
Fever: >103.1°F; >39.5°C

Impact of In Utero Supplementation on Calf Growth

OR

Female Holstein Calves

Male and Female Angus x Holstein Cross Calves

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Impact of In Utero Supplementation on Holstein Calf Growth

	Ctl	$RPC1_{RD}$	$RPC2_{RD}$	$RPC2_{HD}$	*P*-value
Birth Weight, lb	87.6	86.7	89.1	86.5	
1 to 2 week					
ADG, lb	0.4	0.6	0.5	0.7	*0.08 Ctl vs $RPC2_{HD}$*
3 to 8 weeks					
ADG, lb	1.9	1.8	2.0	1.8	

Holdorf et al., ADSA, 2022

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Impact of In Utero Supplementation on Calf Growth

	Ctl	$RPC1_{RD}$	$RPC2_{RD}$	$RPC2_{HD}$	*P*-value
irth Weight, lb					
Female	85.4	92.0	84.7	92.4	
Male	100.1	99.9	104.1	97.0	
to 2 week					
ADG, lb	0.6	0.6	0.6	0.4	
to 8 weeks					
ADG, lb					*0.01 trt x time* *0.08 Ctl vs $RPC2_{HD}$*
Female	2.2	2.0	2.2	2.1	
Male	2.1^{b}	2.2^{ab}	2.4^{ab}	2.6^{b}	

Holdorf et al., ADSA, 2022

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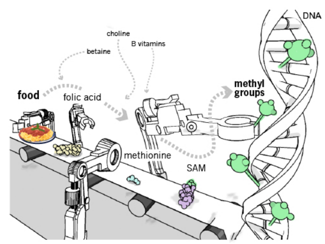
Was there increased DNA methylation with in utero choline exposure?



http://learn.genetics.utah.edu/content/epigenetics/nutrition/

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A Long-Lasting Impact from Choline Supplementation

- Supplementing RP Choline during the transition period increases energy-corrected milk yield even at high production levels
  - Postpartum production relative to prepartum intake, together with long-lasting effects, suggests changes in metabolism or nutrient use efficiency
- Mechanism of RP Choline action is through improved liver function and health
- Supplementation of cows with RP Choline also improves calf growth, immune function, and metabolic health

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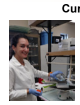
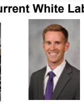
Acknowledgments

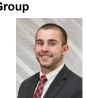
Current White Lab Group



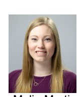
Sophia Kendall, Research Specialist



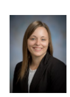
Billy Brown Postdoc



Henry Holdor f



Malia Martin (co-advised)



Faith Baier (Co-advised)

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BALCHEM Real People. Real Science. Real Results.
PURINA

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Questions?

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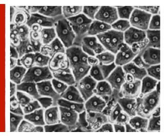

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Relationships Between Transition Cow Nutrition and Management Strategies and Outcomes in Large Dairy Herds in the Northeastern US

Allison L. Kerwin, Ph.D.
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Department of Animal Science, Cornell University

Relationships Between Transition Cow Nutrition and Management Strategies and Outcomes in Large Dairy Herds in the Northeastern US

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Feed Dealer Seminars 2021

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Overview

1. Associations between biomarkers and cow- and herd-level outcomes
2. Associations between nutritional strategies and postpartum outcomes
3. Associations between management strategies and postpartum outcomes

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2

Part I – Identify biomarker thresholds and associations with postpartum outcomes

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3

Background

J. Dairy Sci. 93:546–554
doi:10.3168/jds.2009-2277
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Evaluation of nonesterified fatty acids and β-hydroxybutyrate in transition dairy cattle in the northeastern United States: Critical thresholds for prediction of clinical diseases

P. A. Ospina,* D. V. Nydam,†[1] T. Stokol,† and T. R. Overton*

J. Dairy Sci. 93:1596–1603
doi:10.3168/jds.2009-2852
© American Dairy Science Association®, 2010.

Associations of elevated nonesterified fatty acids and β-hydroxybutyrate concentrations with early lactation reproductive performance and milk production in transition dairy cattle in the northeastern United States

P. A. Ospina,* D. V. Nydam,†[1] T. Stokol,† and T. R. Overton*

J. Dairy Sci. 93:3595–3601
doi:10.3168/jds.2010-3074
© American Dairy Science Association®, 2010.

Association between the proportion of sampled transition cows with increased nonesterified fatty acids and β-hydroxybutyrate and disease incidence, pregnancy rate, and milk production at the herd level

P. A. Ospina,* D. V. Nydam,†[1] T. Stokol,† and T. R. Overton*
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Objective

- Identify thresholds, cow-level performance associations, and herd-alarm levels for metabolic- and inflammation-related biomarkers

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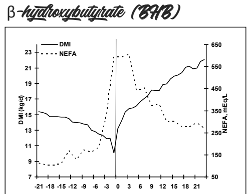
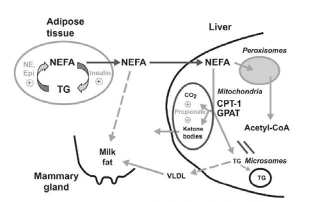
Biomarkers

- *Metabolic-related biomarkers*
  - *Nonesterified fatty acids (NEFA)*
  - β-*hydroxybutyrate (BHB)*



Smith et al., 2004



Modified from Drackley, 1999

Drackley et al., 2006

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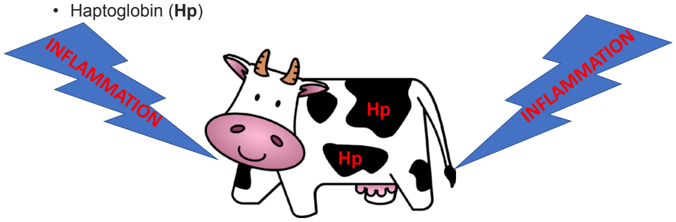
Biomarkers

- Inflammation-related biomarkers
  - Haptoglobin (**Hp**)



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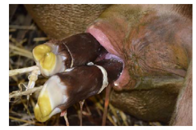
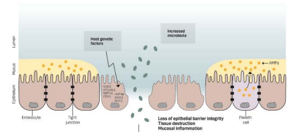
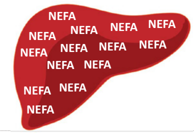
What increases Haptoglobin?







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Skinner et al., 1991; Katoh, 2002; Lomborg et al., 2008; Medzhitov, 2008; Cooke et al., 2011; Huzzey et al., 2011; Horst et al., 2021

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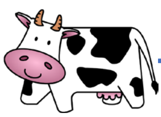
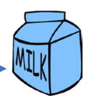
Previous Research



Elevated prepartum NEFA, postpartum NEFA, BHB, and Hp

→ Increased risk of disease incidence

→ Decreased milk production



→ Poorer reproductive performance

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Huzzey et al., 2009; Dubuc et al., 2010; Ospina et al., 2010a; Ospina et al., 2010b; Chapinal et al., 2011; Chapinal et al., 2012; Huzzey et al., 2015; Nightingale et al., 2015

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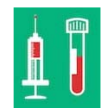
Materials and Methods

n = 72
~58,175 miles

n = 11 to 24



Blood	Postpartum BHB	0 to 21 DIM	n = 1,473
Plasma	Prepartum NEFA	-21 to 0 DIM	n = 1,468
Plasma	Postpartum NEFA	0 to 21 DIM	n = 1,473
Plasma	Postpartum Hp	0 to 12 DIM	n = 988

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Thresholds associated with negative health events

- Prepartum NEFA
  - Threshold: 0.17 mmol/L -> culling within 30 DIM
- Postpartum NEFA
  - Threshold range: 0.46 to 0.59 mmol/L -> Metritis, DA, clinical ketosis, any 3 (DA, metritis, clinical ketosis)
- BHB
  - Threshold range: 0.9 to 1.2 mmol/L -> DA, clinical ketosis, any 3
- Hp
  - Threshold range: 0.45 to 0.96 g/L -> culling within 30 DIM, metritis

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Biomarkers associated with cow-level milk

Biomarker	Threshold	Parity	ME305 difference, kg
Pre- NEFA	≥0.17 mmol/L	Multiparous	-479
Post- NEFA	≥0.46 mmol/L	Primiparous	+446
Post- NEFA	≥0.46 mmol/L	Multiparous	-280
BHB	≥0.9 mmol/L	Primiparous	+552
Hp	≥0.45 g/L	All cows	-492

Multiparous cows

BHB threshold, mmol/L	Difference in ME305, kg	SE	*P*-value
0.7	363	132	0.006
0.8	280	131	0.03
0.9	164	138	0.24
1.0	106	149	0.48
1.1	129	157	0.41
1.2	-2	172	0.99
1.3	-274	184	0.14
1.4	-308	192	0.11
1.5	-376	196	0.06

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Biomarkers associated with cow-level reproductive performance

Post- NEFA (multiparous) ≥0.46 vs. <0.46 mmol/L → 20% decreased risk (*P* = 0.02)

BHB ≥1.1 vs. <1.1 mmol/L → 20% decreased risk (*P* = 0.02)

Hp ≥0.45 vs. <0.45 g/L → 28% decreased risk (*P* < 0.001)

Hp ≥0.45 vs. <0.45 g/L → 0.81 times as likely (*P* = 0.03)

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Herd-Alarm Levels Associated with Disorder Incidence (DA, clinical ketosis)

Biomarker	Proportion of cows	Parity Group	Threshold	Difference in Disorder Incidence	*P*-value
Pre- NEFA	≥30	Multiparous	≥0.17 mmol/L	+6.0%	0.05
Post- NEFA	≥15	Multiparous	≥0.59 mmol/L	+5.8%	0.04
Post- NEFA	≥15	Primiparous	≥0.59 mmol/L	+4.2%	0.02
BHB	≥15	All cows	≥1.2 mmol/L	+8.5%	<0.001
Hp	≥20	All cows	≥0.45 mmol/L	+5.3%	0.05

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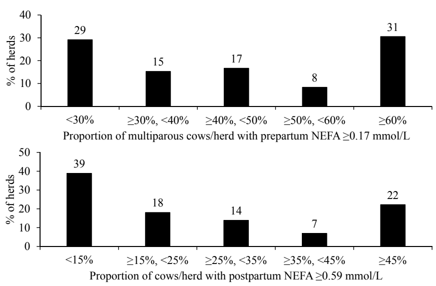
Prevalence of elevated NEFA



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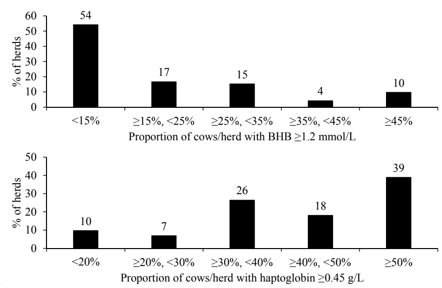
Prevalence of elevated BHB and Hp



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Part II – Associations between transition cow nutritional strategies and postpartum outcomes

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Prepartum Nutritional Strategies

- Controlled energy diet through the dry period has increased in popularity
  - Supported by controlled-research trials for improving postpartum health (Janovick et al., 2011; Mann et al., 2015; Richards et al., 2020)
  - Decreased milk production? (Vickers et al., 2013)
- The "steam-up" approach has largely been abandoned
- Overfeeding energy through the dry period has been associated with:
  - decreased postpartum DMI, increased NEFA and BHB concentrations, and increased disorder incidence (Dann et al., 2006; Janovick et al., 2011; Mann et al., 2015)
  - No evidence that there was a treatment effect on milk yield

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Postpartum Nutritional Strategy

- High starch? Or low starch?
- Varying results on metabolic- and inflammation-related biomarkers
- Hepatic oxidation theory (HOT): Feeding a lower starch diet could result in improved milk production compared to feeding higher levels of fermentable starch (Allen et al., 2009)
  - Supportive: Dann and Nelson, 2011
  - Opposed: Andersen et al., 2003; Rabelo et al., 2003; Rockwell and Allen, 2011; McCarthy et al., 2015)

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Current Challenges

- Recommendations are often driven from controlled research trials or anecdotal observations
- Large-scale data availability is limited
  - Particularly for the periparturient and fresh period
- Previous studies have often been completed in tiestall barns
  - Removes influences of environment and management, potentially resulting in varying outcomes in freestall herds

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Objective

- Identify relationships between dry period and periparturient period nutritional strategies, as characterized by ration contents of starch, forage NDF, or both with:
  - metabolic- and inflammation-related biomarkers
  - health disorders
  - milk production
  - reproductive performance

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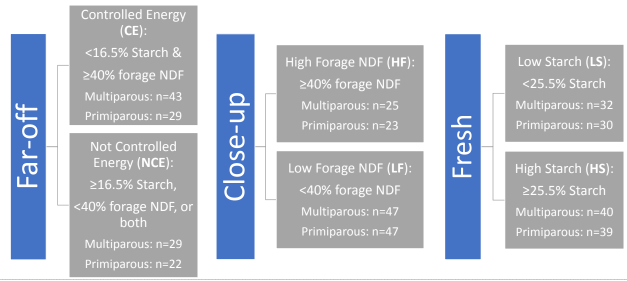
Materials and Methods



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Formulated Nutrient Composition

	Far-off		Close-up		Fresh	
Nutrient	CE	NCE	HF	LF	LS	HS
DM, % of as fed	37.8 ± 5.3	45.3 ± 6.1	42.9 ± 6.3	45.9 ± 5.7	44.9 ± 4.2	45.8 ± 4.2
CP	13.4 ± 2.0	14.0 ± 1.4	13.8 ± 1.1	14.8 ± 1.5	16.5 ± 0.9	16.3 ± 0.9
Soluble protein, % CP	49.4 ± 8.0	38.3 ± 6.9	39.1 ± 6.2	37.0 ± 6.6	36.3 ± 5.0	38.1 ± 5.0
ADF	32.9 ± 2.2	27.3 ± 2.0	29.4 ± 1.5	26.0 ± 2.2	20.6 ± 1.3	19.8 ± 1.3
aNDFom	49.9 ± 3.3	43.3 ± 2.7	46.6 ± 1.9	41.3 ± 3.5	32.9 ± 1.8	31.2 ± 2.1
Forage NDF	48.3 ± 3.8	38.7 ± 3.8	42.7 ± 2.0	34.8 ± 3.4	24.5 ± 1.9	23.6 ± 2.2
Starch	11.8 ± 3.4	17.5 ± 3.9	15.9 ± 2.3	18.5 ± 2.5	23.7 ± 1.4	28.0 ± 1.5
Sugar	2.9 ± 0.8	3.3 ± 1.1	3.3 ± 1.0	3.4 ± 1.0	4.8 ± 1.4	3.7 ± 1.0
NFC	25.2 ± 3.9	30.7 ± 2.7	28.2 ± 2.5	30.6 ± 2.8	37.5 ± 1.6	40.1 ± 1.7
Fermentable starch	7.8 ± 2.6	9.8 ± 2.9	9.4 ± 1.9	10.3 ± 2.0	19.3 ± 3.1	23.4 ± 3.8
Fermentable NDF	13.7 ± 2.5	10.3 ± 2.0	11.2 ± 2.1	9.7 ± 1.7	12.0 ± 1.6	11.0 ± 1.8
Fermentable total carbohydrate	27.1 ± 4.2	25.4 ± 4.5	25.6 ± 4.0	24.8 ± 3.8	39.8 ± 5.4	41.8 ± 5.7
Ether extract	3.28 ± 0.40	3.20 ± 0.52	2.95 ± 0.28	3.61 ± 0.81	5.05 ± 0.71	5.15 ± 0.61
NE_L, Mcal/kg	1.30 ± 0.05	1.37 ± 0.06	1.32 ± 0.06	1.38 ± 0.05	1.59 ± 0.04	1.61 ± 0.04
ME, Mcal/kg of DM	2.02 ± 0.09	2.13 ± 0.09	2.06 ± 0.10	2.15 ± 0.08	2.47 ± 0.06	2.50 ± 0.07
MP, g/kg of DM	70.87 ± 5.62	86.65 ± 7.49	84.43 ± 5.67	91.67 ± 7.94	108.68 ± 6.22	106.58 ± 6.73

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Dry Period – Far-off x close-up

Variable	Prevalence of Elevated BHB	*P*-value
Primiparous cows		
Far-off × close-up		**0.10**
Controlled energy × High forage NDF	7.6 ± 5.1	
Controlled energy × Low forage NDF	15.4 ± 4.3	
Not controlled energy × High forage NDF	16.7 ± 7.9	
Not controlled energy × Low forage NDF	5.8 ± 4.3	
	21-d PR	
Primiparous cows		
Far-off × close-up		**0.07**
Controlled energy × High forage NDF	31.7 ± 2.3	
Controlled energy × Low forage NDF	26.4 ± 2.0	
Not controlled energy × High forage NDF	26.9 ± 3.5	
Not controlled energy × Low forage NDF	30.8 ± 2.0	

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Dry Period – Close-up

Variable	Prevalence of Elevated BHB	*P*-value
Multiparous cows		
Close-up strategy		**0.07**
High forage NDF	13.0 ± 3.6	
Low forage NDF	21.1 ± 2.6	
	Prevalence of Elevated Hp	
All cows		
Close-up strategy		**0.14**
High forage NDF	51.6 ± 3.6	
Low forage NDF	45.0 ± 2.7	
	21-d PR	
Multiparous cows		
Close-up strategy		**0.14**
High forage NDF	22.2 ± 1.4	
Low forage NDF	24.7 ± 1.0	

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Periparturient Period – Close-up x Fresh

Variable	Prevalence of Elevated Post NEFA	*P*-value
Primiparous cows		
Close-up × fresh		**0.05**
High forage NDF × Low starch	16.1 ± 6.7[xy]	
High forage NDF × High starch	28.7 ± 6.5[x]	
Low forage NDF × Low starch	21.9 ± 5.1[xy]	
Low forage NDF × High starch	11.7 ± 4.3[y]	
	Disorder Incidence	
All cows		
Close-up × fresh		**0.009**
High forage NDF × Low starch	18.9 ± 4.0	
High forage NDF × High starch	7.4 ± 4.1	
Low forage NDF × Low starch	9.7 ± 3.2	
Low forage NDF × High starch	17.1 ± 2.7	
	Conception Risk	
Primiparous cows		
Close-up × fresh		**0.14**
High forage NDF × Low starch	40.6 ± 2.8[aby]	
High forage NDF × High starch	50.1 ± 2.7[ax]	
Low forage NDF × Low starch	40.2 ± 2.3[by]	
Low forage NDF × High starch	42.5 ± 1.9[aby]	

[a-b]Means with different superscripts differ ($P < 0.05$).

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Periparturient Period – Fresh

Variable	Prevalence of Elevated BHB	*P*-value
All cows		
Fresh strategy		**0.02**
Low starch	17.8 ± 2.5	
High starch	10.0 ± 2.3	
	Prevalence of Elevated Hp	
Primiparous cows		
Fresh strategy		**0.06**
Low starch	47.2 ± 5.0	
High starch	59.9 ± 4.6	

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Nutritional strategies were *NOT* associated with milk production outcomes

(305-d ME milk ~120 DIM or wk 4 milk yield)

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Part III – Associations between transition cow management strategies and postpartum outcomes

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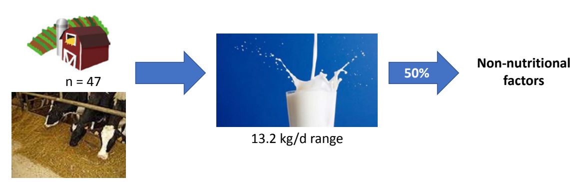
Background



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Bach et al., 2008

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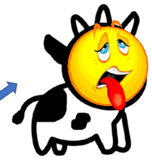
Background

- Non-nutritional management factors
  - Stocking density
  - Pen moves
  - Commingling



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Cook and Nordlund, 2004; von Keyserlingk et al., 2008; Huzzey et al., 2012

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Current Challenges

- Controlled trials typically evaluate the change in 1 management factor, while minimizing other potential stressors
- Limited research has evaluated management factors during the transition cow period and relationships with outcomes

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Objectives

- Identify relationships between putative periparturient management factors at the pen- and herd-level with:
  - metabolic- and inflammation-related biomarkers
  - health disorders
  - milk production
  - reproductive performance

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Management variables assessed

Pen-level

- Stall and bunk stocking density
- Linear water space (cm/cow)
- Penn State Particle Separator
- peNDF, peuNDF240, uNDF240
- Feed pushup frequency
- Feeding frequency
- Commingling

Herd-level

- Vaccination in the calving and fresh pen
- Pre- and postpartum pen moves
- Time spent in the calving and fresh pen
- Time locked up for fresh checks in fresh pen
- Maternity vs. calving pen

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Results – Far-off period

1-% unit increase

Multiparous Cows

- ↓ 0.3-% unit in disorder incidence
- ↓ 0.4-% unit in prevalence of elevated Hp concentrations

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spectrumed.ca

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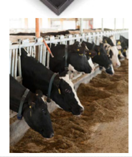
Results – Close-up period

1-% unit ↑

Primiparous Cows

- ↑ 0.1 kg/d at 4th wk of lactation



Primiparous Cows

- ↑ 0.13-% unit in disorder incidence

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spectrumed.ca

36

Results – Fresh period

1-% unit ↑

Multiparous Cows
- ↑ 0.15-% unit in prevalence of elevated NEFA concentrations

peuNDF240, % DM

Primiparous Cows
- ↓ 468 kg of 305-d mature equivalent milk yield at ~120 DIM

peuNDF240, % DM

Multiparous Cows
- ↓ 278 kg of 305-d mature equivalent milk yield at ~120 DIM

uNDF240, % DM

Multiparous Cows
- ↓ 0.9 kg/d at 4 wk of lactation

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Results – Fresh period

Primiparous Cows
- ↓ 8.1-% unit in prevalence of elevated BHB concentrations

Multiparous Cows
- ↓ 18.4-% unit in prevalence of elevated BHB concentrations
- ↓ 7.3-% unit in disorder incidence

Commingling

Primiparous Cows
- ↑ 9.9-% unit in prevalence of elevated BHB concentrations
- ↓ 1.8 kg/d at wk 4 of lactation

Multiparous Cows
- ↓ 18.4-% unit in prevalence of elevated Hp concentrations

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Results – Herd-level

All Cows
- ↑ 12.6-% unit in disorder incidence

Multiparous Cows
- ↓ 4.1 kg/d at 4 wk of lactation

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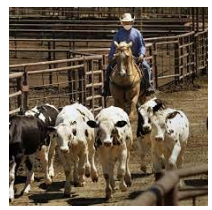
Results – Herd-level



Primiparous Cows

Prepartum pen moves (≥3 vs. < 3)
- ↑ 11.9-percentage unit in prevalence of elevated Hp concentrations

Postpartum pen moves (≥3 vs. < 3)
- ↓ 719 kg of 305-d mature equivalent milk yield at ~120 DIM

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www.journalstar.com

40

Results – Herd-level

>8 h vs. ≤8 h in calving pen

All Cows
- ↑ 22.6-percentage unit in prevalence of elevated postpartum NEFA concentrations
- ↓ 3.6-percentage unit in 21-d PR
- ↓ 4.5-percentage unit in CR
- ↓ 13.7-percentage unit in pregnancy risk to first service

Multiparous Cows
- ↓ 13.0-percentage unit in prevalence of elevated BHB concentrations

Primiparous Cows
- ↑ 19.4-percentage unit in prevalence of elevated BHB concentrations
- ↑ 32.7-percentage unit in prevalence of elevated Hp concentrations

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www.hoards.com

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Takeaways

- In general, elevated concentrations of biomarkers are associated with an increased risk of disorders, decreased milk production, and decreased reproductive performance.
- **BOTH** nutritional and management factors influence transition cow outcomes.
- Feeding a **controlled-energy far-off, high forage NDF close-up, and high starch fresh** diet to **primiparous** cows maximized reproductive performance, minimized the prevalence of elevated BHB, and reduced disorder incidence.
- Feeding a **high forage NDF close-up and high starch fresh** diet to **multiparous** cows resulted in a decreased prevalence of elevated BHB concentrations and reduced disorder incidence.

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Takeaways

- Maximize close-up bunk space.
- Maximize bunk space, avoid commingling, increase the feeding frequency, and avoid high peuNDF240/uNDF240 diets during the fresh period.
- Avoid vaccination in the calving pen, minimize pre- and postpartum pen moves, and avoid long stays (≥8 h) in calving pen after parturition.
- Due to limited data and contradicting results, further research is needed to evaluate management factors.

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Acknowledgements

Study Collaborators
- **Dr. Daryl Nydam**
- **Dr. Buzz Burhans**

Participating farms, nutritionists, and veterinarians

Numerous people who assisted with data collection

NY farm viability INSTITUTE

POULIN GRAIN Leading Animal Nutrition

USDA National Institute of Food and Agriculture U.S. DEPARTMENT OF AGRICULTURE

Elanco

Phibro

Cornell CALS College of Agriculture and Life Sciences

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Feed Intake and Feed Efficiency: Can We Make More With Less?

Dr. Heather White
Associate Professor, Department of Animal & Dairy Sciences
University of Wisconsin-Madison

1

Feed Intake and Feed Efficiency: Can we make more with less?

Dr. Heather White
Associate Professor, Department of Animal and Dairy Sciences
University of Wisconsin-Madison

2

Feed Intake and Feed Efficiency

The simply story. . . .

- Cows eat an amount of feed
- Cows produce a volume of milk

Feed Efficiency = kg milk / kg dry matter intake

3

Feed Intake and Feed Efficiency

Things are rarely as simply as they seem. . . .

- Cows eat an amount of feed, but they also eat an amount of energy (and nitrogen, nutrients, etc.)
- Cows produce a volume of milk but depending on components, this volume has a different energy amount/content and potentially a different economic value
- We feed cows even when they aren't producing milk
- Given this, there are actually many possible ways to express feed or milk efficiency

Feed Efficiency =
FCM / kg DMI
Mcal milk / kg DMI
Milk N / feed N
$ Milk / $ Feed
Feed Saved

4

How do we measure?

- Feed intake?
- Milk yield?
- Milk composition?

by farm? by pen? by cow?

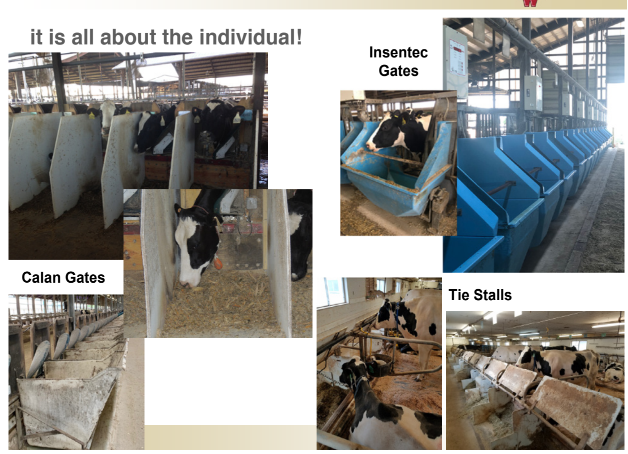
We can collect a lot of pen level feed efficiency data easily,

but that doesn't help us select for feed efficiency or to understand sources of individual animal variance. . .

5

How do we measure in research?

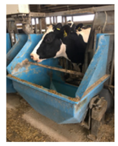
it is all about the individual!

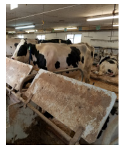


6

What could go wrong?

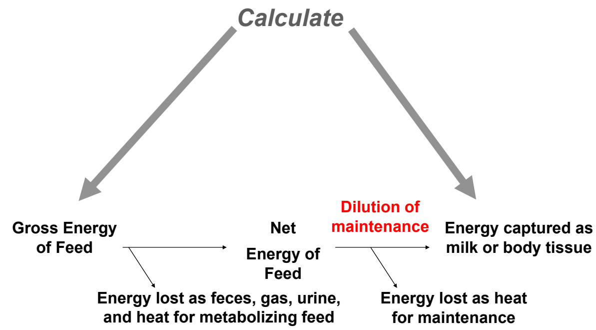
- Cows can appear to be very feed efficient if they steal feed from other cows
  - Result: we select for the most dominant cows
  - Solution: modify facilities to prevent stealing and monitor data closely
- Cows can appear to be very feed efficient if they mobilize body stores to make up energy deficits
  - Result: we select for cows that lose excessive BCS
  - Solution: we measure RFI during mid-lactation and we account body weight change
- Cows can appear less efficient if they spill water into their feed and their feed refusals have more moisture than we account for
  - Result: we select for "neat" cows
  - Solution: modify tie-stalls to prevent





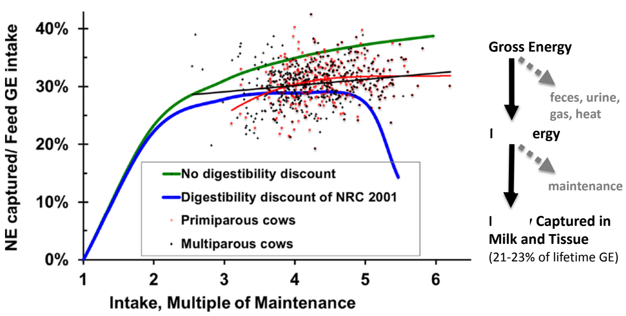
7

What do we do with all this individual cow data?



8

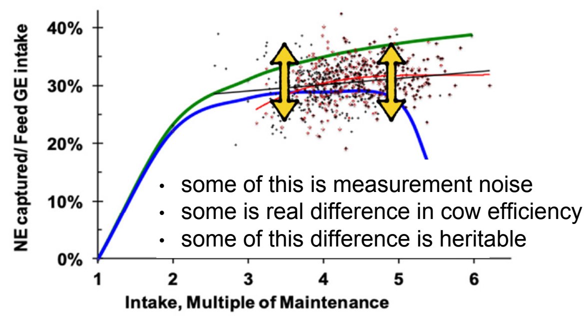
Gross Feed Efficiency vs. Residual Feed Intake



maintenance requirement is about 10 Mcal NE (25 Mcal GE, or 6 kg of feed) and each multiple is about 15 kg of extra milk

9

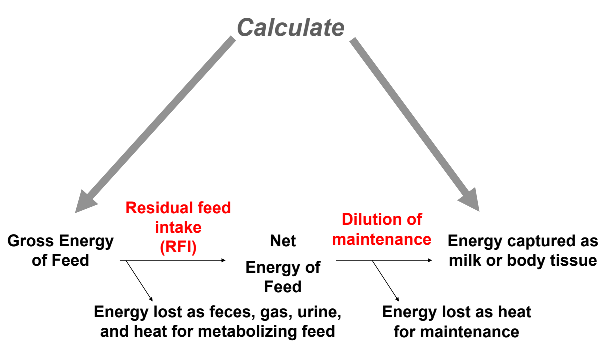
Gross Feed Efficiency vs. Residual Feed Intake



- some of this is measurement noise
- some is real difference in cow efficiency
- some of this difference is heritable

10

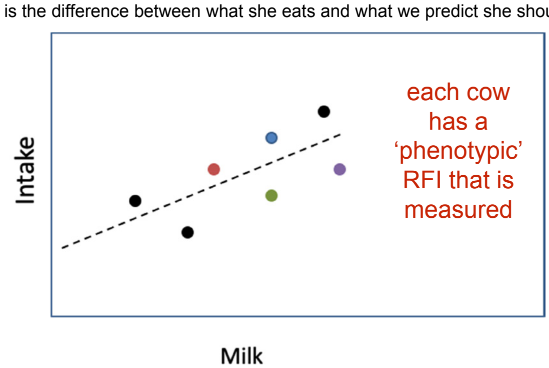
What do we do with all this individual cow data?



11

Residual Feed Intake (RFI): in a simplistic sense

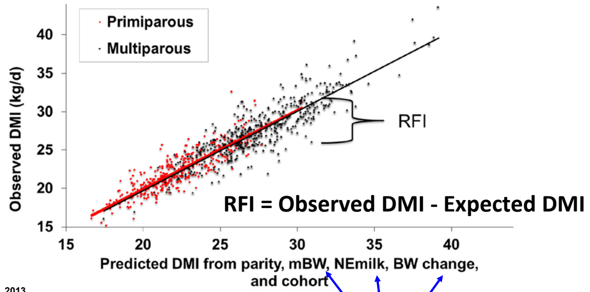
RFI is the variance that is not explained by dilution of maintenance.
It is the difference between what she eats and what we predict she should eat.



Example shown without digestion depression; constant marginal efficiency

12

Residual Feed Intake (RFI): in a realistic sense



VandeHaar, 2013

Energy Sinks: Milk, Maintenance, Weight Gain/Loss

A negative RFI is what we want!
However, there is more to efficiency than RFI.
We also want high production and healthy cows.

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Feed Saved

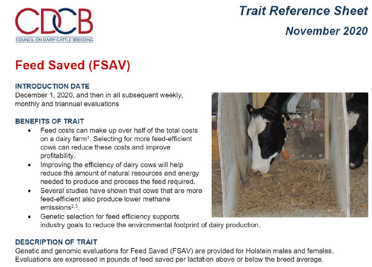
- Although RFI is what we use in research, the real-life outcome is 'Feed Saved'
  - Feed Saved = lb of DM saved by more efficient cows

HOARD'S DAIRYMAN

NEWS BUZZ E-SOURCES IN HOARD'S BLOGS YOUTH BOOKSTORE

Learn more about the new trait "Feed Saved"

BY KRISTEN PARKER GADDIS, COUNCIL ON DAIRY CATTLE BREEDING



CDCB
COUNCIL ON DAIRY CATTLE BREEDING

Trait Reference Sheet
November 2020

Feed Saved (FSAV)

INTRODUCTION DATE
December 1, 2020, and then in all subsequent weekly, monthly and triannual evaluations

BENEFITS OF TRAIT
- Feed costs can make up over half of the total costs on a dairy farm[1]. Selecting for more feed-efficient cows can reduce these costs and improve profitability.
- Improving the efficiency of dairy cows will help reduce the amount of natural resources and energy needed to produce and process the feed required.
- Several studies have shown that cows that are more feed-efficient also produce lower methane emissions[2,3].
- Genetic selection for feed efficiency supports industry goals to reduce the environmental footprint of dairy production.

DESCRIPTION OF TRAIT
Genetic and genomic evaluations for Feed Saved (FSAV) are provided for Holstein males and females. Evaluations are expressed in pounds of feed saved per lactation above or below the breed average.

