Four-State Dairy Nutrition and Management Conference

Wednesday, June 10, 2020

Virtual Conference

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

2020

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Sponsored by Adisseo

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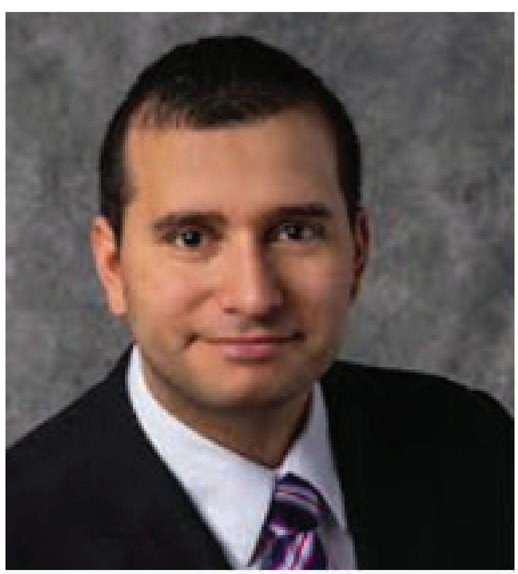
Four-State Dairy Nutrition & Management Conference

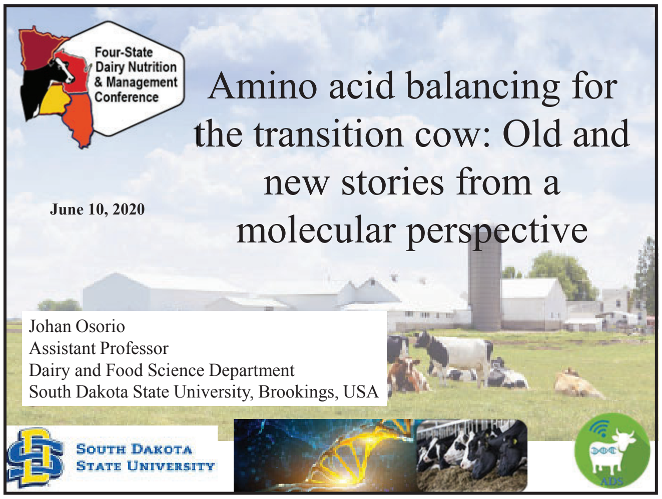
Amino Acid Balancing for the Transition Cow: Old and New Stories from a Molecular Perspective

Johan Osorio, Assistant Professor

Dairy and Food Science Department

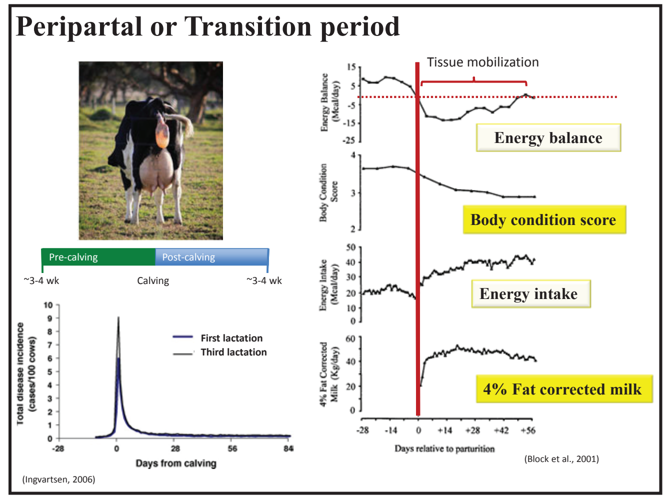
South Dakota State University, Brookings, USA





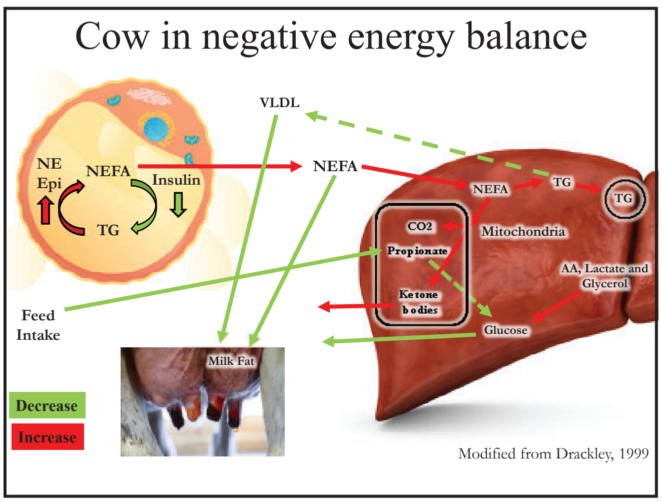
Four-State Dairy Nutrition & Management Conference
Amino acid balancing for the transition cow: Old and new stories from a molecular perspective
June 10, 2020
Johan Osorio
Assistant Professor
Dairy and Food Science Department
South Dakota State University, Brookings, USA
South Dakota State University

1



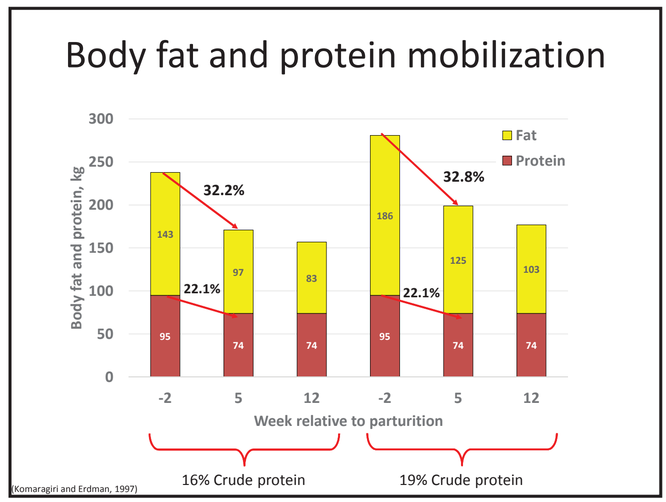
Peripartal or Transition period
Pre-calving
Post-calving
~3-4 wk
Calving
~3-4 wk
Total disease incidence (cases/100 cows)
First lactation
Third lactation
Days from calving
(Ingvartsen, 2006)
Tissue mobilization
Energy Balance (Mcal/day)
Energy balance
Body Condition Score
Body condition score
Energy intake (Mcal/day)
Energy intake
4% Fat Corrected Milk (Kg/day)
4% Fat corrected milk
Days relative to parturition
(Block et al., 2001)

2



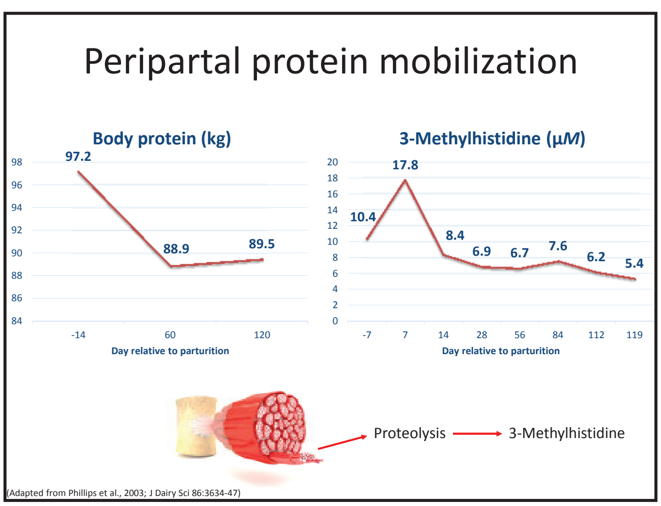
Cow in negative energy balance
VLDL
NE
Epi
NEFA
Insulin
TG
NEFA
NEFA
TG
TG
CO2
Propionate
Mitochondria
AA, Lactate and Glycerol
Ketone bodies
Glucose
Feed Intake
Milk Fat
Decrease
Increase
Modified from Drackley, 1999

3



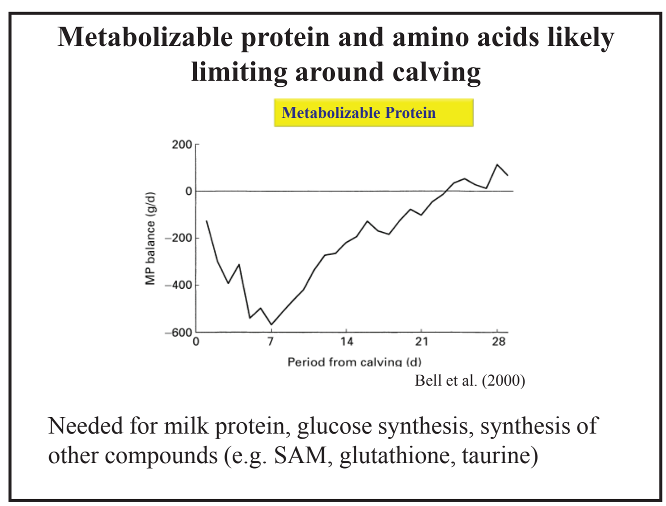
Body fat and protein mobilization
Fat
Protein
Body fat and protein, kg
Week relative to parturition
32.2%
22.1%
32.8%
22.1%
16% Crude protein
19% Crude protein
(Komaragiri and Erdman, 1997)

4



Peripartal protein mobilization
Body protein (kg)
97.2
88.9
89.5
Day relative to parturition
3-Methylhistidine (µM)
10.4
17.8
8.4
6.9
6.7
7.6
6.2
5.4
Day relative to parturition
Proteolysis
3-Methylhistidine
(Adapted from Phillips et al., 2003; J Dairy Sci 86:3634-47)

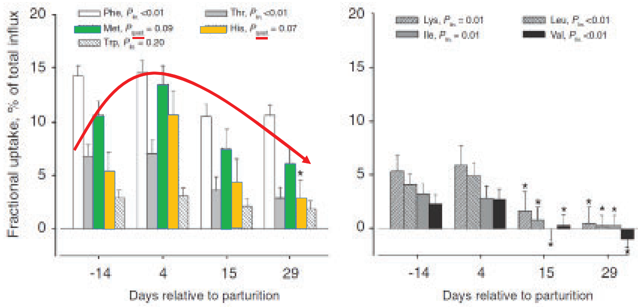
5



Metabolizable protein and amino acids likely limiting around calving
Metabolizable Protein
MP balance (g/d)
Period from calving (d)
Bell et al. (2000)
Needed for milk protein, glucose synthesis, synthesis of other compounds (e.g. SAM, glutathione, taurine)

6

Net liver uptake of Methionine and Histidine increases after calving



(Larsen and Kristensen, 2013)

Net uptake of Met by liver can be enhanced by supplemental RP-Met……..also prevents decrease in blood Met postpartum (Dalbach et al., 2011)

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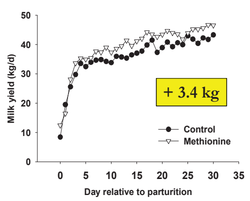
Methionine and the Peripartal Period

Dietary component	Osorio et al., 2013 Control	Osorio et al., 2013 Met	Zhou et al., 2016 Control	Zhou et al., 2016 Met	Batistel et al., 2017 Control	Batistel et al., 2017 Met
CP, % of DM	17.4	17.4	17.2	17.3	17.7	17.7
MP supplied (g/d)	1,563	1,840	2,090	2,374	2,425	2,640
MP balance (g/d)	-574	-616	-434	-573	-118	-160
Lys (% of MP)	6.17	6.07	6.33	6.24	6.40	6.38
Met (% of MP)	1.81	2.15	1.79	2.30	1.70	2.24
Lys:Met	3.43:1	2.82:1	3.54:1	2.71:1	3.78:1	2.88:1

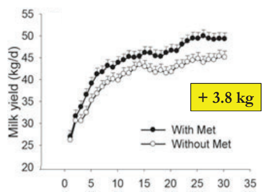
ILLINOIS

8

Methionine and the Peripartal Period



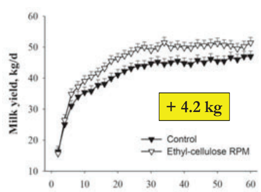
Adapted from Osorio et al., 2013



Adapted from Zhou et al., 2016

Milk Yield

ILLINOIS



Adapted from Batistel et al., 2017

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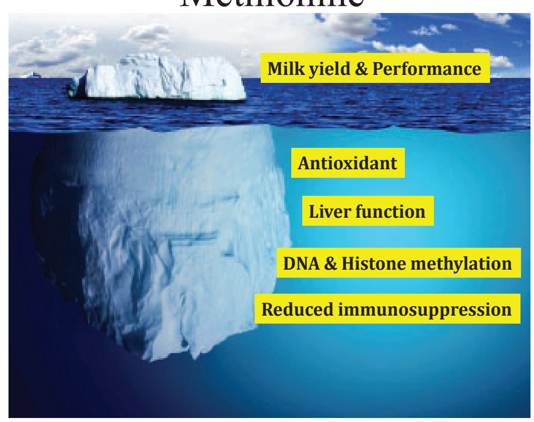
Methionine



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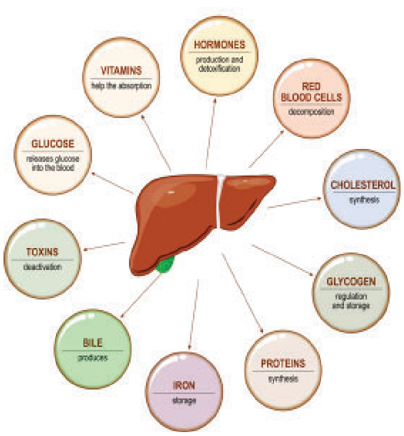
Liver Function



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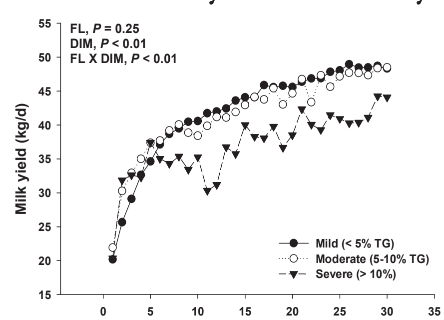
Fatty liver on milk yield



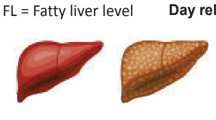
FL = Fatty liver level

n = 100 transition cows

Actual TG mean:
- **Mild = 3.3 ± 1.0**
- **Moderate = 6.5 ± 1.5**
- **Severe = 11.1 ± 0.9**

Actual Milk yield:
- **Mild = 41.9 ± 0.84**
- **Moderate = 41.6 ± 1.5**
- **Severe = 36.9 ± 2.9**

Correlation
- ***r* = -0.2**
- ***P* = 0.06**



Osorio et al., 2013; Zhou et al., 2016; Bastistel et al., 2017

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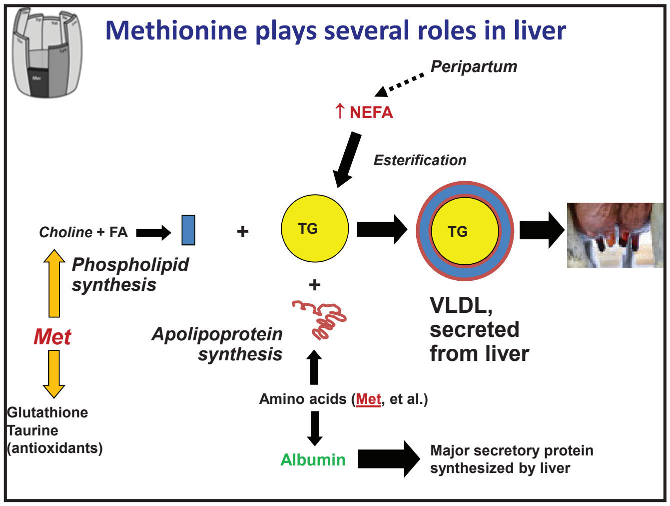