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Limitations

- We are limited by
  - The rate at which we can collect individual cow feed intake and energy output PHENOTYPES
    - Expensive and time-consuming
    - Restricted to a handful of research stations across the country and a few dozen around the world
  - Collection of phenotypes from genetically progressive cows
    - Data becomes outdated quickly
- We are not limited by genotypes. . . .

How do we measure the phenotype in a more high-throughput manner?

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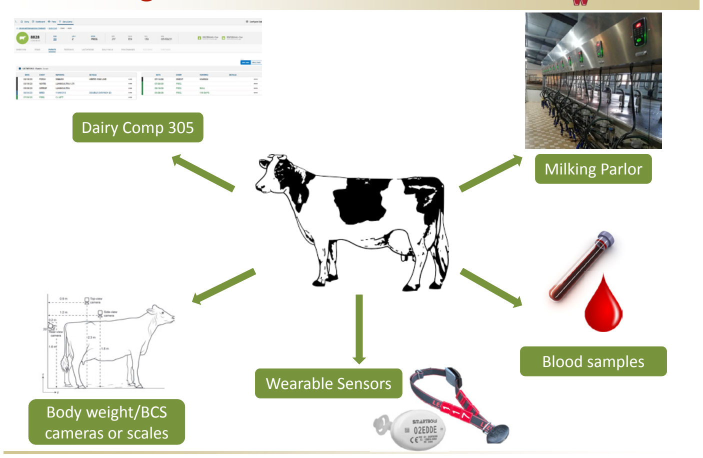
Predicting Feed Intake and RFI



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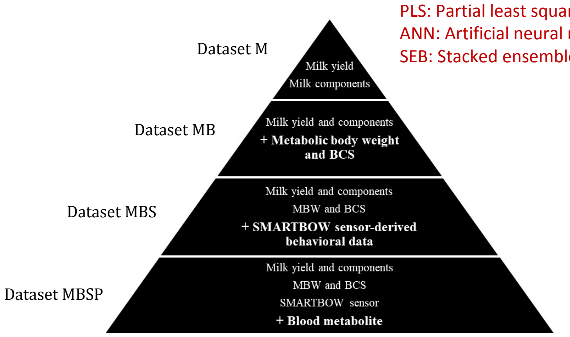
Predicting Feed Intake and RFI

MLR: Multiple linear regression
PLS: Partial least squares regression
ANN: Artificial neural networks
SEB: Stacked ensemble



124 mid-lactation cows (102 multiparous, 22 primiparous) were enrolled across two replicates of 45 d duration

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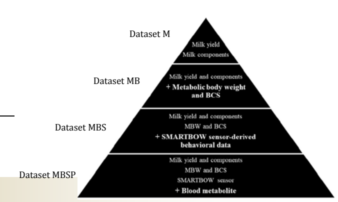
Predicting Feed Intake and RFI

Item[1]	R^2	CCC	RMSEP, kg/d
Multiple linear regression			
Dataset M	0.67	0.80	2.16
Dataset MB	0.80	0.89	1.68
Dataset MBS	0.82	0.90	1.59
Dataset MBSP	0.82	0.90	1.59
Partial least squares			
Dataset M	0.64	0.78	2.26
Dataset MB	0.78	0.88	1.74
Dataset MBS	0.79	0.89	1.71
Dataset MBSP	0.78	0.88	1.76
Artificial neural network			
Dataset M	0.64	0.80	2.31
Dataset MB	0.79	0.88	1.75
Dataset MBS	0.81	0.90	1.64
Dataset MBSP	0.78	0.88	1.78
Stacked ensemble			
Dataset M	0.65	0.79	2.21
Dataset MB	0.77	0.87	1.81
Dataset MBS	0.78	0.87	1.77
Dataset MBSP	0.76	0.87	1.82



Martin et al., 2021

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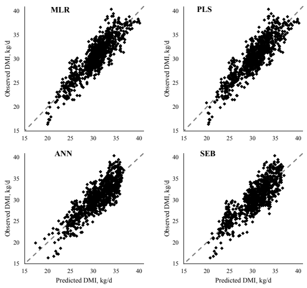
How much data do we need?



- Reasonable predictions were built on 6 wk of milk, body size, and sensor data
- Use of 1 wk of data only marginally reduced predicted accuracy
  - Ex. CCC of 0.90 -> 0.88
- None of the approaches predicted RFI accurately
- Still not practical on privately-owned dairy farms

Can we predict DMI with a "DHI-test worth of data"?

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Single day DMI predictions

- Compiled 315 single-day DMI observations from mid-lactation Holstein cows
  - A morning milk sample with macronutrients and milk fatty acids
  - Body weight and BCS
  - PTA
- Multiple linear regression

Model	Model candidate variables
B	Milk yield and components MBW, BCS, Lact. #, DIM
BY	Model B + Fatty acid yields
BYPE	Model B + Fatty acid yields, Prod. & Eff. PTA

Brown et al., under review; ADSA 2022

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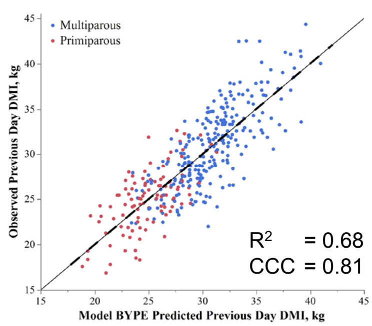
Single day DMI predictions



- Explained 81% of variance in DMI with single-day, DHI-style data
- Ability to more accurately predict DMI could support management and nutrition decision-making on farm
- Can we do better??

Brown et al., under review; ADSA 2022

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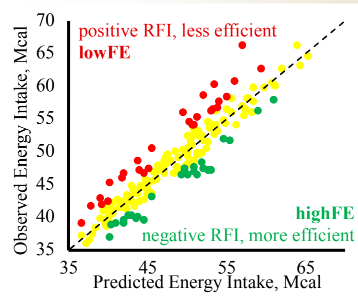
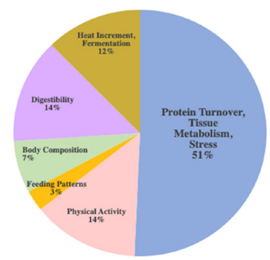
Sources of Variance in RFI





- Post-absorptive nutrient utilization is one of the sources of individual animal variance in RFI
  - Is metabolism different between high and low feed efficient cows?
  - Does better matching nutrient needs influence feed efficiency?

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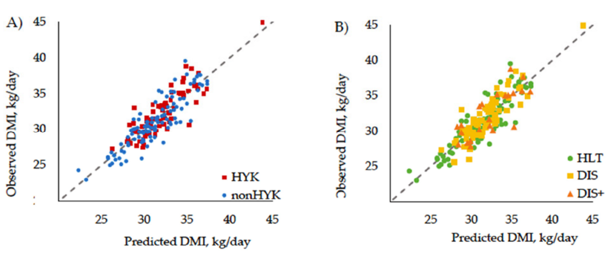
RFI and Postpartum Health



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RFI and Nutrient Use Efficiency

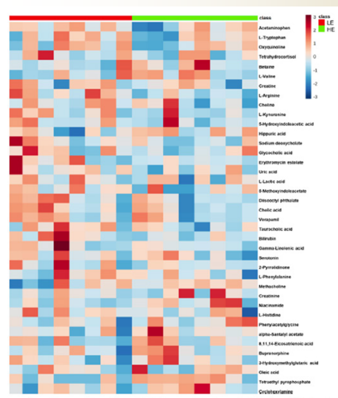
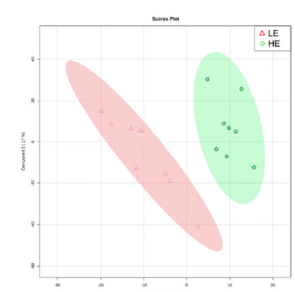


Figure 3. Clustered heatmap of the 39 differential blood plasma metabolites between low feed efficient (LE; red; n = 8) and high feed efficient (HE; green; n = 8) mid-lactation multiparous dairy cows enrolled in a 45-day feed efficiency study. The color scale depicts the scaled concentration of the metabolite.



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Take-Home Messages

- Precision is key for determining phenotypic residual feed intake
- RFI is the difference in what the cow ate vs. what we predict she should have eaten; Feed Saved is the 'tangible' trait
- Predicting feed intake may help inform management and nutrition decisions on farm and increase throughput of FE research
- There are many biological sources of RFI variance and understanding their contribution will help further clarify animal to animal differences
  - Postpartum HYK or other health disorder does not impact mid-lactation RFI
  - Understanding post-absorptive nutrient use and metabolism differences between high and low feed efficient cows may allow us to maximize feed efficiency and metabolic health
  - Many others currently under investigation: feeding behavior, feed bunk competition, starch content, etc.

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Acknowledgements

- UW-Madison Feed Efficiency Team:
  - Francisco Penagaricano, Kent Weigel, Heather White
  - Malia Martin, Jessica Cederquist, Michael Moede, Jessica Mehre, Holly Muth
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- **FFAR** (RC109491-RC110027) and **CDCB**
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  - Partners: Joao Durr and Kristen Parker-Gaddis, Council for Dairy Cattle Breeding

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Utilizing Alternative Feedstuffs in Dairy Rations for Profit & Sustainability

Dr. Gail Carpenter
Department of Animal Science
Iowa State University

Utilizing Alternative Feedstuffs in Dairy Rations for Profit & Sustainability

DR. GAIL CARPENTER
DEPARTMENT OF ANIMAL SCIENCE, IOWA STATE UNIVERSITY

1

What are "alternative feeds"?

- Alternative feeds
  - Byproducts/ Coproducts
  - Alternative forages
    - Biomass crops
    - Cover crops
    - Etc.

2

Feed is expensive!

Hoard's Dairyman
5 hrs

As shelled corn prices are a couple dollars higher per bushel compared to prior years, dairy farmers are asking what alternatives and strategies could be considered to reduce feed costs without sacrificing milk yields or components.

on energy and starch levels

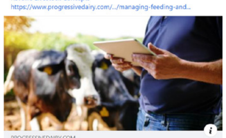
Feed ingredient	Digestible energy (Mcal/kg)	Starch (%)
Shelled corn, dry, coarse grind	3.01	70.4
Shelled corn, dry, medium grind	3.46	70.4
Shelled corn, dry, fine grind	3.55	70.4
Shelled corn, high moisture, 28% DM	3.70	70.9
Corn screenings	3.46	65.6
Corn and cob meal (ear corn), dry	3.35	62.1
Snaplage with variable plant material	3.26	56.7
Corn hominy	3.50	55.6
Corn silage, immature, 31% DM	2.93	30.2
Corn silage, typical, 35% DM	2.93	32.9
Corn silage, mature, 39% DM	2.88	35.5

HOARDS.COM
Faced with $7 corn

Progressive Dairy
March 6 at 12:00 PM

Producers need to be asking questions on an ongoing basis to see where operational and feed costs are and where opportunities exist for improvement.

Reveille Livestock Concepts
https://www.progressivedairy.com/.../managing-feeding-and...

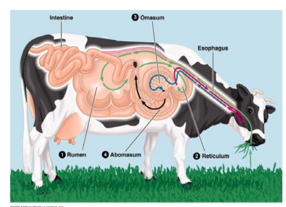


PROGRESSIVEDAIRY.COM
Managing feeding and production costs: What does it cost to reduce your cost?

3

Carbohydrates in the ruminant

- Convert unavailable carbon into highly digestible protein for human consumption
- Utilize a wide variety of forage sources as long as sugar polymers are present
- VFA are produced from microbial digestion
  - Cellulose → acetate, butyrate → lipogenic
  - Starch → propionate → glucogenic



4

Carbohydrates in the ruminant

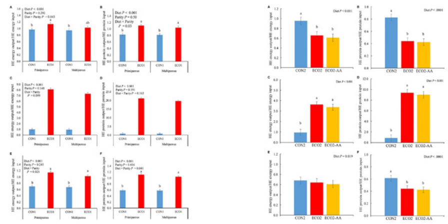
- Variation in digestibility based on factors such as maturity and plant genetics
  - ↑ biomass → ↓ available carbon
- Susceptibility to mold & toxins
- Palatability in TMR

5

Feed vs. Food?

6

Alternative feedstuffs…more sustainable?



Takiya et al., 2019

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Consider producer motivations

	Heifers	Lactating	Dry
1.	Performance*	Performance	Health
2.	Health	Health	Performance*
3.	Simplicity	Cost*	Simplicity
4.	Cost	Simplicity	Cost*
5.	Nutrient management**	Nutrient management**	Nutrient management**

*Lower ranked in western provinces
**Higher ranked in western provinces

Gee et al., 2021

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What are "alternative feeds"?

Alternative feeds
- **Byproducts/ Coproducts**
- **Alternative forages**
  - **Biomass crops**
  - **Cover crops**
  - **Etc.**

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9

What are coproducts?

Cows require nutrients, not ingredients

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Consider the following…

- **What byproducts are you seeing?**
- **How many producers are feeding byproducts? Coproducts?**
- **What are your best practices for incorporating new feeds?**

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11

What are "alternative feeds"?

Alternative feeds
- **Byproducts/ Coproducts**
- **Alternative forages**
  - **Biomass crops**
  - **Cover crops**
  - **Etc.**

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12

What are the “alternatives”?

- Cover crops
- Cocktail mixes
- Biomass crops

✓ Beware of antinutritional factors
✓ Consider appropriate allocation

13

Biomass forages

DAIRY at GUELPH CANADA'S DAIRY UNIVERSITY
Ontario

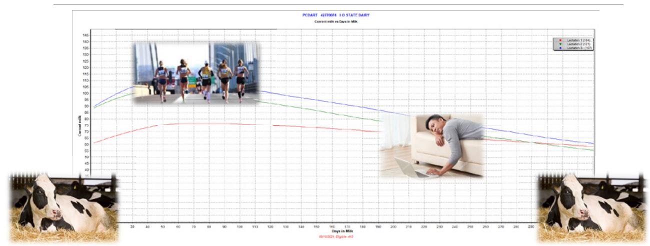
14

Most forages can be useful!*

*Assuming they aren’t spoiled or otherwise gross.

15

Most forages can be useful!*



*Assuming they aren’t spoiled or otherwise gross.

16

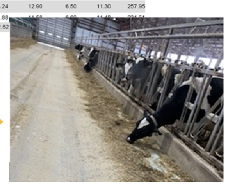
Three Rations

- Inventory/storage
- Frequency of feeding
- Frequency of push-up
- Stocking density
- Bunk availability
- Reduce long forage PS
- Liquid (water or wet molasses)
- Remove refusals

Ration Analysis — PURINA ANIMAL NUTRITION, LLC — Kristina Weld
Iowa State University
ISU Dairy
HERDSMART OUTCOME MODELING
Prepared on:May 10, 2021

Hol Lact decrease CS - Ingredient Detail

Ingredient Name	AF lb	% of AF	DM lb	% of DM	lb/ton AF
CS '20 Bunk1 37DM 33Starch 031121	46.37	45.19	17.16	29.84	903.86
Master Mix 5.7.21	31.13	30.33	27.25	47.38	606.68
Big J Smith 2nd 49dm19cp 152/159RFVQ 04-21	13.24	12.90	6.50	11.30	257.95
Big Brekke 4 21cp 189/208 - 04/21	11.88	[illegible]	[illegible]	[illegible]	[illegible]
Total	102.62	[illegible]	[illegible]	[illegible]	[illegible]



17

Managing rumen fill: peuNDF240

uNDF240
- Undigested NDF
- 0.35-0.40% of BW

peNDF
- Physical effectiveness factor (pef) × NDF
- 21-23% of diet DM

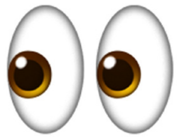
uNDF240 is static, peNDF is not!

Grant et al., 2019. The Nutritionist webinar.

18

Monitoring new rations

- Feed intake
- Cud chewing
  - When cows are resting after eating, at least 50% should be ruminating
  - Can monitor rumination with sensors
- Manure consistency
- Milk components
  - Milk fat should stay the same or increase
  - Consider monitoring *de novo* fatty acids



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Consider the following…

- What alternative forages are you seeing?
- What questions are producers asking about forages?
- What are your best practices?

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Food for thought

- What else can cows recycle?
- How can we prevent bottlenecks in alternative feed utilization?
  - Additives (e.g., enzymes, yeast, amino acids)
  - Supplemental nutrition (e.g., sugar, fat)

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Where to next?

Dr. Gail Carpenter
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(517) 204-4957

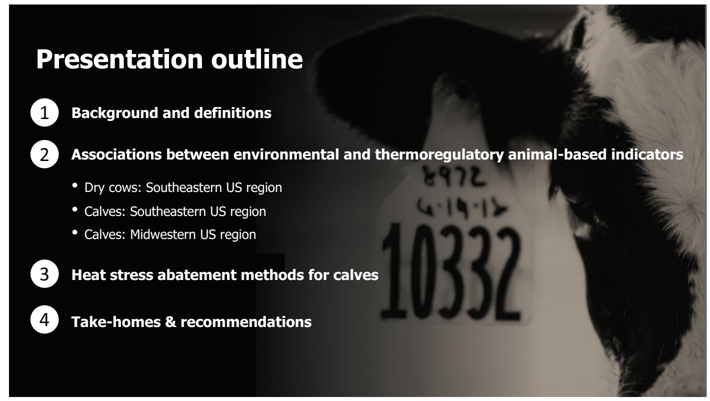
22

22

Heat stress indicators in dry cows and pre-weaned calves: Southeast vs. Midwest

Dr. Jimena Laporta
University of Wisconsin

1



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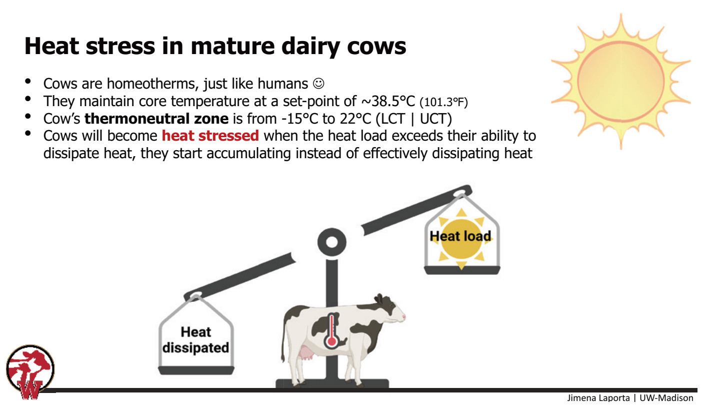

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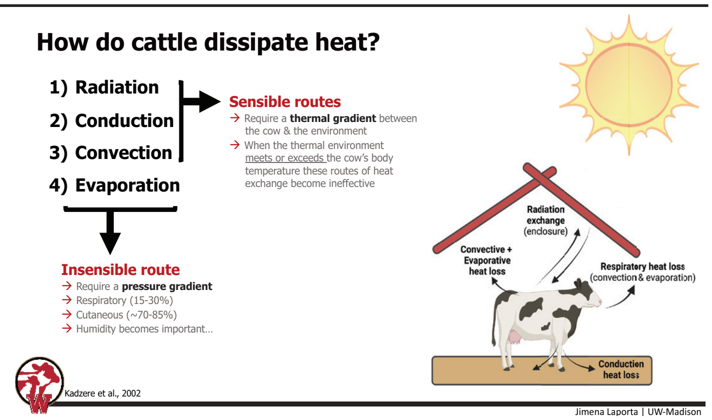

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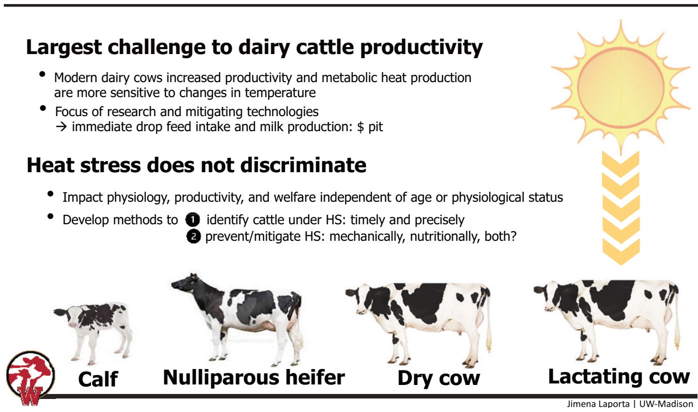

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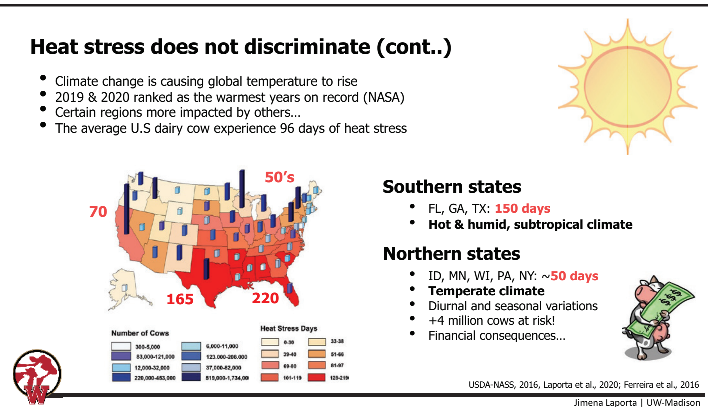


6

How to estimate the impact of "heat" on your cows?

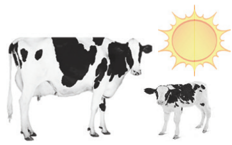
- THI combines ambient temperature & relative humidity to estimate the "heat load" cattle experience
- Lactating cows start to show reductions in milk production at a **THI cut-off: 68**
  → even at THI's 65 rumination begins to change…

Air Temperature (°F)	Relative Humidity (%) 0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
65	61	61	62	62	62	62	62	62	63	63	63	63	63	64	64	64	64	64	65	65	65
70	63	64	64	64	65	65	65	66	66	66	67	67	67	68	68	68	69	69	69	70	70
75	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
80	68	69	69	70	70	71	72	72	73	73	74	74	75	76	76	77	78	78	79	79	80
85	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
90	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
95	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
100	77	78	79	80	82	83	84	85	86	87	88	90	91	92	93	94	95	97	98	99	100
105	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	104	105
110	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110

Animal Handling During Heat Stress | UW-Madison Division of Extension

What about non-lactating cattle?

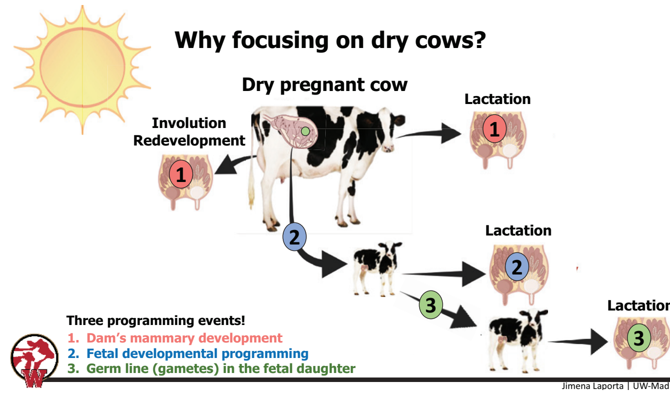
→ more thermotolerant (non-lactating state)
→ unknown animal & environmental indicators to identify HS onset timely & precisely



Ravagnolo et al., 2020; Zimbelman et al., 2009

7

Why focusing on dry cows?



Three programming events!
1. Dam's mammary development
2. Fetal developmental programming
3. Germ line (gametes) in the fetal daughter

8

Associations between environmental & thermoregulatory animal-based indicators of heat stress in dry cows

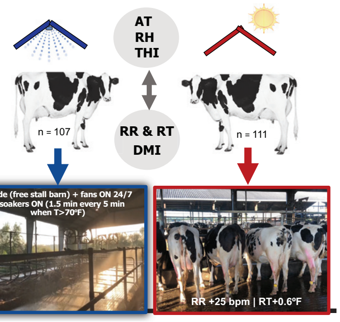

frontiers in Animal Science

Critical Temperature-Humidity Index Thresholds for Dry Cows in a Subtropical Climate

Véronique Ouellet[1], Izabella M. Toledo[2], Bethany Dado-Senn[3], Geoffrey E. Dahl[4] and Jimena Laporta[3]*

[1] Department of Animal Sciences, Université Laval, Québec City, QC, Canada, [2] Institute of Food and Agricultural Sciences Extension, University of Florida, Gainesville, FL, United States, [3] Department of Animal and Dairy Sciences, University of Wisconsin-Madison, Madison, WI, United States, [4] Department of Animal Sciences, University of Florida, Gainesville, FL, United States

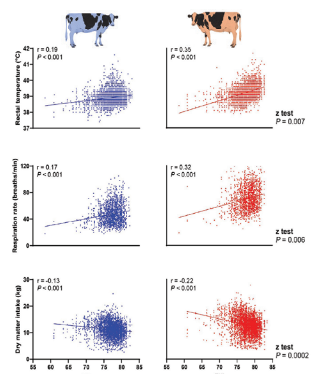
- Determine environmental thresholds at which dry cows exhibit signs of HS in a **subtropical climate**
- Analyzed records of dry cow studies conducted over **5 years** in Florida (N=218)
- Cows with or without access to heat abatement (CL vs. HS, respectively) the last 7 weeks of gestation, concurrent with the entire dry period



9

Correlations between THI and each animal-based indicators

- Correlations in HS-dry cows are moderate to strong (r = –0.22 to r = 0.35), with the strongest correlation between THI and RT followed by RR
- Correlations in CL-dry cows were collectively weaker (r = –0.13 to r = 0.19)
- All Z-scores were significantly different CL-dry vs HS-dry
- Coefficients in dry cows are much lower than those estimated for lactating cows in a similar (subtropical) environment (Dikmen and Hansen, 2009)

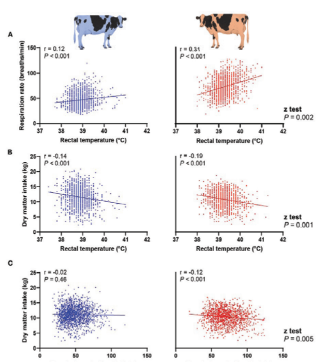


Ouellet et al., 2021

10

Correlations between animal-based indicators

- Correlations in CL-dry cows were collectively weaker (r = –0.02 to r = 0.12)
  No significant correlation between DMI and RR
- Stronger correlations between the different animal-based indicators in HS-dry cows (r = –0.12 to r = 0.31)
  Strongest correlation between RR and RT
  Negative/significant correlation between DMI and RR
- All Z-scores were significantly different CL-dry vs HS-dry



Ouellet et al., 2021

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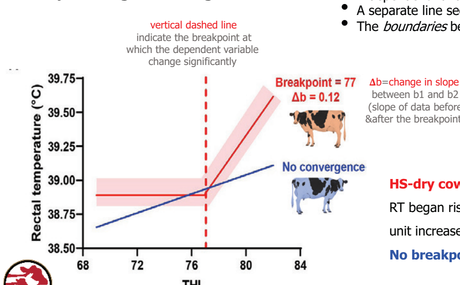
Thresholds or "break-points" for dry cows

Two-phase segmented regression models

- Independent variable is partitioned into intervals
- A separate line segment is fit to each interval
- The *boundaries* between the segments are *breakpoints*



HS-dry cows had a THI breakpoint of 77

RT began rising at a rate of 0.12 °C for every unit increase in THI above the threshold

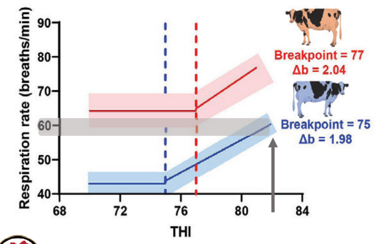
No breakpoint for CL-dry cows was detected

Ouellet et al., 2021

12

Thresholds or "break-points" for dry cows

Two-phase segmented regression models



HS-dry cows had a THI breakpoint of 77

CL-dry cows had a breakpoint of 75

RR began rising at a rate of ~2 bpm for every unit increase in THI above the threshold!

- No THI threshold was detected for **DMI** or **skin temperature** within the THI range of 68 to 82 evaluated herein

Ouellet et al., 2021

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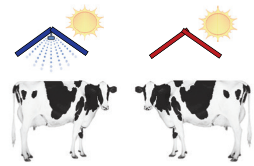
Thresholds or "break-points" for dry cows



Dry cows not provided with active cooling should be closely monitored **when or before THI reaches 77**

When they begin to rise respiration rates and core body temperature

...associated with thermal discomfort and heat stress

- The THI threshold established for lactating cows *is not* suitable to accurately assess HS in dry cows
- Provision of active cooling devices skewed the correlation THI/animal-based indicators
- These results should aid with proper identification and monitoring of HS in dry cows
- Improve dry cow welfare and provide accurate management of dry cows in a subtropical climate!

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What about dairy calves?

Pre-weaned dairy calves feel the heat too!

- Calves do not regulate body temperature very well
  - → Thrive in environments between 12–25 °C (53 – 77°F) UCT: 25–32 °C (77 – 89.6°F) Above that, nutrients consumed will be diverted towards heat dissipation at the expense of growth and immune function
- Heat abatement is rarely considered for dairy calves
  - → larger surface to mass ratio and lower metabolic heat production
- Low-cost options and best management practices
  - → Most studies emphasize in hutch material, shade supplementation
    - Lammers et al., 1996; Coleman et al., 1996; Hill et al., 2011, Carter et al., 2014; Manriquez et al., 2018
  - → Active ventilation?
    - Stott et al., 1976 & Hill et al., 2011

Limited data on methods to assess and prevent heat stress!

Visible signs of HS

• open-mouthed panting

• faster respiratory rate

15

What about dairy calves?

Pre-weaned dairy calves feel the heat too!


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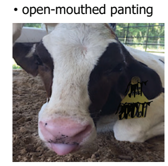
Methods for assessing heat stress in preweaned dairy calves exposed to chronic heat stress or continuous cooling

B. Dado-Senn, V. Ouellet, G. E. Dahl, and J. Laporta†
Department of Animal Sciences, University of Florida, Gainesville 32611

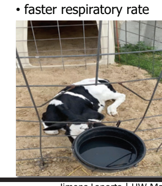
- When do calves begin to experience thermal discomfort?
- When should we start monitoring them?
- How should we monitor them?
- Can we "actively" cool calves?

Visible signs of HS

• open-mouthed panting



• faster respiratory rate



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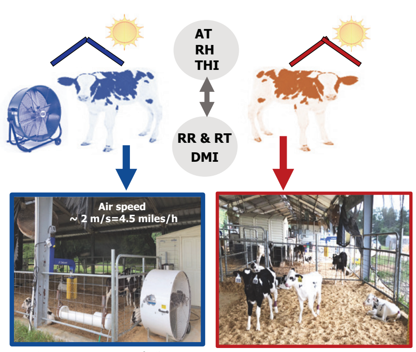
Environmental & thermoregulatory animal-based indicators of heat stress in dairy calves

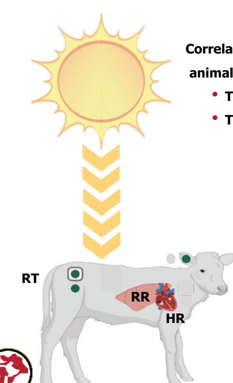
- → Automatic feeders, grouped-housed
- → One barrel fan at the calf level and one oscillating fan above the ground
  - forces air movement
  - promotes convective cooling
  - lowers calves' thermal indices



n = 6 calves per pen | 4.6 x 9.1 m, ~7 m²/calf
VMK42-2-O 107 cm barrel fan; Schaefer
DeLaval CF1000X

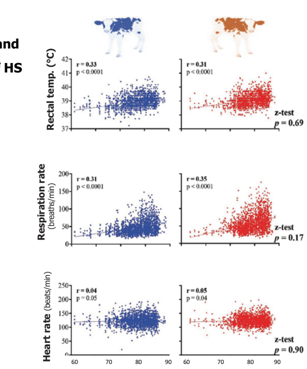
Dado-Senn et al., 2020

17



Correlations between THI and animal-based indicators of HS

- **THI – RR or RT<0.30**
- **THI – HR ~ 0**



Dado-Senn et al., 2020

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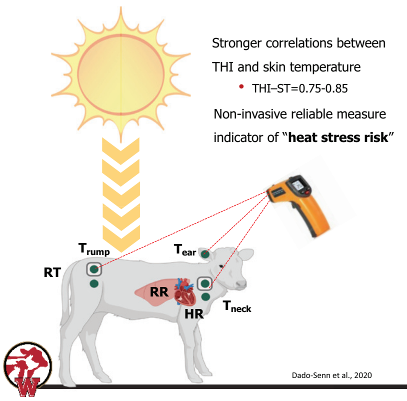
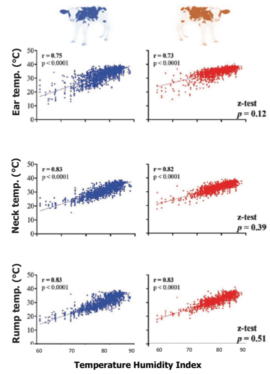


Stronger correlations between THI and skin temperature
- THI–ST=0.75-0.85

Non-invasive reliable measure indicator of "**heat stress risk**"



Dado-Senn et al., 2020

Jimena Laporta | UW-Madison

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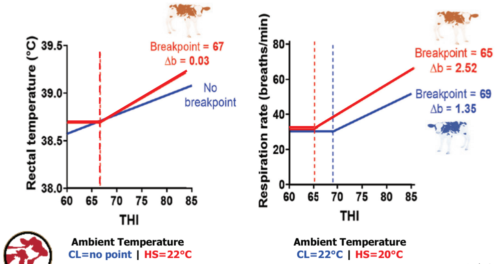
When do calves begin to feel thermal discomfort?

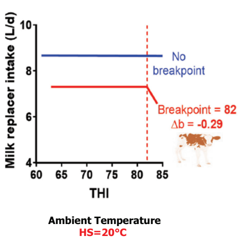
- Segmented regressions to find thresholds at which significant changes in physiological responses occur
- **Monitor calves *before* THI reaches 65 to prevent risks of heat stress**

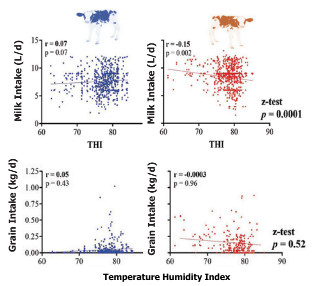


Dado-Senn et al., 2020

20

When do calves begin to reduce intake?