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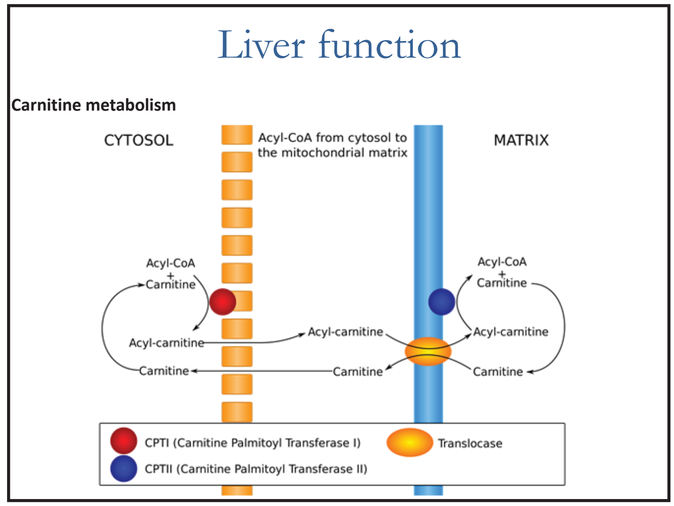

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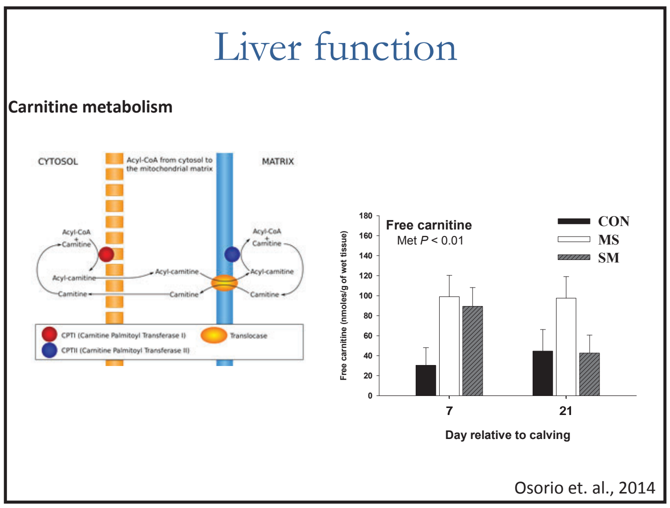

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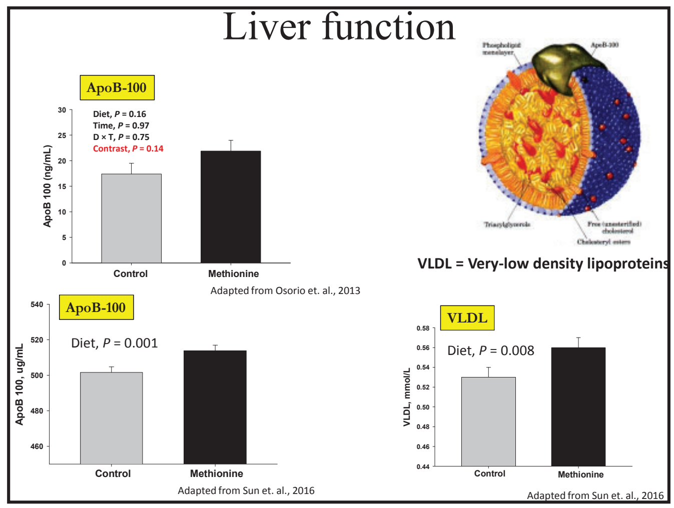

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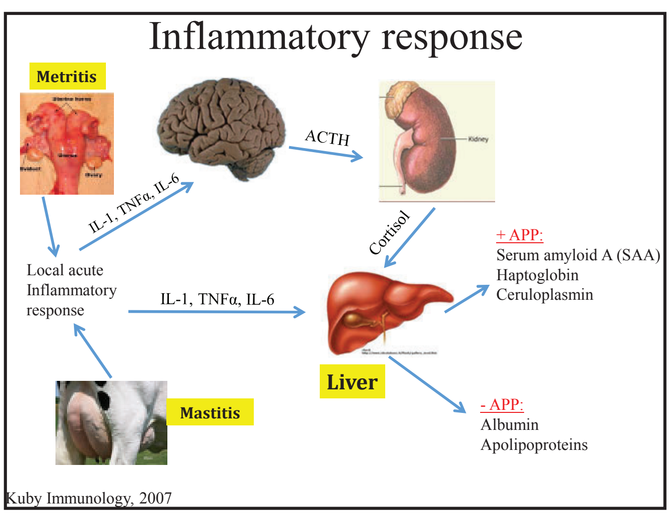

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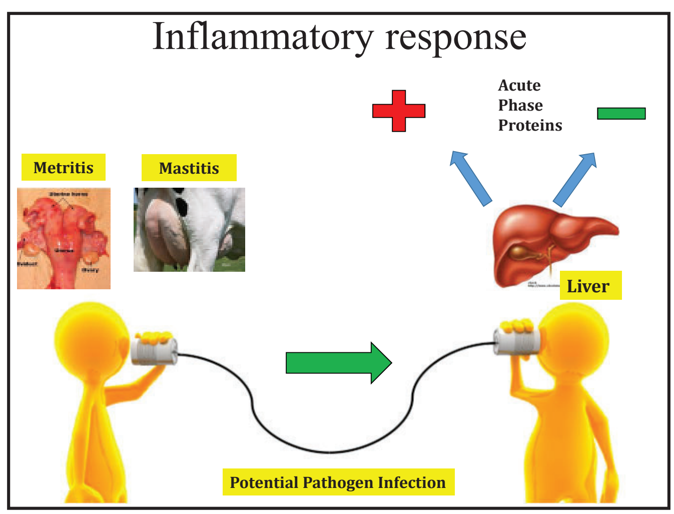

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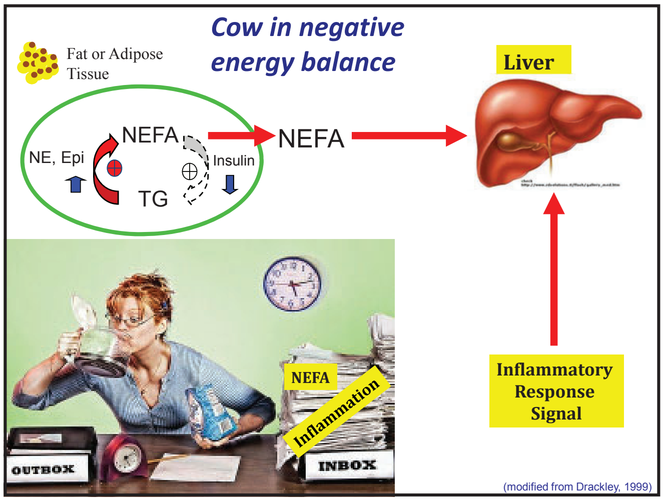

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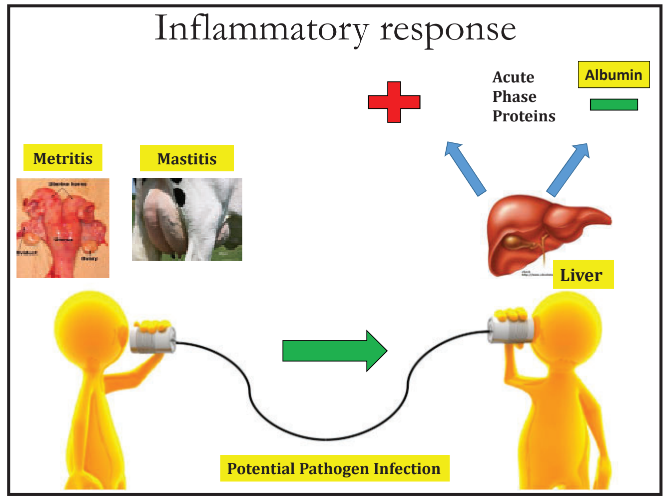

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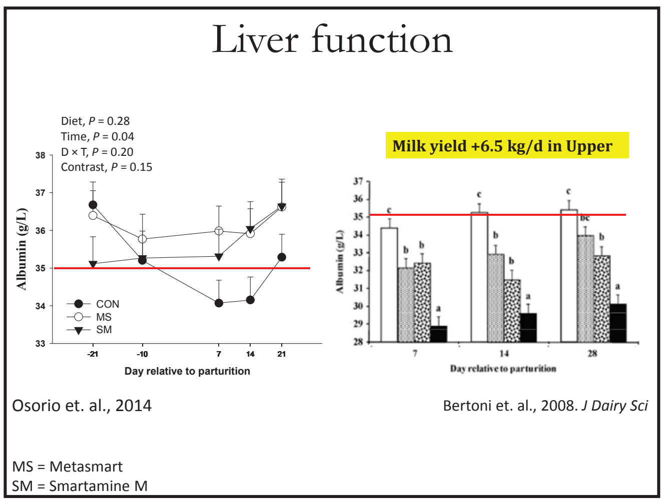

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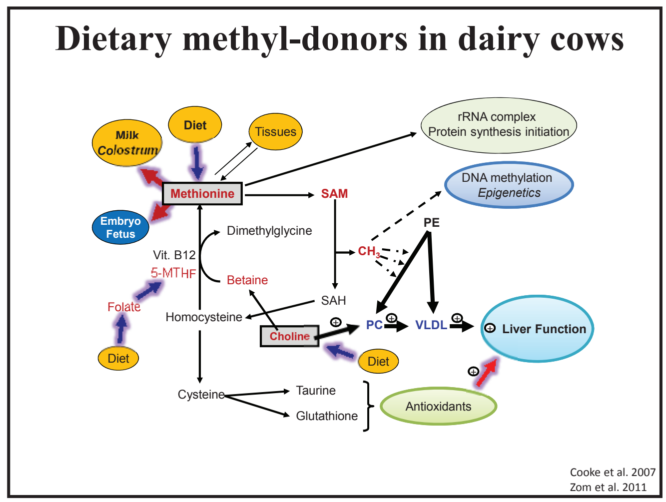

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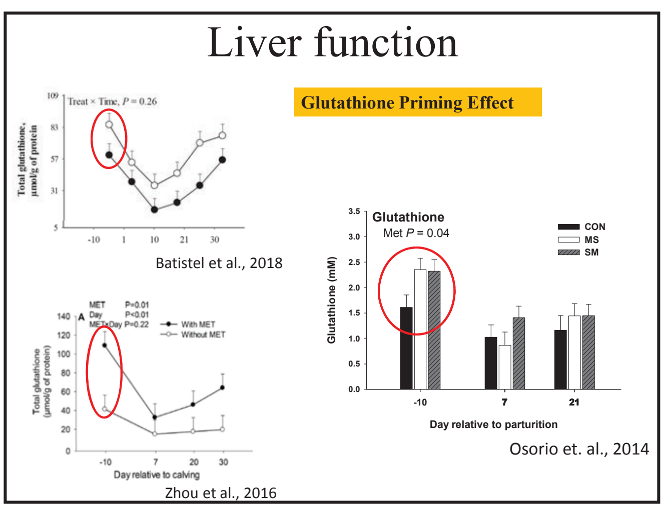

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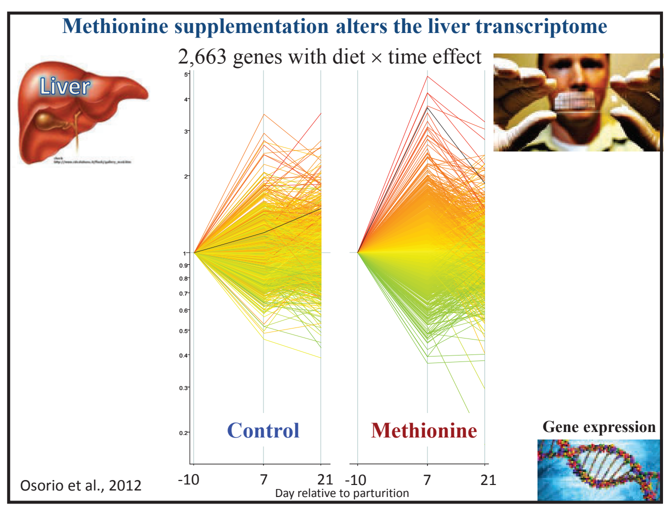

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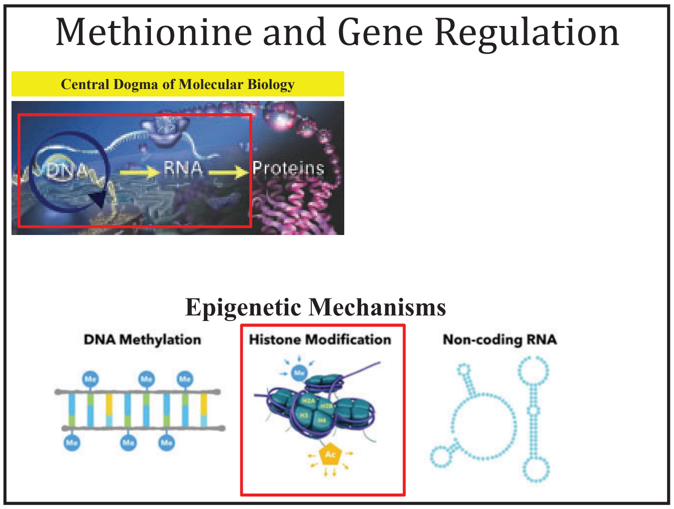

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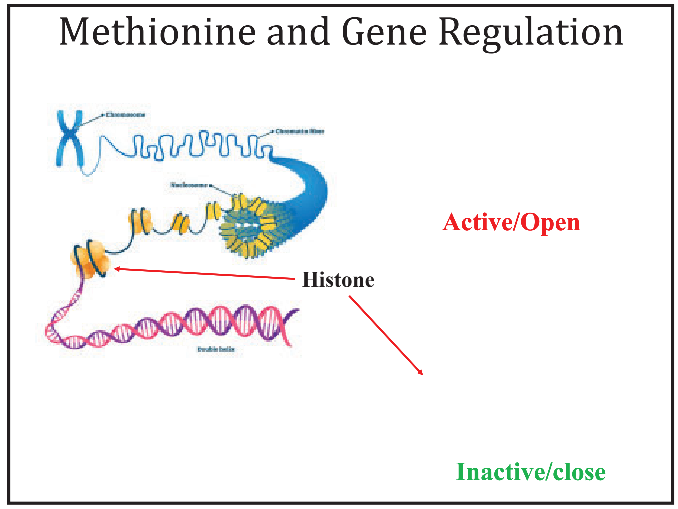

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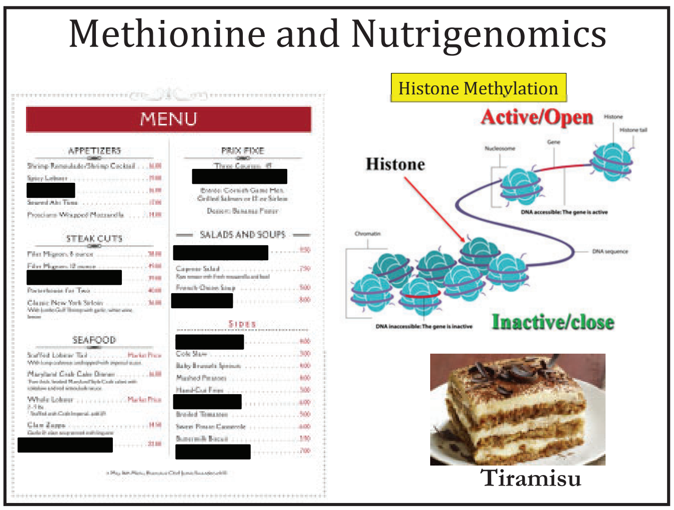

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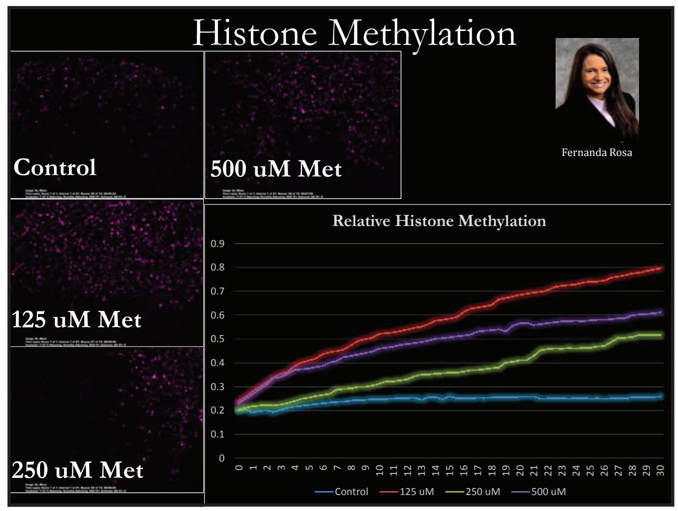

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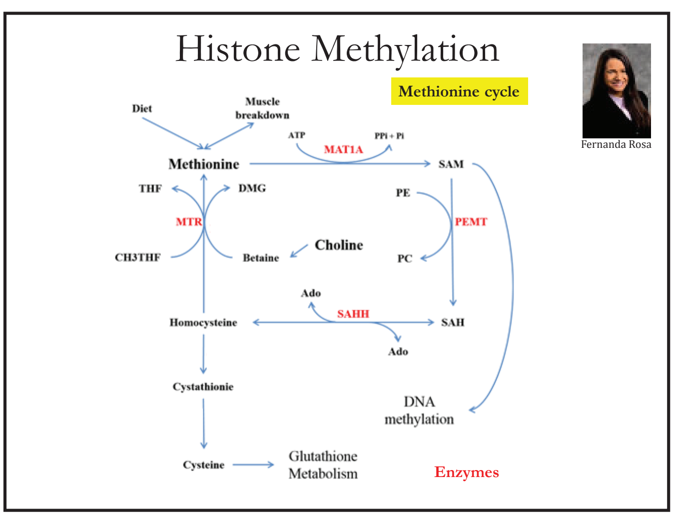

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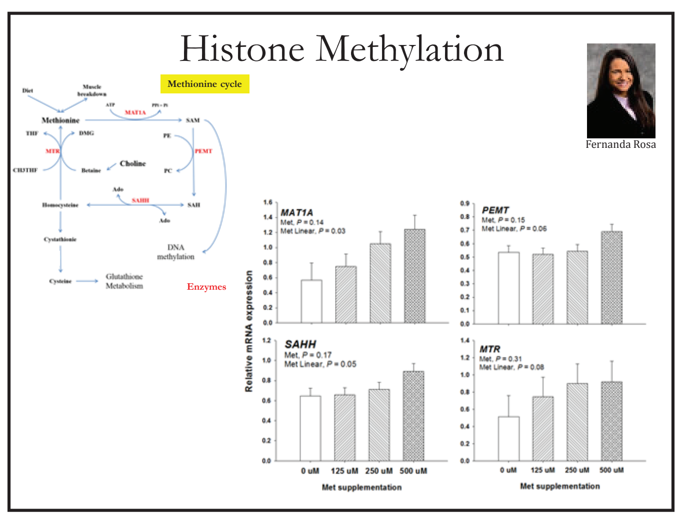

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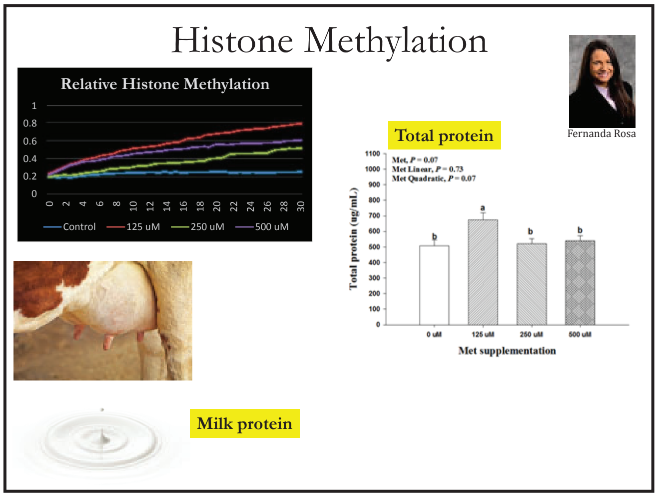
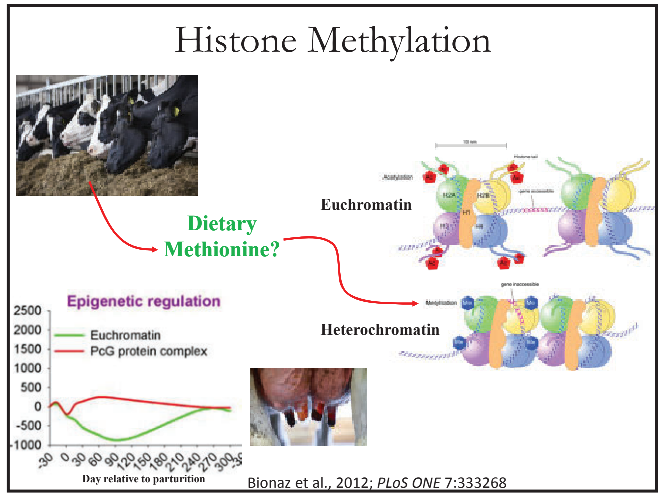

Histone Methylation
Relative Histone Methylation
Control
125 uM
250 uM
500 uM
Fernanda Rosa
Total protein
Met, P = 0.07
Met Linear, P = 0.73
Met Quadratic, P = 0.07
Total protein (ug/mL)
Met supplementation
Milk protein

31


Histone Methylation
Dietary
Methionine?
Euchromatin
Heterochromatin
Epigenetic regulation
Euchromatin
PcG protein complex
Day relative to parturition
Bionaz et al., 2012; PLoS ONE 7:333268

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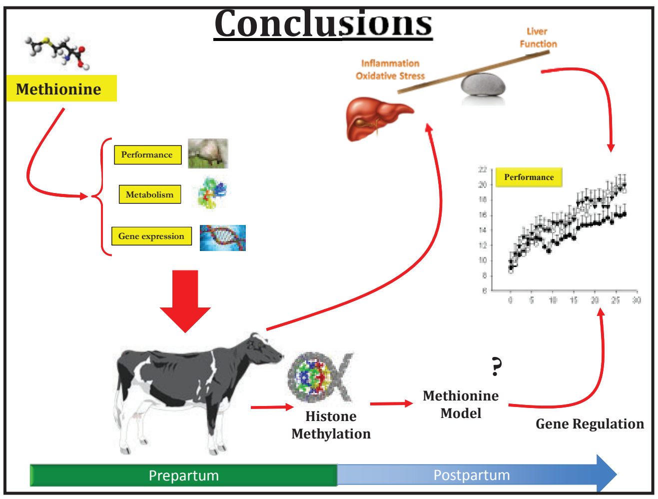
Conclusions
Methionine
Performance
Metabolism
Gene expression
Inflammation
Oxidative Stress
Liver
Function
Performance
Histone
Methylation
Methionine
Model
?
Gene Regulation
Prepartum
Postpartum

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Thanks!
Johan.Osorio@sdstate.edu
Research
South Dakota
State University

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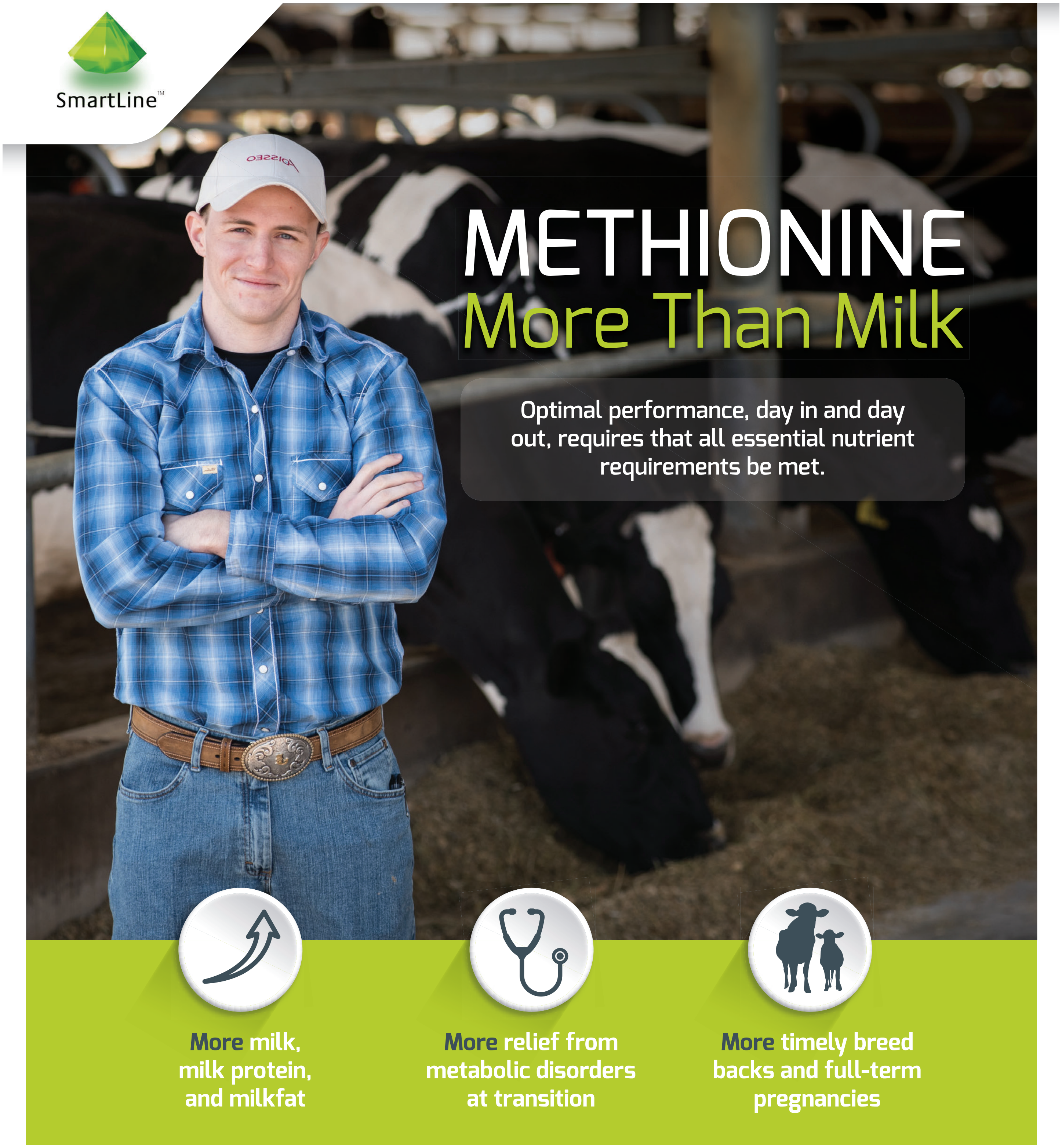
SmartLine™
METHIONINE
More Than Milk
Optimal performance, day in and day out, requires that all essential nutrient requirements be met.
More milk, milk protein, and milkfat
More relief from metabolic disorders at transition
More timely breed backs and full-term pregnancies

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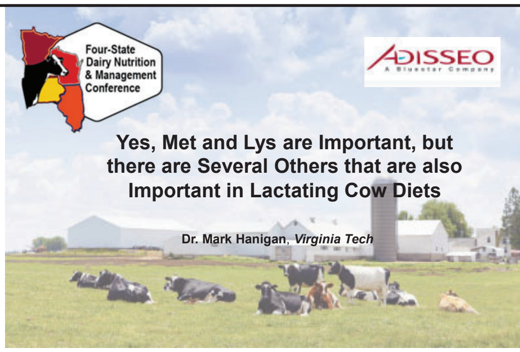
Yes, Met and Lys are Important, but there are Several Others that are also Important in Lactating Cow Diets

Dr. Mark Hanigan
Virginia Tech



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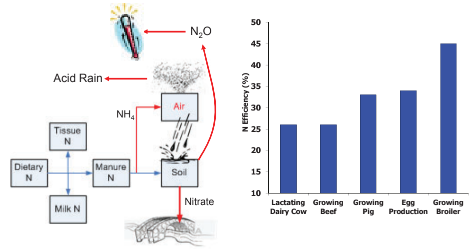
1

N Efficiencies are Low for Ruminants

↑ efficiency = ↑ food/ac and ↓ environmental loading!



Bequette et al., 2003

2

Ohio Dairy Nutrient Values – 5-year Average

Nutrient values derived using Sesame
Buckeye Dairy News: Vol 22, Issue 2 (March, 2020)

Nutrient	Cost/Unit	Daily Supply*	Cost/cow/d
NEL (3X, NRC 2001) MCal	$0.08	35.4 Mcal	$2.83
Metabolizable Protein (NRC) Lbs	$0.43	5.44 lbs	$2.34
Effective NDF (forage NDF) Lbs	$0.14	10.4 lbs	$1.46
Non-effective NDF (Total NDF – Forage NDF) Lbs	-$0.02	7.3 lbs	-$0.15
Total Cost for Energy, Protein and Fiber			$6.48

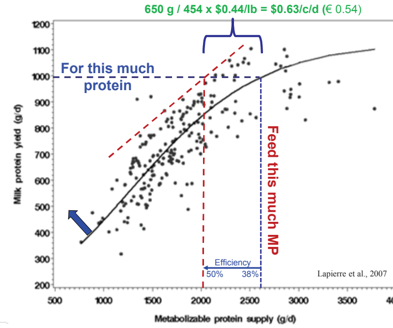
* 1600 lb cow, 80 lbs milk/d, 3.0% protein, 3.5% fat

https://dairy.osu.edu/newsletter/buckeye-dairy-news/volume-22-issue-2/milk-prices-costs-nutrients-margins-and-comparison
Sesame can be licensed and used for local markets

3

Milk Protein vs Metabolizable Protein

650 g / 454 x $0.44/lb = $0.63/c/d (€ 0.54)



How do we achieve this?

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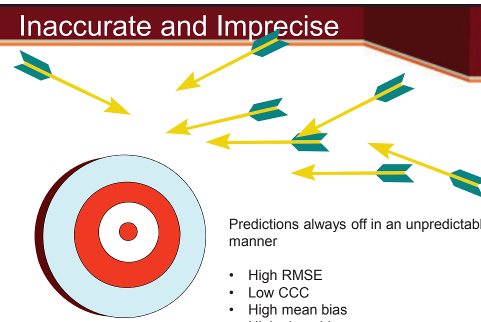
4

Ration Balancer: Behind the User Interface

5

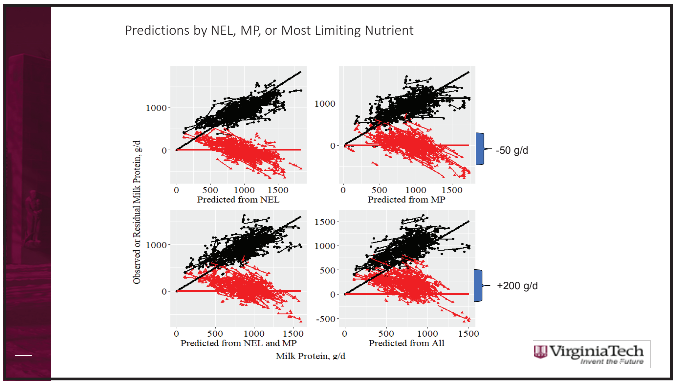
Inaccurate and Imprecise



Predictions always off in an unpredictable manner

- High RMSE
- Low CCC
- High mean bias
- High slope bias
- May be useful but difficult calibration
- NRC 2001

6


Predictions by NEL, MP, or Most Limiting Nutrient
Observed or Residual Milk Protein, g/d
Predicted from NEL
Predicted from MP
Predicted from NEL and MP
Predicted from All
Milk Protein, g/d
-50 g/d
+200 g/d
VirginiaTech
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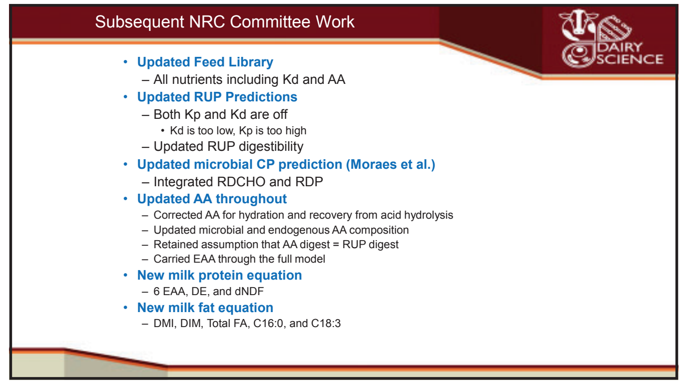
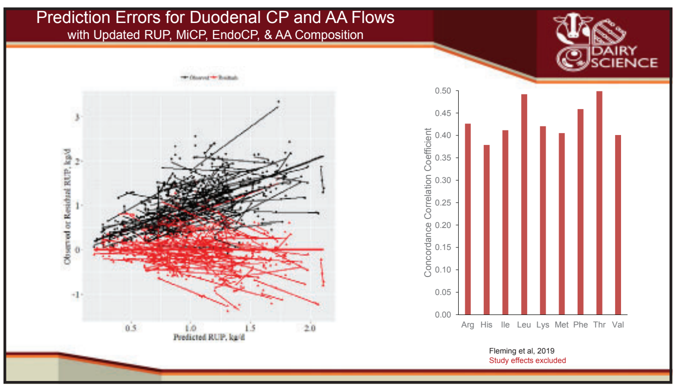
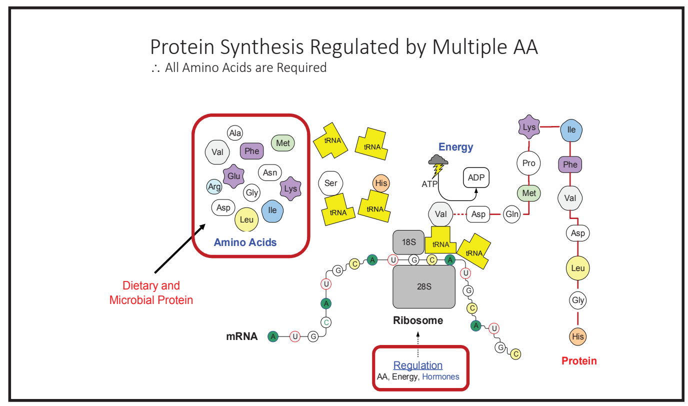
7