Dado-Senn et al., 2020

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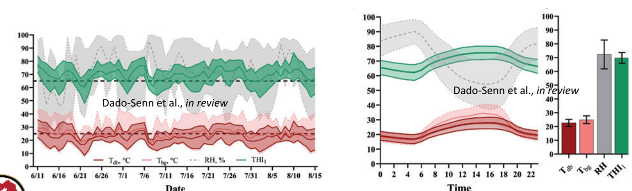
Correlations & thresholds in a continental climate?

- Temperate humid continental climate
- Temperatures vary greatly from summer to winter and cooler evening diurnal patterns
- Data from 2007-2013 (June-Aug): RH=70, Temp=69.3 F, THI=73 (max 88!)
- 2021 (June-Aug): **cattle are under risk of HS for 12-13 h/d**



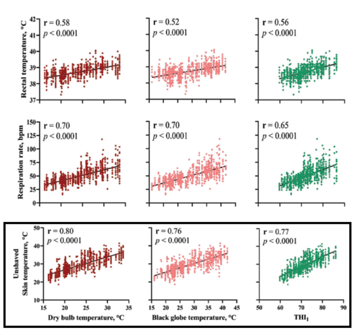
Dado-Senn et al., *in review*

Jimena Laporta | UW-Madison

22

Correlations between environmental & animal-based indicators of heat stress in dairy calves: continental climate

- Hutch-housed dairy calves (n=63; 14 to 42 doa) across summer (June to August 2021)
- Passively ventilated hutches
- Measures: RR, RT, ST, 2x/d; 3d/wk
  No treatment comparison



Dado-Senn et al., *in review*

Jimena Laporta | UW-Madison

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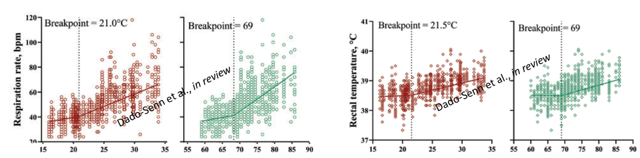
When do calves begin to feel thermal discomfort?

- Thresholds for dairy calves raised in outdoor hutches in **continental climate**
- **Monitor calves before THI of 69 or dbT of 21.0°C to prevent risks of heat stress**



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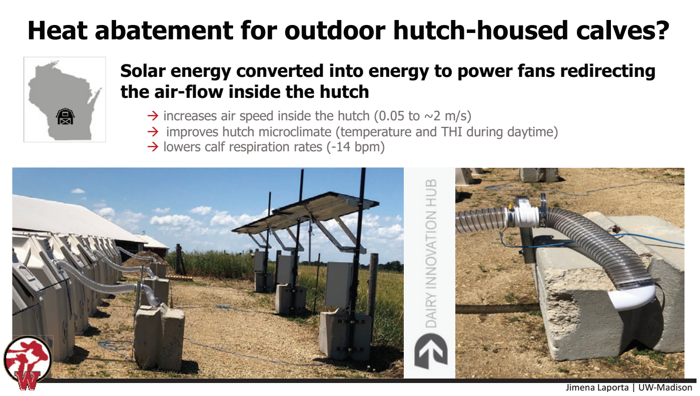
Heat abatement for outdoor hutch-housed calves?
Solar energy converted into energy to power fans redirecting the air-flow inside the hutch
→ increases air speed inside the hutch (0.05 to ~2 m/s)
→ improves hutch microclimate (temperature and THI during daytime)
→ lowers calf respiration rates (-14 bpm)
DAIRY INNOVATION HUB
Jimena Laporta | UW-Madison

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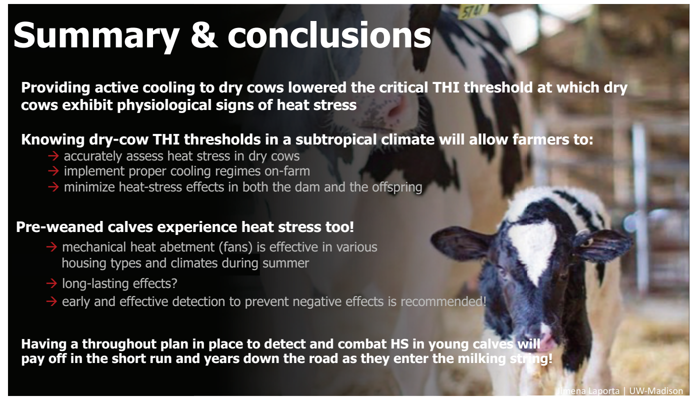
Summary & conclusions
Providing active cooling to dry cows lowered the critical THI threshold at which dry cows exhibit physiological signs of heat stress
Knowing dry-cow THI thresholds in a subtropical climate will allow farmers to:
→ accurately assess heat stress in dry cows
→ implement proper cooling regimes on-farm
→ minimize heat-stress effects in both the dam and the offspring
Pre-weaned calves experience heat stress too!
→ mechanical heat abetment (fans) is effective in various housing types and climates during summer
→ long-lasting effects?
→ early and effective detection to prevent negative effects is recommended!
Having a throughout plan in place to detect and combat HS in young calves will pay off in the short run and years down the road as they enter the milking string!
Jimena Laporta | UW-Madison

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Thank you!
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https://lactationbiology.webhosting.cals.wisc .edu/laporta/

27

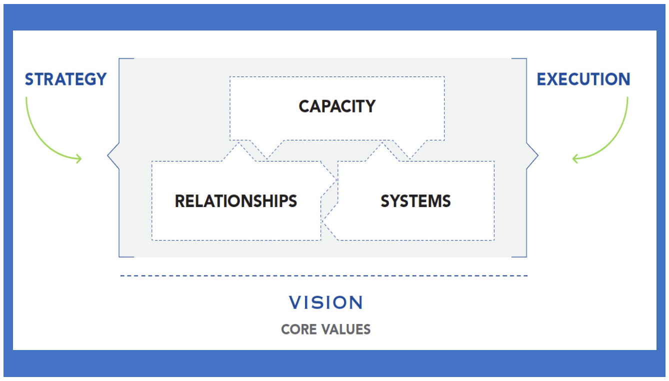
Developing your People for High Performance Business

Jay Joy, CEO Milk Money, LLC
moneycfo.com
785-275-2772

MILK MONEY
IDENTIFY. INVEST. SUCCEED.

Develop your BUSINESS by Developing your PEOPLE

1



2

What is Strategy?

PLAN your Plan, Organize Action

Define "What"……
- Product/Service we are offering
- Is our Target Market
- Does our "Ideal" Customer look like
- **CAPACITIES** do we need to serve our customers and employees
- **RELATIONSHIPS** do we need to serve our customers and employees
- **SYSTEMS** do we need to serve our customers and employees

3

What is Execution?

DO your Plan, Take Action

How do we……
- Provide the Product/Service are we offering
- Engage with our Target Market
- Influence our "Ideal" Customer
- Develop the **CAPACITY** we need to serve the customer
- Develop the **RELATIONSHIPS** we need to serve the customer
- Develop the **SYSTEMS** we need to have in place to execute for the customer

4

Capacity

"The ability or power to do, experience, or understand something"

- Physical
- Mental
- Emotional
- Financial
- Social
- Spiritual

5

Relationships

"The way in which two or more concepts, objects, or people are connected; or the way they behave toward each other"

- Trusted
- Collaborative
- Transactional
- Co-Existence
- Avoidance
- Dysfunctional

6

Systems

"A set of principles or procedures according to which something is done; an organized framework or method"

- Sales & Marketing
- Operational
- Financial
- Administrative
- People Development

7

VISION

"A mental image of what the future will or could be like"

- New or Unique Product or Service
- A specific "Way of Being"
- Size or Geographic Characteristics

8

Core Values

"An organization's fundamental beliefs and standards of behavior; judgment of what is most important"

- Behavioral
- Visible through Actions
- Present without Definition

9

Leadership Q&A

1. How do I serve customers and employees if I don't understand (or know) their personal VISION and Core Values?
2. How do I expect employees to "buy in" emotionally if I haven't defined our VISION and Core Values?
3. What happens if the VISION and Core Values of customers and employees don't align with the organization's?

10

Other Thoughts?

1. What **capacities** do our people need to serve our customers that they currently don't have?
2. What **relationships** do our people need to serve our customers that they currently don't have
3. What **systems** do our people need to serve our customers that they currently don't have?
4. **HOW DO WE HELP THEM GET THEM???**

11

MILK MONEY
IDENTIFY. INVEST. SUCCEED.

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12

Carbohydrates in NASEM 2021

Mary Beth Hall, PhD
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USDA
United States Department of Agriculture

Carbohydrates in NASEM 2021

Mary Beth Hall, PhD
USDA – Agricultural Research Service
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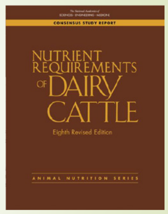


1

Carbohydrates

- 70 to 80% of diet dry matter.
- Main source of volatile fatty acids (VFA) that can provide up to 70% of energy needs.
- Essential for microbial protein production.

2

Dairy NRC, 2001

TABLE 4-3 Recommended Minimum Concentrations (% of DM) of Total and Forage NDF and Recommended Maximum Concentrations (% of DM) of NFC for Diets of Lactating Cows When the Diet is Fed as a Total Mixed Ration, the Forage has Adequate Particle Size, and Ground Corn is the Predominant Starch Source[a]

Minimum forage NDF[b]	Minimum dietary NDF	Maximum dietary NFC[c]	Minimum dietary ADF[d]
19[e]	25[e]	44[e]	17[e]
18	27	42	18
17	29	40	19
16	31	38	20
15[e]	33	36	21

[a]Values in this table are based on the assumption that actual feed composition has been measured; values may not be appropriate when values from feed tables are used.
[b]All feeds that contain substantial amounts of vegetative matter are considered forage. For example, corn silage is considered a forage, although it contains significant amounts of grain.
[c]Nonfiber carbohydrate is calculated by difference 100 - (%NDF + %CP + %Fat + %Ash).
[d]Minimum dietary ADF recommendations were calculated from NDF concentrations (See text).
[e]Diets that contain less fiber (forage NDF, total NDF or total ADF) than these minimum values and more NFC than 44 percent should not be fed.

Only NonFiber Carbohydrates (NFC) by difference and Neutral Detergent Fiber (NDF) were considered.
Lignin or 48 h NDF in vitro digestibility was used to estimate digestibility of NDF.

9 pages

3

8th Revised Edition (12 pages)

Neutral Detergent-Soluble Carbohydrates (NDSC)
- Starch
- Water-soluble carbohydrates (WSC)
- Neutral detergent-soluble fiber

Residual organic matter

Neutral detergent fiber (NDF)
- Forage and nonforage
- Lignin

Carbohydrate digestibility

Physically effective & physically adjusted NDF*

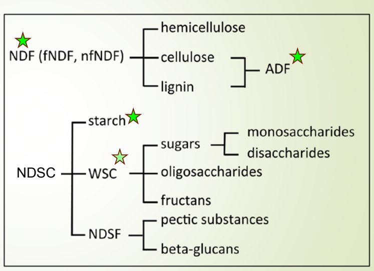
4

Carbohydrates

NDF, WSC, & NDSF: carbohydrates based on solubility.

NDSC ≠ NFC
No organic acids, by analysis, not by difference.

Recommended methods are in the Feed Analysis chapter.
Discussions in text.



5

Feed Analyses

- When in doubt, go back to the cited paper for allowable variants, unless specified in this chapter.
- Requires a representative subsample.
- Recommended analyses likely matter more for the empirical assays than for analytes.

http://www.aafco.org/Publications/GOODTestPortions

6

Residual Organic Matter (ROM)

= 100 – ash – crude protein – NDF - fatty acids/fat factor – starch

- NDF: no CP and ash correction.
- CP in nonprotein nitrogen: actual mass, not x 6.25.
- Fatty acids/fat factor: gives a value for glycerol.
- Includes WSC, NDSF, organic acids, glycerol, components not in analyzed feed fractions, and analytical error.

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Neutral Detergent Fiber (NDF)

Hemicellulose, cellulose, & lignin. Discussion on research findings, primarily on rumen function and estimating digestion.

Ruminal NDF fermentation is affected by

- NDF composition -- lignin
- physical form – forage vs. nonforage
- pH
- retention time
- fragility
- rate of fermentation
- RDP(?)
- Entire diet
- …

P. J. Van Soest
1929 - 2021

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Predicting Carbohydrate Digestion

- **Tables**: Utility? Values are too variable.
- **Single in vitro time points**:
  - Provide important relative information.
  - In vivo digestibility affected by many more factors.
  - For NDF: May not equal in vivo, but 48 h* was correlated with intake and milk yield.
- **Digestion & Passage**: No values for passage of nutrient fractions of individual feeds.
- **Use the measures to which your equations / model are calibrated.**

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Recommendations

Need to be based on published data.

Committee worked with what was available.

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NDSC

Recommendations on formulation with NDSC?

To give specific feeding recommendations on the different NDSC, we need more research data across more varied diets with WSC, starch, and NDSF composition, particle size, etc. reported for diets and feeds.

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Energy & Carbohydrates

Starch, NDF, and residual organic matter (ROM) were used to predict energy in the diet.

dNDF_NDF_base
= {0.075 x (NDF – Lignin) x [1 – (Lignin/NDF)$^{0.667}$]}/NDF
Or = 0.12 + 0.61 x 48h IVNDFD
Further affected by dry matter intake and starch in the diet.

dStarch_Starch_base
Tabular: for corn 0.94 steam flaked, 0.92 fine, 0.77 coarse
Changes at DMI > or < 3.5% of BW (1%unit/1%unit)

dROM_base
= ROM x 0.96

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Protein & Carbohydrates: Ruminal Effects

Ruminally digestible NDF and starch support microbial growth.

Ruminally Degraded NDF

=[-31.9 – (0.721 x NDF) – (0.247 x Starch) + (6.63 x CP) – (0.211 x CP²) – (38.7 x ADF/NDF) – (0.121 x WetForage) + (1.51 x DMI)] x ((NDF/100) x DMI)]/100

Ruminally Degraded Starch

[(71.2 – (1.45 x DMI) + (0.424 x ForageNDF) + (1.39 x Starch) – (0.0219 x Starch²) – (0.154 x WetForage)] x ((Starch/100) x DMI)]/100

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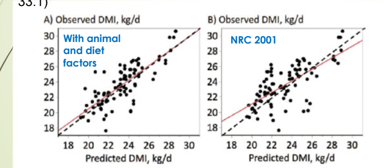
Dry Matter Intake

DMI (kg/d) = [3.7 + Parity x 5.7) + 0.305 x MilkE (Mcal/d) + 0.22 x BW (kg) + (– 0.689 –1.87 x Parity) x BCS] x [1 – (0.212 + Parity x 0.136) x $e^{(-0.053 \times DIM)}$]

DMI (kg/d) = 12.0 – 0.107 x fNDF + 8.17 x ADF/NDF + 0.0253 x fNDFD – 0.328 x (ADF/NDF – 0.602) x (fNDFD – 48.3) + 0.225 x MY + 0.00390 x (fNDFD – 48.3) x (MY – 33.1)



- DMI Models with only animal factors over-predicted at high DMI, and underpredicted at low DMI.

Allen et al., 2019. J. Dairy Sci. 102:7961

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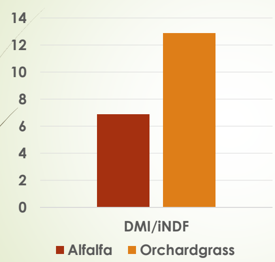
Dry Matter Intake



uNDF240 to predict DMI?

- uNDF240 alone is not limiting
- Relationship varies.

In vitro uNDF240 with second inoculation at 120 h.
Kammes and Allen, 2012. J. Dairy Sci. 95:3288

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Physically Effective NDF

Physical form affects the rumen environment:

- Enhance rumination
- Allow ruminal retention
- Maintain desirable rumen pH

- Forage has greater impact than nonforage NDF.
- Research focus.

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Approach 1: Forage NDF

Formulate for forage NDF relative to dietary starch content.

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

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Approach 1: Forage NDF

Adjustments.

Optimal diet forage NDF concentration

15 — 25

<- Higher dry matter intake

Faster ruminal clearance rate of forage NDF ->

Finely chopped forages ->

Higher diet starch, lower NFFS concentrations ->

Higher diet starch degradability ->

<- Supplemental buffers

Grain fed separately, infrequently ->

Limited feed bunk space, slug feeding ->

Greater daily variation in diet composition ->

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Approach 2: Physically Adjusted NDF (paNDF)

- Penn State Particle Separator
- Factors that affect the need for or effectiveness of fiber.
- The target ruminal pH (6.0-6.1) is a proxy for a desirable rumen environment, not a prediction.
- Derived from 60 publications that had 241 treatment means and used an ensemble model approach.

White et al. 2017. JDS 100:9551
White et al., 2017 JDS 100:9569

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A System Using On-Farm Measurements?

Courtesy of Ken Nordlund

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The Problem With Research Studies

Low Starch
High Forage
High ADF/NDF
Low Forage
Low ADF/NDF
High Starch

Researchers set up diets to answer their own questions. The data you find won't be complete or balanced for all key variables.

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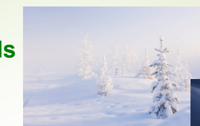
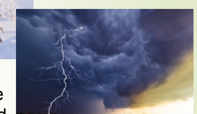
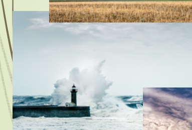
Ensemble Models

Technique that takes a core concept (i.e. rumen pH) and converts it into a "*constellation*" of models.



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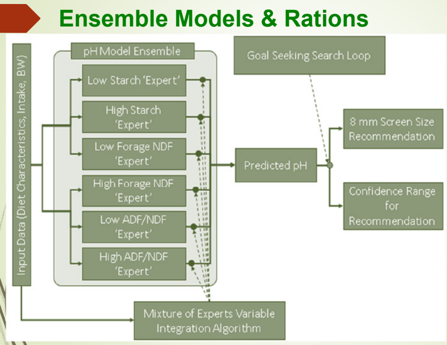
Ensemble Models & Rations



Ensemble models bring together predictions from multiple different models to yield a mean and range of responses.

Compared to individual models, gives more reliable predictions of events, confidence intervals, and is less likely to generate systematic errors.

White et al. 2017. JDS 100:9551

23

Physically Adjusted NDF (paNDF)

Inputs:

- Diet characteristics, % of dry matter
  - Forage NDF, total forage, wet forage
  - Cottonseed: whole, hulls, meal
  - NDF, ADF, CP, starch
- Body weight
- Penn State Particle Separator (PSPS)
  - % of TMR DM on 0.75" / 19 mm sieve (1.18 optional)

Output predictions:

- Recommended % of TMR DM on 0.315" / 8 mm sieve
- Minutes per day of rumination

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A System Using On-Farm Measurements?

Courtesy of Ken Nordlund

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High Forage
High ADF/NDF
Low Forage
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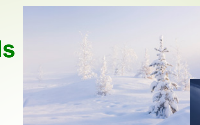
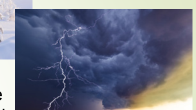
Ensemble Models

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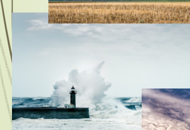

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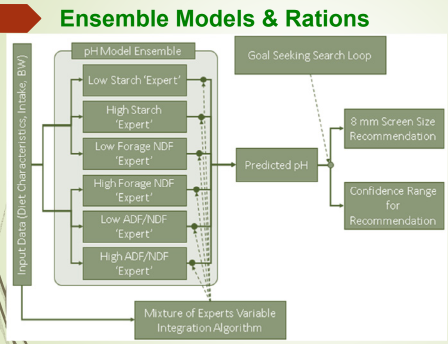
Ensemble Models & Rations



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White et al. 2017. JDS 100:9551

23

29

Physically Adjusted NDF (paNDF)

Inputs:
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  - Cottonseed: whole, hulls, meal
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- Body weight
- Penn State Particle Separator (PSPS)
  - % of TMR DM on 0.75" / 19 mm sieve (1.18 optional)

Output predictions:
- Recommended % of TMR DM on 0.315" / 8 mm sieve
- Minutes per day of rumination

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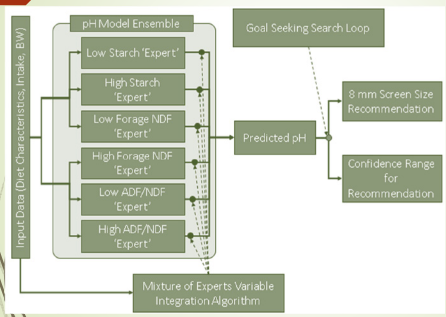
Ensemble Models & Rations



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White et al. 2017. JDS 100:9551

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Transition Cow Myths and How They Influence the Interpretation of a Nutritionist's Success

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[1]Iowa State University, Ames, IA; baumgard@iastate.edu
[2]Elanco Animal Health
[3]Innovative Liquids

Introduction

Suboptimal milk yield limits the U.S. dairy industry's productive competitiveness, marginalizes efforts to reduce inputs into food production, and increases animal agriculture's carbon footprint. There are a variety of circumstances in a cow's life which activate the immune system and result in hindered productivity (i.e., metritis, mastitis, intestinal dysfunction). Although there are many etiological origins, a commonality among them is increased production of inflammatory biomarkers and markedly altered nutrient partitioning. Importantly, nutrition programs are frequently inculpated for poor transition cow performance because of the (likely fallacious) presumed adverse effects of elevated lipid metabolites and hypocalcemia on production and immunosuppression. In contrast, we suggest that many post-calving undesirable phenotypes (reduced dry matter intake [DMI], hypocalcemia, elevated non-esterified fatty acids [NEFA], hyperketonemia) are a direct consequence of immune activation and not themselves causative of transition cow maladies. For a more detailed description of the areas covered herein, see our recent review (Horst et al., 2021).

Traditional Dogmas

Long-standing tenets describe a causal role of hypocalcemia, increased NEFA, and hyperketonemia in the incidence of transition diseases and disorders (Figure 1). Hypocalcemia has traditionally been considered a gateway disorder leading to ketosis, mastitis, metritis, displaced abomasum, impaired reproduction, and decreased milk yield (Curtis et al., 1983; Goff, 2008; Martinez et al., 2012; Chapinal et al., 2012; Riberio et al., 2013; Neves et al., 2018a,b). The proposed mechanisms by which hypocalcemia leads to these ailments include impaired skeletal muscle strength and gastrointestinal motility (Goff, 2008; Oetzel, 2013; Miltenburg et al., 2016), decreased insulin secretion (Martinez et al., 2012, 2014), and the development of immunosuppression (Kimura et al., 2006). Like hypocalcemia, increased NEFA and hyperketonemia are presumed causative to illnesses such as DA, retained placenta, metritis, reduced lactation performance, poor reproduction, and an overall increased culling risk (Cameron et al., 1998; LeBlanc et al., 2005; Duffield et al., 2009; Ospina et al., 2010; Chapinal et al., 2011; Huzzey et al., 2011). Excessive NEFA mobilization and the affiliated increase in hepatic lipid uptake, triglyceride (TG) storage, and ketone body production has been traditionally believed to be the driving factor leading to ketosis and fatty liver (Grummer, 1993; Drackley, 1999). Additionally, elevated NEFA and ketones are thought to compromise immune function (Lacetera et al., 2004; Hammon et al., 2006; Scalia et al., 2006; Ster et al., 2012) and suppress feed intake (Allen et al., 2009). Thus, the magnitude of changes in NEFA, BHB and Ca have traditionally thought to be predictors of future performance and problems.

Inflammation in the Transition Period

Regardless of health status (Humblet et al., 2006), increased inflammatory biomarkers are observed in nearly all cows during the periparturient period (Ametaj et al., 2005; Humblet et al., 2006; Bionaz et al., 2007; Bertoni et al., 2008; Mullins et al., 2012). The magnitude and persistency of the inflammatory response seems to be predictive of transition cow performance (Bertoni et al., 2008; Bradford et al., 2015; Trevisi and Minuti, 2018). During the weeks surrounding calving, cows are exposed to a myriad of stressors which may permit endotoxin entry into systemic circulation and thereby initiate an inflammatory response (Khafipour et al., 2009; Kvidera et al., 2017c; Proudfoot et al., 2018; Barragan et al., 2018; Koch et al., 2019). The frequency and severity of these inflammation-inducing insults presumably determines the level of inflammation that follows (Bertoni et al., 2008; Trevisi and Minuti, 2018). Common origins of endotoxin entry include the uterus (metritis) and mammary gland (mastitis). Additionally, we believe the gastrointestinal tract may contribute as many of the characteristic responses (rumen acidosis, decreased feed intake, and psychological stress) occurring during the transition period can compromise gut barrier function (Horst et al., 2021).

Although an overt inflammatory response is present around calving, numerous reports have described a reduction in immune competence during this time (Kehrli et al., 1989; Goff and Horst, 1997; Lacetera et al., 2005). Traditionally, hypocalcemia and hyperketonemia have been primary factors considered responsible for periparturient immunosuppression (Goff and Horst, 1997; Kimura et al., 2006; LeBlanc, 2020); however, recent evidence suggests this is more complex than originally understood and that the systemic inflammatory milieu may be mediating the immune system to become "altered" and not necessarily "suppressed" around calving (Trevisi and Minuti, 2018; LeBlanc, 2020). Whether or not the "immune incompetence" frequently reported post-calving is causative to future illnesses or is a consequence of prior immune stimulation needs further attention.

The Importance of Glucose

To adequately recognize the connection between inflammation and transition period success, an appreciation for the importance of glucose is a prerequisite. Glucose is the precursor to lactose, the milk constituent primarily driving milk volume through osmoregulation (Neville, 1990). Approximately 72 g of glucose is required to synthesize 1 kg of milk (Kronfeld, 1982). A variety of metabolic adaptations take place in lactating mammals including increased liver glucose output and peripheral insulin resistance which allows for skeletal muscle to have increased reliance upon lipid-derived fuel (i.e., NEFA and BHBA) to spare glucose for milk synthesis and secretion by the mammary gland (Baumgard et al., 2017). The immune system is also heavily reliant on glucose when activated. The metabolism of inflammation (discussed below) has its own unique metabolic footprint to direct glucose toward the immune system. Consequently, when the onset of inflammation and lactation coincide, glucose becomes an extremely valuable and scarce resource.\

Ketogenesis occurs when glucose is in short supply. This can come from a combination of factors including lack of substrate (i.e., reduced feed intake and ruminal fermentation) or high glucose utilization by other tissues (i.e., the immune system or mammary gland). When glucose demand is high, the TCA cycle intermediate oxaloacetate leaves the cycle to supply carbon for gluconeogenesis. Oxaloacetate is also the molecule that combines with acetyl CoA (the end-product of adipose-derived NEFA) to allow the TCA cycle to continue progressing. If the TCA cycle is limited in its progression due to lack of oxaloacetate, acetyl CoA enters into ketogenesis. The link between onset of lactation, immune system activation, and lack of glucose leading to ketogenesis may help to explain the metabolic footprint of a poorly transitioning dairy cow.

Metabolism of Inflammation

Inflammation has an energetic cost which redirects nutrients away from anabolic processes (see review by Johnson, 2012) and thus compromises productivity. Upon activation, most immune cells become obligate glucose utilizers via a metabolic shift from oxidative phosphorylation to aerobic glycolysis (not anaerobic glycolysis typically learned about in biochemistry classes), a process known as the Warburg effect (Figure 2).

This metabolic shift allows for rapid ATP production and synthesis of important intermediates which support proliferation and production of reactive oxygen species (Calder et al., 2007; Palsson-McDermott and O'Neill, 2013). In an effort to facilitate glucose uptake, immune cells become more insulin sensitive and increase expression of GLUT3 and GLUT4 transporters (Maratou et al., 2007; O'Boyle et al., 2012), whereas peripheral tissues become insulin resistant (Poggi et al., 2007; Liang et al., 2013). Furthermore, metabolic adjustments including hyperglycemia or hypoglycemia (depending upon the stage and severity of infection), increased circulating insulin and glucagon, skeletal muscle catabolism and subsequent nitrogen loss, and hypertriglyceridemia occur (Filkins, 1978; Wannemacher et al., 1980; Lanza-Jacoby et al., 1998; McGuinness, 2005). Interestingly, despite hypertriglyceridemia, circulating BHB often decreases following LPS administration (Waldron et al., 2003a,b; Graugnard et al., 2013; Kvidera et al., 2017a). The mechanism of LPS-induced decreases in BHB has not been fully elucidated but may be explained by increased ketone oxidation by peripheral tissues (Zarrin et al., 2014). Collectively, these metabolic alterations are presumably employed to ensure adequate glucose delivery to activated leukocytes.

Energetic Cost of Immune Activation

The energetic costs of immunoactivation are substantial, but the ubiquitous nature of the immune system makes quantifying the energetic demand difficult. Our group recently employed a series of LPS-euglycemic clamps to quantify the energetic cost of an activated immune system. Using this model, we estimated approximately 1 kg of glucose is used by an intensely activated immune system during a 12-hour period in lactating dairy cows. Interestingly, on a metabolic body weight basis the amount of glucose utilized by LPS-activated immune system in mid- and late-lactation cows, growing steers and growing pigs were 0.64, 1.0, 0.94, 1.0, and 1.1 g glucose/kg BW0.75/h, respectively; Kvidera et al., 2016, 2017a,b, Horst et al., 2018, 2019). A limitation to our model is the inability to account for liver's contribution to the circulating glucose pool (i.e., glycogenolysis and gluconeogenesis). However, both glycogenolytic and gluconeogenic rates have been shown to be increased during infection (Waldron et al., 2003b; McGuinness, 2005) and Waldron et al. (2006) demonstrated that ~87 g of glucose appeared in circulation from these processes. Furthermore, we have observed both increased circulating glucagon and cortisol (stimulators of hepatic glucose output) following LPS administration (Horst et al., 2019) suggesting we are underestimating the energetic cost of immunoactivation. The reprioritization of glucose trafficking during immunoactivation has consequences as both are considerable glucose-demanding processes. Increased immune system glucose utilization occurs simultaneously with infection-induced decreased feed intake: this coupling of enhanced nutrient requirements with hypophagia obviously decrease the amount of nutrients available for the synthesis of valuable products (milk, meat, fetus, wool, etc.).

Inflammation and Metabolic Disorders

The periparturient period is associated with substantial metabolic changes involving normal homeorhetic adaptions to support glucose sparing for milk production. Early lactation dairy cows enter a normal physiological state during which they are unable to consume enough nutrients to meet maintenance and milk production costs and typically enter negative energy balance (NEB; Drackley, 1999; Baumgard et al., 2017). During NEB, cows mobilize NEFA in order to partition glucose for milk production in a homeorhetic strategy known as the "glucose sparing." However, increasing evidence suggests that chronic inflammation may be an additional energy drain that initiates the sequence of these disorders (Bertoni et al., 2008; Eckel and Ametaj, 2016) and this is supported by human, rodent, and ruminant literature which demonstrate effects of lipopolysaccharide (LPS) and inflammatory mediators on metabolism and hepatic lipid accumulation (Li et al., 2003; Bradford et al., 2009; Ilan et al., 2012; Ceccarelli et al., 2015). We and others have demonstrated that cows which develop ketosis and fatty liver postpartum have a unique inflammatory footprint both pre- and post-partum (Ohtsuka et al., 2001; Ametaj et al., 2005; Abuajamieh et al., 2016; Mezzetti et al., 2019; Figure 3). Because the activated immune system has an enormous appetite for glucose, it can exacerbate a glucose shortage by both increasing leukocyte glucose utilization and reducing gluconeogenic substrates by inhibiting appetite. Reduced DMI is a highly conserved response to immune activation across species (Brown and Bradford, 2021) which can further increase NEFA mobilization and hepatic ketogenesis (Figure 4).

Inflammation and Subclinical Hypocalcemia

Subclinical hypocalcemia remains a prevalent metabolic disorder afflicting ~25% of primiparous and ~50% of multiparous cows in the United States (Reinhardt et al., 2011). Although no overt symptoms accompany SCH, it has been loosely associated with poor gut motility, increased risk of DA, reduced production performance (i.e., milk yield and feed intake), increased susceptibility to infectious disease, impaired reproduction, and an overall higher culling risk (Seifi et al., 2011; Oetzel and Miller, 2012; Caixeta et al., 2017). Recent reports indicate that the severity of negative health outcomes observed in SCH cows appears dependent on the magnitude, persistency, and timing of SCH (Caixeta et al., 2017; McArt and Neves, 2020). For example, Caixeta et al. (2017) classified cases as either SCH or chronic SCH and observed more pronounced impairments on reproductive performance with chronic SCH. Similarly, McArt and Neves (2020) classified cows into 1 or 4 groups based on post-calving Ca concentrations: normocalcemia (>2.15 mmol/L at 1 and 2 DIM), transient SCH (≤ 2.15 mmol/L at 1 DIM), persistent SCH (≤ 2.15 mmol/L at 1 and 2 DIM), or delayed SCH (> 2.15 mmol/L at 1 DIM and ≤ 2.15 mmol/L at 2 DIM). Cows experiencing transient SCH produced more milk and were no more likely to experience a negative health event when compared to normocalcemic cows, whereas the opposite (i.e., higher health risk and hindered productivity) was observed in cows experiencing either persistent or delayed SCH. Clearly not all cases of SCH are equivalent; in fact, transient hypocalcemia appears to be correlated with improved "health" and productivity and this may explain why inconsistencies exist in the relationship between SCH and reduced productivity and health (Martinez et al., 2012; Jawor et al., 2012; Gidd et al., 2015). However, it remains unclear why despite successful implementation of mitigation strategies, SCH remains prevalent, why SCH is associated with a myriad of seemingly unrelated disorders, and what underlying factors may be explaining the different "types" of SCH.

Impressively, immune activation was originally hypothesized by early investigators to be involved with milk-fever (Thomas, 1889; Hibbs, 1950), but until recently (Eckel and Ametaj, 2016) it has rarely been considered a contributing factor to hypocalcemia. Independent of the transition period, we and others have repeatedly observed a marked and unexplainable decrease in circulating calcium following LPS administration in lactating cows (Griel et al., 1975; Waldron et al., 2003; Kvidera et al., 2017b; Horst et al., 2018, 2019; Al-Qaisi et al., 2020). Infection-induced hypocalcemia is a species conserved response occurring in humans (Cardenas-Rivero et al., 1989), calves (Tennant et al., 1973; Elsasser et al., 1996;), dogs (Holowaychuk et al., 2012), horses (Toribio et al., 2005), pigs (Carlstedt et al., 2000) and sheep (Naylor and Kronfeld, 1986). Additionally, hypocalcemia occurs in response to ruminal acidosis in dairy cows (Minuti et al., 2014). It is unlikely that cows (even those that are presumably "healthy") complete the transition period without experiencing at least one immune stimulating event and we are likely underestimating its contribution to postpartum hypocalcemia. In summary, it is probable that immune activation is at least partially explaining the incidence of SCH in the postpartum period (Figure 4). It is intriguing to suggest that cases of delayed, persistent, and chronic SCH recently described by Caixeta et al. (2017) and McArt and Neves (2020) may be related to the severity of the periparturient inflammatory response. This hypothesis may explain why these cases of SCH are associated with reduced "health", as these represent direct consequences of immune activation rather than being related or caused by decreased Ca.