Subsequent NRC Committee Work
DAIRY SCIENCE
• Updated Feed Library
– All nutrients including Kd and AA
• Updated RUP Predictions
– Both Kp and Kd are off
• Kd is too low, Kp is too high
– Updated RUP digestibility
• Updated microbial CP prediction (Moraes et al.)
– Integrated RDCHO and RDP
• Updated AA throughout
– Corrected AA for hydration and recovery from acid hydrolysis
– Updated microbial and endogenous AA composition
– Retained assumption that AA digest = RUP digest
– Carried EAA through the full model
• New milk protein equation
– 6 EAA, DE, and dNDF
• New milk fat equation
– DMI, DIM, Total FA, C16:0, and C18:3

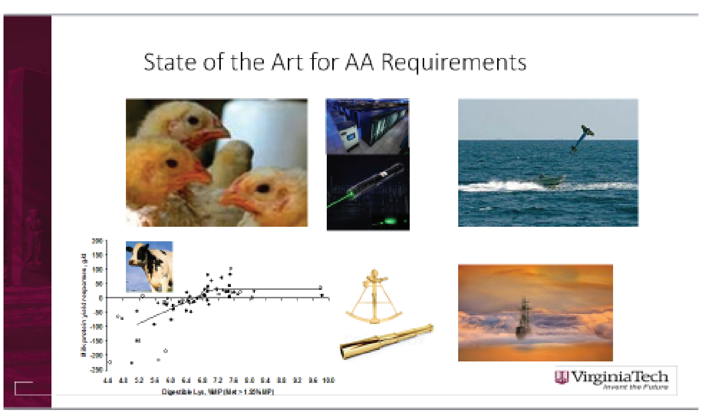
8


Prediction Errors for Duodenal CP and AA Flows
with Updated RUP, MiCP, EndoCP, & AA Composition
DAIRY SCIENCE
Observed or Residual RUP, kg/d
Predicted RUP, kg/d
Concordance Correlation Coefficient
Arg His Ile Leu Lys Met Phe Thr Val
Fleming et al, 2019
Study effects excluded

9


Protein Synthesis Regulated by Multiple AA
∴ All Amino Acids are Required
Amino Acids
Dietary and
Microbial Protein
Energy
ATP
ADP
mRNA
Ribosome
Regulation
AA, Energy, Hormones
Protein

10


State of the Art for AA Requirements
VirginiaTech
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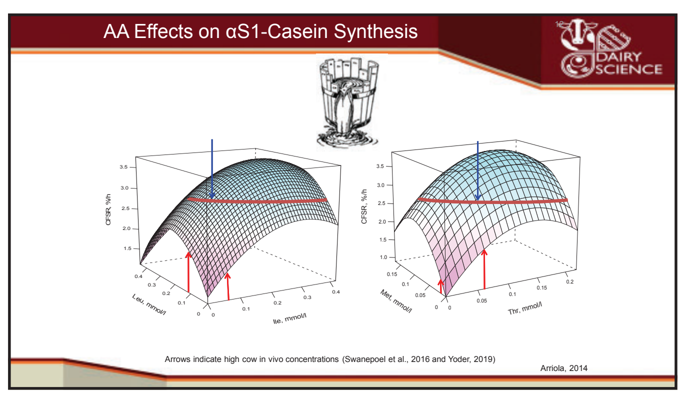
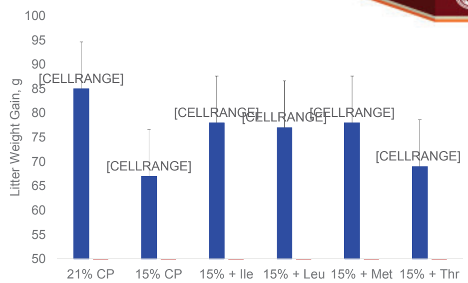

AA Effects on αS1-Casein Synthesis
DAIRY SCIENCE
Arrows indicate high cow in vivo concentrations (Swanepoel et al., 2016 and Yoder, 2019)
Arriola, 2014

12

Lactational Responses to Individual Essential AA in Mice



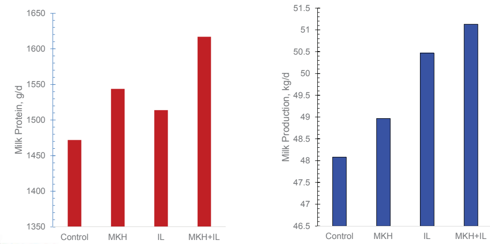
Liu et al., 2017

13

Additive Responses to EAA in Cows

15% CP Diet
38% N Efficiency

	Effect (P-values)		
	MKH	IL	MKH*IL
Milk	0.39	**0.02**	0.89
Milk Protein	**0.002**	**0.02**	0.500



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

Yoder et al., 2020

14

Integrated Milk Protein Predictions from Meta-analysis

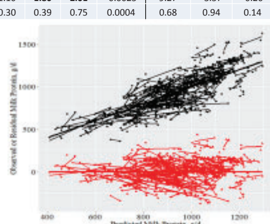
$$mPrt = \beta His + \chi Ile + \delta Leu + \varepsilon Lys + \phi Met + \varphi Thr + \lambda DEI + \kappa dNDF + \mu BW + \lambda(\sum EAA^2)$$

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

Cross Evaluation Results – 500 Iterations

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

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



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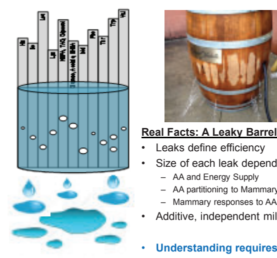
Metabolic Representation



Alternative Facts

Real Facts: A Leaky Barrel

- Leaks define efficiency
- Size of each leak depends on the mix of nutrients
  - AA and Energy Supply
  - AA partitioning to Mammary
  - Mammary responses to AA and energy
- Additive, independent milk protein responses
- **Understanding requires a change in thought!**

16

How Low Can We Go?

Assumptions: 23 kg DMI, MP ~ 0.6 * CP, MP = $0.4375/lb, Milk Prt = $2/lb

	16.5% CP	14.5% CP
MP, g/d	2280	2000
EAA, g/d	1170	1025
Milk Prt, g/d (lb/d)	1080 (2.38)	1064 (2.34)
Abs His, g/d	56	49
Abs Leu, g/d	214	188
Abs Lys, g/d	179	157
Abs Met, g/d	54	47
MP, $/d	$2.20	$1.93
Milk Prt, $/d	$4.76	$4.69
Net, $/d		$0.20

? Is MP cost nonlinear vs reduced dietary CP.

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How Low Can We Go?

$$Milk\ Protein\ (g/d) = 328 - 0.831(DIM) - 62.6(MilkFat\%) + 9.42(DEI) + 4.95(Arg) - 0.021(Arg)^2 + 1.28(His)$$
$$+0.687(Ile) + 1.63(Leu) - 0.003(Leu)^2 + 0.393(Lys) + 1.024(Met) - 4.34(Val) + 0.009(Val)^2$$

Assumptions: 23 kg DMI, MP ~ 0.6 * CP, MP = $0.4375/lb, Milk Prt = $2/lb

	16.5% CP	14.5% CP	12.5% CP	12.5% + rpAA
MP, g/d	2280	2000	1725	1885
EAA, g/d	1170	1025	885	1007
Milk Prt, g/d (lb/d)	1080 (2.38)	1064 (2.34)	1042 (2.30)	1114 (2.45)
Abs His, g/d	56	49	42	56 (+14)
Abs Leu, g/d	214	188	162	214 (+52)
Abs Lys, g/d	179	157	135	179 (+44)
Abs Met, g/d	54	47	41	54 (+13)
MP, $/d	$2.20	$1.93	$1.66?	>$1.66?
Milk Prt, $/d	$4.76	$4.69	$4.59	$4.91
Net, $/d		$0.20	$0.36	$0.68

? MP cost is nonlinear vs reduced dietary CP.

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Diet Optimization Using Different Strategies

RP His, Lys, Ile, Leu, Met, and Thr offered

	Least Cost	Maximum IOFC[a]	IOFC + N Penalty[b]	IOFC ↓ Milk$[c]	IOFC ↓↓ Milk$[d]
Diet Cost, $/d/c	$6.38	$7.72	$7.81	$7.46	$6.80
Milk Value, $/d/c	$14.59	$16.74	$16.18	$12.31	$7.75
Milk Protein, g/d	1110	1286	1210	1262	1189
ME, mcal/kg	2.92	3.01	3.12	3.00	2.98
MP, g/d	2039	3067	2110	2907	2364
Dietary CP, %	14.9	21.8	14.7	20.6	17.1
N Efficiency, %	29.7	23.6	33.0	24.5	27.8
Neutral Detergent Fiber, %	35.7	32.8	34.5	33.4	35.3
Starch, %	26.2	24.1	25.2	24.8	25.9
Fatty Acids, %	2.53	3.17	5.83	2.96	2.77

[a] Milk protein = $4 / lb and milk fat = $2 / lb; assumed high potential production
[b] Excreted N = $4.54 / lb
[c] Milk protein = $3 / lb and milk fat = $1.50 / lb
[d] Milk protein = $2 / lb and milk fat = $1 / lb

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Conclusions

DAIRY SCIENCE

- ✓ Updated feed library
- ✓ Revised RUP and Microbial CP predictions
- ✓ New concepts for milk protein predictions
  - 6 to 8 EAA, DEI, dNDF
  - Marginal responses to individual AA not high
  - AA responses > MP and RPAA input cost
  - Energy supply very important
  - No such thing as a single-limiting AA
- ✓ Milk Protein equations in trial version of NDS
- ✓ AMTS waiting on me
- ✓ NRC out in 2021
- ✓ ☒**Optimize** or ☐**Plug and Chug**?
  - dNDF, dStarch, RDP, dFat, 8 dEAA, 2 dFA, 38 MV, Ingr$, M
  - How much money are you leaving on the table????

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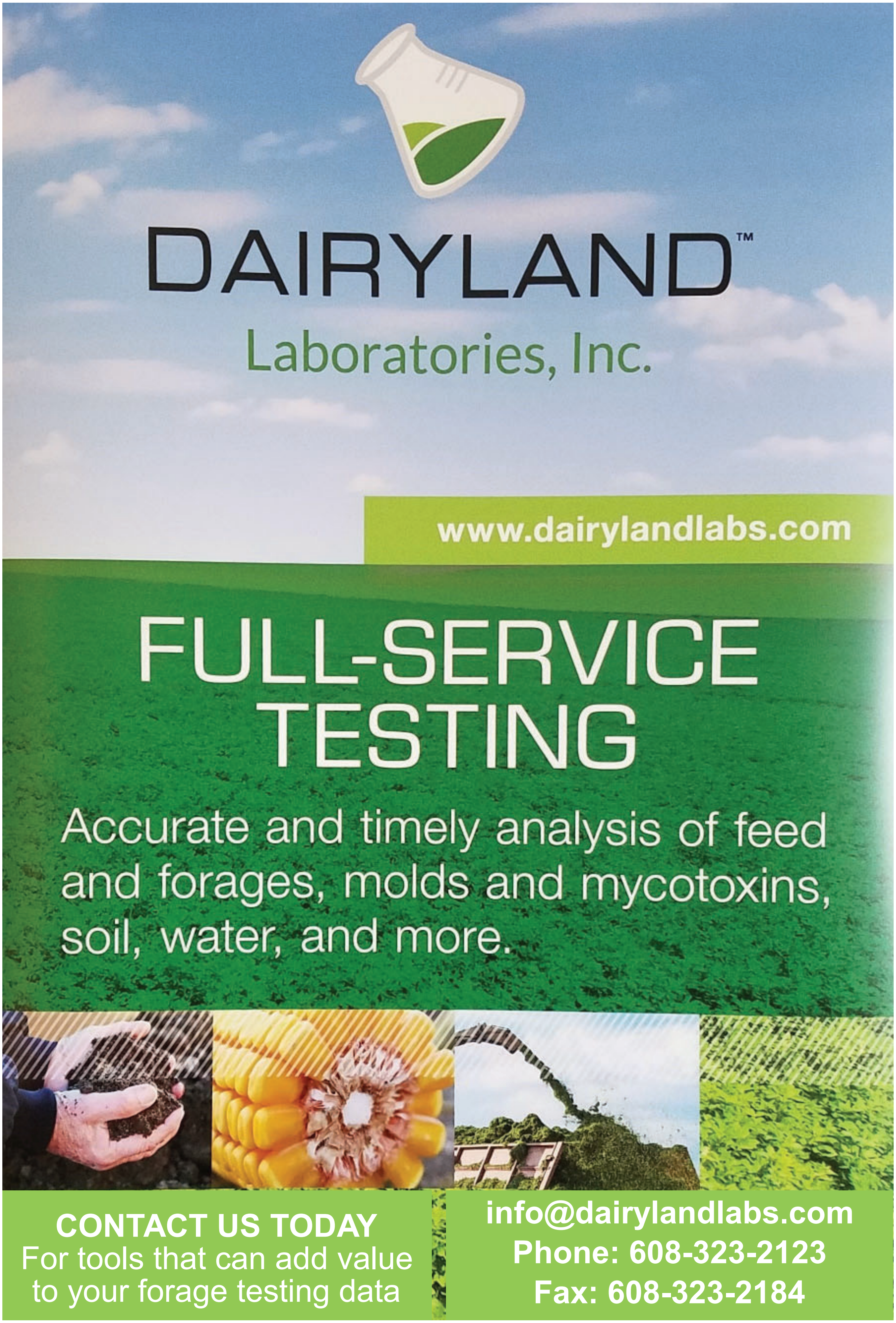
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Functional Amino Acids: The Concept, Present Reality, and Future Prospects Using Reproduction as an Example

Milo C. Wiltbank, Mateus Z. Toledo, Randy D. Shaver
University of Wisconsin-Madison

Julio Giordano, Matias Stangaferro, Michael Van Amburgh
Cornell University

Four-State Dairy Nutrition & Management Conference

ADISSEO
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Functional Amino Acids: The Concept, Present Reality, and Future Prospects Using Reproduction as an Example.

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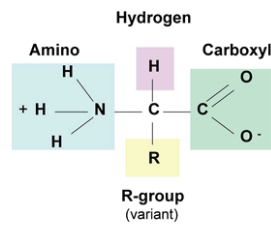
AA Nutrition

- Over 700 AA occur in nature, but 20 are incorporated into proteins.
- Amino acids are required nutrients.
- Essential vs. Non Essential.

Essential	Non Essential
Arg	Ala
His	Asp
Ile	Asn
Leu	Cys
Lys	Glu
Met	Gln
Phe	Gly
Thr	Pro
Trp	Ser
Val	Tyr

Amino Acid Structure



Wu, 2010

2

Functions of amino acids

- **Protein Synthesis**
- **Source of energy**
- **"Functional" actions such as:**
  - **Cell signaling (neurotransmitters such as glutamate)**
  - **Regulation of blood flow (NO is made from arginine)**
  - **Regulatory molecules (methionine)**

3

Functional amino acid definition

"There is growing recognition that besides their role as building blocks of proteins and polypeptides, some AA regulate key metabolic pathways that are necessary for maintenance, growth, reproduction, and immunity. They are called functional AA."

Guoyao Wu, 2009. Amino acids: metabolism, functions, and nutrition. Amino Acids 37:1-17.