In addition to SCH, there are on-farm milk-fever situations that are biologically difficult to explain. For example, even while strictly adhering to a pre-calving calcium strategy, there remains a small percentage (~<1%) of cows that develop clinical hypocalcemia. Additionally, reasons for why a mid-lactation cow develops milk-fever are not obvious. Further, there appears to be an undecipherable seasonality component to clinical hypocalcemia in the southwest and western USA that coincides with the rainy season. Inarguably, there remain some aspects of Ca homeostasis that continue to evade discovery.

Conclusion

New evidence and thinking around inflammation is challenging the traditional dogmas surrounding hypocalcemia, elevated NEFA, and hyperketonemia as the causative factors in transition cow disease. We suggest, based upon the literature and on our supporting evidence, that activation of the immune system may be the causative role in transition cow failure rather than the metabolites themselves as inflammation markedly alters nutrient partitioning and these metabolites as a means of supporting the immune response (Figure 4). More research is still needed to understand the causes, mechanisms, and consequences of immune activation and how to prevent immune activation or support its efficacy to provide foundational information for developing strategies aimed at maintaining productivity.

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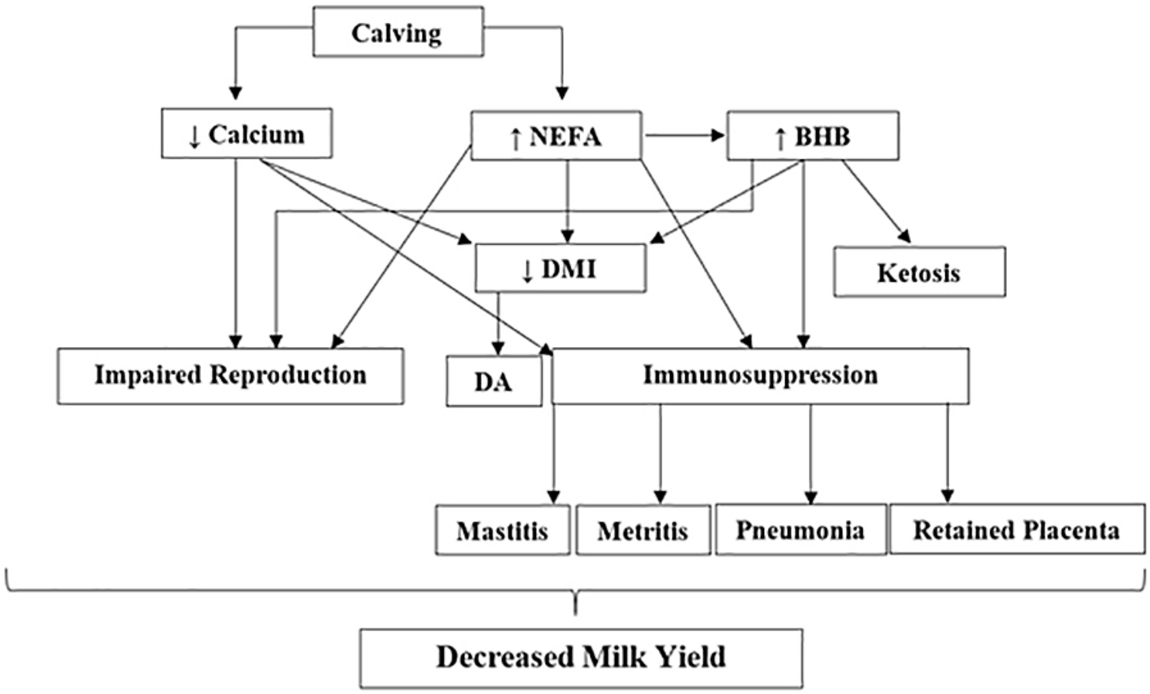

Figure 1. Traditional mechanisms by which hypocalcemia and increased NEFA and ketones are thought to cause poor transition cow health and performance

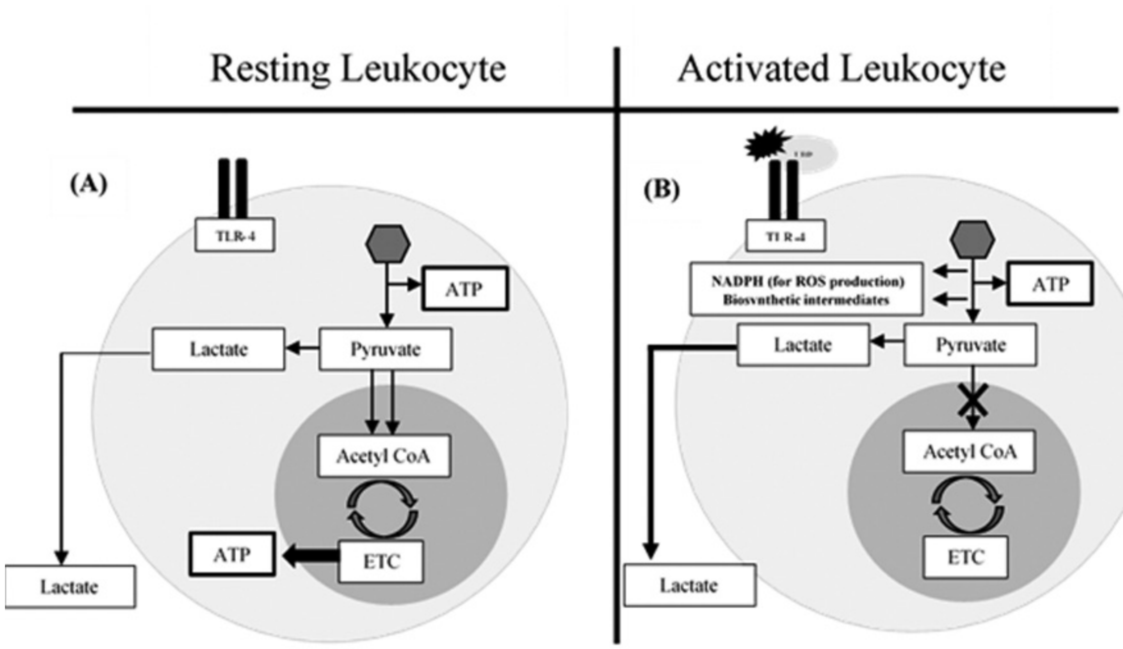

Figure 2. Metabolic pathway of a resting (A) vs. activated (B) leukocyte

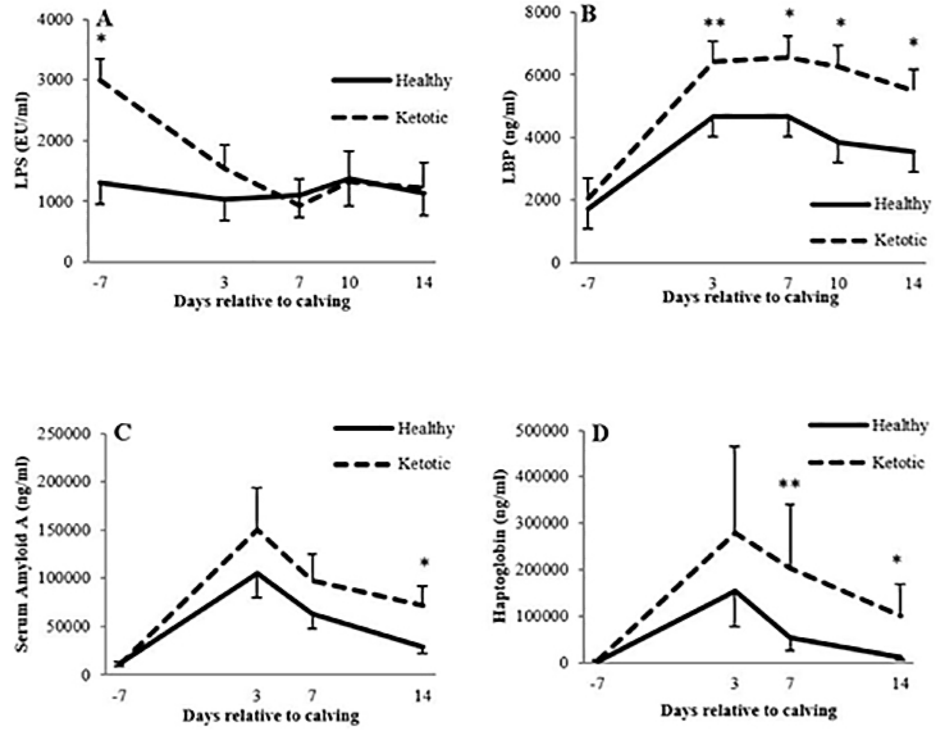

Figure 3. Markers of inflammation in healthy (solid line) and ketotic (dashed line) transition cows

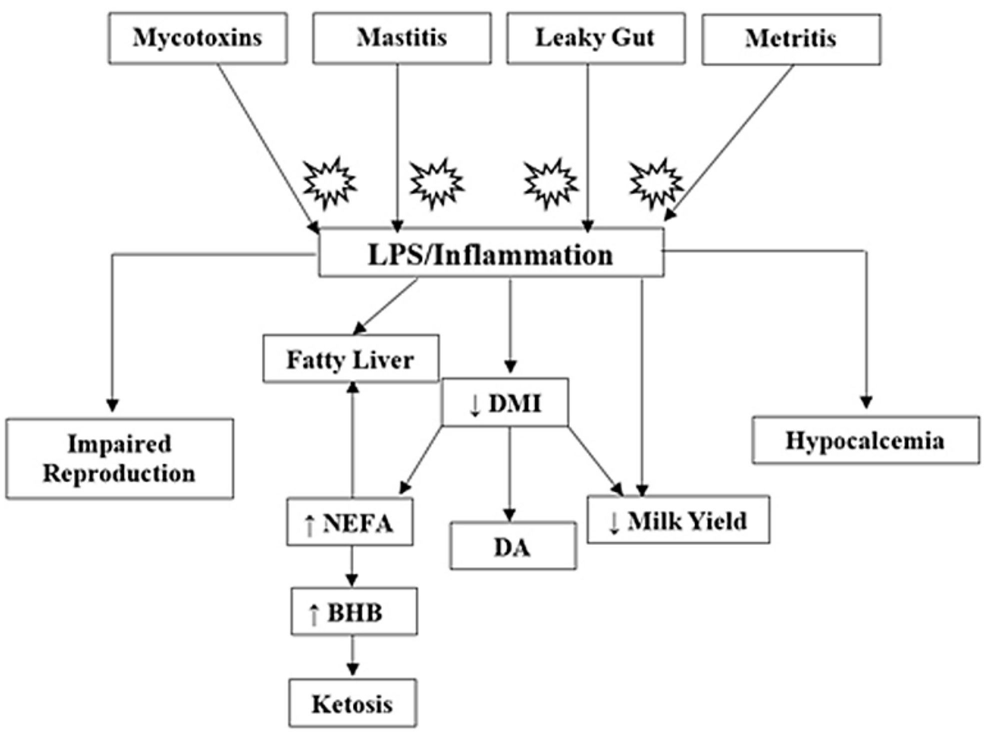

Figure 4. Potential downstream consequences of immune activation. In this model, decreased feed intake, hypocalcemia, excessive NEFA, hyperketonemia and hepatic lipidosis are not causative to poor transition cow performance and health, but rather a reflection of prior immune stimulation.

Why Heifer Maturity MattersThe Peter Pan Problem

Dr. Gavin Staley
BVSc | MMedVet | Dipl. ACT
Technical Service Specialist
Diamond V

Why Heifer Maturity Matters
The Peter Pan Problem

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BVSc | MMedVet | Dipl. ACT
Technical Service Specialist

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The Trusted Experts In Nutrition & Health

1

Heifer maturity – what does that mean?

- Heifer Maturity Definition*:* The phenotypic characteristics (frame and body weight) that allow full expression of genetic potential (e.g. milk production) over the animal's lifetime

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Economic incentives to breed heifers earlier

- **Begin** milk production earlier
- **Reduce** heifer inventory
- **Lower** heifer feed costs

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Heifers needed to maintain herd size at different culling rates and AGEFR

Age at first calving	Cull rate %	Total number of heifers/100 cows required to maintain herd size
24	40	88
23	40	84
22	40	80
21	40	77
24	35	77
23	35	74
22	35	70
21	35	67
24	30	67
23	30	63
22	30	60
21	30	58

Source: Terry Batchhelder, Ph.D in Progressive Dairymen, Dec 2018

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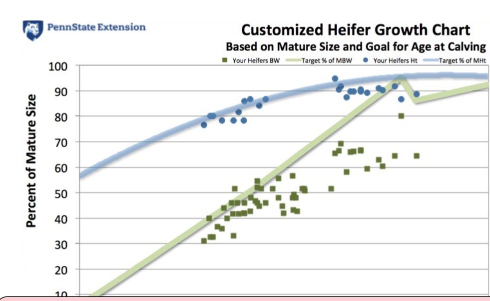
4

Mature heifer growth guidelines



Fresh heifers need to be **85% of mature body** weight post-calving and close-up heifers should be **95% of mature body weight**

Source: Pennsylvania State Extension

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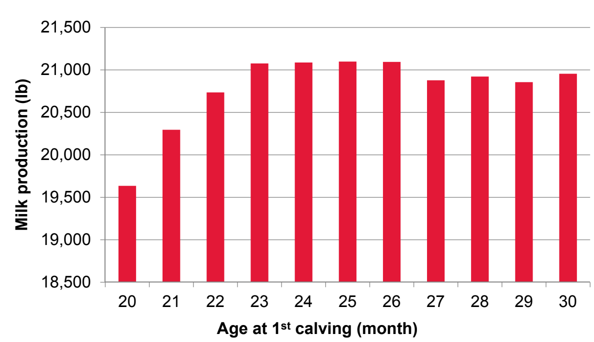
5

Age at calving impacts maturity



Source: Curran et al., 2013, Professional Animal Scientist 29:1-9

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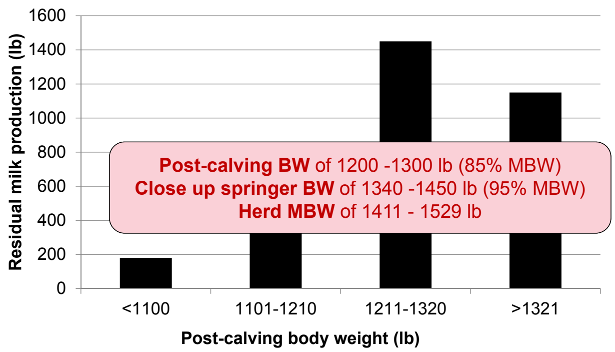
Weight at calving impacts maturity



 Source: Van Amburgh et al., 1998, JDS Feb 81: 527-538

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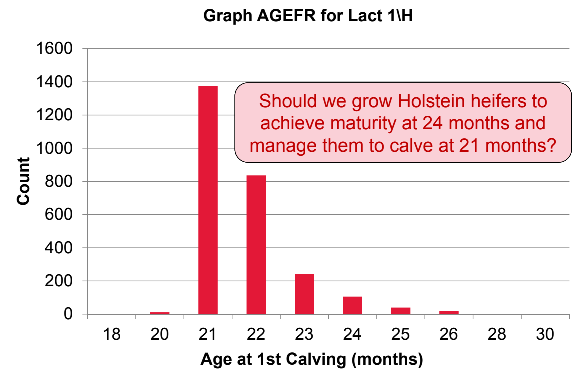
Average Daily Gain (lb/day) is critical



 Source: DairyComp

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Anecdotal evidence: a tale of two dairies

Dairy A: rBST

Dairy B: no rBST

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Dairy A: rBST supplementation

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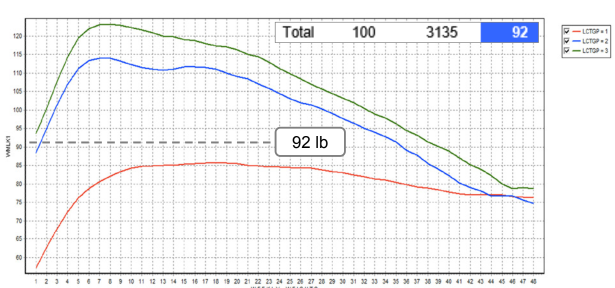
Dairy A: Holstein, 3X, with rBST supplement



 Source: DairyComp

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Dairy B: no rBST supplement

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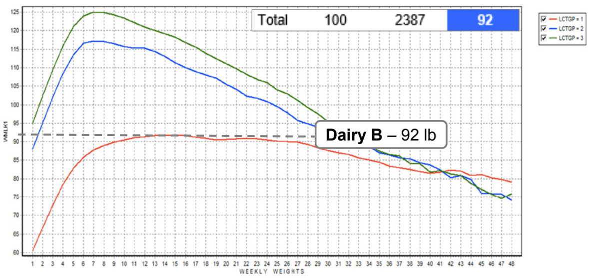
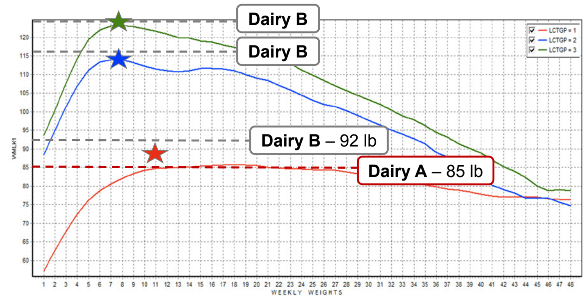
Dairy B: Holstein, 3X, no rBST supplement



 Source: DairyComp

13

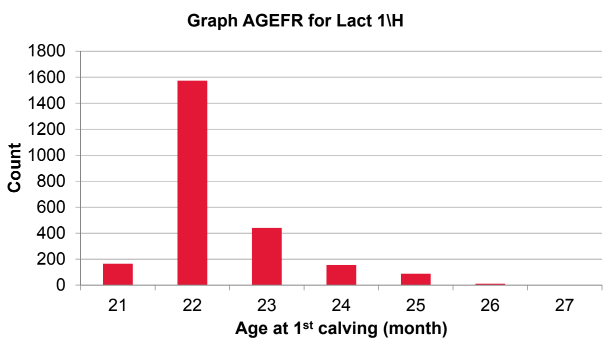
Dairy A (with **Dairy B** lctgp production)



 Source: DairyComp

14

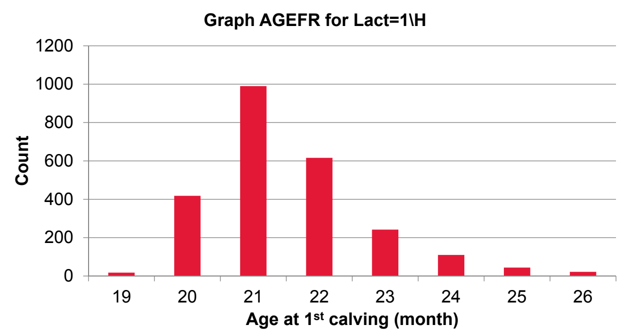
Dairy B (No rBST)
(Age at 1st breeding virgin heifers)



 Source: DairyComp

15

Dairy A (rBST)
(Age at 1st breeding virgin heifers)



 Source: DairyComp

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Observations 1-4

1 2 3 4

- Week 10 Lact 1 milk approximates herd annual avg. milk
- The difference in milk between Lact 1 and Lact 2 animals at Week 5 of lactation is 30 pounds (for Holsteins)
- AGEFR impacts Lact 1 milk production
- AGEFR impacts Lact 2 milk production

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Observation 1

1

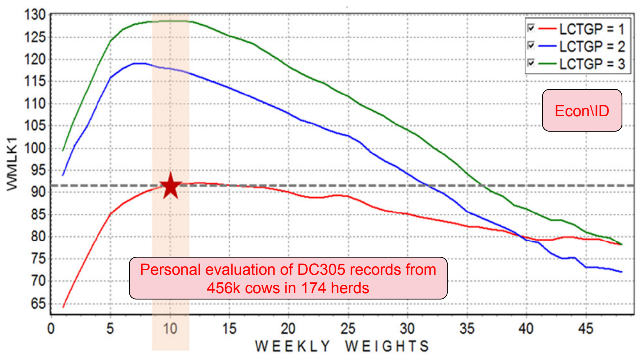
- **Week 10 Lact 1 milk approximates herd annual avg. milk**
- The difference in milk between Lact 1 and Lact 2 animals at Week 5 of lactation is 30 pounds (for Holsteins)
- AGEFR impacts Lact 1 milk production
- AGEFR impacts Lact 2 milk production

18

Observation 1

1

Week 10 Lact 1 milk approximates herd annual avg. milk



 Source: DairyComp

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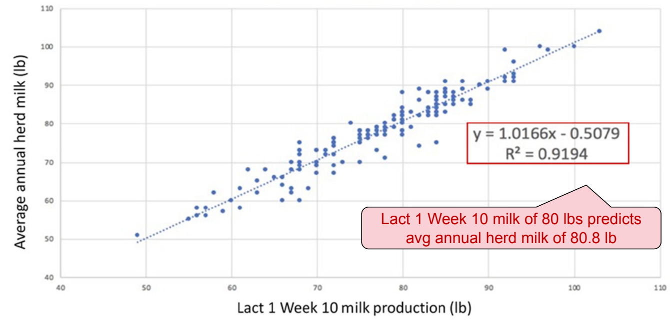
Lact 1 Week 10 & annual herd milk

1



 Source: DairyComp, sample of 401,000 cows in 149 herds

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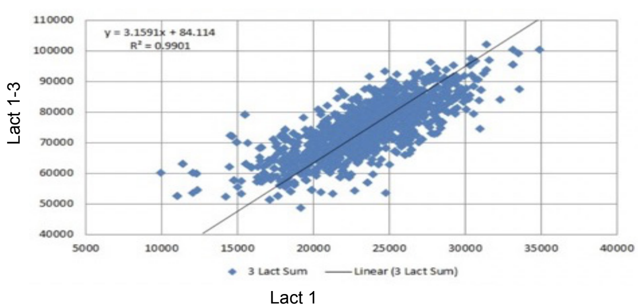
20

Lact 1 milk impacts later lactations

1

M305 (Sum of Lact 1-3, same cows) versus M305 (Lact 1)



 Source: Dr.Todd Birkle, DVM

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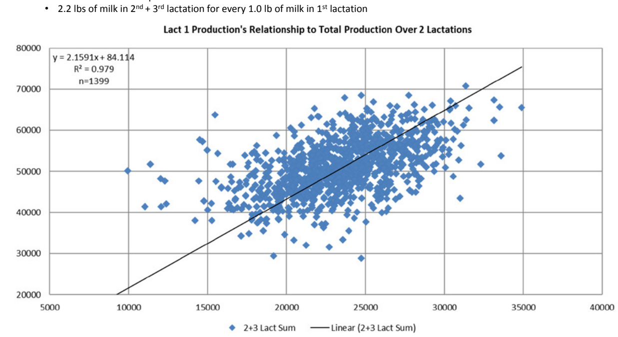
Lact 1 milk impacts later lactations

1

- All animals have completed 3 lactations
- 2.2 lbs of milk in 2nd + 3rd lactation for every 1.0 lb of milk in 1st lactation



 Source: Dr.Todd Birkle, DVM

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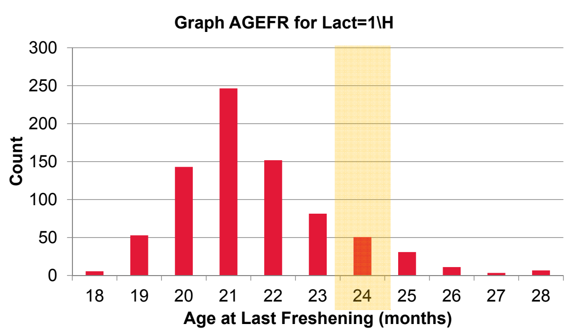
Example: age at calving and milk production



Peter Pan Problem?

 Source: Dr. David Vagnoni, Ph.D, Cal Poly; DairyComp

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Implications of Observation 1

1

- Predict average annual milk for the ENTIRE herd from one single value (and vice versa)
- Lact 1 milk production sets "ceiling" for whole herd
- Herd cannot outperform production level set by Lact 1
  - Example: a herd with 75 lb Lact 1 "peaks" (Week 10 milk) will not be capable of reaching 85 lb herd avg

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Observation 2

2

- Week 10 Lact 1 milk approximates herd annual avg. milk
- **The difference in milk between Lact 1 and Lact 2 animals at Week 5 of lactation is 30 pounds (for Holsteins)**
- AGEFR impacts Lact 1 milk production
- AGEFR impacts Lact 2 milk production

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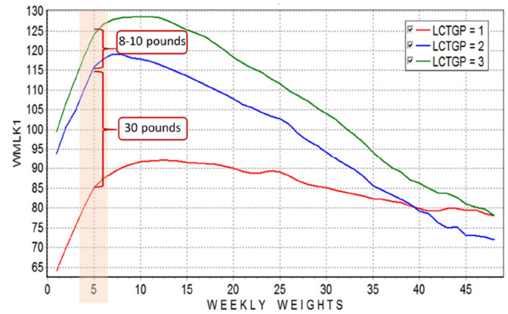
Observation 2

2

The difference in milk between Lact 1 and Lact 2 animals at Week 5 of lactation is 30 pounds (for Holsteins)



 Source: DairyComp

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Implications of Observation 2

2

- Lact 2 and 3 production tightly linked to Lact 1 production
- For Holsteins at Week 5:
  - the difference between Lact 1 and Lact 2 is **30 lb**
  - the difference between Lact 2 and Lact 3 is **8-10 lb**
- This difference appears to be independent of the level of production or milking frequency.

"A rising tide lifts all boats"

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Observation 3

3

- Week 10 Lact 1 milk approximates herd annual avg. milk
- The difference in milk between Lact 1 and Lact 2 animals at Week 5 of lactation is 30 lb (for Holsteins)
- **AGEFR impacts Lact 1 milk production**
- AGEFR impacts Lact 2 milk production

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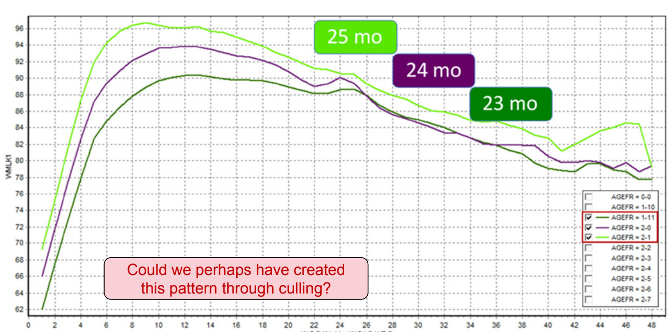
Observation 3

3

AGEFR impacts Lact 1 milk production



 Source: DairyComp

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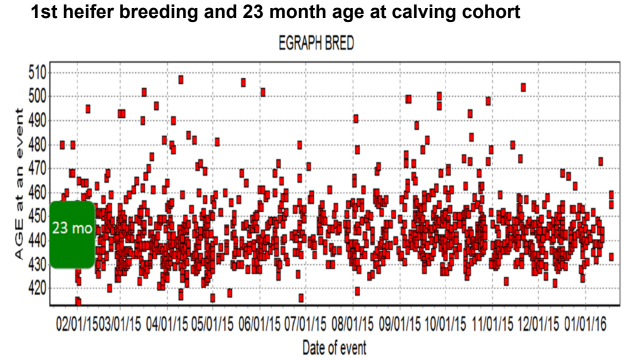
Heifer breeding and age at calving

3

1st heifer breeding and 23 month age at calving cohort



 Source: DairyComp

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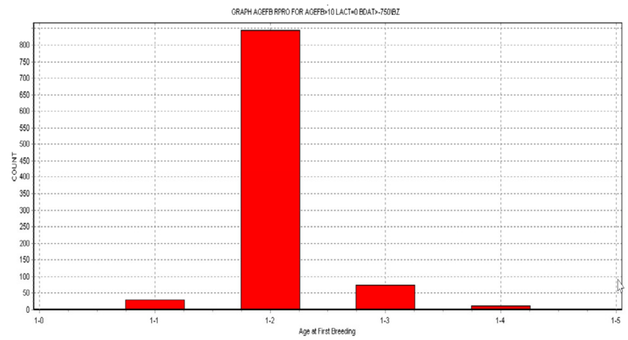
Breeding Heifers – on **AGE**

3



Source: DairyComp
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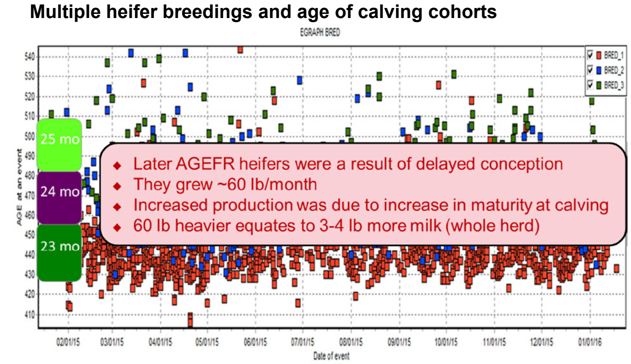
Heifer breeding and age at calving

3

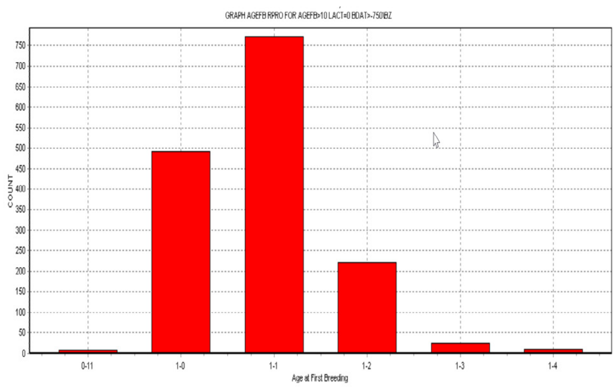
Multiple heifer breedings and age of calving cohorts



Source: DairyComp
Diamond V

Breeding Heifers – on **SIZE**

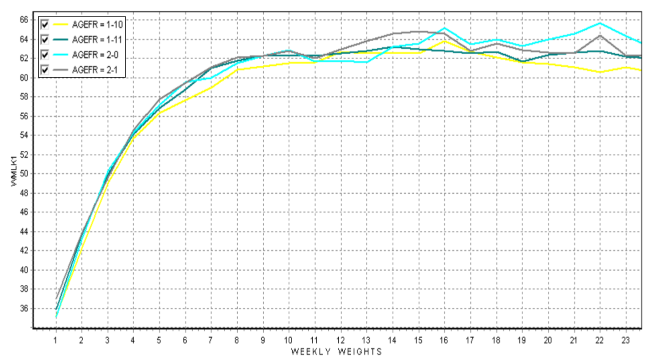
3



Source: DairyComp
Diamond V

Selecting Heifers – on **SIZE**

3



Source: DairyComp
Diamond V

Observation 4

4

- Week 10 Lact 1 milk approximates herd annual avg. milk
- The difference in milk between Lact 1 and Lact 2 animals at Week 5 of lactation is 30 pounds (for Holsteins)
- AGEFR impacts Lact 1 milk production
- **AGEFR impacts Lact 2 milk production**

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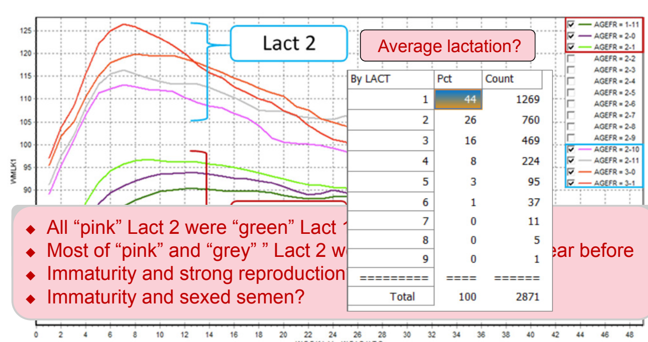
Observation 4

4

AGEFR can impact Lact 2



By LACT	Pct	Count
1	44	1269
2	26	760
3	16	469
4	8	224
5	3	95
6	1	37
7	0	11
8	0	5
9	0	1
=========	====	======
Total	100	2871

Source: DairyComp
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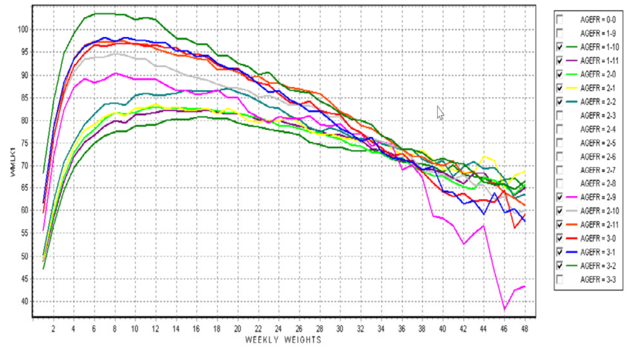
Lact 1 and 2 by AGEFR (3X, Hol)

4



 Source: DairyComp

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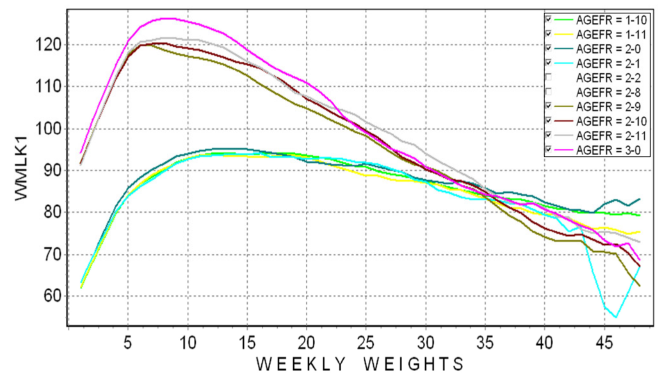
Heifer breeding on Size and Lact2 lactation curves