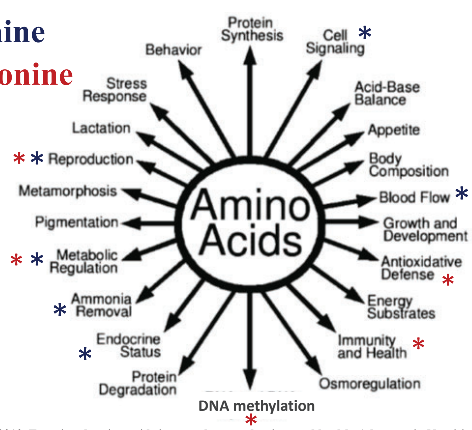
"A growing body of literature leads to a new concept of functional AA, which are defined as those AA that regulate key metabolic pathways to improve health, survival, growth, development, lactation, and reproduction of organisms. Both NEAA and EAA should be considered in the classic "ideal protein" concept or formulation of balanced diets to maximize protein accretion and optimize health in animals and humans."

Guoyao Wu, 2010. Functional amino acids in growth, reproduction, and health. Advances in Nutrition 1:31-37.

4

Functional amino acid definition

Arginine
Methionine



Guoyao Wu, 2010. Functional amino acids in growth, reproduction, and health. Advances in Nutrition 1:31-37.

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The effect of various AA on reproduction (up to 2017)

AA	Major functions	Number of studies	Species	Year of first publication
Arg	**Synthesis of nitric oxide and polyamines; increased litter size**	**33**	**Pig, sheep, horse, cattle, rats and mouse**	**1996**
Gly	Increased embryonic development in vitro; some ovarian, uterine effects	7	Cattle, pig, mouse, hamster	1990
Gln	Metabolic fuel	5	Pig, sheep, cattle, and mice	1990
Leu	mTOR	2	Rats and mice	2012
Pro	Precursor for polyamines	2	Pig and sheep	2005
Tau	Oxidative balance	2	Cattle and Cat	1998
His	Hemoglobin structure; histamine	-	-	-
Lys	Prevent weight loss	7	Pig and cattle	1991
Met	**Methylation of DNA, synthesis of choline, antioxidant**	**8**	**Cattle and rats**	**1989**

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Reproductive effects of Arg feeding in pigs

Study	Period	% Arg	Litter Size	Birth Weight
Mateo et al 2007	Days 30-114	0.83%	Increase 2.0	Increase 24%
Cambell 2009	Days 14-28	1%	Increase 1.0	Increase 6.4%
De Blasio et al. 2009	Days 17-33	1%	Increase 1.2	Not Determined
Berrard & Bee 2010	Days 14-28	0.87%	Increase 3.7	Increase 32%
Li et al., 2011	Days 14-25	0.4%	Increase 2.2	No Effect
Li et al., 2011	Day 0-25	0.8%	Decrease 3.1	Decrease 34%
Gao et al., 2012	Days 22-114	0.8%	Increase 1.1	Increase 11%
Nuntapaitoon et al. 2018	Days 20-80	0.8%	Increased 2.1	Increased 23%
14 Total Studies			10+; 2-; 2NE	9+; 2-; 2NE

7

Reproductive effects of Arg feeding in ruminants?

Study	Period	Arg Treatment	Lambs born	Birth/weaning Weight
Lassala et al. 2011 – Sheep with multiple fetuses	100-121	i.v. infusion 3X/d 345 ug	Decrease 23% born dead	Birth: Increase 23%
Crane et al. 2016	0-14	i.v. once daily of 30 mg/kg BW	No effect	Weaning: 6.1 % increase in litter weight
Luther et al. 2009	0-15	i.v. once daily 27 mg/kg of BW	46 % more lambs	Birth: No effect

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Functional amino acids: The concept, present reality, and future prospects using reproduction as an example: Arginine

Concept: When higher amounts of Arg are fed, effects on reproduction and immune function will be observed.

Present Reality: Feeding Arg increases uterine blood flow and improves reproduction in litter-bearing species. No studies have been done on reproduction in dairy cattle. Large, controlled studies are needed.

Future Prospects: An effective rumen-protected Arg is needed. Perhaps feeding N-carbomylglutamate will work. Effects on pregnancy loss and stillbirth seem possibly economically-important endpoints.

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Potential Arg effects on reproduction in dairy cows

Pregnancy loss in single and twin pregnancies in cool vs. warm temperatures in lactating dairy cows

Singletons	Preg Loss	n	*P*-value
Cool	4.6%	37/805	
Warm	12.7%	64/505	
Total	**7.7%**	**1,310**	**< 0.0001**
Twins	**Preg Loss**	**n**	***P*-value**
Cool	17.6%	16/91	
Warm	53.7%	22/41	
Total	**28.8**	**132**	**< 0.0001**

Lopez-Gatius et al., 2004

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Percentage of stillbirth

Reference	Country	# Herds	# Calves	% Stillbirth
Overton and Dhuyvetter, 2020	USA	50	120,500	5.7
Mahnani et al., 2017	Iran	10	53,265	4.2
Vieira Neto et al., 2017	USA	2	8,095	9.8
Kayano et al., 2016	Japan	5,172	1,281,737	7.7
Lombard et al., 2007	USA	3	7,788	8.2
Meyer et al., 2001	USA	≈ 2,821	666,341	7.0
Total	-	**8,058**	**2,137,726**	**7.3**

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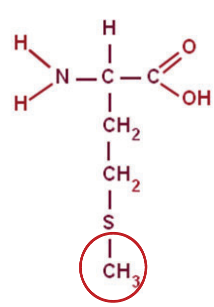
Methionine



- Most common "start" signal for protein initiation
- Can be a rate-limiting amino acid in dairy cattle

One-Carbon Pathway:

- DNA methylation
- Synthesis of other compounds (choline, creatine, polyamines)
- Antioxidant balance

Brosnan et al., 2007; Zanton et al., 2014

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Functional amino acids: The concept, present reality, and future prospects using reproduction as an example: Methionine

Concept: Increased Met is needed for optimal milk production but feeding higher amounts of Met may improve reproduction and health traits.

Present Reality:

Future Prospects:

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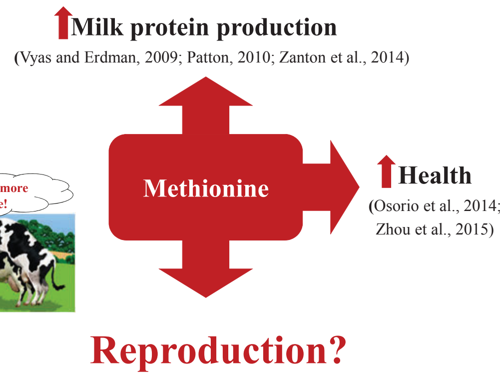
Methionine



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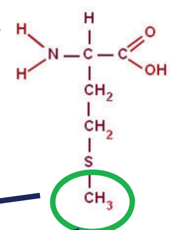
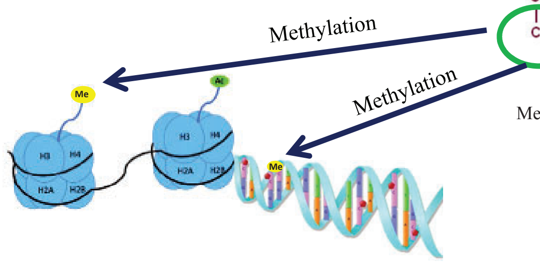
PREG: Pregnancy Retention through Epigenetic Guidance





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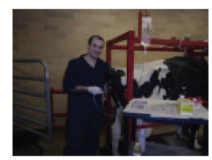
Effect of dietary methionine supplementation in early lactation dairy cows: I - Lactation performance & II - Embryo quality

Souza, Carvalho, Dresch, Vieira, Hackbart, Luichini, Bertics, Betzold, Wiltbank & Shaver



- Holstein cows (n=72)
- Dry period:
  - Housed in a single pen & fed same basal diet
- From calving to 70 DIM:
  - Individual tie-stalls and milked twice daily
- At calving, cows blocked by parity & calving date randomly assigned to two treatments differing in content methionine:
  - **MET**, formulated to deliver 2875g MP with **6.8 Lys %MP** & **2.43 Met %MP** (fed 26 g/d Smartamine M)
  - **CON**, formulated to deliver 2875g MP with **6.8 Lys %MP** & **1.89 Met %MP**

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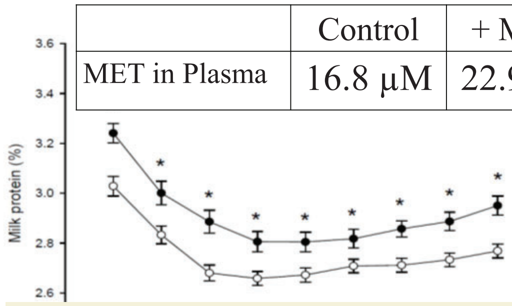
PROTEIN%

	Control	+ MET
MET in Plasma	16.8 µM	22.9µM



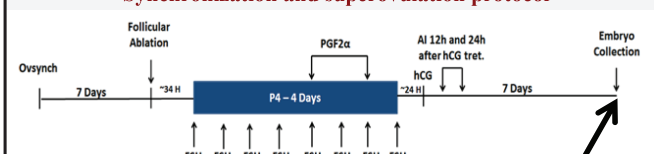
- Supplemental dietary rumen-protected methionine increased plasma methionine concentrations and milk protein concentration & milk protein yield.

17

Effect of dietary methionine supplementation in early lactation dairy cows: I - Lactation performance & II - Embryo quality

Souza, Carvalho, Dresch, Vieira, Hackbart, Luichini, Bertics, Betzold, Wiltbank & Shaver

Synchronization and superovulation protocol



Embryo Morphology – All embryos (> 500)
RNA-Sequencing - Grade I Embryos
(n = 8 cows/treatment group)

Flushed Embryos

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Embryos of superovulated cows fed MET or CON

Total 571 embryos/oocytes; n=	MET 35	CON 37	*P*-value
CL number	17.0 ± 1.3	17.7 ± 1.5	*0.90*
% Fertilized ova	74.7 ± 5.6	82.2 ± 3.8	*0.27*
% Transferable embryos	56.3 ± 6.5	62.5 ± 6.0	*0.49*
% Degenerate embryos	18.5 ± 4.6	19.7 ± 4.7	*0.83*

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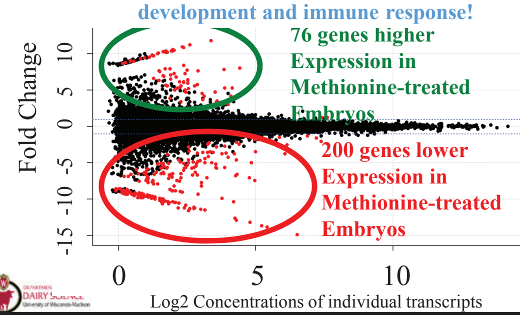
OPEN ACCESS Freely available online PLOS ONE

Effect of Maternal Methionine Supplementation on the Transcriptome of Bovine Preimplantation Embryos

Francisco Peñagaricano[1], Alex H. Souza[2], Paulo D. Carvalho[2], Ashley M. Driver[1], Rocio Gambra[1], Jenna Kropp[1], Katherine S. Hackbart[2], Daniel Luchini[3], Randy D. Shaver[2], Milo C. Wiltbank[2]*, Hasan Khatib[1]*

Several of the most significant genes are related to embryonic development and immune response!



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Present Reality based on RNA-Seq trial:

- Methionine has functional effects on embryos
- Methionine supplementation of the dam changes gene expression in the embryo (Epigenetics).
- Most genes are down-regulated by methionine supplementation.

Gene Expression Is Different

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PLOS | ONE

RESEARCH ARTICLE

Effect of feeding rumen-protected methionine on productive and reproductive performance of dairy cows

Mateus Z. Toledo[1], Giovanni M. Baez[1na], Alvaro Garcia-Guerra[1,2nb], Nelson E. Lobos[1], Jerry N. Guenther[1], Eduardo Trevisol[1], Daniel Luchini[3], Randy D. Shaver[1], Milo C. Wiltbank[1,2]*

1 Department of Dairy Science, University of Wisconsin-Madison, Madison, Wisconsin, Unites States of America, 2 Endocrinology and Reproductive Physiology Program, University of Wisconsin-Madison, Madison, WI, United States of America, 3 Adisseo USA Inc., Alpharetta, Georgia, Unites States of America

Department of Dairy Science, University of Wisconsin-Madison

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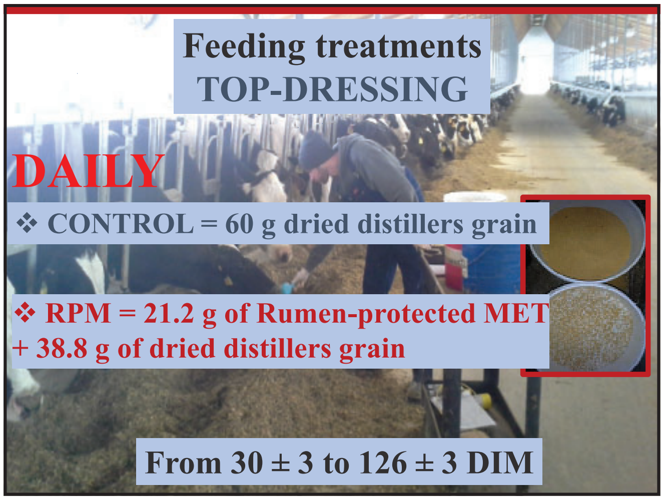

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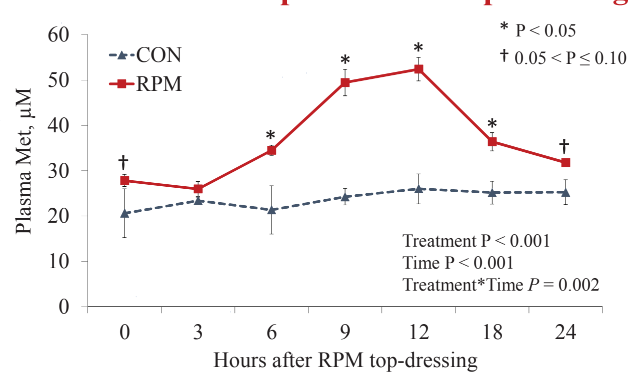
Plasma methionine profile after top-dressing



CON=2 pools, RPM=3 pools (n=4 cows each pool, total 20 cows)

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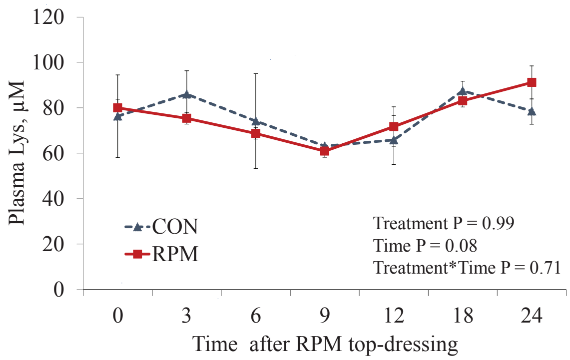
Plasma Lys



CON=2 pools, RPM=3 pools (n=4 cows each pool, total 20 cows)

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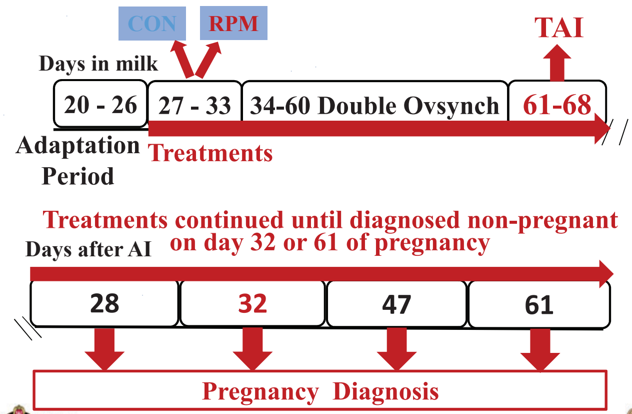
Experimental design timeline



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Double-Ovsynch

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					GnRH	
					PGF	
	GnRH					
	GnRH					
	PGF	PGF	GnRH	TAI		

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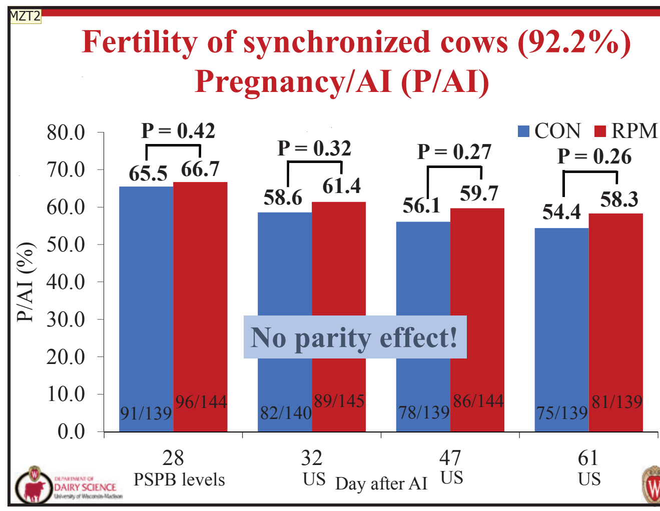
Fertility of synchronized cows (92.2%) Pregnancy/AI (P/AI)



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Embryo size

- Measurements – Software, Image J (National Institutes of Health, Bethesda, MD)
- Recorded for 15 seconds and the ideal position and orientation of the conceptus was selected
- 2 independent people analyzed the videos

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Mateus Z. Toledo

Methionine & Embryo Size

Trt & Parity	n	Amnionic Vesicle (mm^3)	Crown-Rump Length (mm)	Abdominal Diam. (mm)
Pri-Con	36	**617.1**	**10.5**	**5.6**
Pri-RPM	38	**596.0**	**10.9**	**5.7**
P-Value		*0.67*	*0.21*	*0.53*
Mul-Con	37	**479.4**	**10.6**	**5.3**
Mul-RPM	45	**593.9**	**11.0**	**5.9**
P-Value		*0.04*	*0.22*	*0.01*

Multiparous Cows supplemented with RP-Methionine had larger embryos.