4



 Source: DairyComp

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Observations 1-4

1 2 3 4

- Week 10 Lact 1 milk approximates herd annual avg. milk
- The difference in milk between Lact 1 and Lact 2 animals at Week 5 of lactation is 30 pounds (for Holsteins)
- AGEFR impacts Lact 1 milk production
- AGEFR impacts Lact 2 milk production

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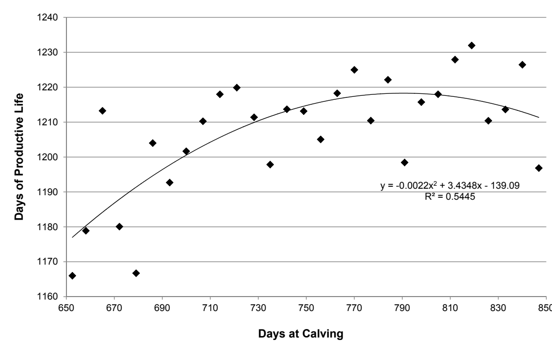
Productive Life by AGEFR



Productive life: days from first calving to culling

 Source: Dr Albert de Vries, Ph.D, University of Florida
DHIA data: calvings in New York State, 2009; sample of 246,286 cows

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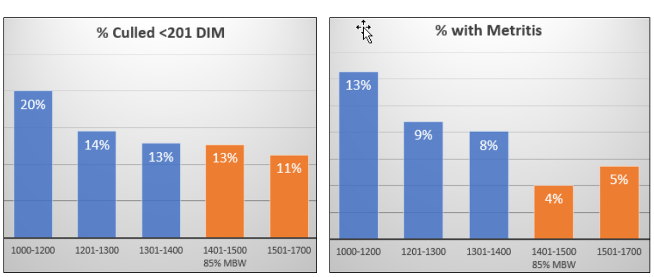
Weight at calving – survival / disease



Sample of 1,880 cows
Animals weighed approximately 1-12 hrs post-calving

 Source: Dr. Todd Birkle, DVM

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Corroborating articles

J. Dairy Sci. 103:4466–4474
https://doi.org/10.3168/jds.2019-17545
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Body weight of dairy heifers is positively associated with reproduction and stayability

R. C. Handcock,[1*] N. Lopez-Villalobos,[1] L. R. McNaughton,[2] P. J. Back,[1] G. R. Edwards,[3] and R. E. Hickson[1]
[1]School of Agriculture and Environment, Massey University, Palmerston North 4442, New Zealand
[2]Livestock Improvement Corporation, Hamilton 3240, New Zealand
[3]Faculty of Agriculture and Life Sciences, Lincoln University, Lincoln 7647, Christchurch, New Zealand

J. Dairy Sci. 102:4577–4589
https://doi.org/10.3168/jds.2018-15229
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Positive relationships between body weight of dairy heifers and their first-lactation and accumulated three-parity lactation production

R. C. Handcock,[1*] N. Lopez-Villalobos,[1] L. R. McNaughton,[2] P. J. Back,[1] G. R. Edwards,[3] and R. E. Hickson[1]
[1]School of Agriculture and Environment, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand
[2]Livestock Improvement Corporation, Private Bag 3016, Hamilton 3240, New Zealand
[3]Faculty of Agriculture and Life Sciences, PO Box 85084, Lincoln University, Lincoln 7647, Christchurch, New Zealand

 Source: Journal of Dairy Science 2018-2019

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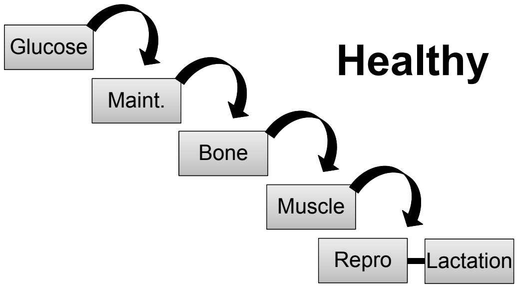
Energy Partitioning – growth priorities



Healthy

If an animal does **not** reach the required level of maturity **BEFORE** calving, she will reach it **DURING** lactation … at the expense of production

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Growing during lactation is costly

Heifer Growth Stage and % Mature Wt.	Mature Bodyweight					
	1,000[1]		1,400[2]		1,800[3]	
	Target Wt. Lbs.	Approx. ADG to Next Target Lbs.	Target Wt. Lbs.	Approx. ADG to Next Target Lbs.	Target Wt. Lbs.	Approx. ADG to Next Target Lbs.
Birth	60	1.1	80	1.4	90	1.6
Weaning 56 days	120	1.7	160	2.0	180	2.4
First breeding 55%	550	1.0	770	1.4	990	1.8
Post-calving, 1st calf 85%	850	0.3	1,190	0.3	1,530	0.4

Energetic cost of growth

- 2.3 Mcal/lb growth
- 0.3 Mcal/lb milk
- Nets out to **8:1 ratio**

Pre-calving maturity deficit will be **paid back in lactation**
Every missing lb BW will **cost 8 lbs milk** ("Heifer Shrink")
Growth will be **7x slower** after calving than before

 Source: Dairy Calf and Heifer Association 2016 Gold Standards

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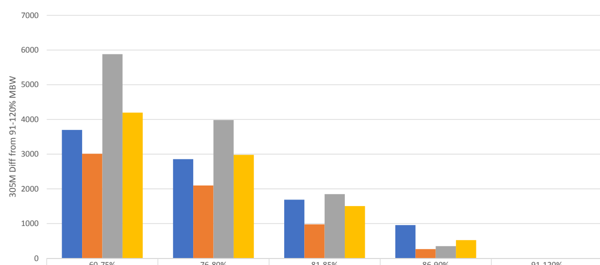
Difference in 305M for Lact=1 at different % MBW (post-calving) compared to animals at 91-120% MBW



	60-75%	76-80%	81-85%	86-90%	91-120%
Herd 1	3699	2856	1688	956	0
Herd 2	3011	2098	978	265	0
Herd 3	5881	3983	1849	349	0
Average	4197	2979	1505	523	0

Source: Dr. Todd Birkle, DVM

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Field Example
(Holstein, Post-calving Lact 1 Weights)

Command ? SUM W8MK BY WEIGH FOR LACT=1 WEIGH>1040\Q4

SUM W8MK

By WEIGH	Pct	Count	Av W8MK
1172	25	56	71.6
1261	25	56	79.1
1330	26	59	83.2
1428	25	57	88.7
Total	100	228	80.3

 Source: DairyComp

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Field Example
(Holstein, Pre-calving Lact 1 Weights)

ADG	By CUWGT	Pct	Count	Av W8MK	AvAGEFR	Av AGED
1.5 lb/d	1144	24	10	60.4	23	838
1.6 lb/d	1220	26	11	61.3	23	839
1.7 lb/d	1299	26	11	68.2	23	833
1.9 lb/d	1412	24	10	68.5	23	840
	Total	100	42	64.6	23	837

 Source: DairyComp

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Field Example
(Jersey, Lact 1-3 M305, same animals

Backup Date	8/1/2017	Suggested
L1 FDAT Max	5/1/2014	5/1/2014
L1 FDAT Min	5/1/2013	

Age Fresh 1		#	%	1st 305M	2nd 305M	3rd 305M	Sum	Deviation from Avg. for Sum
		Inclusion	8%					
>	<=							
19	21	40	12.0%	16151	18838	21893	56882	-1154
21	22	163	49.1%	16876	18761	21591	57228	-808
22	23	102	30.7%	17644	18954	22085	58683	648
23	24	39	11.7%	17784	19695	21871	59350	1314
24	25	19	5.7%	FALSE	FALSE	FALSE		FALSE
25	26	2	0.6%	FALSE	FALSE	FALSE		FALSE
26	27	4	1.2%	FALSE	FALSE	FALSE		FALSE
27	28	3	0.9%	FALSE	FALSE	FALSE		FALSE
28	29	0	0.0%	FALSE	FALSE	FALSE		FALSE
	SUM	372				Avg	58036	

 Source: Dr. Todd Birkle, DVM

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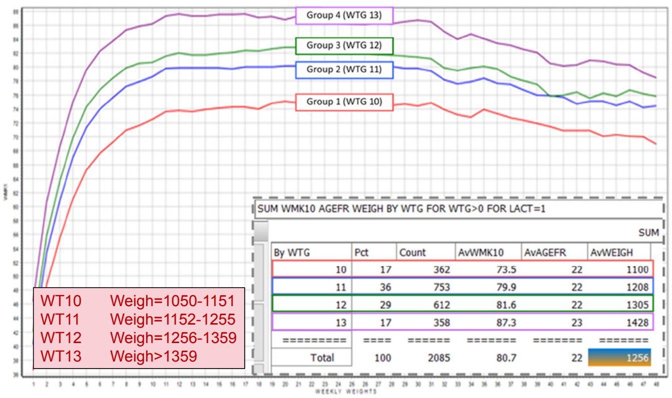
Field Example
(Holstein, 6k, Post-calving Lact 1 weights) by WGT



SUM WMK10 AGEFR WEIGH BY WTG FOR WTG>0 FOR LACT=1

SUM

By WTG	Pct	Count	AvWMK10	AvAGEFR	AvWEIGH
10	17	362	73.5	22	1100
11	36	753	79.9	22	1208
12	29	612	81.6	22	1305
13	17	358	87.3	23	1428
=========	====	======	=======	=======	=======
Total	100	2085	80.7	22	1256

 Source: DairyComp Diamond V

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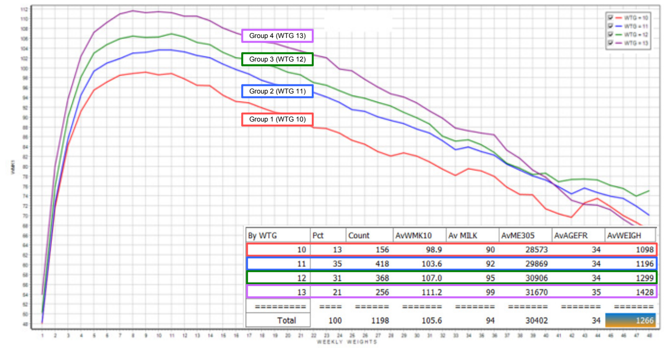
Field Example
(Holstein, Post-calving Lact 2) by WGT



By WTG	Pct	Count	AvWMK10	Av MILK	AvME305	AvAGEFR	AvWEIGH
10	13	156	98.9	90	28573	34	1098
11	35	418	103.6	92	29869	34	1196
12	31	368	107.0	95	30906	34	1299
13	21	256	111.2	99	31670	35	1428
=========	====	======	=======	=======	=======	=======	=======
Total	100	1198	105.6	94	30402	34	1266

 Source: DairyComp Diamond V

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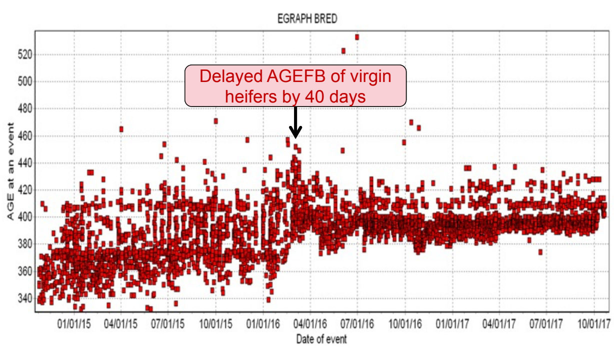
What happened at **Dairy A**?
(AGEFB in days of age)



 Source: DairyComp Diamond V

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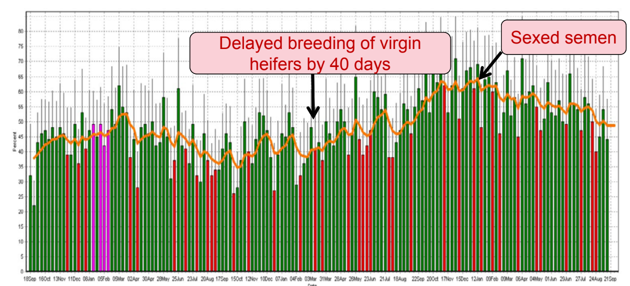
Dairy A: Virgin Heifer Conception Rate
(3 years rolling average)



Virgin heifer CR increased by **20 percentage points** (conventional semen)

 Source: DairyComp Diamond V

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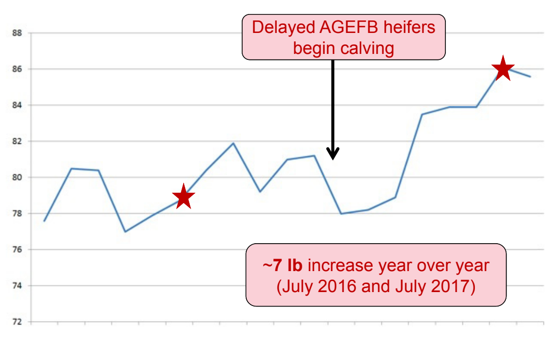
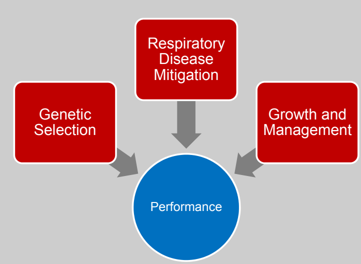
Dairy A: Milk Production
(Wk 6 Milk by MYFSH for Lact 1)



 Source: DairyComp Diamond V

53

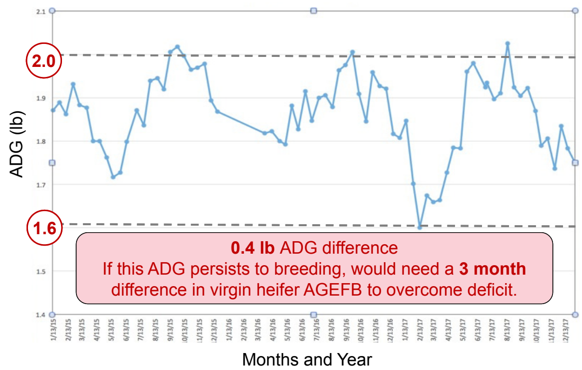
Three key areas impact heifer performance



 Source: Dr. Todd Birkle, DVM Diamond V

54

Graph of Seasonal Fluctuation in ADG
(Heifers of 4-5 months age, average bodyweight of cohort)



 Source: Dairy A

55

Has Calving Immature Heifers been Successful?

- No! ... Why not?
- Calved heifers earlier without changing management.
- Immaturity affects entire productive life not just Lact 1
- Lact 1 do not “catch up” (there is no compensatory growth, no “reset to factory settings”!).

56

Has Calving Immature Heifers been Successful?

- Focus on heifer health (mortality), not on growth.
- Focus on raising heifers cheaply with little regard to growth.
- Common management practices e.g. overcrowding
- No or little actionable, objective monitoring (weights, heights).

A profound disconnect between growth rate (ADG) and AGEFR has occurred on many dairies

57

So what’s the solution?
(Caveat: FRAME not just weight)

- Weigh Lact 3 and Lact 4 cows (80-120 DIM) - MBW
- Weigh Springers (DCC>260) (Goal: 95% MBW) or fresh cows (Goal: 85% MBW). May need to do several times (seasonality)
- Calculate weight difference between desired and actual weights
- Calculate ADG that heifer raising system is achieving
- Determine ADG or AGEFB required to achieve maturity at critical stages (esp. at breeding of heifers)
- Set heifer health and growth goals for all key stages of growth from birth to calving (Colostrum to Calving)
- **Goal is to calve mature heifers as early as possible**

Manage and Monitor for ***Maturity.***

58

DC305 Commands used

- Average annual herd milk:
  - Econ\ID; Select Reports
- Lactation Group curves (to determine Lact 1 wk10mk and calculate difference between Lact 1 & 2 at wk5mk):
  - Plot wmlk1 by lctgp (or lgrp)
- Lactation 1 and 2 lactations by age at calving (impact of agefr on production curves):
  - Plot wmlk1 by agefr for lact=1-2 agefr<40

59

Why Productive Life Matters

Dr. Gavin Staley
BVSc | MMedVet | Dipl. ACT
Technical Service Specialist
Diamond V

Why Productive Life matters

Dr. Gavin Staley

BVSc | MMedVet | Dipl. ACT
Technical Service Specialist

1

Productive life – what is it?

- "Productive lifespan of dairy cattle may be defined as the time from first calving to exit from the herd when the cow is no longer sufficiently productive."
  - Albert De Vries PhD, (JDS 2020, Vol 103, No. 4)
- "A long productive life ("PL") is a desirable trait from several different perspectives. Longevity combines all of the characteristics that are directly associated with a cow's ability to successfully stay in the herd."
  - Tsuruta et. al, (JDS 2005, Vol 88, No. 3)

2

Why should the dairy industry be concerned with Productive Life?

- Economics
  - Profitability
  - Survival in future markets
- Societal Concerns
  - Animal Welfare
    Maintaining high animal welfare up to death is increasingly more important. The public has also indicated a willingness to pay for improved dairy cattle welfare (Wolf and Tonsor, 2017).
  - Climate Change
    A herd with a high proportion of young animals emits more methane and excretes more phosphorus in the environment per unit of milk compared with a herd with a greater proportion of multiparous cows (Hristov et al., 2013)

3

Global trends in Productive Life

Country	Average productive life*
New Zealand	4.2
United Kingdom	3.9
The Netherlands	3.7
Poland	3.3[4]
France	3.2[5]
China	2.7[6]
USA	2.7[7]
Canada	2.7[8]
Israel	2.5

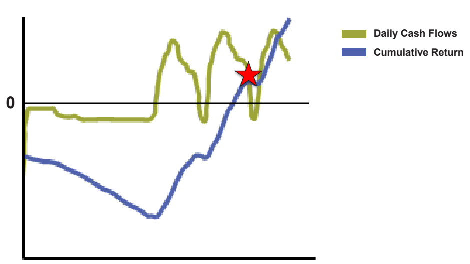
*Productive life = time span between first calving and culling
Source: FAO[9]

4

Why is productive life important?

Breakeven point – lactations with cumulative return

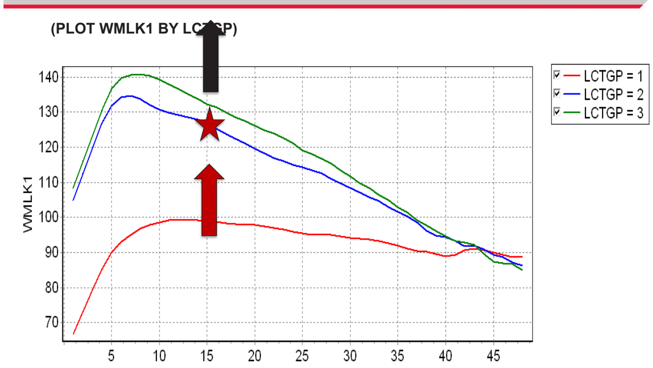
Breakeven point: point at which a cow has created sufficient income from milk production to cover the costs of raising (typically achieved mid-2nd lactation).



Source: Ferguson and Galligan, Western Canadian Dairy Symposium, 1995.

5

Lactation Groups with breakeven point

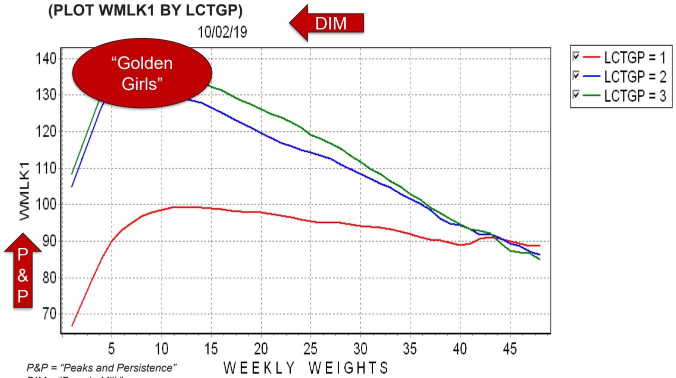


Source: DairyComp 305

6

Lact>2 cows are "Golden Girls"

(PLOT WMLK1 BY LCTGP)



P&P = "Peaks and Persistence"
DIM = "Days in Milk"
Source: DairyComp 305

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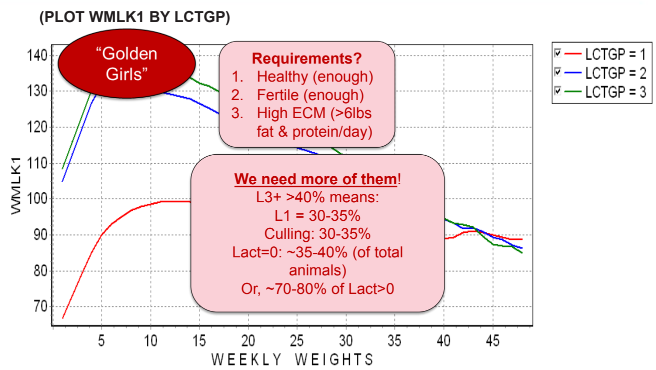
7

"Golden Girls" and demographics

(PLOT WMLK1 BY LCTGP)



Source: DairyComp 305

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8

Where's the value? Follow the money…

(DC305: SUM BY LCTGP FOR LACT>0)

By LCTGP	Pct	Count	AvP305M	Av MILK
1	40	1267	24301	83
2	26	836	28477	96
3	34	1068	29603	104
Total	100	3171	27193	93

5,300lb M305 difference

Source: DairyComp 305

Diamond V

9

Where's the value? Follow the money…

By LCTGP	Pct	Count	Av 305M	Av MILK
1	30	1033	16764	60
2	23	809	20013	73
3	47	1608	21602	80
Total	100	3450	19842	73

Jersey
Ave Lact: 2.6

Jersey
- 47% L3: 1,608 cows, previously 37% L3
- 1,276 cows
- So, 332 more L3 cows

Producing 4,800 lb more milk per lactation (M305)
Equals 1.6M lb more milk for same number of cows

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10

Where's the value? Follow the money…

By LACT	Pct	Count	Av MILK	AvP305M	AvME305
1	33	707	87	21873	29259
2	25	540	109	28103	33243
3	19	394	116	29878	32432
4	12	264	117	29806	30908
5	7	144	116	28879	29277
6	3	67	121	28667	29386
7	0	8	114	25775	26748
Total	100	2124	104	26646	31085

~8,000 lbs

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11

"Lactree"

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12

Where's the value? Follow the money…

By LACT	Pct	Count	AvP305M	Av305ME	AvME305	Av RELV
1	30	1074	24249	31218	31727	99
2	25	880	28692	32105	33569	102
3	18	630	29690	31352	32103	99
4	14	482	30352	31154	31353	99
5	8	274	29990	30788	30419	98
6	4	134	30368	31218	30790	99
7	1	45	29812	31150	30311	99
8	0	15	28371	29918	29071	95
9	0	2	26720	30190	28215	96
=========	====	======	=======	=======	=======	=======
Total	100	3536	27919	31413	32032	100

	A	B
1	Age Fresh	January
2	19	141
3	19.5	139
4	20	137
5	20.5	136
6	21	133
7	21.5	132
8	22	131
9	22.5	130
10	23	129
11	23.5	128
12	24	127
13	24.5	125
14	25	125
15	25.5	123
16	26	122

Source: California dairy, DairyComp

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13

Culling rate and number of heifers needed

Age at first calving	Cull rate %	Total number of heifers/100 cows required to maintain herd size
24	40	88
23	40	84
22	40	80
21	40	77
24	35	77
23	35	74
22	35	70
21	35	67
24	30	67
23	30	63
22	30	60
21	30	58

Source: Terry Batchhelder, Ph.D in Progressive Dairymen, Dec 2018

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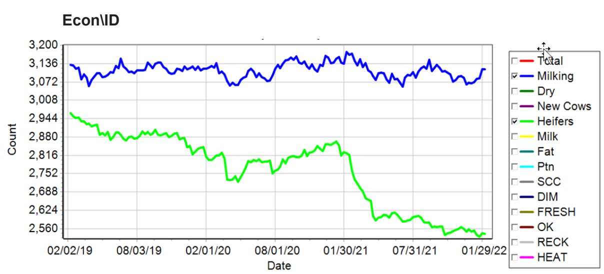
14

Excessive heifers (sexed semen, ~30% 21-day PR) "Heifer Pressure"



Source: DairyComp 305

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15

How many heifers do you need?

Equation: 2*(Herd size)*(**TOR**)*(**AFC**/24)*(1+**NCR**)

Variables:

TOR
- Turnover rate ("culling rate")
- Expressed as a decimal fraction

AFC
- Age at first calving (months)

NCR
- Non-completion rate
- Heifers born alive (not DOA) that leave before entering the herd
- Expressed as a decimal fraction

Source: David Vagnoni, Ph.D, Cal Poly

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16

Typical herd lactation demography

(DC305: SUM BY LCTGP)

By LCTGP	Pct	Count
0	52	3458
1	19	1245
2	14	902
3	16	1052
=========	====	======
Total	100	6657

How many heifers produced and non-completion rate?
- Econ for Lact=0 gndr=F\E (current)
- Events\3SD (set 12 mth interval 3 yrs prior; subtract DOA's)
- Events\2SI1415 ID BDAT FDAT ARDAT for lact=0 gndr=F BDAT=?-? (set same 12mth interval and set parameters to allow 2 yrs to pass for all animals)

Source: California dairy, DairyComp

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17

Dairy with high number of heifers

By LCTGP	Pct	Count
---------	----	------
0	50	4951
1	20	1988
2	14	1444
3	16	1598
=========	====	======
Total	100	9981

This dairy has **50% heifers** (of all animals)**:**
1. Heifer attrition birth to calving (~24%)
2. So ~40% will calve
3. % heifers minus attrition will be herd culling rate

If the dairy only needs 30% Heifers (Lact=0) to maintain a 30% Cull Rate, there are **~10% TOO MANY heifers**

10% of 4951 =495 heifers
495 X $2/day X 365 =$361,000

Source: DairyComp 305

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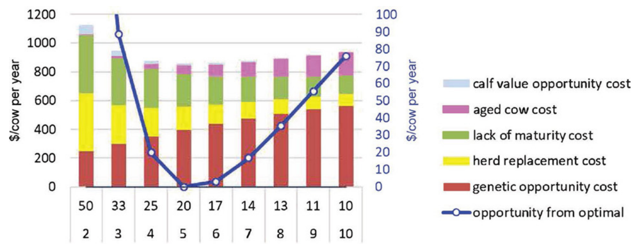
18

Five key factors influencing herd parity demographic

"The five drivers of total cost of maintaining herd structure"



Top: Annual cull rate (%)
Bottom: Average number of lactations

Source: Albert De Vries PhD, JDS, 2020, Vol. 103, No. 4

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19

Zoetis/Compeer Financial Evaluation

Table 1. Correlations between NFI and key measures.

Variable	Correlation with NFI	Key Learnings
ECM shipped, lb/cow/day	0.18**	More milk per cow is profitable — effect of marginal milk
Heifer survival rate, %	0.15**	Keeping calves healthy is beneficial
21-day pregnancy risk	0.13*	Increased days open is expensive (small sample)
Number heifers	0.10*	Maintaining heifer inventory that aligns with cow cull rate can improve profitability; excess heifer inventory is costly
ECM shipped, herd total, cwt	0.10**	Profitability is related to cwt of milk shipped
Herd size, lactating	0.08*	Due to economy of scale, larger herds that ship more milk are more profitable.
Death loss, %	-0.11**	Death losses negatively impact profitability
Somatic cell count (SCC)	-0.12**	Investing to produce high quality milk is profitable
Labor cost[a]	-0.17**	A well-paid workforce is profitable
Net herd turnover cost[b]	-0.29**	Targeted culling and minimizing death losses improves profitability by increasing revenue from cow and milk sales

Correlation different from zero: $^{*}P < 0.05$; $^{**}P < 0.01$
[a] Labor cost, $/cwt ECM (includes wages, benefits, Social Security, owner draw)
[b] Net herd replacement cost, $/cwt ECM (difference between replacement cow value and book value of dead + sold cull cows [for dairy or beef])

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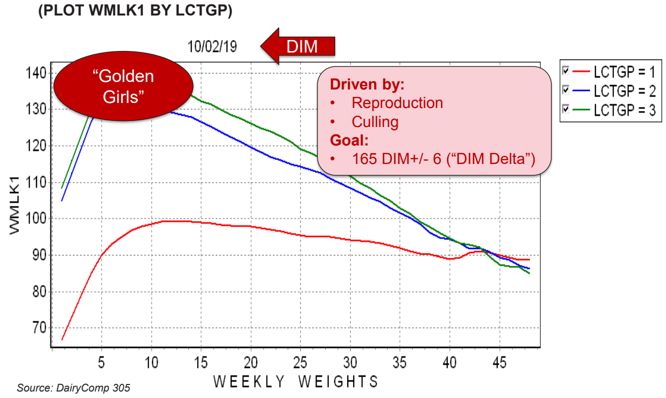
20

Part 1: DIM factors (reproduction + culling)

(PLOT WMLK1 BY LCTGP)



Source: DairyComp 305

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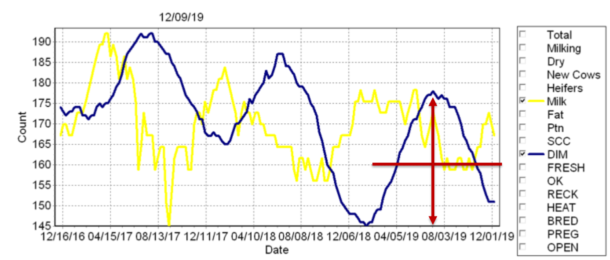
21

Milk and DIM – "DIM Delta"

(DC305: ECON\ID; DIM; 3 years)



Source: DairyComp 305

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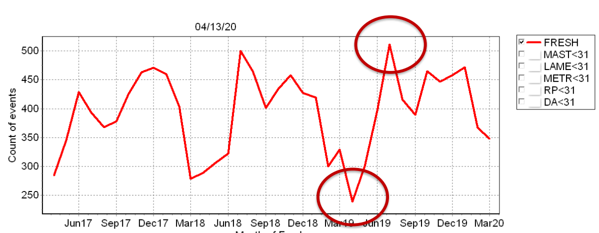
22

Transition "slugs" (100% difference in calving/month)

(DC305, GUIDE, Transition, Summary, Fresh Events)



Source: DairyComp 305

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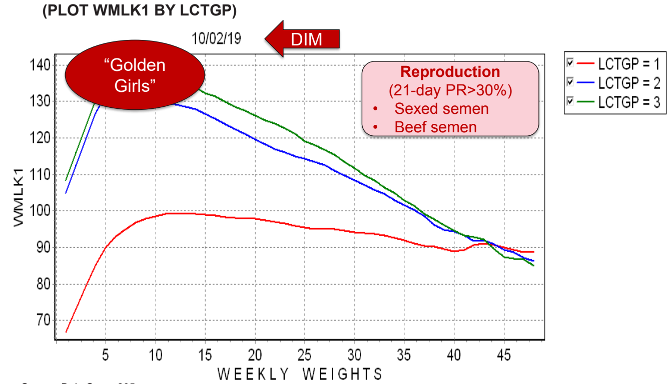
23

DIM: Reproduction

(PLOT WMLK1 BY LCTGP)



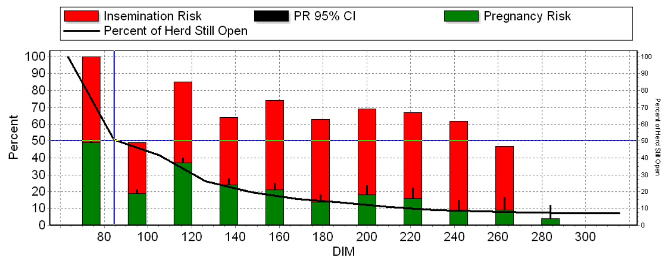
Source: DairyComp 305

Diamond V

24

Reducing DIM: 21-day PR (longitudinal analysis)

(DC305: Bredsum \ar, Option E, Graph)



Source: DairyComp 305

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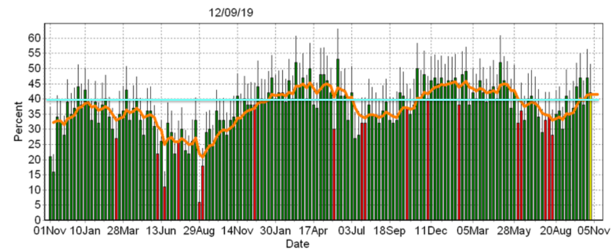
25

Reducing DIM – heat stress & conception rate (3-yr)

By date from 11/6/16 through 11/18/19



Source: California dairy, DairyComp 305, VAS

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26

Culling information for cows

(DC305, Econ for Lact>0\E; Events, Option 6)

Cows sold/dead from 10/ 2/18 through 10/ 2/19

DCAR	Jan19	Feb19	Mar19	Apr19	May19	Jun19	Jul19	Aug19	Sep19	Oct**	Nov18	Dec18	Total
Sold -- dairy	0	1	0	0	0	0	0	0	0	0	0	0	1
Sold -- low production	49	77	49	72	26	18	45	12	18	30	15	36	447
Sold -- injury, sick	21	19	27	20	14	11	25	25	9	22	13	22	228
Died	15	18	12	16	17	13	12	10	11	18	16	12	170
Sold -- mastitis	4	9	7	3	0	4	5	1	22	14	3	7	79
Abort	0	0	1	1	0	5	0	3	0	1	0	2	13
Totals	89	124	96	112	57	51	87	51	60	85	47	79	938

Cows	
2383	cows in this group

Event	Total	<31	60	90	120	150	180
FRESH	2524	2524	0	0	0	0	0
OK	568	14	37	118	34	77	71
RECK	1089	1	9	12	351	174	164
HEAT	3066	556	1560	133	218	142	108
BRED	6341	1	0	2469	1228	894	584
PREG	1958	0	0	867	362	272	175
OPEN	3472	1	0	1262	676	497	332
PREV	19	0	0	0	1	7	1
DRY	1648	0	0	0	0	0	0
ABORT	257	0	0	0	6	48	41
DNB	403	33	21	27	23	19	18
SOLD	768	63	42	43	58	43	52
DIED	170	71	12	11	12	9	6

938 Sold & Died
Culls: 938/2383 = **39%**

Source: DairyComp 305

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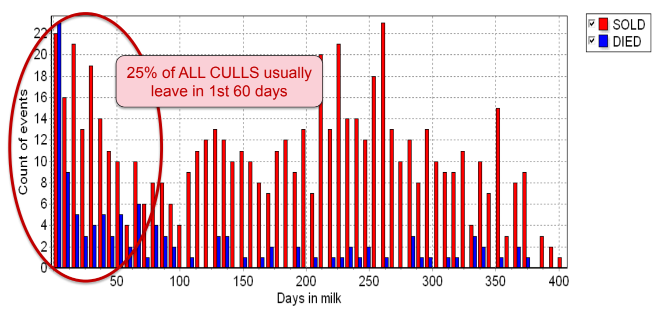
27

When are cows being culled?