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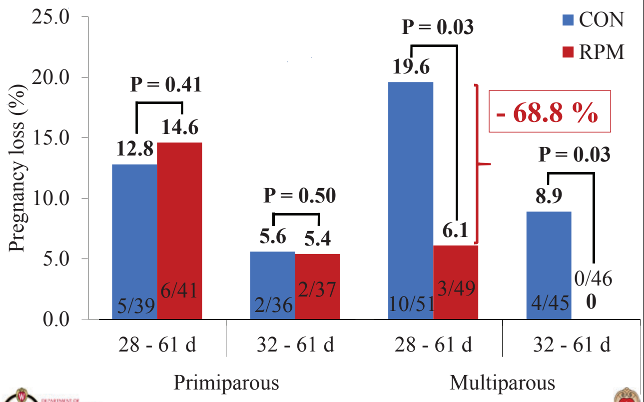
Pregnancy loss by parity



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Conclusions from Methionine Supplementation Trials.

- Methionine supplementation of the dam:
  - ↑Size of embryo (+22%) in multiparous cows
  - ↓Pregnancy loss (19.6 vs. 6.1%) in multi cows

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Feeding Rumen-Protected Methionine Pre- and Postpartum in Dairy Cows: Impact on Health, Productive and Reproductive Performance

M.Z.Toledo*, M.Stangaferro*, R.S.Gennari, P. L. J. Monteiro Jr., R.V. Barletta, C. A. Gamarra, A.B. Prata, J. Dorea, D. Luchini, M.M. Perez, M. Masello, R. Wijma, M.E. Van Amburgh, R.D. Shaver , J.O. Giordano, and M.C. Wiltbank

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Hypotheses

- We hypothesized that feeding RPM pre- and postpartum incorporated into TMR from -21 d until 147 DIM would:
  - **Increase plasma Met and milk protein production**
  - **Improve overall health**
  - **Enhance embryo development**
  - **Improve reproductive efficiency**

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Experimental Design

- 470 multiparous Holstein cows
  - **Cornell University Ruminant Center (CU; n = 235)**
  - **Emmons Blaine Dairy Research Center (UW; n = 235)**
- Housed in replicated pens:

	UW	CU	n cows
Close-up	4	2	10
Lactation	6	12	16

CON = 9 MET = 9

- Cows were enrolled between 3 and 4 weeks before calving
- Randomly assigned to either a control **(CON; no Smartamine M)** or treatment diet **(MET; 12 g (Pre) and 27 g (Post) Smartamine M)**

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Methionine Crew Acknowledgments

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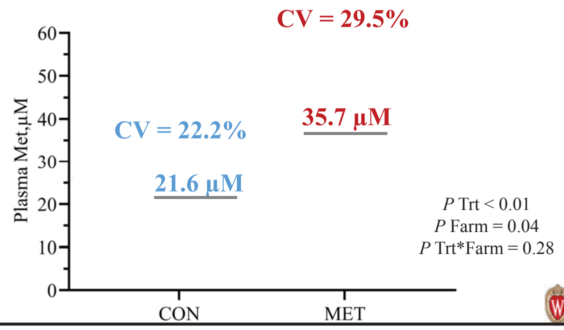
Does feeding RPM increase plasma Met?

- Blood samples collected from 72 cows [0 – 3 h after feeding (UW=24; CU= 48) only; 80 DIM] and individually analyzed for free AA by LC-MS



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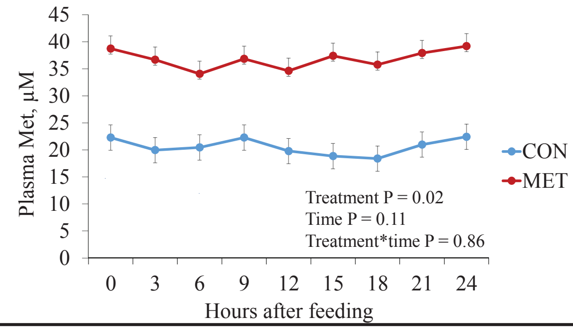
Does plasma Met vary during the day?

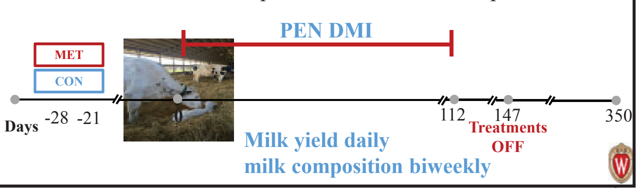
- Blood samples collected from 16 cows (UW only; 60-85 DIM) every 3 h and analyzed for free AA by LC-MS



38

Outline

- Background
- Amino acids (AA) nutrition in dairy cattle
- Met importance and functions
- Studies feeding Met during pre- and postpartum and evaluating health and productive performance?
- **Does feeding RPM pre- and postpartum improve:**
- Production?, Health?, Reproduction?, HealthXReproduction?



39

Lactation performance: 0-112 DIM

	CON	MET	Trt	Farm
DMI, Kg/d	28.0	27.9	0.96	< 0.01
Milk yield, Kg/d	49.2	48.7	0.36	0.61

Time P : < 0.001; No interaction Trt x time and Trt x farm

40

Productive performance: 0-112 DIM

	CON	MET	Trt	Farm
DMI, Kg/d	28.0	27.9	0.96	< 0.01
Milk yield, Kg/d	49.2	48.7	0.36	0.61
Fat, %	3.77	3.87	0.03	0.04
Fat, kg	1.83	1.86	0.36	0.11
Protein, %	2.95	3.07	< 0.01	0.17
Protein, kg/d	1.43	1.48	0.02	0.04
Lactose, %	4.88	4.86	0.22	< 0.01
Lactose, kg/d	2.41	2.37	0.32	0.34

0.11 % units of milk fat

0.12 % units of milk protein

40 g of milk protein yield

Time P : < 0.001; No interaction Trt x time and Trt x farm

41

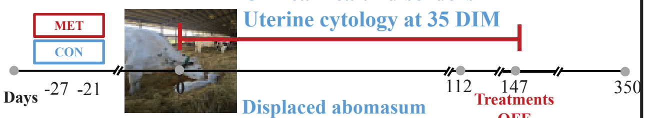
Productive performance: 16 weeks

	CON	MET	Trt	Farm
DMI, Kg/d	28.0	27.9	0.96	< 0.01
Milk yield, Kg/d	49.2	48.7	0.36	0.61
Fat, %	3.77	3.87	0.03	0.04
Fat, kg	1.83	1.86	0.36	0.11
Protein, %	2.95	3.07	< 0.01	0.17
Protein, kg/d	1.43	1.48	0.02	0.04
Lactose, %	4.88	4.86	0.22	< 0.01
Lactose, kg/d	2.41	2.37	0.32	0.34
SCC x 10^3, cells/ml	76.3	68.5	0.45	< 0.01
MUN, mg/dl	10.3	10.5	0.44	< 0.01
Milk:DMI	1.79	1.79	0.96	< 0.01
Efficiency of N use	0.306	0.320	0.04	< 0.01

Time P : < 0.001; No interaction Trt x time and Trt x farm

42

Outline



Clinical health disorders
Uterine cytology at 35 DIM

Displaced abomasum
ketosis – urine sticks, BHB ≥ moderate
Retained placenta – Lack of expulsion in 24 h
Mastitis
Respiratory problems
Lameness

- Prevalence of health disorders?

43

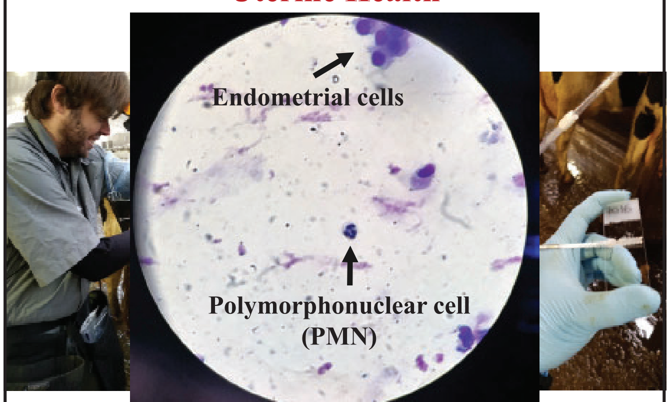
Proportion of health disorders

	CON	RPM		P-value	
Number of health disorders	Proportion, % (n)		SEM	Trt	Farm
None	49.4 (117)	48.7 (114)	2.8	0.86	0.63
Single	28.3 (67)	30.4 (71)	3.0	0.61	0.69
Multiple	22.3 (53)	20.6 (48)	2.7	0.65	0.93
Type of health disorder					
Displaced abomasum	2.9 (8)	3.3 (8)	1.1	0.81	0.12
Ketosis	13.9 (33)	9.9 (23)	2.1	0.18	0.58
Mastitis	20.9 (49)	17.4 (41)	3.0	0.40	0.40
Retained placenta	7.8 (19)	9.7 (23)	2.0	0.48	0.11
Respiratory problems	11.3 (27)	11.5 (28)	2.3	0.95	0.16
Lameness	5.0 (15)	3.9 (12)	1.7	0.62	0.01

All Trt*Farm interaction $P > 0.10$, except lameness and cytological endometritis.
Multiple health disorders includes cytological endometritis.
Cytological endometritis: cows with ≥ 10 % in the uterine smear at 35 DIM. There was no trt effect (P = 0.94) on percentage of PMN.

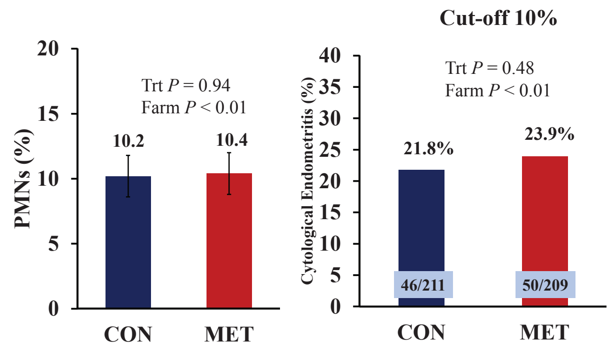
44

Uterine Health



45

Uterine Health on Day 35 after calving



46

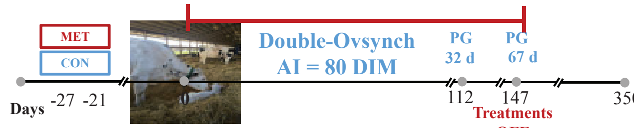
The Effect of Feeding Met on Health

Author	Health
Griel et al.	not evaluated
Overton et al.	not evaluated
Xu et al.	**Blood TG levels**
Phillips et al.	**Body protein mobilization**
Piepenbrink et al.	NS
Socha et al.	NS
Johnson-VanWieringen et al.	not evaluated
Ordway et al.	not evaluated
Preynat et al.	NS
Preynat et al.	NS
Osorio et al. I, II	**Ketosis, immune response, liver function, oxidative stress**
Zhou et al. I, II	**Ketosis, RP, liver function, immune response**
Batistel et al. I, II	**NEFA, liver function, immune response, oxidative stress**

47

Outline

Culling
Time to Pregnancy
Pregnancy/AI and pregnancy loss



Embryo Development

- Reproductive performance and herd exit dynamics?

48

Pregnancies per AI and pregnancy loss
Synchronized cows (84%)

P/AI	CON	MET	*P*-value
Day 25 (based on PSPB)	**63.9%** (115/180)	**64.4%** (112/174)	0.45
Day 29 (based on PSPB)	**60.6%** (109/180)	**62.6%** (109/174)	0.34
Day 32 (based on TUS)	**53.9%** (97/180)	**55.2%** (96/174)	0.41
Day 67 (based on TUS)	**48.0%** (86/179)	**51.2%** (89/174)	0.29

49

Pregnancies per AI and pregnancy loss

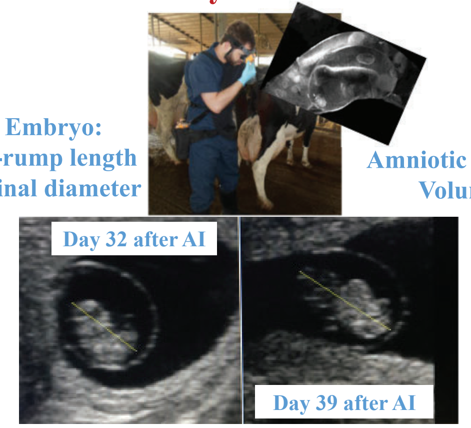
Pregnancy loss	CON	MET	*P*-value
Day 25 - 29	**5.2%** (6/115)	**2.7%** (3/112)	0.17
Day 29 - 32	**11.0%** (12/109)	**11.9%** (13/109)	0.43
Day 25 - 67	**24.6%** (28/114)	**20.5%** (23/112)	0.24
Day 32 - 67	**10.4%** (10/96)	**7.3%** (7/96)	0.23

50

Embryonic Size

Embryo:
Crown-rump length
Abdominal diameter

Amniotic vesicle:
Volume



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Embryonic Size

	Day 32		Day 39		
	CON	MET	CON	MET	*P* Trt
Amniotic vesicle volume (mm³)	559.8	527.8	3,282.3	3,079.5	0.16
Crown-rump length (mm)	10.8	10.7	18.2	17.9	0.42
Abdominal diameter (mm)	5.7	5.6	9.5	9.4	0.23

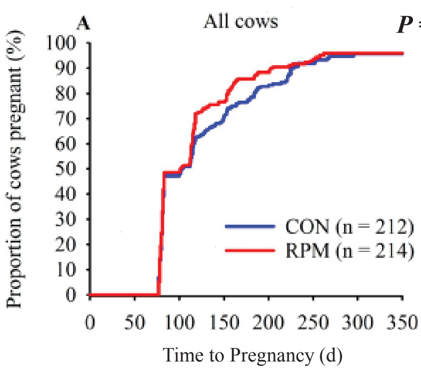
*Interaction treatment by time P > 0.10

52

Time to pregnancy

Hazard Ratio: 1.14

***P* = 0.20**



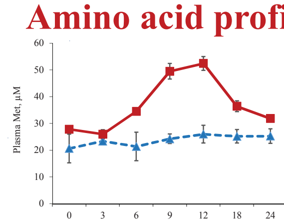
CON (n = 212)
Median: 130 d

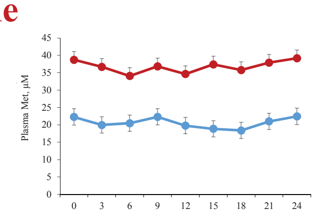
MET (n = 214)
Median: 119 d

53

Differences between studies?