(GRAPH SOLD;15 BY DIM FOR LACT>0 DIM<400)



Source: DairyComp 305

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28

Reasons for Culling

Table 1. Reasons for Culling Cows from Dairy Herds

	Reasons for Culling	Percent of the Total Cull Rate (percent+/-SE)
Voluntary Culling		
	Poor production	18.3 +/-2.2
	Sold for replacements	4.6 +/-1.3
	Aggressive temper	0.7 +/-0.2
	Other	3.2 +/-0.8
Involuntary Culling		
	Infertility	23.3 +/-1.8
	Mastitis	18.6 +/-1.3
	Lameness	9.1 +/-0.7
	Injuries	3.5 +/-0.7
	Respiratory	2.4 +/-0.3
	Metritis	2.2 +/-0.7
	Displaced Abomasum	2.0 +/-0.2
	Other*	12.1
	Death	6.2 +/-0.5

*Includes reasons and deaths that occurred less than two percent

Penn State Extension, Oct 2020, 2018 USDA/NAHMS health and Management practices

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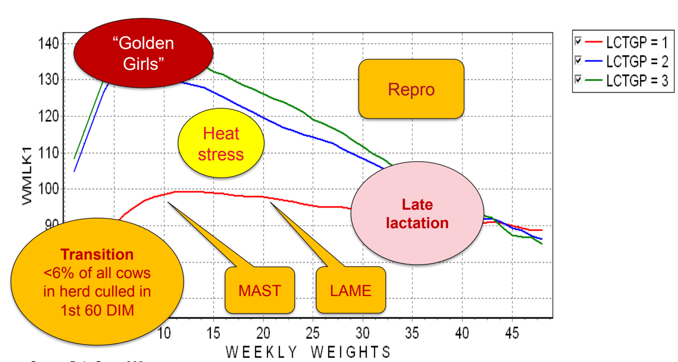
29

Culling and "The Four Horsemen of the Apocalypse"

(PLOT WMLK1 BY LCTGP)



Source: DairyComp 305

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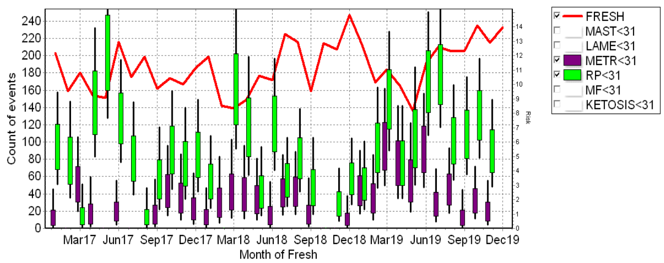
30

Involuntary culls: “Leaky Bucket” Transition disease

(DC305, Guide, Transition, Summary of fresh events)



Source: DairyComp 305

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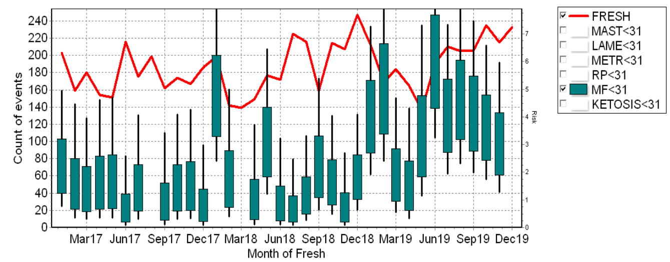
31

Involuntary culls: “Leaky Bucket” Transition disease

(DC305, Guide, Transition, Summary of fresh events)



Source: DairyComp 305

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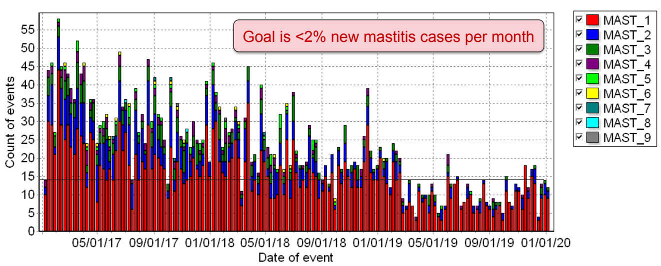
32

Involuntary culls: “Leaky Bucket” MAST

(DC305: GRAPH MAST:10 FOR LACT>0)



Source: DairyComp 305

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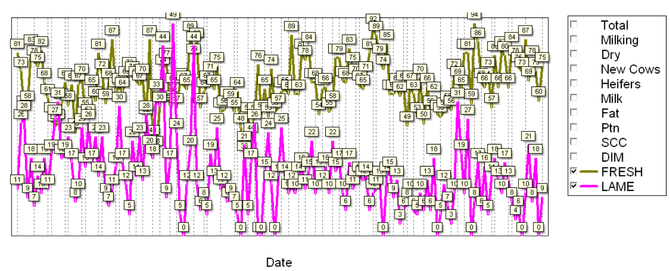
33

Involuntary culls: “Leaky Bucket” LAME

(DC305: Econ\ID)



Source: DairyComp 305

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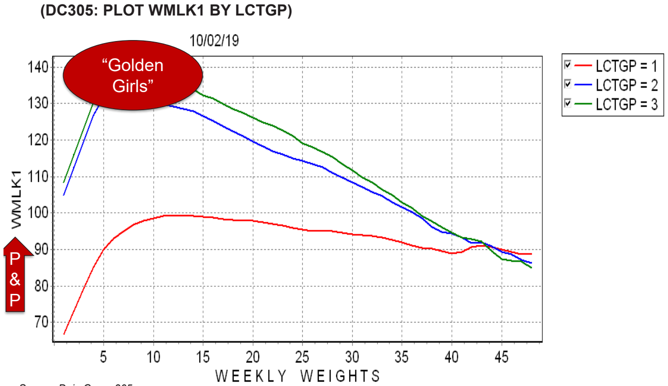
34

Part 2: Peaks and Persistence

(DC305: PLOT WMLK1 BY LCTGP)



Source: DairyComp 305

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35

Increasing productive life: “Peaks and Persistence"

1. Heifer maturity (“Peter Pan Problem”)
2. Production (ECM, >6lb fat and protein)*
3. Smooth Transition (Disease %)
4. Cow comfort (Facilities, Bedding, Rubber)
5. Genetics (Crossbreds, Health traits)
6. Forage Quality (corn and winter silage, byproducts)
7 Optimize heat abatement (Holding pen, Fans, Soakers)

Source: Steve Bodart, Compeer

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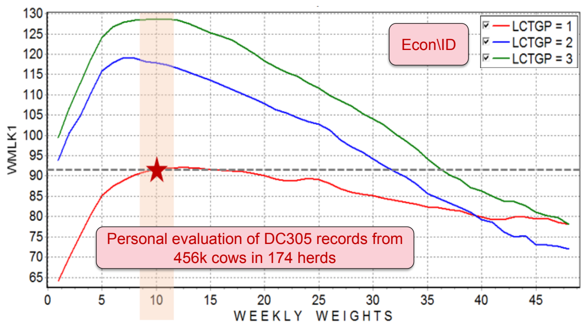
36

Heifer maturity: importance of Lact=1 peak milk

Week 10 Lact 1 milk approximates herd annual avg. milk



Source: California dairy, DairyComp 305, VAS

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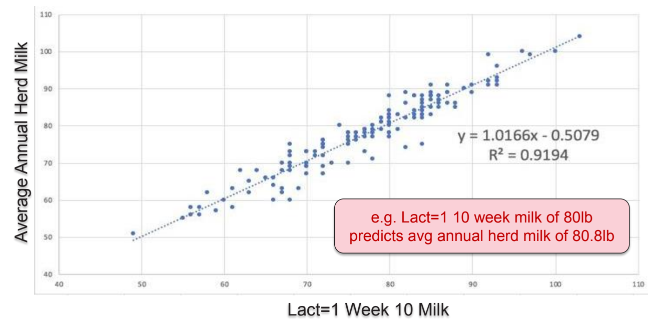
Importance of heifer maturity

Lact =1 10 week milk & avg annual herd milk



Source: 401k cows in 149 herds

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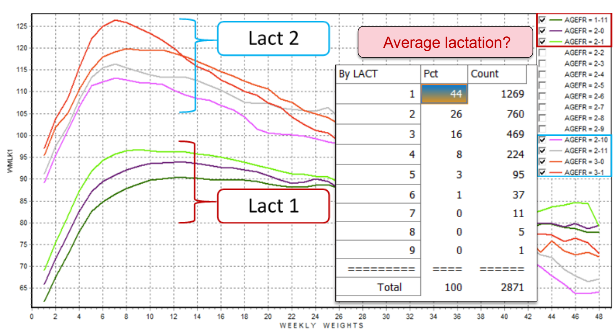
38

Impact of heifer maturity on Lact 1 and 2

AGEFR can impact Lact 2



By LACT	Pct	Count
1	44	1269
2	26	760
3	16	469
4	8	224
5	3	95
6	1	37
7	0	11
8	0	5
9	0	1
=========	====	======
Total	100	2871

Source: California dairy, DairyComp 305, VAS

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39

Increasing productive life: reducing DIM & variability

8. DIM (160 +\- 5 days) (seasonal calving variability)
9. Pregnancy Rates (synch. programs, 21-day PR>25%, abortions)
10. Heat abatement (Bredsum\r, “Slugging”)
11. Culling (late lactation, voluntary)

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40

Involuntary culls: stopping the “Leaky Bucket”

12. Mastitis (% clinical and subclinical, parlor efficiency)
13. Lameness (alleyways, %, type, occurrence, hoof trimming)
14. Transition Disease
15. People (attitude, skill, loyalty)

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Summary I/II

- The average lactation of most dairy herds is low (2.1-2.2) which means productive life is limited
- Many cows still have a replacement cost “mortgage” since breakeven point is in 2nd lactation
- Healthy mature cows (Lact>2) are most profitable
- Two key factors are: (1) lowering DIM and (2) increasing peaks and persistence

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Summary II/II

- Limiting heifer inventory is key to lowering culling rate ("Heifer Pressure")
- Managing/mitigating the causes for involuntary culling ("The 4 Horsemen of the Apocolypse") are critical to increasing the number of healthy mature cows
- Dairies can shift the demographics to mature the herd ("graduate cows")
- This is a primarily a voluntary management decision on most dairies

Diamond V

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Dry-off Inflammation and its Association with Transition Cow Performance

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Introduction

Suboptimal milk yield limits the U.S. dairy industry's productive competitiveness, marginalizes efforts to reduce inputs into food production, and increases animal agriculture's carbon footprint. There are a variety of circumstances in a cow's life which activate the immune system and result in hindered productivity (i.e., metritis, mastitis, intestinal dysfunction). Although there are many etiological origins, a commonality among them is increased production of inflammatory biomarkers and markedly altered nutrient partitioning. Importantly, nutrition programs are frequently inculpated for poor transition cow performance because of the (likely fallacious) presumed adverse effects of elevated lipid metabolites and hypocalcemia on production and immunosuppression. In contrast, we suggest that many post-calving undesirable phenotypes (reduced dry matter intake [DMI], hypocalcemia, elevated non-esterified fatty acids [NEFA], hyperketonemia) are a direct consequence of immune activation and not themselves causative of transition cow maladies. For a more detailed description of the areas covered herein, see our recent review (Horst et al., 2021).

Traditional Dogmas

Long-standing tenets describe a causal role of hypocalcemia, increased NEFA, and hyperketonemia in the incidence of transition diseases and disorders (Figure 1). Hypocalcemia has traditionally been considered a gateway disorder leading to ketosis, mastitis, metritis, displaced abomasum, impaired reproduction, and decreased milk yield (Curtis et al., 1983; Goff, 2008; Martinez et al., 2012; Chapinal et al., 2012; Riberio et al., 2013; Neves et al., 2018a,b). The proposed mechanisms by which hypocalcemia leads to these ailments include impaired skeletal muscle strength and gastrointestinal motility (Goff, 2008; Oetzel, 2013; Miltenburg et al., 2016), decreased insulin secretion (Martinez et al., 2012, 2014), and the development of immunosuppression (Kimura et al., 2006). Like hypocalcemia, increased NEFA and hyperketonemia are presumed causative to illnesses such as DA, retained placenta, metritis, reduced lactation performance, poor reproduction, and an overall increased culling risk (Cameron et al., 1998; LeBlanc et al., 2005; Duffield et al., 2009; Ospina et al., 2010; Chapinal et al., 2011; Huzzey et al., 2011). Excessive NEFA mobilization and the affiliated increase in hepatic lipid uptake, triglyceride (TG) storage, and ketone body production has been traditionally believed to be the driving factor leading to ketosis and fatty liver (Grummer, 1993; Drackley, 1999). Additionally, elevated NEFA and ketones are thought to compromise immune function (Lacetera et al., 2004; Hammon et al., 2006; Scalia et al., 2006; Ster et al., 2012) and suppress feed intake (Allen et al., 2009). Thus, the magnitude of changes in NEFA, BHB and Ca have traditionally thought to be predictors of future performance and problems.

Inflammation in the Transition Period

Regardless of health status (Humblet et al., 2006), increased inflammatory biomarkers are observed in nearly all cows during the periparturient period (Ametaj et al., 2005; Humblet et al., 2006; Bionaz et al., 2007; Bertoni et al., 2008; Mullins et al., 2012). The magnitude and persistency of the inflammatory response seems to be predictive of transition cow performance (Bertoni et al., 2008; Bradford et al., 2015; Trevisi and Minuti, 2018). During the weeks surrounding calving, cows are exposed to a myriad of stressors which may permit endotoxin entry into systemic circulation and thereby initiate an inflammatory response (Khafipour et al., 2009; Kvidera et al., 2017c; Proudfoot et al., 2018; Barragan et al., 2018; Koch et al., 2019). The frequency and severity of these inflammation-inducing insults presumably determines the level of inflammation that follows (Bertoni et al., 2008; Trevisi and Minuti, 2018). Common origins of endotoxin entry include the uterus (metritis) and mammary gland (mastitis). Additionally, we believe the gastrointestinal tract may contribute as many of the characteristic responses (rumen acidosis, decreased feed intake, and psychological stress) occurring during the transition period can compromise gut barrier function (Horst et al., 2021).

Although an overt inflammatory response is present around calving, numerous reports have described a reduction in immune competence during this time (Kehrli et al., 1989; Goff and Horst, 1997; Lacetera et al., 2005). Traditionally, hypocalcemia and hyperketonemia have been primary factors considered responsible for periparturient immunosuppression (Goff and Horst, 1997; Kimura et al., 2006; LeBlanc, 2020); however, recent evidence suggests this is more complex than originally understood and that the systemic inflammatory milieu may be mediating the immune system to become "altered" and not necessarily "suppressed" around calving (Trevisi and Minuti, 2018; LeBlanc, 2020). Whether or not the "immune incompetence" frequently reported post-calving is causative to future illnesses or is a consequence of prior immune stimulation needs further attention.

The Importance of Glucose

To adequately recognize the connection between inflammation and transition period success, an appreciation for the importance of glucose is a prerequisite. Glucose is the precursor to lactose, the milk constituent primarily driving milk volume through osmoregulation (Neville, 1990). Approximately 72 g of glucose is required to synthesize 1 kg of milk (Kronfeld, 1982). A variety of metabolic adaptations take place in lactating mammals including increased liver glucose output and peripheral insulin resistance which allows for skeletal muscle to have increased reliance upon lipid-derived fuel (i.e., NEFA and BHBA) to spare glucose for milk synthesis and secretion by the mammary gland (Baumgard et al., 2017). The immune system is also heavily reliant on glucose when activated. The metabolism of inflammation (discussed below) has its own unique metabolic footprint to direct glucose toward the immune system. Consequently, when the onset of inflammation and lactation coincide, glucose becomes an extremely valuable and scarce resource.

Ketogenesis occurs when glucose is in short supply. This can come from a combination of factors including lack of substrate (i.e., reduced feed intake and ruminal fermentation) or high glucose utilization by other tissues (i.e., the immune system or mammary gland). When glucose demand is high, the TCA cycle intermediate oxaloacetate leaves the cycle to supply carbon for gluconeogenesis. Oxaloacetate is also the molecule that combines with acetyl CoA (the end-product of adipose-derived NEFA) to allow the TCA cycle to continue progressing. If the TCA cycle is limited in its progression due to lack of oxaloacetate, acetyl CoA enters into ketogenesis. The link between onset of lactation, immune system activation, and lack of glucose leading to ketogenesis may help to explain the metabolic footprint of a poorly transitioning dairy cow.

Metabolism of Inflammation

Inflammation has an energetic cost which redirects nutrients away from anabolic processes (see review by Johnson, 2012) and thus compromises productivity. Upon activation, most immune cells become obligate glucose utilizers via a metabolic shift from oxidative phosphorylation to aerobic glycolysis (not anaerobic glycolysis typically learned about in biochemistry classes), a process known as the Warburg effect (Figure 2).

This metabolic shift allows for rapid ATP production and synthesis of important intermediates which support proliferation and production of reactive oxygen species (Calder et al., 2007; Palsson-McDermott and O'Neill, 2013). In an effort to facilitate glucose uptake, immune cells become more insulin sensitive and increase expression of GLUT3 and GLUT4 transporters (Maratou et al., 2007; O'Boyle et al., 2012), whereas peripheral tissues become insulin resistant (Poggi et al., 2007; Liang et al., 2013). Furthermore, metabolic adjustments including hyperglycemia or hypoglycemia (depending upon the stage and severity of infection), increased circulating insulin and glucagon, skeletal muscle catabolism and subsequent nitrogen loss, and hypertriglyceridemia occur (Filkins, 1978; Wannemacher et al., 1980; Lanza-Jacoby et al., 1998; McGuinness, 2005). Interestingly, despite hypertriglyceridemia, circulating BHB often decreases following LPS administration (Waldron et al., 2003a,b; Graugnard et al., 2013; Kvidera et al., 2017a). The mechanism of LPS-induced decreases in BHB has not been fully elucidated but may be explained by increased ketone oxidation by peripheral tissues (Zarrin et al., 2014). Collectively, these metabolic alterations are presumably employed to ensure adequate glucose delivery to activated leukocytes.

Energetic Cost of Immune Activation

The energetic costs of immunoactivation are substantial, but the ubiquitous nature of the immune system makes quantifying the energetic demand difficult. Our group recently employed a series of LPS-euglycemic clamps to quantify the energetic cost of an activated immune system. Using this model, we estimated approximately 1 kg of glucose is used by an intensely activated immune system during a 12-hour period in lactating dairy cows. Interestingly, on a metabolic body weight basis the amount of glucose utilized by LPS-activated immune system in mid- and late-lactation cows, growing steers and growing pigs were 0.64, 1.0, 0.94, 1.0, and 1.1 g glucose/kg BW0.75/h, respectively; Kvidera et al., 2016, 2017a,b, Horst et al., 2018, 2019). A limitation to our model is the inability to account for liver's contribution to the circulating glucose pool (i.e., glycogenolysis and gluconeogenesis). However, both glycogenolytic and gluconeogenic rates have been shown to be increased during infection (Waldron et al., 2003b; McGuinness, 2005) and Waldron et al. (2006) demonstrated that ~87 g of glucose appeared in circulation from these processes. Furthermore, we have observed both increased circulating glucagon and cortisol (stimulators of hepatic glucose output) following LPS administration (Horst et al., 2019) suggesting we are underestimating the energetic cost of immunoactivation. The reprioritization of glucose trafficking during immunoactivation has consequences as both are considerable glucose-demanding processes. Increased immune system glucose utilization occurs simultaneously with infection-induced decreased feed intake: this coupling of enhanced nutrient requirements with hypophagia obviously decrease the amount of nutrients available for the synthesis of valuable products (milk, meat, fetus, wool, etc.).

Inflammation and Metabolic Disorders

The periparturient period is associated with substantial metabolic changes involving normal homeorhetic adaptions to support glucose sparing for milk production. Early lactation dairy cows enter a normal physiological state during which they are unable to consume enough nutrients to meet maintenance and milk production costs and typically enter negative energy balance (NEB; Drackley, 1999; Baumgard et al., 2017). During NEB, cows mobilize NEFA in order to partition glucose for milk production in a homeorhetic strategy known as the "glucose sparing." However, increasing evidence suggests that chronic inflammation may be an additional energy drain that initiates the sequence of these disorders (Bertoni et al., 2008; Eckel and Ametaj, 2016) and this is supported by human, rodent, and ruminant literature which demonstrate effects of lipopolysaccharide (LPS) and inflammatory mediators on metabolism and hepatic lipid accumulation (Li et al., 2003; Bradford et al., 2009; Ilan et al., 2012; Ceccarelli et al., 2015). We and others have demonstrated that cows which develop ketosis and fatty liver postpartum have a unique inflammatory footprint both pre- and post-partum (Ohtsuka et al., 2001; Ametaj et al., 2005; Abuajamieh et al., 2016; Mezzetti et al., 2019; Figure 3). Because the activated immune system has an enormous appetite for glucose, it can exacerbate a glucose shortage by both increasing leukocyte glucose utilization and reducing gluconeogenic substrates by inhibiting appetite. Reduced DMI is a highly conserved response to immune activation across species (Brown and Bradford, 2021) which can further increase NEFA mobilization and hepatic ketogenesis (Figure 4).

Inflammation and Subclinical Hypocalcemia

Subclinical hypocalcemia remains a prevalent metabolic disorder afflicting ~25% of primiparous and ~50% of multiparous cows in the United States (Reinhardt et al., 2011). Although no overt symptoms accompany SCH, it has been loosely associated with poor gut motility, increased risk of DA, reduced production performance (i.e., milk yield and feed intake), increased susceptibility to infectious disease, impaired reproduction, and an overall higher culling risk (Seifi et al., 2011; Oetzel and Miller, 2012; Caixeta et al., 2017). Recent reports indicate that the severity of negative health outcomes observed in SCH cows appears dependent on the magnitude, persistency, and timing of SCH (Caixeta et al., 2017; McArt and Neves, 2020). For example, Caixeta et al. (2017) classified cases as either SCH or chronic SCH and observed more pronounced impairments on reproductive performance with chronic SCH. Similarly, McArt and Neves (2020) classified cows into 1 or 4 groups based on post-calving Ca concentrations: normocalcemia (>2.15 mmol/L at 1 and 2 DIM), transient SCH (≤ 2.15 mmol/L at 1 DIM), persistent SCH (≤ 2.15 mmol/L at 1 and 2 DIM), or delayed SCH (> 2.15 mmol/L at 1 DIM and ≤ 2.15 mmol/L at 2 DIM). Cows experiencing transient SCH produced more milk and were no more likely to experience a negative health event when compared to normocalcemic cows, whereas the opposite (i.e., higher health risk and hindered productivity) was observed in cows experiencing either persistent or delayed SCH. Clearly not all cases of SCH are equivalent; in fact, transient hypocalcemia appears to be correlated with improved "health" and productivity and this may explain why inconsistencies exist in the relationship between SCH and reduced productivity and health (Martinez et al., 2012; Jawor et al., 2012; Gidd et al., 2015). However, it remains unclear why despite successful implementation of mitigation strategies, SCH remains prevalent, why SCH is associated with a myriad of seemingly unrelated disorders, and what underlying factors may be explaining the different "types" of SCH.

Impressively, immune activation was originally hypothesized by early investigators to be involved with milk-fever (Thomas, 1889; Hibbs, 1950), but until recently (Eckel and Ametaj, 2016) it has rarely been considered a contributing factor to hypocalcemia. Independent of the transition period, we and others have repeatedly observed a marked and unexplainable decrease in circulating calcium following LPS administration in lactating cows (Griel et al., 1975; Waldron et al., 2003; Kvidera et al., 2017b; Horst et al., 2018, 2019; Al-Qaisi et al., 2020). Infection-induced hypocalcemia is a species conserved response occurring in humans (Cardenas-Rivero et al., 1989), calves (Tennant et al., 1973; Elsasser et al., 1996;), dogs (Holowaychuk et al., 2012), horses (Toribio et al., 2005), pigs (Carlstedt et al., 2000) and sheep (Naylor and Kronfeld, 1986). Additionally, hypocalcemia occurs in response to ruminal acidosis in dairy cows (Minuti et al., 2014). It is unlikely that cows (even those that are presumably "healthy") complete the transition period without experiencing at least one immune stimulating event and we are likely underestimating its contribution to postpartum hypocalcemia. In summary, it is probable that immune activation is at least partially explaining the incidence of SCH in the postpartum period (Figure 4). It is intriguing to suggest that cases of delayed, persistent, and chronic SCH recently described by Caixeta et al. (2017) and McArt and Neves (2020) may be related to the severity of the periparturient inflammatory response. This hypothesis may explain why these cases of SCH are associated with reduced "health", as these represent direct consequences of immune activation rather than being related or caused by decreased Ca.

In addition to SCH, there are on-farm milk-fever situations that are biologically difficult to explain. For example, even while strictly adhering to a pre-calving calcium strategy, there remains a small percentage (~<1%) of cows that develop clinical hypocalcemia. Additionally, reasons for why a mid-lactation cow develops milk-fever are not obvious. Further, there appears to be an undecipherable seasonality component to clinical hypocalcemia in the southwest and western USA that coincides with the rainy season. Inarguably, there remain some aspects of Ca homeostasis that continue to evade discovery.

Conclusion

New evidence and thinking around inflammation is challenging the traditional dogmas surrounding hypocalcemia, elevated NEFA, and hyperketonemia as the causative factors in transition cow disease. We suggest, based upon the literature and on our supporting evidence, that activation of the immune system may be the causative role in transition cow failure rather than the metabolites themselves as inflammation markedly alters nutrient partitioning and these metabolites as a means of supporting the immune response (Figure 4). More research is still needed to understand the causes, mechanisms, and consequences of immune activation and how to prevent immune activation or support its efficacy to provide foundational information for developing strategies aimed at maintaining productivity.

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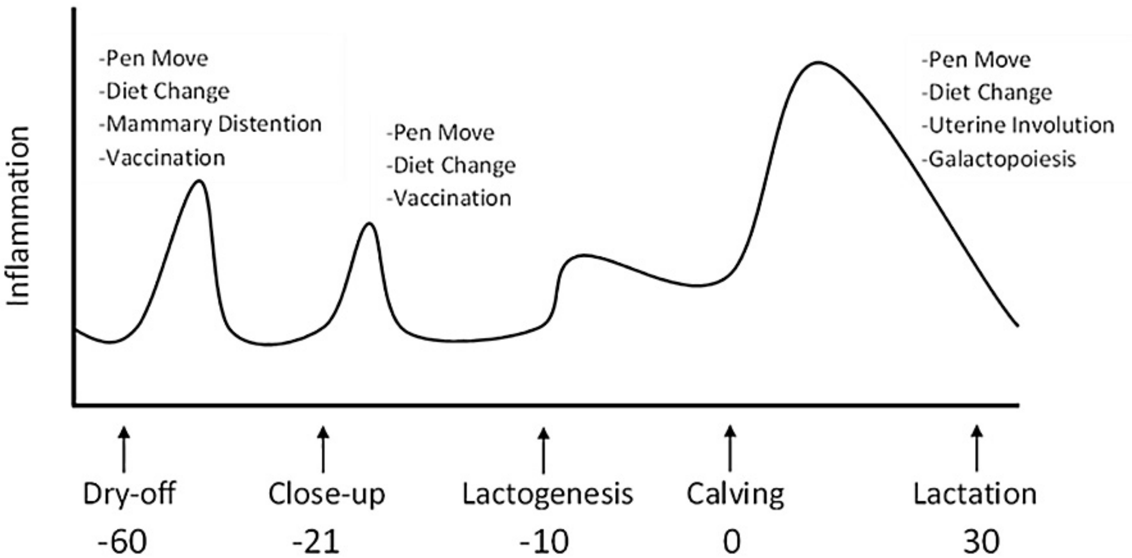
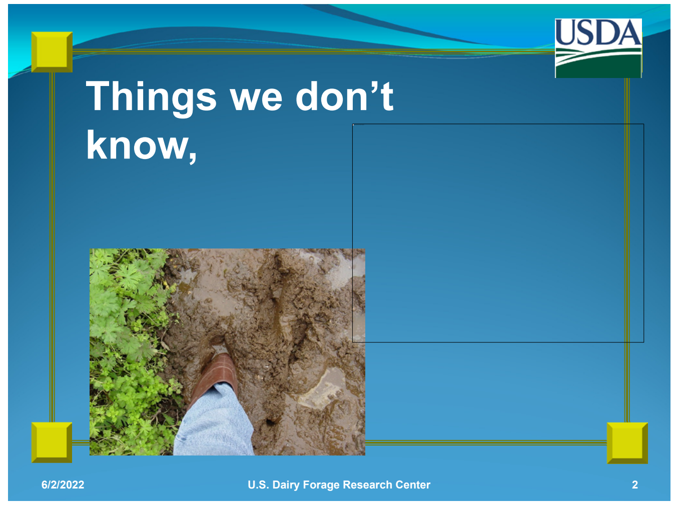


Figure 1: The inflammatory response associated with the multiple insults occurring to dairy cows from dry-off to calving

Modifying Milk Components: Day Is Not Always Our Time Step (?)