Amino acid profile

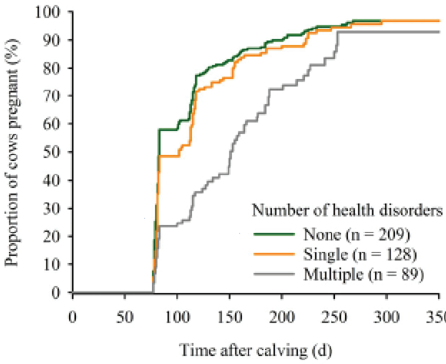




Environment (Stress, overcrowding)

54

Health disorders and time to pregnancy



None — CON / MET

Median: 83 d

HR:1.05
P = 0.71

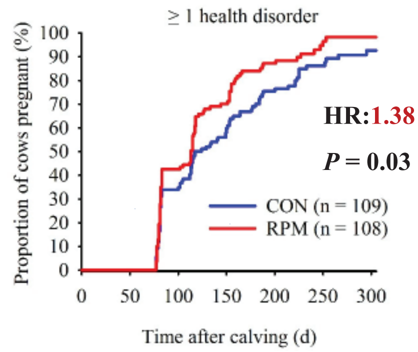
Multiple

Median: 151 d

HR:2.11 *P* < 0.01

55

Cows with at least one health disorders and time to pregnancy



HR:1.38

P = 0.03

CON

Median: 148 d

MET

Median: 125 d

56

Productive Performance by Health Status Category

Item	None CON	None RPM	Single CON	Single RPM	Multiple CON	Multiple RPM	Trt *P*-value None	Trt *P*-value Single	Trt *P*-value Multiple
n	103	106	62	66	47	42			
Milk yield, kg/d	50.3	49.4	50.1	49.7	48.6	48.9	0.20	0.62	0.73
ECM, kg/d	50.5	50.8	50.1	50.8	48.1	49.4	0.73	0.47	0.20
NE_L in milk, Mcal/d	35.9	36.1	35.5	36.0	33.9	35.0	0.73	0.46	0.17
Milk components yield, kg/d									
Fat	1.86	1.88	1.85	1.88	1.76	1.82	0.53	0.44	0.28
Protein	**1.46**	**1.49**	**1.43**	**1.48**	**1.36**	**1.44**	**0.12**	**0.07**	**0.01**
Lactose	2.48	2.41	2.45	2.41	2.36	2.38	0.12	0.50	0.69
Milk composition									
Fat, %	3.74	3.86	3.72	3.82	3.68	3.75	0.10	0.21	0.51
Protein, %	**2.93**	**3.06**	**2.89**	**3.01**	**2.84**	**2.96**	**< 0.01**	**< 0.01**	**< 0.01**
Lactose, %	4.92	4.89	4.87	4.86	4.84	4.85	0.13	0.45	0.87
MUN, mg/dl	10.4	10.8	10.2	10.4	10.1	10.1	0.18	0.67	0.99
SCC x 10^3, cells/ml	77.5	65.8	96.5	105.6	182.6	132.4	0.34	0.64	0.18

80 g of milk protein

Feeding RPM seems to improve functional properties of cows that suffer diseases (production, reproduction, herd exit).

57

Herd Exit Dynamics
Cows that were sold during lactation (350 DIM)

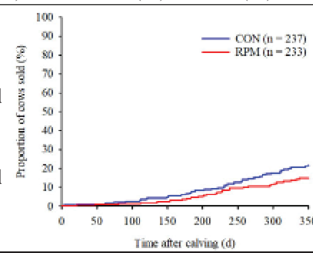
Item	CON	RPM	SEM	*P*-value Trt	*P*-value Farm
	Proportion, % (n)				
Sold	**20.6 (49)**	**13.4 (32)**	**2.6**	**0.06**	**0.14**
Died	6.6 (5)	7.1 (10)	1.5	0.85	< 0.01
Left (Sold + Died)	22.8 (54)	17.8 (42)	2.3	0.13	0.91

CON

Mean: 310 d

MET

Mean: 315 d



67% (54/81)

Had one or more health disorders

HR:1.53 *P* = 0.06

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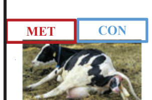
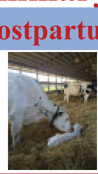
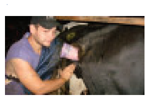
Summary & Conclusions

Pre- and postpartum RPM







Dry Period (last 3 wks) | Early Post-partum (3 wks) | Pre-AI (1 wk) | First two months of Pregnancy

Improved lactation performance:
Milk protein % and yield, and milk fat %

No effects on health disorders, embryo development and 1st service P/AI and pregnancy loss

May reduce time to pregnancy, particularly in cows with at least one health disorder, and appears to decrease likelihood of cows being sold.

59

Functional amino acids: The concept, present reality, and future prospects using reproduction as an example: Methionine

Concept: Increased Met is needed for optimal milk production but feeding higher amounts of Met may improve reproduction and health traits.

Present Reality: There are physiologic effects of Met:
Change in gene expression in embryo when dam is fed Met.
Reduced pregnancy loss in multiparous with Met feeding.
Improved reproductive efficiency with Met for unhealthy cows.

Large, randomized, controlled studies are needed to determine effects of functional amino acids on economically important traits of dairy cattle.

60

Future Prospects: Amounts and timing of RPM feeding still needs to be optimized.

Rumen-protected methionine – Need more data on reproductive efficiency and health effects under field conditions (stress, overcrowding, diseases).

Changing amino acids in uterine histotroph and during pregnancy may improve reproduction.

Effect of decreased or maintained amino acid concentrations during the transition period on health and reproduction.

61

Association of Amino acids profile during pre- and postpartum with health disorders, productive and reproductive performance

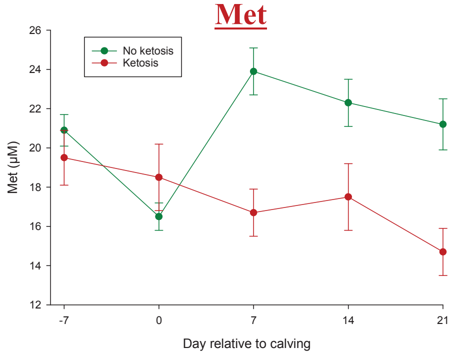
Mateus Z. Toledo, Pedro Monteiro Jr., Rodrigo Gennari, João Dorea, Daniel Luchini, Randy Shaver and Milo Wiltbank

Preliminary data
44 cows (20 %)

Loading…

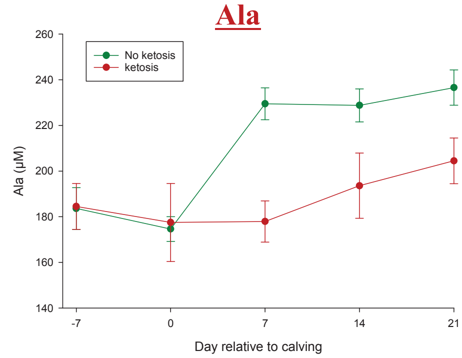
62

Met



63

Ala



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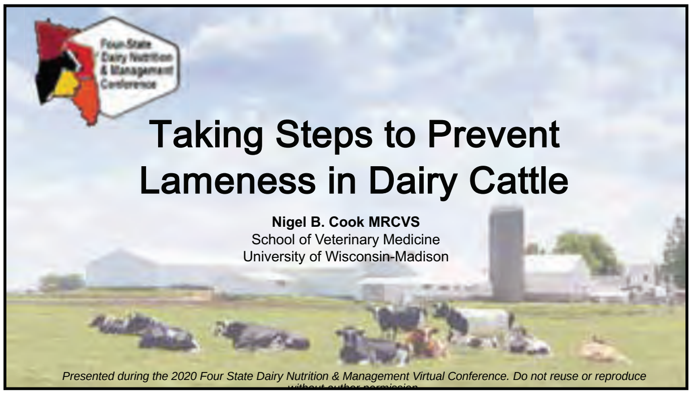
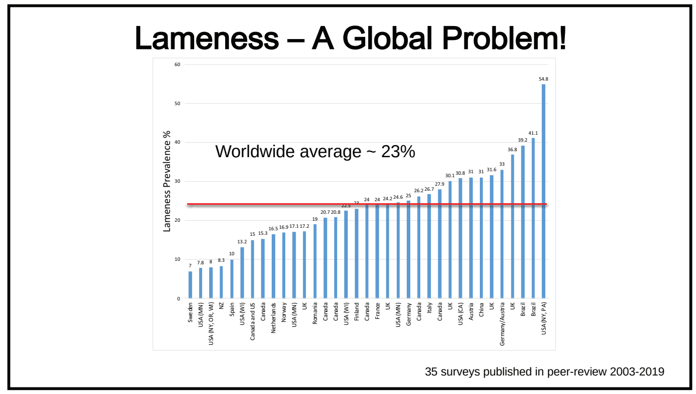
Taking Steps to Prevent Lameness in Dairy Cattle

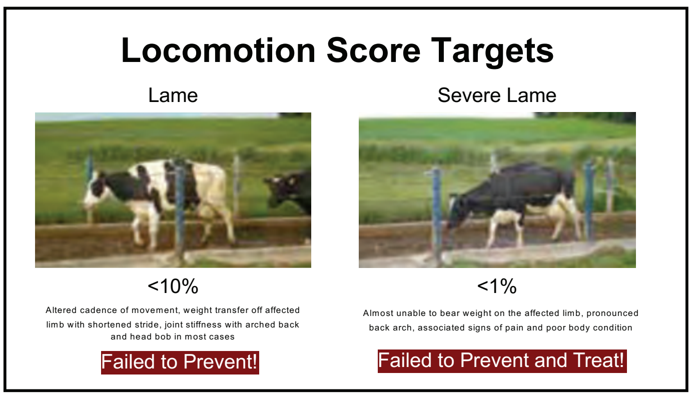
Nigel B. Cook MRCVS
School of Veterinary Medicine
University of Wisconsin-Madison


Four-State Dairy Nutrition & Management Conference
Taking Steps to Prevent Lameness in Dairy Cattle
Nigel B. Cook MRCVS
School of Veterinary Medicine
University of Wisconsin-Madison
Presented during the 2020 Four State Dairy Nutrition & Management Virtual Conference. Do not reuse or reproduce

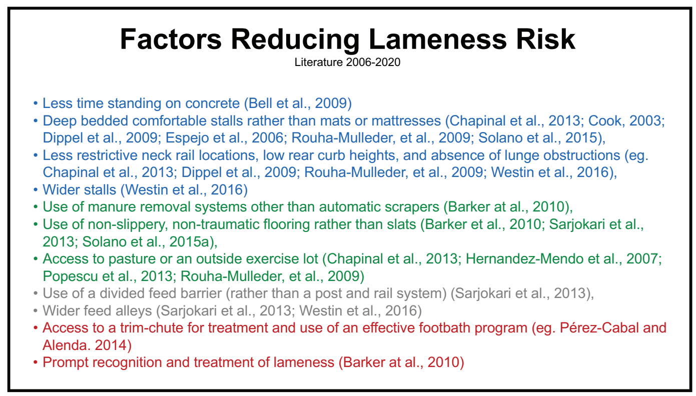
1


Lameness – A Global Problem!
Worldwide average ~ 23%
Lameness Prevalence %
35 surveys published in peer-review 2003-2019

2


Locomotion Score Targets
Lame
Severe Lame
<10%
Altered cadence of movement, weight transfer off affected limb with shortened stride, joint stiffness with arched back and head bob in most cases
Failed to Prevent!
<1%
Almost unable to bear weight on the affected limb, pronounced back arch, associated signs of pain and poor body condition
Failed to Prevent and Treat!

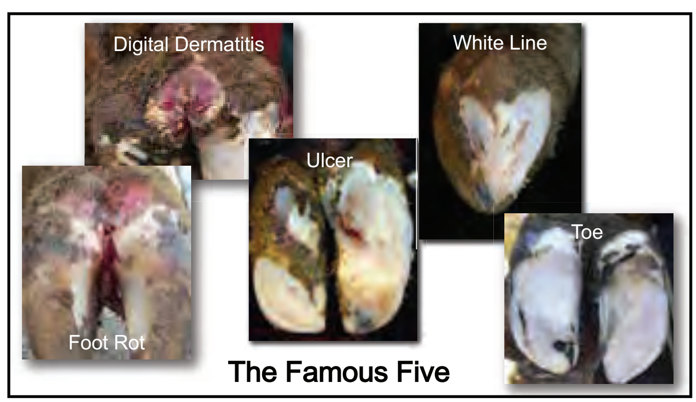
3


Factors Reducing Lameness Risk
Literature 2006-2020
• Less time standing on concrete (Bell et al., 2009)
• Deep bedded comfortable stalls rather than mats or mattresses (Chapinal et al., 2013; Cook, 2003; Dippel et al., 2009; Espejo et al., 2006; Rouha-Mulleder, et al., 2009; Solano et al., 2015),
• Less restrictive neck rail locations, low rear curb heights, and absence of lunge obstructions (eg. Chapinal et al., 2013; Dippel et al., 2009; Rouha-Mulleder, et al., 2009; Westin et al., 2016),
• Wider stalls (Westin et al., 2016)
• Use of manure removal systems other than automatic scrapers (Barker at al., 2010),
• Use of non-slippery, non-traumatic flooring rather than slats (Barker et al., 2010; Sarjokari et al., 2013; Solano et al., 2015a),
• Access to pasture or an outside exercise lot (Chapinal et al., 2013; Hernandez-Mendo et al., 2007; Popescu et al., 2013; Rouha-Mulleder, et al., 2009)
• Use of a divided feed barrier (rather than a post and rail system) (Sarjokari et al., 2013),
• Wider feed alleys (Sarjokari et al., 2013; Westin et al., 2016)
• Access to a trim-chute for treatment and use of an effective footbath program (eg. Pérez-Cabal and Alenda. 2014)
• Prompt recognition and treatment of lameness (Barker at al., 2010)

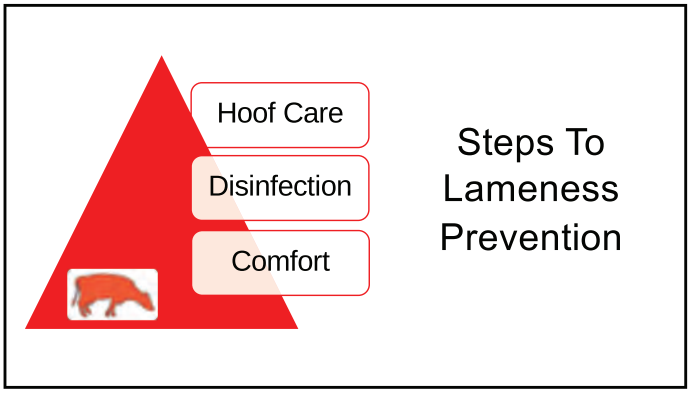
4


Lameness systematically undermines the management of the herd!
No other disease has such fundamental and extensive effects on production, reproduction and risk for early removal.

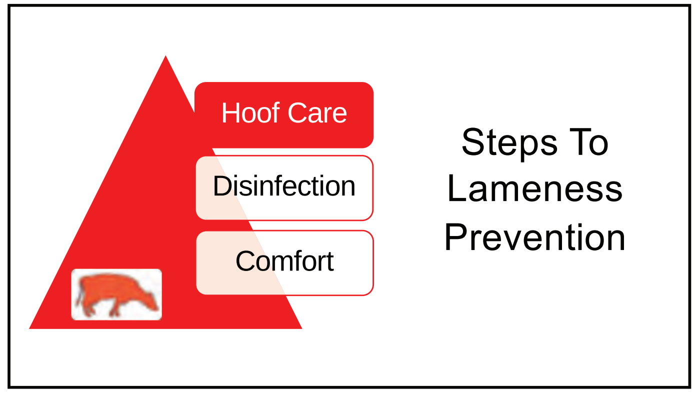
5


Digital Dermatitis
White Line
Ulcer
Toe
Foot Rot
The Famous Five

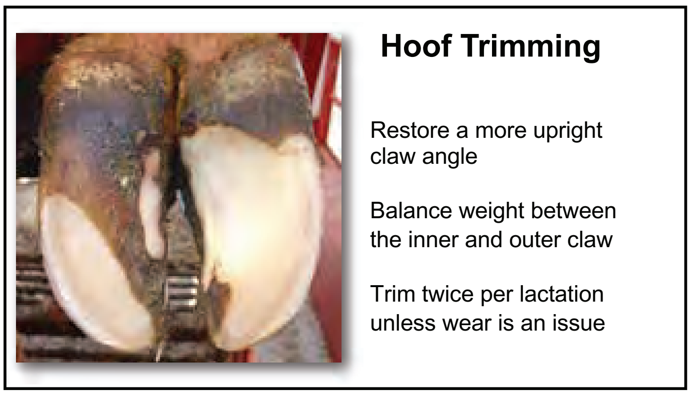
6


Hoof Care
Disinfection
Comfort
Steps To Lameness Prevention

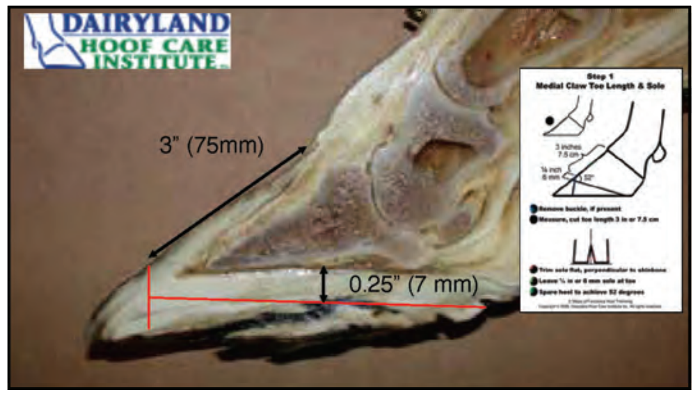
7


Hoof Care
Disinfection
Comfort
Steps To Lameness Prevention

8


Hoof Trimming
Restore a more upright claw angle
Balance weight between the inner and outer claw
Trim twice per lactation unless wear is an issue

9


DAIRYLAND HOOF CARE INSTITUTE
3" (75mm)
0.25" (7 mm)

10


Avoid Doing Harm!