Mary Beth Hall, PhD
ISDA

1



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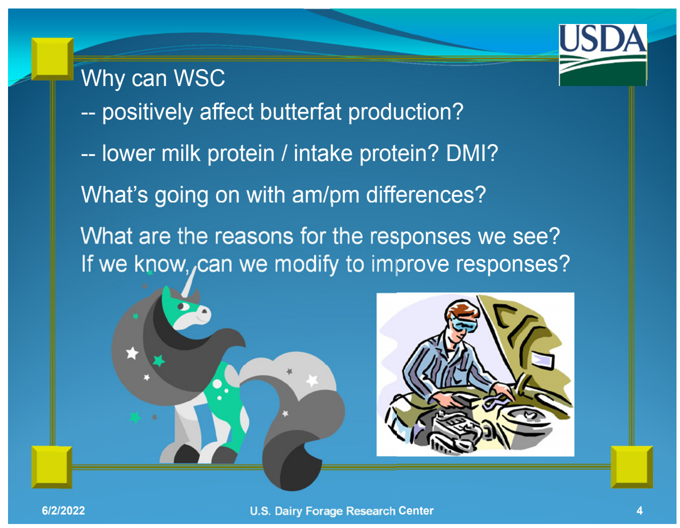

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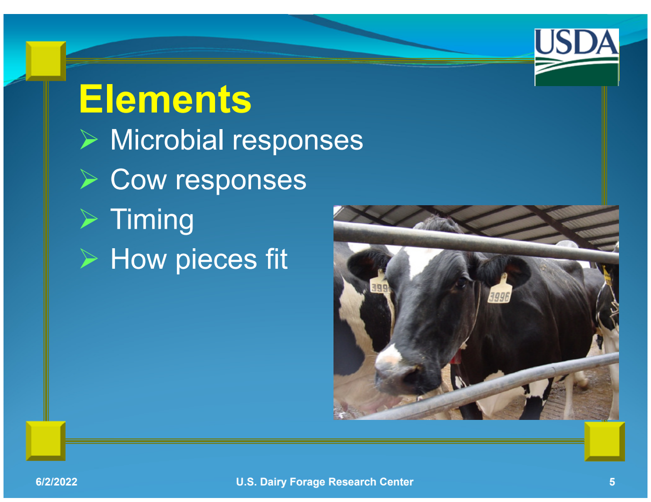

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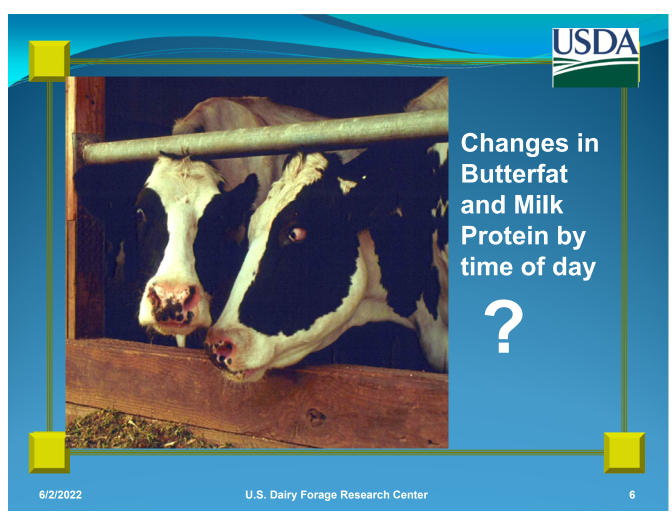

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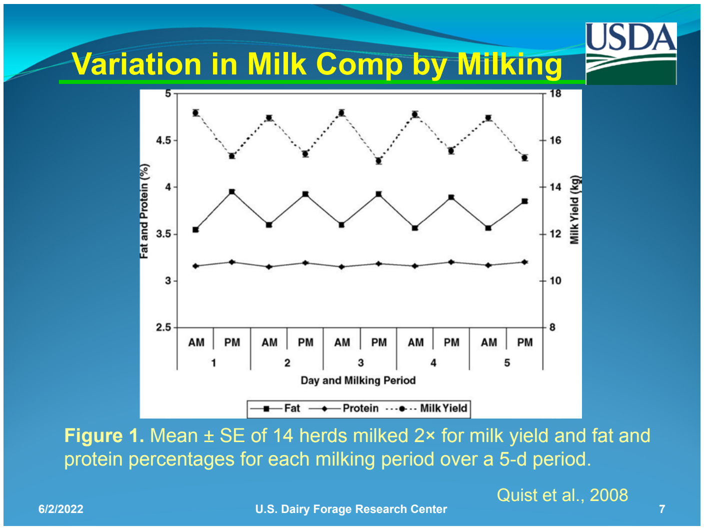

Variation in Milk Comp by Milking
USDA
Fat and Protein (%)
Milk Yield (kg)
AM PM AM PM AM PM AM PM AM PM
1 2 3 4 5
Day and Milking Period
Fat Protein Milk Yield
Figure 1. Mean ± SE of 14 herds milked 2× for milk yield and fat and protein percentages for each milking period over a 5-d period.
Quist et al., 2008
6/2/2022
U.S. Dairy Forage Research Center
7

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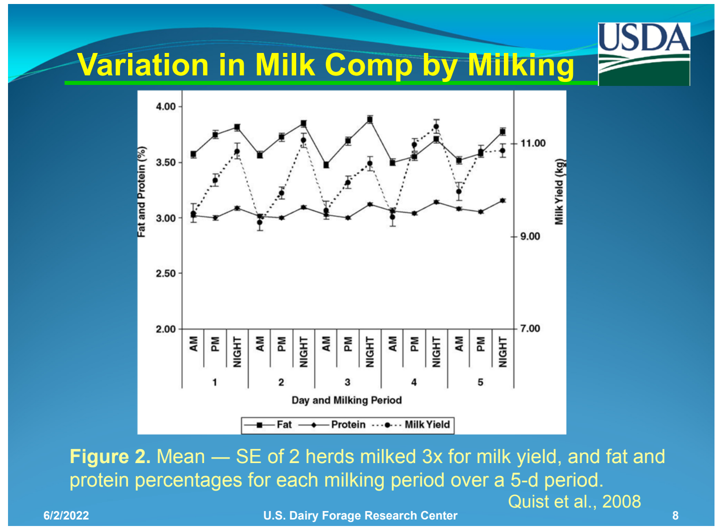
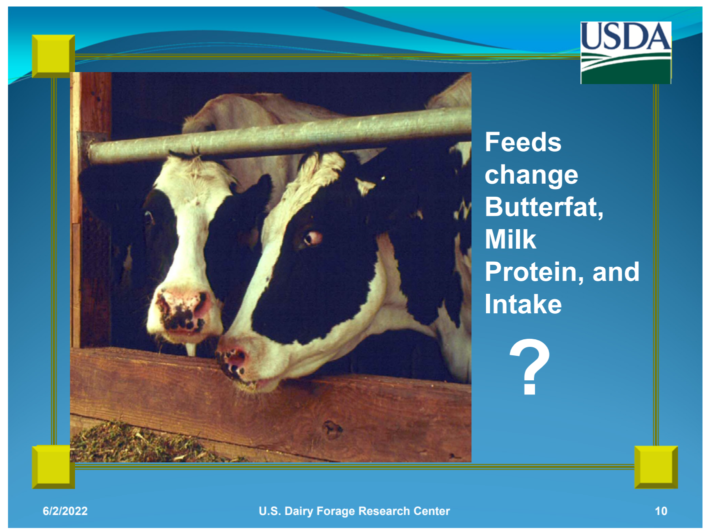


Variation in Milk Comp by Milking
USDA
Fat and Protein (%)
Milk Yield (kg)
AM PM NIGHT AM PM NIGHT AM PM NIGHT AM PM NIGHT AM PM NIGHT
1 2 3 4 5
Day and Milking Period
Fat Protein Milk Yield
Figure 2. Mean — SE of 2 herds milked 3x for milk yield, and fat and protein percentages for each milking period over a 5-d period.
Quist et al., 2008
6/2/2022
U.S. Dairy Forage Research Center
8

8

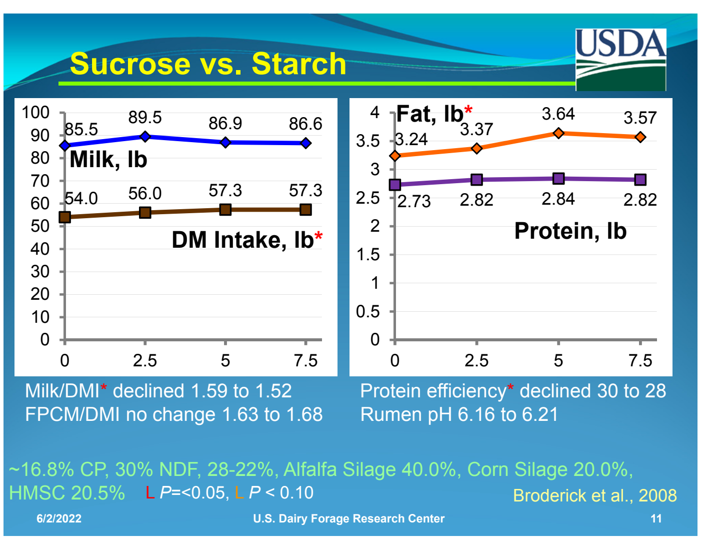
Need Groceries?
USDA
To make milk and components, animals need nutrients.
When were they last fed / did they eat? How much?
Even feed intake or slug feeding?
Diurnal patterns?
Nutrients in excess of basal needs?
Which groceries?
At what time?
6/2/2022
U.S. Dairy Forage Research Center
9

9



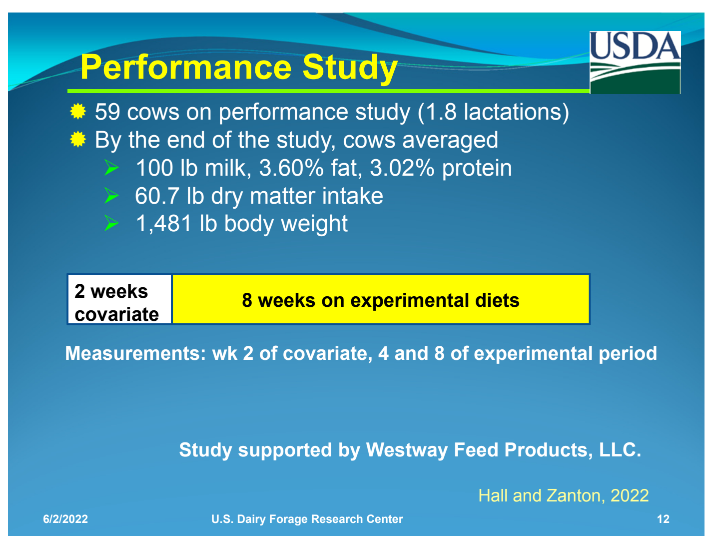
USDA
Feeds change Butterfat, Milk Protein, and Intake
?
6/2/2022
U.S. Dairy Forage Research Center
10

10



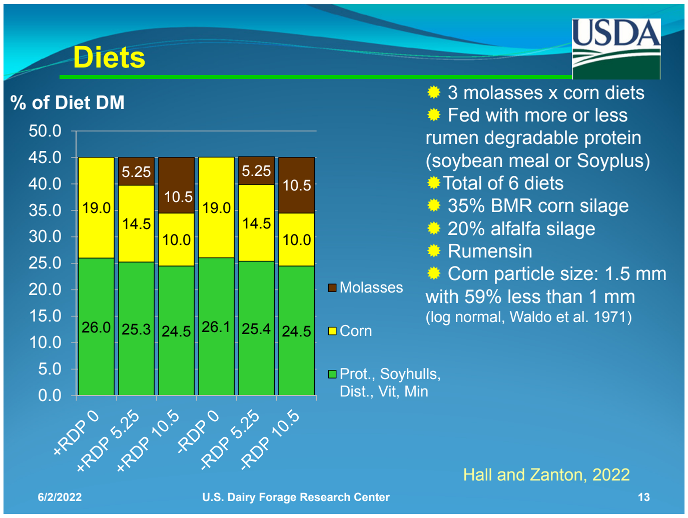
Sucrose vs. Starch
USDA
Milk, lb
85.5 89.5 86.9 86.6
DM Intake, lb*
54.0 56.0 57.3 57.3
0 2.5 5 7.5
Fat, lb*
3.24 3.37 3.64 3.57
Protein, lb
2.73 2.82 2.84 2.82
0 2.5 5 7.5
Milk/DMI* declined 1.59 to 1.52
FPCM/DMI no change 1.63 to 1.68
Protein efficiency* declined 30 to 28
Rumen pH 6.16 to 6.21
~16.8% CP, 30% NDF, 28-22%, Alfalfa Silage 40.0%, Corn Silage 20.0%, HMSC 20.5%
L P=<0.05, L P < 0.10
Broderick et al., 2008
6/2/2022
U.S. Dairy Forage Research Center
11

11



Performance Study
USDA
59 cows on performance study (1.8 lactations)
By the end of the study, cows averaged
100 lb milk, 3.60% fat, 3.02% protein
60.7 lb dry matter intake
1,481 lb body weight
2 weeks covariate
8 weeks on experimental diets
Measurements: wk 2 of covariate, 4 and 8 of experimental period
Study supported by Westway Feed Products, LLC.
Hall and Zanton, 2022
6/2/2022
U.S. Dairy Forage Research Center
12

12



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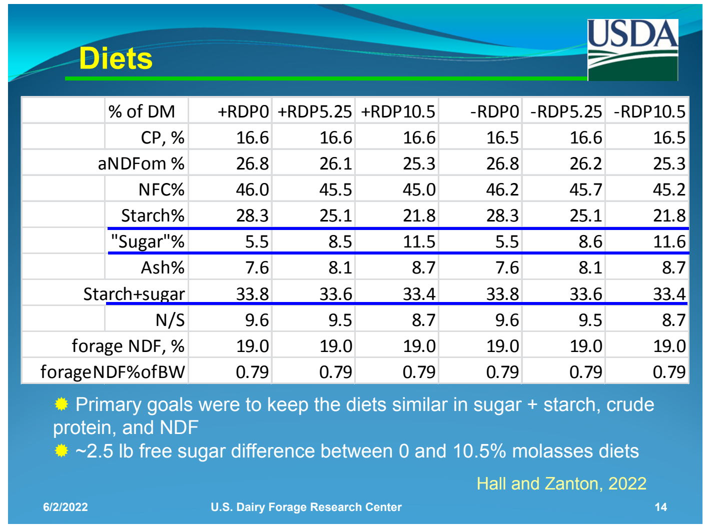
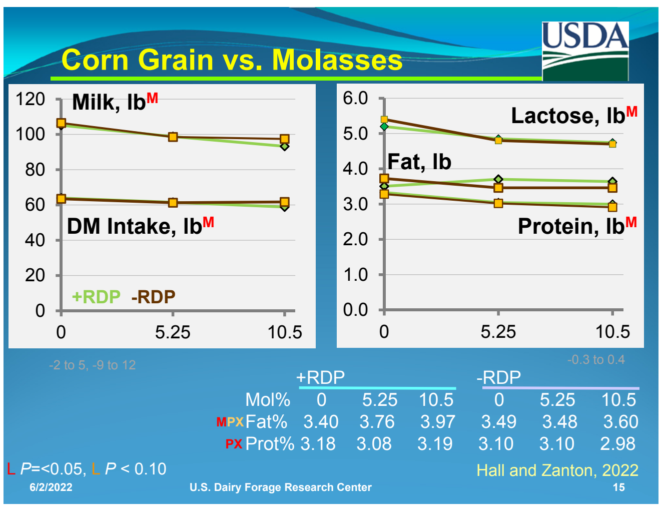


% of DM	+RDP0	+RDP5.25	+RDP10.5	-RDP0	-RDP5.25	-RDP10.5
CP, %	16.6	16.6	16.6	16.5	16.6	16.5
aNDFom %	26.8	26.1	25.3	26.8	26.2	25.3
NFC%	46.0	45.5	45.0	46.2	45.7	45.2
Starch%	28.3	25.1	21.8	28.3	25.1	21.8
"Sugar"%	5.5	8.5	11.5	5.5	8.6	11.6
Ash%	7.6	8.1	8.7	7.6	8.1	8.7
Starch+sugar	33.8	33.6	33.4	33.8	33.6	33.4
N/S	9.6	9.5	8.7	9.6	9.5	8.7
forage NDF, %	19.0	19.0	19.0	19.0	19.0	19.0
forageNDF%ofBW	0.79	0.79	0.79	0.79	0.79	0.79

14



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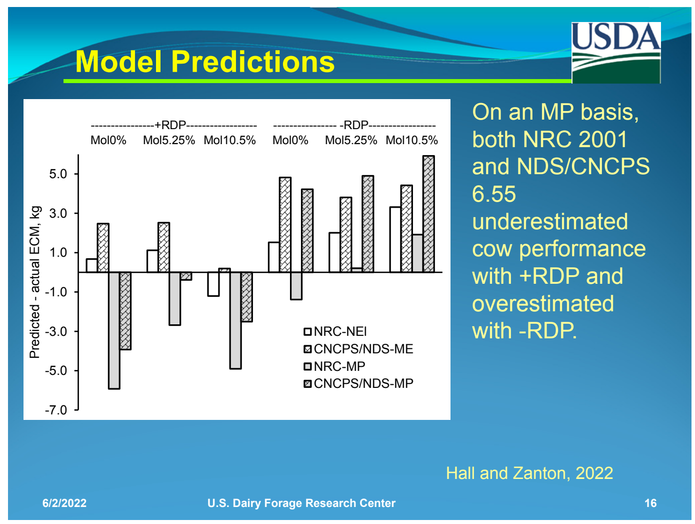

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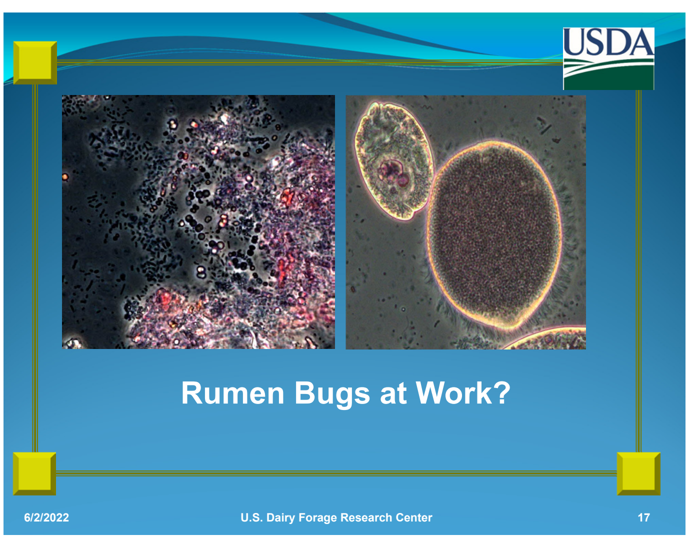

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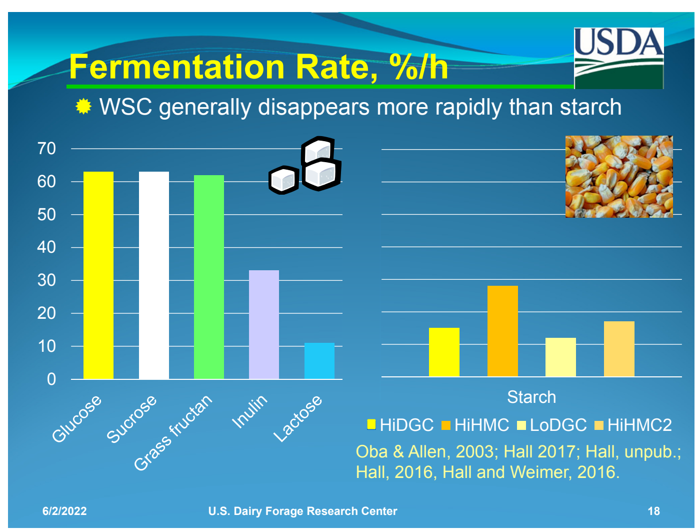

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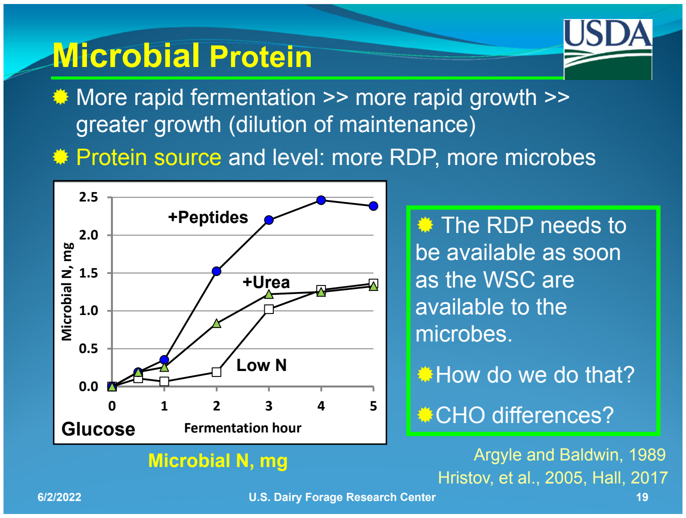

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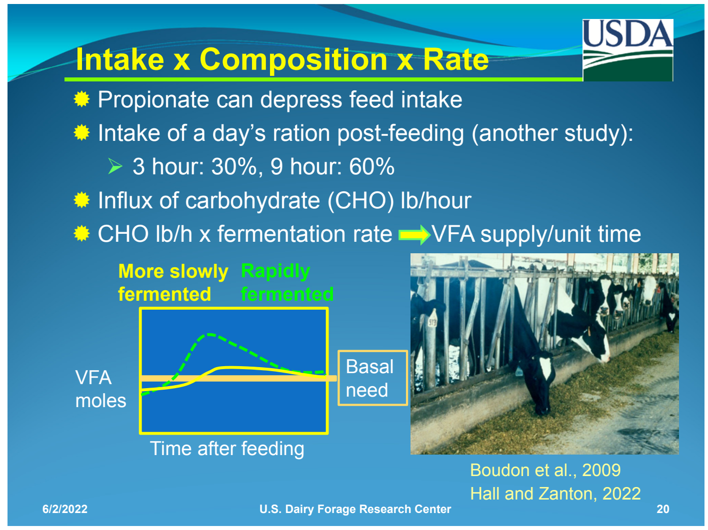

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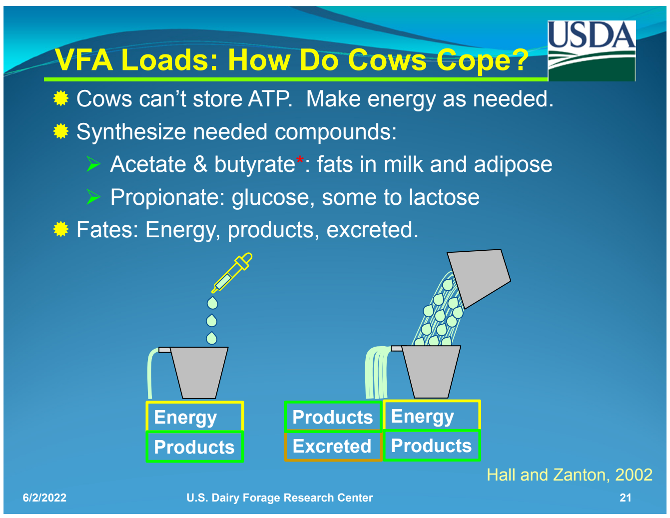

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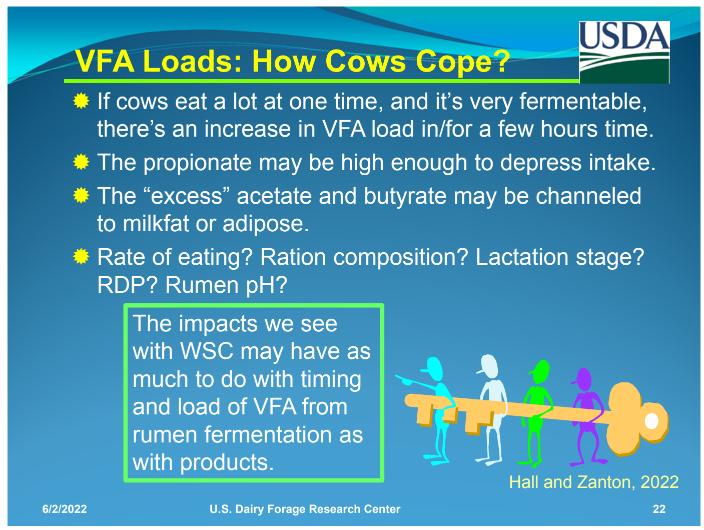

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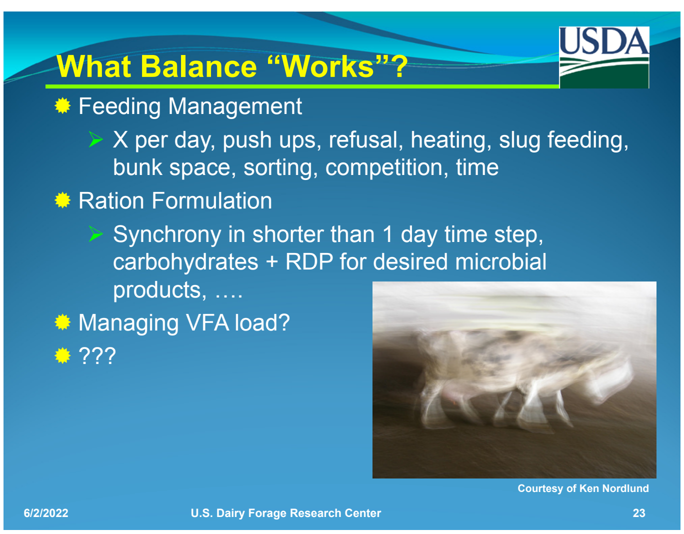

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Circadian Feeding Strategies to Improve Performance

Dr. Isaac J. Salfer
University of Minnesota

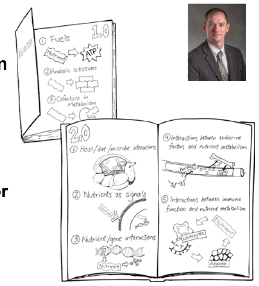
Circadian Feeding Strategies to Improve Performance

Dr. Isaac J. Salfer
4-State Dairy Nutrition and Management Conference
June 1 – 2, 2022

University of Minnesota
Department of Animal Science

1

Nutrition



- Traditional dairy nutrition has focused only on the role of nutrition as substrates for milk & body weight synthesis
- "Next-Gen Nutrition" - Understand how nutrients interact with the physiology of the cow to impact regulation of milk production or cow health
  - "Nutrigenomics"
  - Host-Microbiome Interactions
  - Nutrition-immune interactions
  - **Chrono-nutrition**
    - Biological Rhythms & Nutrition

Bradford et al 2016, *J Dairy Sci.* https://doi.org/10.3168/jds.2015-10271

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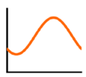
2

Biological rhythms



- What are biological rhythms?
  - Repeating cycles of behavior & physiology that are generated by an internal mechanism within an organism
- Why do organisms have them?
  - Predict changes in their environment before they occur
  - Coordinate physiology with environment
  - Social/reproductive timing
  - Offset biochemically incompatible processes
- How are they generated?
  - Sensing external environment to set the rhythm
  - Cycles of gene expression within individual cells create "gears of clock"
  - Hormone/neural signals to communicate between cells

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3

Circadian disruption predisposes people to metabolic disorders

Polymorphisms in clock genes
- *CLOCK variants*: ↑ energy intake ↑ non-alcoholic fatty liver disease
- *PER2*: hyperglycemia, abdominal obesity
- *BMAL1*: hypertension, type II diabetes

Social Jet Lag
- ↑ BMI

Shift Work Disorder
- ↑ Obesity
- ↑ Cardiovascular disease
- ↑ Cancer
- ↑ Stroke

Dairy Farmers
- ?

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4

Is there potential to use "Chrono-Nutrition" Strategies for Dairy Cows

- Cows are creatures of habit
  - Cow's life is dictated by schedules of feeding & milking
  - Daily patterns of feed intake & milk production
- Many large dairy farms operate nearly 24 h/d
- New technologies allow us to better understand & adapt to cows daily schedules

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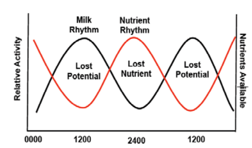
5

Are we losing efficiency if the feeding pattern and mammary circadian clock are not aligned



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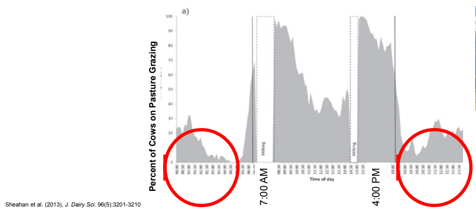
The feeding pattern of cows nearly is crepuscular active at dawn dusk



Ruminants typically eat 8 to 14 'meals' per day, a total of 3 to 5 h

2 large bouts of feed intake in the morning (~6 to 9 AM) and afternoon (~2 to 5 PM)

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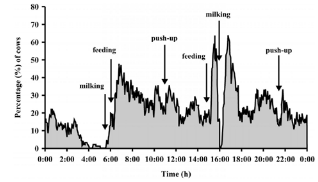
Feeding pattern of cattle in commercial settings

- **Delivering fresh feed** – stimulates feed intake
- **Milking** – stimulates eating after return from parlor
- **Pushing up feed** – doesn't really stimulate eating unless cows previously couldn't eat
- **Social behavior** – cows will be stimulated to eat if other cows are eating, unless barn is overstocked or bully cow is eating



DeVries et al. (2003), J. Dairy Sci. 86(12):4079-4082

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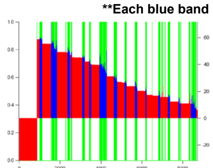
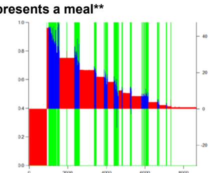
8

Individual Variations in Feeding Behavior

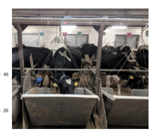
Each blue band represents a meal



Cow 2166
Average Meals/d: 13.1
Average Meal Length: 24 min
Average Meal Size: 49 kg



Cow 2400
Average Meals/d: 9.3
Average Meal Length: 35 min
Average Meal Size: 44 kg



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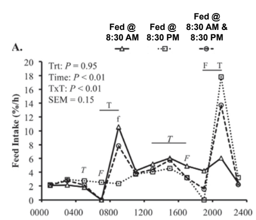
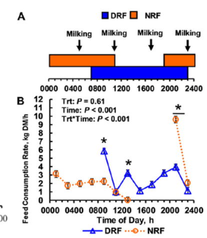
Effect of feeding time on feeding pattern





If fed 1x/d, cows will shift feeding behavior to align with feeding time

Cows on DRF had ↑63% post-feeding DMI

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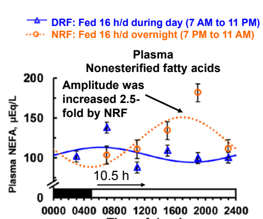
Salfer

10

"Starvation Response" greater when cows were fasted during the afternoon



Trt	Mean	Amp	Acro	P-value
DRF	104	9.33[b]	0614[a]	0.01
NRF	119	31.2[a]	1657[b]	< 0.001

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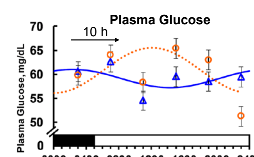
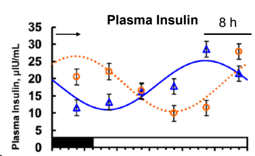
Plasma glucose and insulin concentrations were shifted by the time of feed restriction



Trt	Mean	Amp	Acro	P-value
DRF	59.1	1.90[b]	0218[a]	0.03
NRF	60.8	4.74[a]	1205[b]	< 0.001



Trt	Mean	Amp	Acro	P-value
DRF	18.1	7.08[b]	1851[b]	< 0.001
NRF	17.3	8.00[a]	0253[a]	< 0.001

DRF: Fed 16 h/d during day (7 AM to 11 PM)
NRF: Fed 16 h/d overnight (7 PM to 11 AM)

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Should we feed cows at night to fight heat stress

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Should we feed cows at night to fight heat stress

- During summer heat stress several dairy farms feed cows in the evening to try to get cows to eat when it is cooler out
- However, this results in cows having least fresh feed during the mid-afternoon when intake is high, and the cows will get hungry during this period
- Cows will 'slug feed' after evening feed delivery, causing rumen pH drop and exacerbation of heat stress
- Better plan: feed 2x or feed in heat of the afternoon to stimulate additional meals

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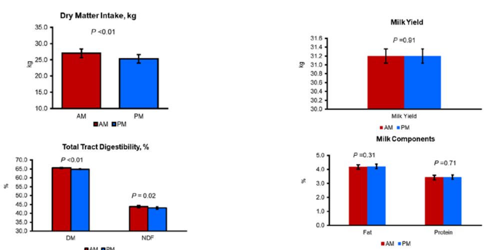
Effect of Night Feeding in the Summer



Niu et al. (2018) doi.org/10.3168/jds.2017-13635

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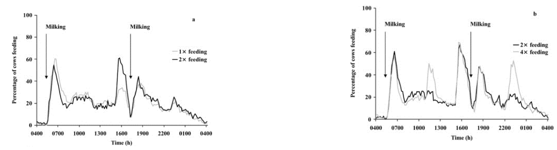
Effect of feeding frequency on feeding pattern



Increasing feeding frequency spreads out feed intake across the day (more, smaller meals)

Dairy herds that feed 2x/d:
- Average 3.1 lbs/day greater dry matter intake (Sova et al. 2013)
- Average 4.4 lbs/day greater milk yield (Sova et al. 2013)
- Have greater milk fat synthesis (Woolpert et al. 2017)

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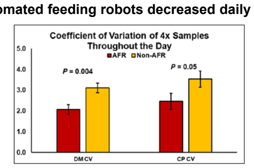
Implementation of Automated Feeding Robots to Improve Feed Consistency

- Milk & TMR collected from 16 herds in MN, WI, IA
  - 8 with automated feeding robots & AMS
  - 8 pairs with similar geography, herd size & breed w/AMS
  - TMR collected 4x/d analyzed for nutrients & particle distribution
- Feeding with automated feeding robots decreased daily variation in DM and CP of TMR



- No major differences in production/components –will measure FA profile soon!
- Kamau et al. 2022 abstract submitted to ADSA annual meeting

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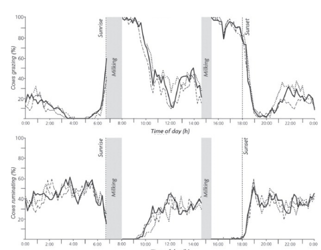
Rumination pattern is inverse of feed intake



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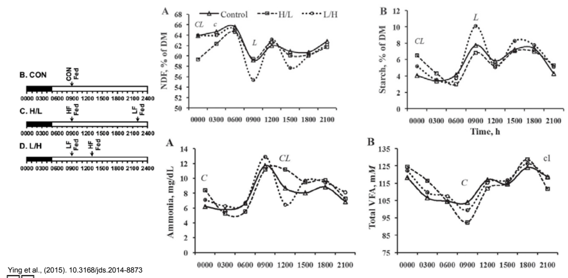
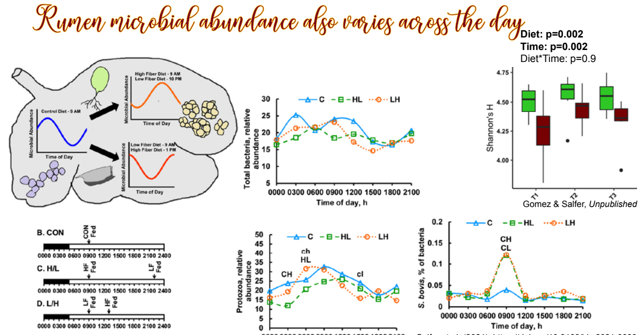
Nutrients in the Rumen Vary Across the Day



Ying et al., (2015). 10.3168/jds.2014-8873

19

Rumen microbial abundance also varies across the day



Salfer et al. (2021). https://doi.org/10.3168/jds.2021-0099

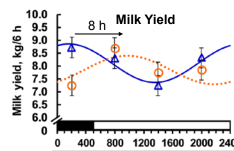
20

The "Konefal Method"

- Canadian rancher Gus Konefal observed that feeding pregnant beef cows at night (9:30 to 10 PM) caused them to calve during the day
  - This became a popular anecdotal strategy for increasing daytime calvings
- Subsequent research has confirmed that feeding in late evening/night results in 85% of calvings to occur during the day (6 AM to 6 PM)
- Daytime calving carries into future parturitions
- Mechanism unknown

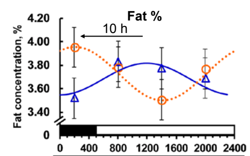
21

Milk yield, and components have a daily rhythm shifted by feeding time

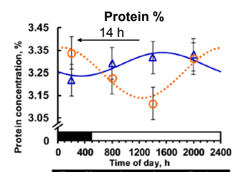


Trt	Mean	Amp[1]	Acro[2]	P-value[3]
DRF	8.14	0.74[a]	0134[a]	<0.0001
NRF	7.19	0.56[b]	0944[b]	<0.0001

DRF: Fed 16 h/d during day (7 AM to 11 PM)
NRF: Fed 16 h/d overnight (7 PM to 11 AM)



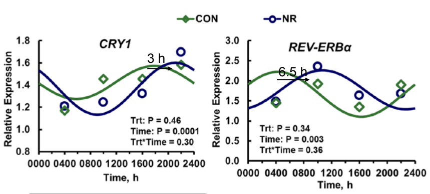
Trt	Mean	Amp	Acro	P-value
DRF	3.68	0.14[b]	1156[b]	0.06
NRF	3.73	0.23[a]	0207[a]	< 0.0001



Trt	Mean	Amp	Acro	P-value
DRF	3.29	0.05[b]	1525[b]	0.02
NRF	3.25	0.11[a]	0029[a]	< 0.0001

22

Feeding shifts the genes associated with the mammary cellular circadian clock



	Mean	Amp	Acro	Rhythm Fit
CON	1.42	0.15[a]	1749[a]	$P = 0.01$
NR	0.89	0.23[b]	2103[b]	$P = 0.02$

	Mean	Amp	Acro	Rhythm Fit
CON	1.66	0.56	0416[a]	$P = 0.05$
NR	1.77	0.49	1041[b]	$P = 0.03$

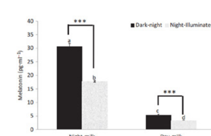
***CRY1* and *REV-ERBα*: Circadian proteins involved in the cellular circadian clock**

...lfer et al. (2020). Unpublished

23

Melatonin follows a daily pattern in milk

Evening milk: Greater melatonin concentration



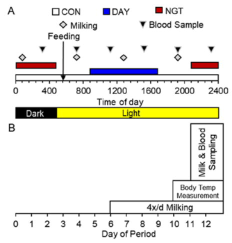
Lullaby Milk®

Can we produce more melatonin in milk for baby formulas?

Asher et al. (2015) *Chronobiology Intl.* 32(1):1409 - 1416

24

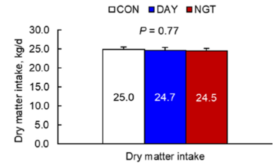
Which nutrients entrain the daily rhythms of milk synthesis



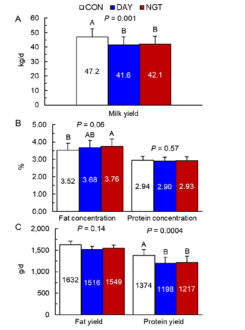
25

Limiting the time of fat infusion decreased milk yield protein yield but NGT increased fat concentration

350 g/d high oleic acid oil

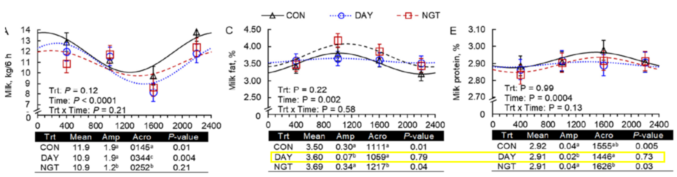


Salfer et al. (2019) *ADSA Annual Meeting*



26

Day infusion of fat lowered daily variation in milk fat and protein percent



Salfer et al. (2019) *ADSA Annual Meeting*

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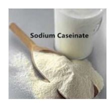
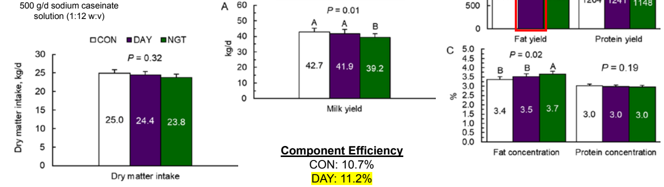
The timing of protein infusion



500 g/d sodium caseinate solution (1:12 w:v)



Component Efficiency
CON: 10.7%
DAY: 11.2%
NGT: 10.7%

Salfer et al. (2019) *ADSA Annual Meeting*

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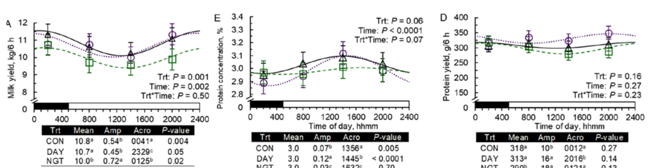
The rhythm of milk protein concentration was ablated in night infusion



29

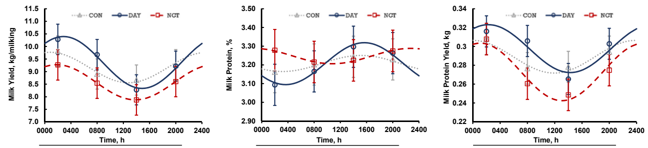
Timing of sodium acetate infusion does not impact milk production

10 mol/d ruminally-available sodium acetate

Variable	Treatment[1]			SE	P-value[2]
	CON	DAY	NIGHT		
Yield, kg/d					
Milk	36.0	36.6	34.1	2.13	0.35
Fat	1.55	1.46	1.42	0.11	0.60
Protein	1.19	1.17	1.06	0.08	0.34
Milk Composition, %					
Fat	4.22	4.10	4.21	0.24	0.74
Protein	3.20	3.23	3.20	0.11	0.77

30

Time of infusion of acetate affected the rhythm of milk and protein production



TRT	Mean	Amp	Acro	*P*-value
CON	9.16	0.61[b]	0.79[c]	0.03
DAY	9.36	1.03[a]	2.86[a]	0.02
NGT	8.57	0.70[b]	1.82[b]	0.05

TRT	Mean	Amp	Acro	*P*-value
CON	3.21	0.04[b]	15.16[b]	<0.01
DAY	3.20	0.11[a]	15.65[b]	<0.01
NGT	3.25	0.04[b]	22.78[a]	<0.01

TRT	Mean	Amp	Acro	*P*-value
CON	0.29	0.02[b]	23.92[a]	0.55
DAY	0.30	0.03[a]	2.27[b]	0.12
NGT	0.27	0.03[a]	1.06[c]	<0.01

DAY infusion increased the robustness and phase-advanced the rhythm of milk yield. DAY infusion increased the robustness of the rhythm of milk protein concentration and NGT phased advanced the rhythm. Only NGT infusion elicited a rhythm on milk protein yield.

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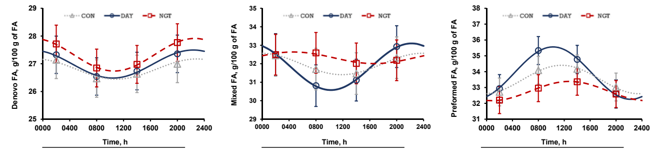
Night infusion dampened a rhythm in mixed and preformed fatty acids



TRT	Mean	Amp	Acro	*P*-value
CON	26.81	0.36[c]	22.92[a]	<0.01
DAY	26.99	0.51[b]	22.38[b]	<0.01
NGT	27.33	0.59[a]	22.60[ab]	<0.01

TRT	Mean	Amp	Acro	*P*-value
CON	31.99	0.58[b]	23.85[a]	<0.01
DAY	31.84	1.26[a]	22.22[b]	<0.01
NGT	32.32	0.31[c]	4.65[c]	0.33

TRT	Mean	Amp	Acro	*P*-value
CON	33.50	1.65[a]	10.26[c]	<0.01
DAY	33.91	0.90[b]	11.60[b]	<0.01
NGT	32.78	0.61[c]	12.81[a]	0.09

NGT treatment increased the robustness of the rhythm of de novo FA concentration, while DAY decreased it. DAY treatment increased the robustness of the rhythm of mixed source FA. DAY treatment decreased the robustness of the rhythm of preformed FA while NGT dampened it.

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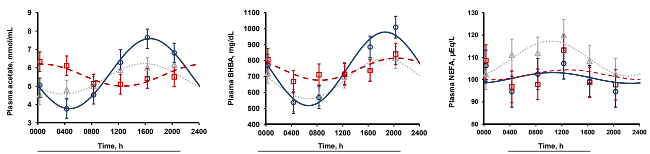
Day infusion increased the robustness of the rhythm of plasma acetate



TRT	Mean	Amp	Acro	*P*-value
CON	5.40	0.83[b]	16.05[b]	<0.01
DAY	5.68	1.91[a]	16.91[a]	<0.01
NGT	5.60	0.60[c]	0.88[c]	<0.01

TRT	Mean	Amp	Acro	*P*-value
CON	686	124.92[b]	18.79[b]	<0.01
DAY	748	230.52[a]	18.85[b]	<0.01
NGT	746	69.44[c]	20.71[a]	0.33

TRT	Mean	*P*-value
CON	109	0.08
DAY	100	0.92
NGT	102	0.97

DAY infusion increased the robustness and phase advanced the rhythm of plasma acetate while NGT infusion decreased the robustness and phase delayed the rhythm. NGT dampened the rhythm of plasma BHBA and there was no detectable rhythm for plasma NEFA.

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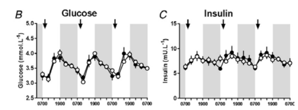
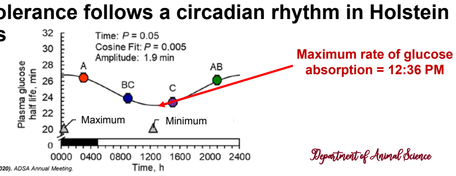
Circadian rhythms and glucose metabolism in ruminants

- **Plasma glucose & insulin concentration follow circadian rhythms in sheep & cattle**

Glucose peaks at ~ 2 AM
Insulin peaks at ~ 6 PM



- **Glucose tolerance follows a circadian rhythm in Holstein dairy cows**



Salfer et al. (2020). ADSA Annual Meeting.

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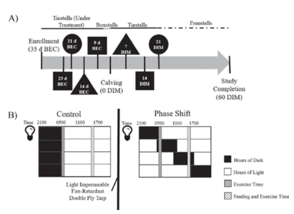
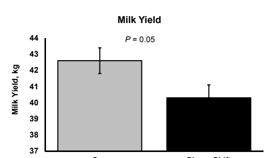
Chronic Phase Shift during Dry Period Decreased Milk Yield in Subsequent Lactation





McCabe et al. (2021) doi.org/10.3168/jds.2020-19250

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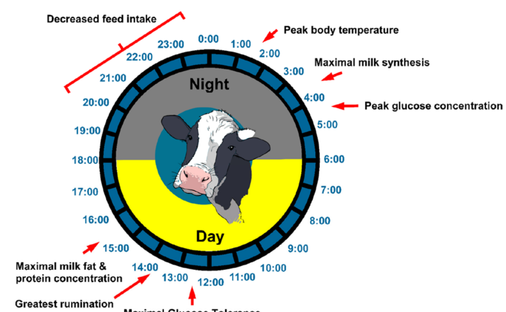

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Summary

- Time of feeding has major impacts on systemic metabolism & rhythms of milk yield in dairy cows
- Changes in mammary rhythms are at least partially modulated by changes in the molecular clock
- Total daily production is altered by timing of post-ruminal fat & protein availability
  - AM or PM limited infusion of fat – reduced milk yield
  - AM limited infusion of protein – increased milk fat
- Daily pattern of rumen microbes is susceptible to dietary changes
- Insulin-stimulated glucose uptake follows a daily pattern in dairy cows

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Acknowledgements

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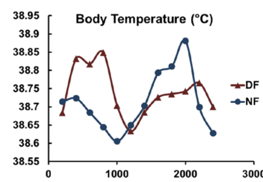
Body Temperature is a Marker of Central Circadian Rhythm



Daily Rhythm of Body Temperature is Modified by Feeding Time

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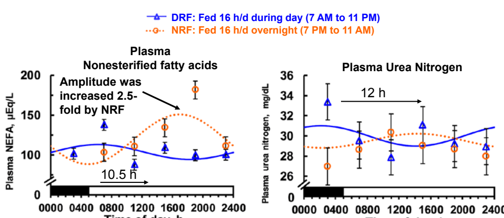

Trt	Mean	Amp	Acro	P-value
DRF	104	9.33[b]	0614[a]	0.01
NRF	119	31.2[a]	1657[b]	< 0.001

Trt	Mean	Amp	Acro	P-value
DRF	27.0	14.1[b]	0209[a]	0.08
NRF	30.3[a]	18.3[a]	1420[b]	0.02

Nonesterified fatty acids were shifted 10 h and amplitude was increased by night-restricted feeding

Plasma urea nitrogen was inverted by night-restricted feeding

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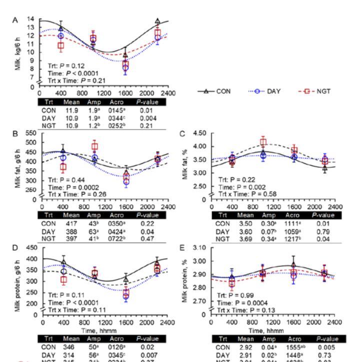

A

Trt	Mean	Amp	Acro	P-value
CON	11.9	1.9[a]	0145[a]	0.01
DAY	10.9	1.9[a]	0344[c]	0.004
NGT	10.9	1.2[b]	0252[b]	0.21

B

Trt	Mean	Amp	Acro	P-value
CON	417	43[b]	0350[a]	0.22
DAY	388	63[a]	0424[a]	0.04
NGT	397	41[b]	0722[b]	0.47

C

Trt	Mean	Amp	Acro	P-value
CON	3.50	0.30[a]	1111[a]	0.01
DAY	3.60	0.07[b]	1059[a]	0.79
NGT	3.69	0.34[a]	1217[b]	0.04

D

Trt	Mean	Amp	Acro	P-value
CON	346	50[a]	0126[a]	0.02
DAY	314	56[a]	0345[c]	0.007
NGT	315	31[b]	0234[b]	0.37

E

Trt	Mean	Amp	Acro	P-value
CON	2.92	0.04[a]	1555[ab]	0.005
DAY	2.91	0.02[b]	1446[a]	0.73
NGT	2.91	0.04[a]	1626[b]	0.03

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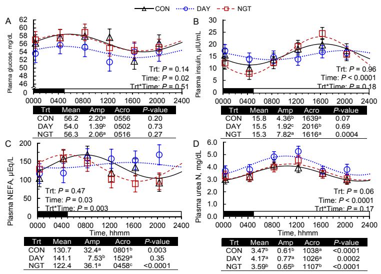

A

Trt	Mean	Amp	Acro	*P*-value
CON	56.2	2.20[a]	0556	0.20
DAY	54.0	1.39[b]	0502	0.73
NGT	56.3	2.06[a]	0516	0.27

B

Trt	Mean	Amp	Acro	*P*-value
CON	15.8	4.36[b]	1639[a]	0.07
DAY	15.5	1.92[c]	2016[b]	0.69
NGT	15.3	7.82[a]	1616[a]	0.0004

C

Trt	Mean	Amp	Acro	*P*-value
CON	130.7	32.4[a]	0801[b]	0.003
DAY	141.1	7.53[b]	1529[a]	0.35
NGT	122.4	36.1[a]	0458[c]	<0.0001

D

Trt	Mean	Amp	Acro	*P*-value
CON	3.47[b]	0.61[b]	1038[a]	<0.0001
DAY	4.17[a]	0.77[a]	1026[a]	0.0002
NGT	3.59[b]	0.65[b]	1107[b]	<0.0001

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31

Alternative Forages for the Dry Cow Diet

Phil Cardoso
University of Illinois

INTRODUCTION

Dairy operations large and small continue to be plagued by a high incidence of metabolic disorders and infectious diseases around calving. Turbulent transitions increase health care expenses, decrease milk production, impair reproductive performance, and result in premature culling or death. Farm profitability and animal well-being both suffer. Despite many years of research and field emphasis, practical management strategies to minimize health problems while still promoting high milk production have remained vague. Overall, research data fail to demonstrate that steam-up diets (high-energy solely based on corn silage) consistently improve production, body condition, reproduction, or health after calving. Is there a better way? Controlled energy during the dry period. Over the last decades, our research group has investigated whether controlling energy intake during the dry period might lead to better transition success. Our solution to the potential for cows to over-consume energy is to formulate rations of relatively low energy density (0.59 – 0.63 Mcal NEL/lb DM) that cows can consume free choice without greatly exceeding their daily energy requirements. It is important to note that we are not proposing to limit energy intake to less than cows' requirements but rather to feed them a bulky diet that will only meet their requirements when cows consume all they can eat.

The strategy

Controlling energy with high-fiber rations seems to improve DMI after parturition, thereby avoiding excessive adipose tissue lipid mobilization (Douglas et al., 2006). Milk production is similar when compared with higher energy close-up programs (Douglas et al., 2006; Janovick and Drackley, 2010; Mann et al., 2015). Additionally, the benefits of the controlled-energy diet prepartum seems to have a positive effect on cows' fertility (Cardoso et al., 2013, 2019). This dietary strategy aims to formulate and feed rations with relatively low energy density (0.59 – 0.63 Mcal NEL/lb DM) during the entire dry period. The incorporation of low-energy ingredients (straw or low-quality grass hays) allows cows to consume the diet ad libitum without exceeding their daily energy requirements (Janovick and Drackley, 2010).

Nutritionally balanced diets must be fed and the TMR must be physically processed appropriately so that cows do not sort the bulkier ingredients. Feeding bulky forage separately from a partial TMR, or improper forage processing (i.e., nonhomogeneous chop length of the forage) will lead to variable intake among cows, with some consuming too much energy and some too little (DeVries et al., 2005). Underfeeding relative to requirements, where nutrient balance also is likely limiting, leads to increased incidence of retained placenta and metritis (Mulligan et al., 2006). Merely adding straw to a diet is not the key principle; rather, the diet must be formulated to limit energy intake (approximately 0.64 Mcal of NEL/lb of DM, to limit intake to about 15 to 16 Mcal/d for typical Holstein cows), and at the same time meet the requirements for protein, minerals, and vitamins. Less is known about diet formulation for the immediate postpartum period to optimize transition success and subsequent reproduction. Proper dietary formulation during the dry period or close-up period will maintain or enable rumen adaptation to higher grain diets after calving. Failure to do so may compromise early lactation productivity. For example, Silva-del-Rio et al. (2010) attempted to duplicate the dietary strategy of Dann et al. (2006) by feeding either a low-energy far-off diet for 5 wk followed by a higher-energy diet for the last 3 wk before parturition, or by feeding the higher-energy diet for the entire 8-wk dry period. Authors reported that cows fed the higher-energy diet for only 3 wk before parturition produced less milk than cows fed the diet for 8 wk (43.8 vs. 48.5 kg/d).

Recently, researchers have reported that Holstein cows consuming a prepartum diet (29% wheat straw on a DM basis; 13.2% CP, 1.5 Mcal of NEL/kg) with wheat straw chopped shorter (short straw chopped) had greater TMR DMI (15.6 kg/d; SE = 0.16) in the dry period than cows consuming wheat straw chopped longer (long straw chopped; 15.0 kg/d; SE = 0.16) (Havekes et al., 2019). Wheat straw was chopped using a bale processor using a 2.54-cm screen for the short straw chopped and a 10.16-cm screen for the long straw chopped

(Havekes et al., 2019). Additionally, cows consuming the longer chopped wheat straw had higher blood BHB in the wk 3 postcalving than cows consuming the shorter chopped wheat straw (1.3 ± 0.11 vs. 0.8 ± 0.10 mmol/L; respectively) (Havekes et al., 2019). It is still to be determined if particle size and sorting is even more relevant in moderate- to high-energy diets (0.68 Mcal of NEL/lb) when compared with CE diets (0.59 Mcal of NEL/lb) prepartum.

What forage to use?

To accomplish the goal of controlled energy intake requires that some ingredient or ingredients of lower energy density be incorporated into diets containing higher-energy ingredients such as corn silage, good quality grass or legume silage, or high-quality hay. Cereal straws, particularly wheat straw, are well-suited to dilute the energy density of these higher-energy feeds, especially when corn silage is the predominant forage source available. Therefore, wheat silage has the potential to be an alternative to wheat straw (Figure 1). Harvest probably should begin when the wheat just reaches the boot stage; if harvest proceeds quickly without interruptions from weather, etc., the last silage cut should be in the early head stage. Its higher crude protein (16% of DM) and moderate starch (21% of DM) contents may allow for savings in feeding corn and soybean meal in the dry cow diet. Usually, wheat silage is high in chloride (1.30% of DM), making it easier to balance for a negative dietary cation anion difference (DCAD).

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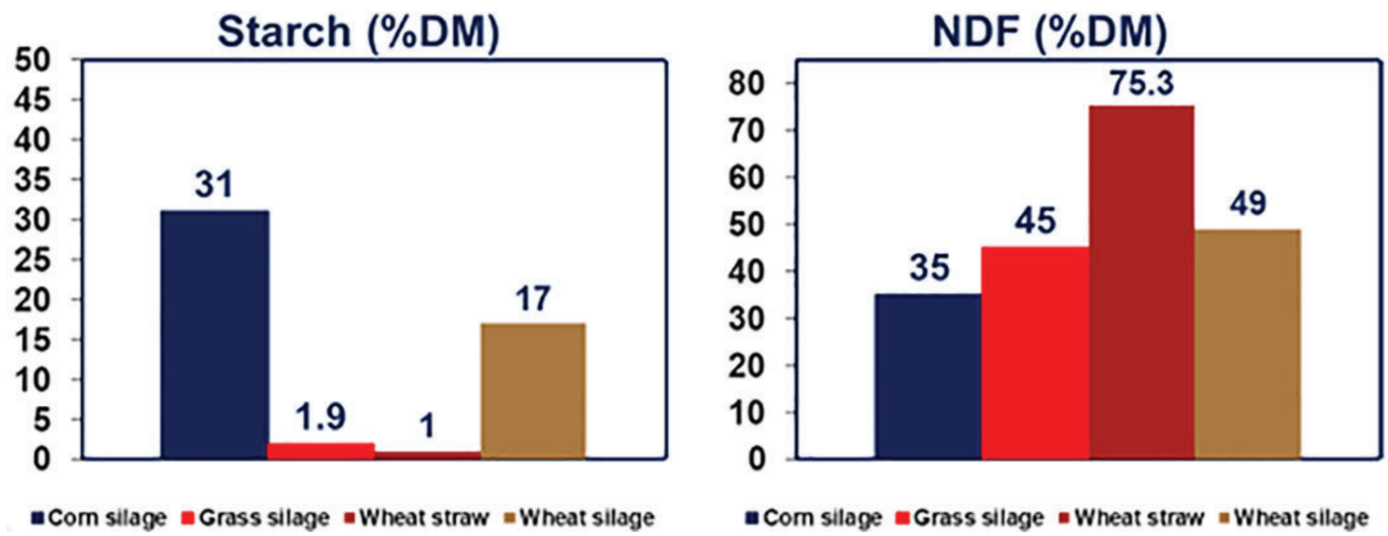

Figure 1. Chemical analysis of common forages used in dry cow diets.

Field-applied Microbial Inoculants Can Improve Silage Yield and Quality, Increase Milk Production and Reduce Greenhouse Gas Emissions

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There are novel technologies coming to market that will affect plant growth, yield, nutrient content and digestibility and carbon footprint of forage crops. Microbial inoculants applied to seeds or as a foliar treatment is one of these emerging technologies that are available for many agricultural crops including alfalfa, grasses and whole plant corn.

Microbial inoculants are widely used on fresh-cut forages to improve silage fermentation, decrease dry matter losses, improve feed cleanliness and increase aerobic stability. Decades of research across many different microbial inoculants have shown how a small amount of a bacterial additive can dramatically affect the ensiling outcome. This concept applies to the rumen as well, with yeast and bacteria-based additives that can affect oxygen levels in the rumen, pH and digestion efficiency.

Soil and field applied microbial inoculants added to seeds and plants can also affect growing plants. While we're early in these technologies' development and evaluation, microbial inoculants applied to seeds, in the furrow at planting or by foliar methods have the potential to improve forage yields, improve seedling vigor, increase plant growth and development, and improve nutritional value of forages. Preliminary results from on-farm trials and controlled experiments suggest that certain strains of bacteria, when applied as a seed treatment or as a foliar treatment, may also affect silage fermentation. There is also limited pilot data that suggests that these products may reduce greenhouse gas (GHG) emissions, primarily by decreasing ruminal methane production. Future work will likely continue to evaluate rumen methane reduction potential, and also carryover effects into the manure lagoon. Manure lagoon methane emissions is known to be a substantial contributing factor to GHG emissions. There is currently active research to determine if manure from cattle fed crops that have been treated with certain strains of bacteria alter GHG.

Seed- or foliar- applied microbial inoculants are generally classified under three general modes of action.

Plant growth regulators. Microbial inoculants that impact plant growth and development by modulating growth within the plant tissues. Microbes can release compounds that affect plant growth and development. Several species of Bacillus (Bacillus subtilis, Bacillus megaterium, Bacillus licheniformis) increase root development and improve drought tolerance in corn and wheat and canola.

Beneficial Microbes. These are specific microbial strains of bacteria when applied as seed treatments or in the furrow that provide nitrogen fixing bacteria, phosphorus-solubilizing microbes or mycorrhizal fungi that may out-compete less desirable epiphytic soil microbes that exist in the soil. The results are improved seedling vigor and greater root mass. Beneficial microbes can also improve plant resistance to stressors or due to drought, nematodes and / or plant disease. Certain strains of microbes also can work to counteract certain soil-born or foliar pests (Pseudomonas fluorescens, Bacillus amyloliquefaciens Metarhizium anisopliae).

Bio-stimulants. Microbial inoculants that stimulate plant growth. Certain strains of microbes increase nutrient uptake by more efficiently decomposing soil organic matter and recycling dead plant material and fodder. M-trophs are an example of these biological products. These biological products may also improve nitrogen and phosphorus uptake within plants, and have been referred to as "Bio-fertilizers".

Biological seed treatments or foliar inoculant impact upon forage yield, feed quality, animal performance and the carbon life cycle on farms is an emerging research area. Preliminary studies suggest that biological seed treatments can alter plant growth and nutrient recycling within the soil, which in turn can improve crop forage yields by as much as 20%, and also increase grain yields in corn. Preliminary and pilot in vitro rumen observations indicate that forages grown after seed, soil or foliar treatment with biological inoculants may mitigate rumen methane emissions, however more work is needed in this area.

Application of beneficial microbes via seed, furrow or as foliar treatment is not a new idea. Legume inoculation with N_2-fixing bacteria has been practiced for over 100 years. Genetic selection for microbial inoculant strains which regulate growth, improve plant health and disease resistance or stimulate nutrient uptake have also been documented in the literature over decades While research has shown the potential, the commercial challenge has been in developing natural microbial inoculant products that can perform within a wide range of environmental conditions, and out-compete epiphytic microbes in varying environmental conditions. New techniques for screening and cataloging candidate microbes, and application of genomic mapping on a large industrial scale have opened up opportunities to develop new microbial products for commercial use. Continued commercial field trial evaluation, and research, will likely eventually lead to this technology being an accepted norm such as forage inoculants or probiotics in animal nutrition.

SPEAKERS

Lance Baumgard

Lance grew up on a mixed livestock and row-crop farm in southwestern Minnesota. He received his B.S. and M.S. degrees from the University of Minnesota and a PhD from Cornell University. Lance joined the University of Arizona's Animal Science department in 2001 and then joined Iowa State University in 2009 as the Norman Jacobson Professor of Nutritional Physiology.

James K. Drackley, Ph.D.

Dr. Drackley is Professor of Animal Sciences at the University of Illinois Urbana-Champaign. His research program has focused on nutrition and metabolism of dairy cows during the transition from pregnancy to lactation, fat utilization and metabolism, and aspects of calf nutrition and management. Dr. Drackley has published extensively, has supervised more than 45 graduate students to MS or PhD degrees, and has received numerous professional awards. Drackley is widely sought by the global dairy industry for speaking and consulting services. He served on the National Academies of Science, Engineering, and Medicine committee to prepare the 8th edition of Nutrient Requirements of Dairy Cattle.

Jeff Firkins, Ph.D.

Jeff Firkins earned his Ph.D. in ruminant nutrition and pursued postdoctoral research in dairy nutrition at the University of Illinois. He was promoted to Professor at OSU in 2000. He has advised and served on committees of dozens of graduate students, including 7 Ph.D.'s from other countries. He served multiple terms on USDA competitive grant panels and has been a member of planning committees for international conferences in gut microbiology and ruminant physiology. He has served as a section editor for three different journals. He was a member of the update committee for NASEM's Nutrient Requirements of Dairy Cattle. He has published more than 250 articles, including about 150 refereed journal articles, invited reviews, and book chapters. He has over 175 invited presentations in more than 20 countries. He was awarded the ADSA Applied Dairy Nutrition award (2003), AFIA Dairy Nutrition Research Award (2012), and Fellow of ADSA (2020). He enjoys family time, gardening, reading, classic movies, and sports.

Dr. Jesse Goff

Jesse Goff grew up in New York State, received his BS in microbiology from Cornell University and worked on Salmonella in poultry for nearly 2 years before deciding to go to graduate school at Iowa State University. He went on to earn a MS, DVM and PhD degree majoring in Veterinary Physiology and Pharmacology and Nutritional Physiology. He joined the Metabolic Diseases and Immunology department at the USDA National Animal Disease Center in Ames, IA and together with Ron Horst, Travis Littledike, Tim Reinhardt and Marcus Kehrli began a 23 year stint doing research on dairy, beef, hogs and poultry. The group made many discoveries on vitamin D metabolism, parathyroid hormone function, and the role of DCAD on calcium metabolism. During that time Goff served on the 2001 NRC committee to revise the "Nutrient Requirements of Dairy Cattle" and the 2005 "Mineral Tolerances of Domestic Animals". In 2007, Goff became R&D director for the West Central Farmers co-operative where Soychlor was refined as a means of lowering DCAD to reduce hypocalcemia. In 2008 Goff joined the faculty at the Iowa State University College of Veterinary Medicine, teaching Veterinary Nutrition courses and Veterinary Physiology courses. Goff recently became professor emeritus and started his own company to produce supplements for pigs and cattle , and work as a nutritional consultant.

Dr. Mary Beth Hall

Dr. Hall is a research scientist working in dairy cattle nutrition for the USDA-Agricultural Research Service at the U.S. Dairy Forage Research Center in Madison, WI, USA. Her degrees in Animal Science are from Cornell University and Virginia Tech. Dr. Hall's research focuses on the nonfiber carbohydrates in dairy cattle diets: their chemical analysis for diet formulation, as well as their digestion, passage, and use by dairy cattle and rumen microbes. She promotes taking an integrative approach to describing complex systems, and doing so with an eye to practical application of research findings. She currently serves on the U.S. National Research Council committee that is revising the Nutrient Requirements of Dairy Cattle. She lives in Wisconsin with her husband and a varied pack of rescued dogs.

Andrew LaPierre Ph.D, Cornell University

Andrew LaPierre is a post-doctoral associate in Dr Mike Van Amburgh's lab in the Department of Animal Sciences. He holds a bachelor's degree from Cornell University, Master's degree from the University of Illinois at Urbana-Champaign, and PhD from Cornell University. In his postdoctoral position, Andrew takes an active role in the biological and structural development of the Cornell Net Carbohydrate and Protein System (CNCPS) model, with particular emphasis on CNCPS v.7 and its rollout from a research setting. Current efforts towards CNCPS development include improvements in the estimation of nitrogen and amino acid requirements to provide a reduced, yet more balanced supply of amino acids to cattle.

Dr. Jimena Laporta

Jimena Laporta received her Ph.D. in Dairy Science from UW-Madison and was a faculty member in the Department of Animal Sciences at the University of Florida for five years before joining the Department of Animal and Dairy Sciences UW-Madison in 2020 as an Assistant Professor in lactation physiology. She investigates how endocrine, autocrine, and environmental factors affect mammary gland development and function and how maternal influences during gestation might program the developing fetus long-term. Her current research efforts center around understanding how late-gestation hyperthermia alters daughter's and granddaughter's epigenome.

Anita Menconi, D.V.M., M.Sc., Ph.D.

Dr. Anita Menconi is the Technical & Marketing Director for Evonik North America. She is a Veterinarian with experience in poultry production, health, and microbiology. She graduated from the University of Arkansas with a Master's and PhD degrees in Poultry Science.

Gavin Staley, BVSc MMedVet (Therio) DiplACT

Graduated from the Faculty of Veterinary Science, University of Pretoria, South Africa as a veterinarian in 1984. After military service, joined the same Faculty of Veterinary Science as a senior lecturer in reproduction. Completed a MMedVet in Reproduction and qualified as a Veterinary Specialist (Theriogenology). Joined the largest dairy practice in South Africa in 1993 as a partner, with dairy and equine focus. Emigrated to the USA in 1998 and joined a dairy practice in Door County, Wisconsin. While in practice in Wisconsin, qualified as a Diplomate of the American College of Theriogenologists (2001). Relocated to the Central Valley of California in 2003 and has worked in industry for past 18 years in Technical Services positions.

International and national dairy consultant. Has presented at World Dairy Expo, AABP and various other national and international meetings. Particular interest in record evaluation, heifer maturity and dairy productive life.

Thomas R. Overton, Ph.D.

Thomas R. Overton, Ph.D., is Professor of Dairy Management and Chair of the Department of Animal Science at Cornell University. Tom is recognized widely for his research and extension efforts relating to nutritional physiology of the transition dairy cow. He serves as Director of the statewide PRO-DAIRY extension program at Cornell. He teaches the dairy cattle nutrition course for undergraduates and co-teaches a similar course for veterinary students. He served as Associate Director, Agriculture and Food Systems, for Cornell Cooperative Extension from 2014 to 2019. In this college-level position, he worked to build additional regional agriculture specialist extension teams and strengthened several college-level extension programs through his leadership. Tom assumed the role of interim chair of the Department of Animal Science in July 2019 and was appointed chair in November 2020.

Tom has a B.S. degree from Cornell University and M.S. and Ph.D. degrees from the University of Illinois. He has authored or co-authored more than 90 peer-reviewed scientific publications and numerous conference proceedings, extension publications, and popular press articles. He was awarded the Cargill Animal Nutrition Young Scientist Award by the American Dairy Science Association in 2006 and the ADSA Foundation Scholar Award in 2007. In 2013, he was named a Faculty Fellow of the David R. Atkinson Center for a Sustainable Future at Cornell University.

Dana J. Tomlinson, Ph.D, PAS, Dipl ACAN

I currently serve as Research Nutritionist - Global Technical Services - IsoFerm at Zinpro Performance Minerals. This position includes directing product research and technical services support of global sales teams, customers and prospects related to isoacid nutrition. Research responsibilities include Zinpro IsoFerm sponsored research and product development in both ruminants and monogastic animals. Recent emphasis has been on the role of isoacids on rumen NDF digestibility and microbial protein production through utilization of branched chain volatile fatty acids. Growing our global knowledge of dairy production efficiency and sustainability is a key focus. Prior responsibilities were in research and technical services related to trace mineral effects on dairy performance, health and wellbeing in addition to skin integrity, hair and fur quality, footpad health, growth and immune function (allergy response) in companion animals. Additional investigations have involved the effects of Zinpro minerals on inflammatory response and recovery in stressed yearling Quarter horses. My current tenure with Zinpro Corporation is over 22 years (2000 - present).

Advanced degrees (MS - 1988, PhD - 1990) in Animal Nutrition and Dairy Management were received from Virginia Polytechnic Institute and State University, Blacksburg. I received my undergraduate degree in Dairy Science from The Ohio State University, Columbus.

I was raised on a dairy in Northeast Ohio with registered Guernsey cattle, Suffolk sheep, Border Collies and lots of cats.

Dr. Heather White

Dr. Heather White received her BS in 2005 from St. Mary's College and MS and PhD from Purdue University. After serving as a post-doctoral fellow at Indiana University School of Medicine, she joined the University of Connecticut as an Assistant Professor in 2011. She joined the University of Wisconsin, Madison as an Assistant Professor in nutritional physiology in 2013 and earned tenure and promotion to Associate Professor in 2018. Dr. White's research program focuses on the health and nutrition of dairy cows during the transition period and is centered on hepatic and whole-animal nutrient partitioning and metabolism. Notably, Dr. White's research strives to determine the mechanism of nutrient partitioning, feed efficiency, and metabolic health in order to provide science-based solutions and interventions to improve dairy cow health and productivity. Heather is also a "hands on" researcher, mentor, and instructor at both the graduate and undergraduate level. Additionally, Dr. White is serving as the Faculty Director of the Dairy Innovation Hub. Heather lives in Albany, WI with her husband and two young sons, Gabe and Alex.