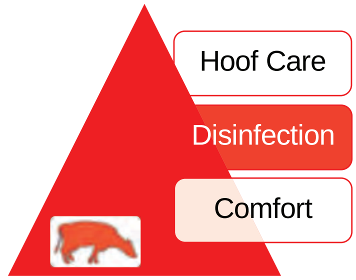
11


Provide Facilities and Equipment

12

Easy access to a chute for individual cow attention is essential in an AMS unit

13



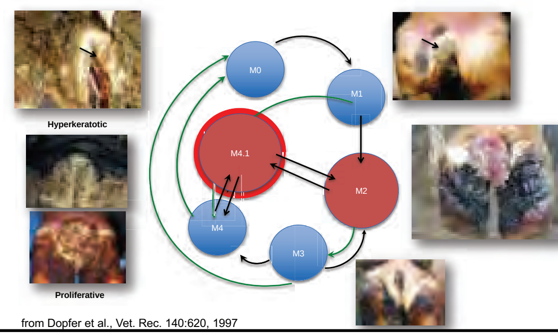
Steps To Lameness Prevention

14

Foot Rot (Phlegmon)

15

Digital Dermatitis Dynamics



from Dopfer et al., Vet. Rec. 140:620, 1997

16

- Hygiene (Rodriguez-Lainz et al. PVM 28:117, 1996)
- Genetics (Schopke et al., JDS 98:1-11, 2015)
- Nutrition (Gomez et al. JDS 97:6211, 2014)
- Infectious agents – *Treponeme spp* (Gomez et al. JDS 95:1821, 2012)

17

DD occurrence during the first lactation by DD experience during the rearing period

	DD during the rearing period		
	No DD (Type I)	1 DD case (Type II)	>1 DD case (Type III)
% First Lactation Heifers Suffering a DD event	13.7	45.6*	67.6*

Gomez, et al., JDS 98:4487, 2015

18

Treatment vs Disinfection

ACUTE/ACTIVE M2 — CHRONIC/INACTIVE M4

Treat these topically — Footbath these

19

The Ideal Footbath – 2-3 immersions per foot

Cook et al., Vet.J. 193, 669-673, 2012

20

Do Longer footbaths improve efficacy?

(Logue et al., Vet. J. 193:664, 2012)

- 3 herds with 7’ (2.2m) long baths and 3 herds with 14’ (4.4m) long baths
- Tested 5% $CuSO_4$ and a test product in split bath design BID for 3d per week, for 15 wks

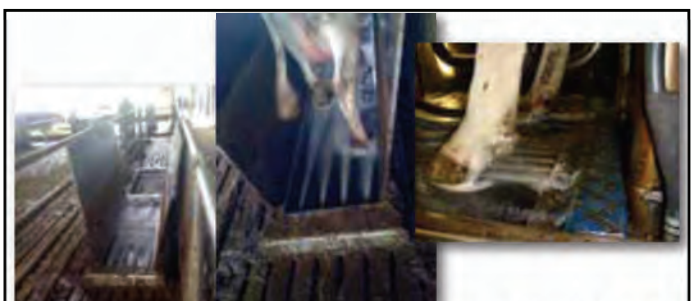
Reduction in DD lesion Score Effect	OR (95% CI)	P-Value
5% copper sulfate v test product	1.6 (1.14-2.32)	<0.01
Longer footbath v shorter footbath	3.39 (2.07-5.19)	<0.001
Parity	1.13 (1.02-1.25)	<0.05

21

Footbath Best Management Practice

- Use a well-designed footbath with adjacent mixing facility
- Footbath 4 milkings per week and adapt based on outcome to achieve a minimum frequency to maintain control
- Use an antibacterial with evidence of efficacy against DD and footrot
  - No higher than 5% $CuSO_4$ and monitor soil copper levels
  - No higher than 4% formalin and avoid in cold weather
  - Use of acidifier to pH no lower than 3.0
- Use the bath as long as it is effective ~ 150-300+ cow passes
- Don’t forget to include all life stages of the cow!

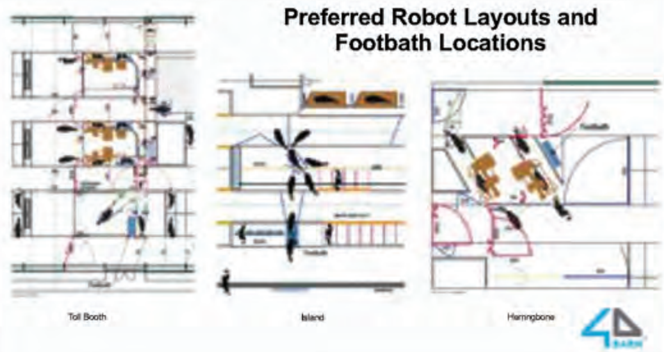
22



Water baths alone will not control DD, but the improvement in hygiene coupled with surveillance and topical therapy helps!

23

Preferred Robot Layouts and Footbath Locations



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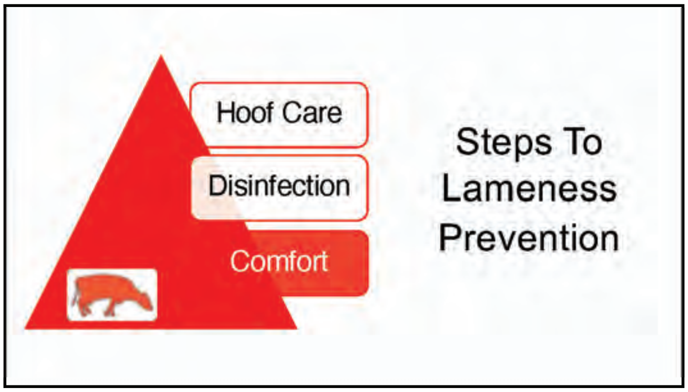

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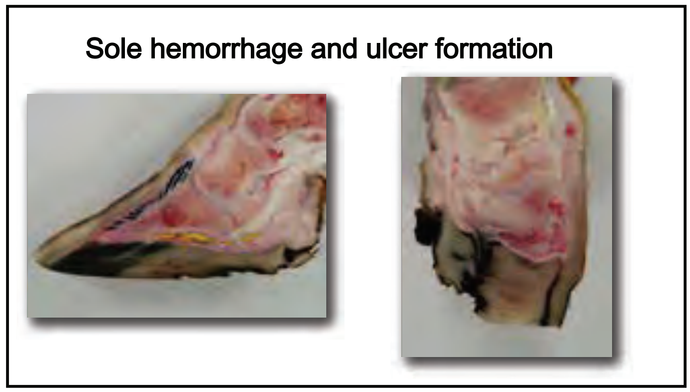
The primary lesion is an injury to the corium of the sole beneath the pedal bone (third phalanx)

The big question is why?

27



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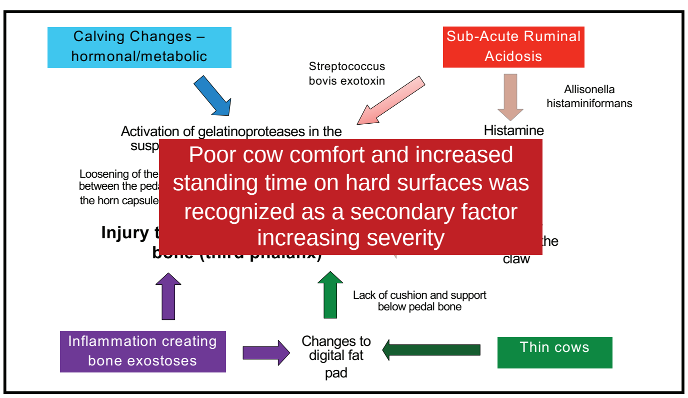

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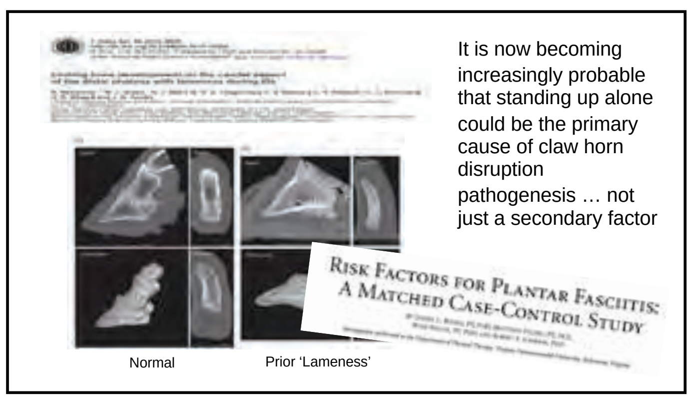

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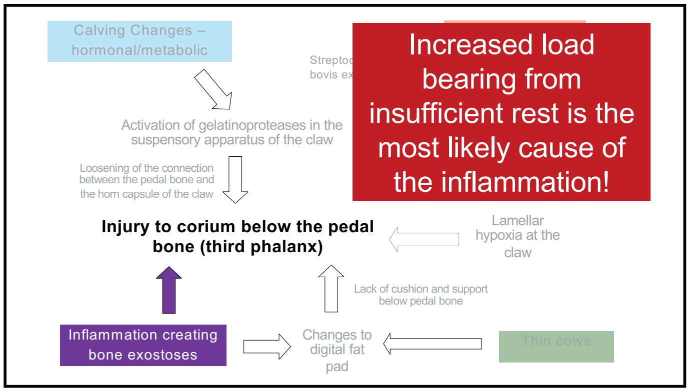

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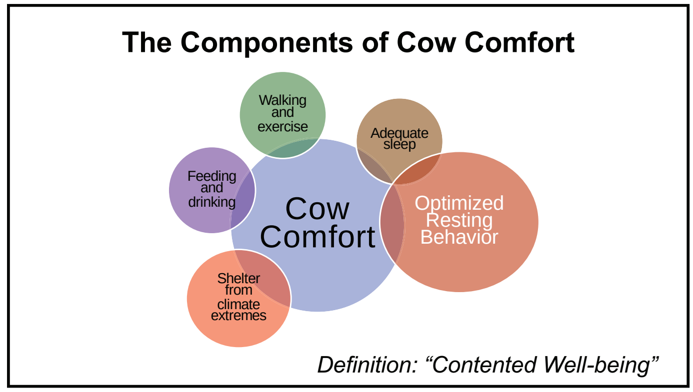

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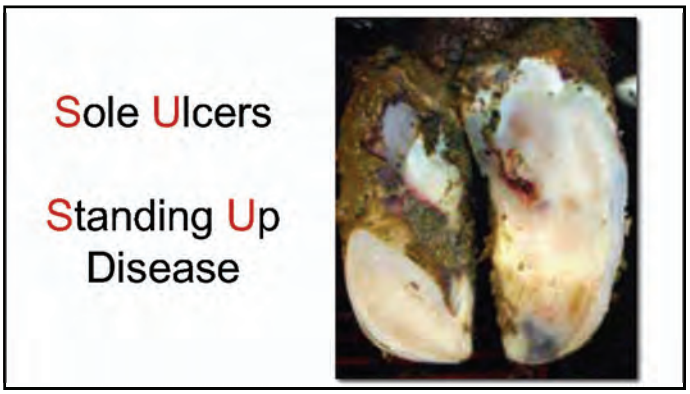

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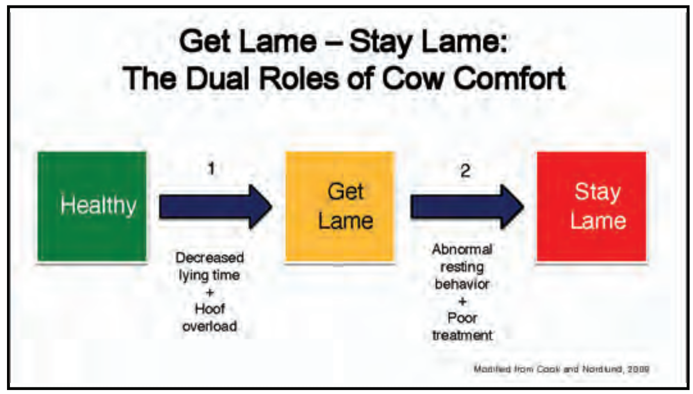

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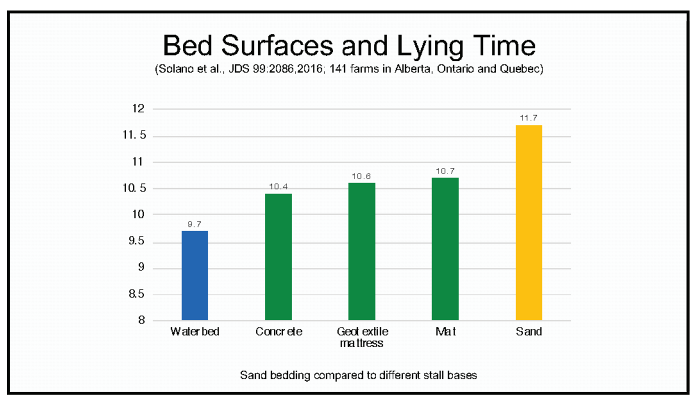

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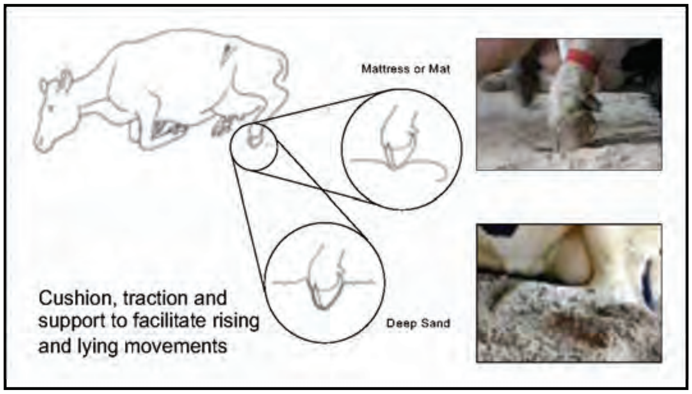

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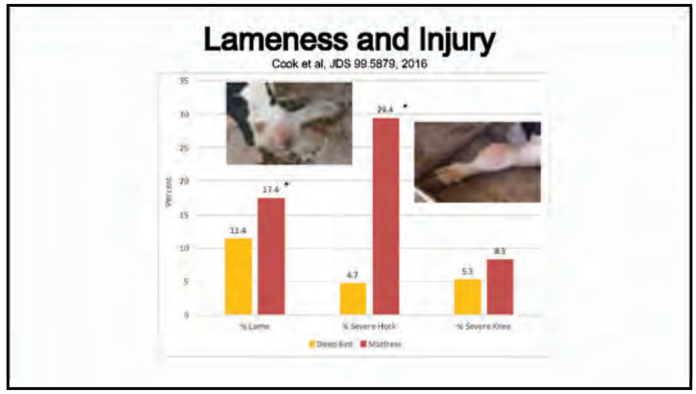

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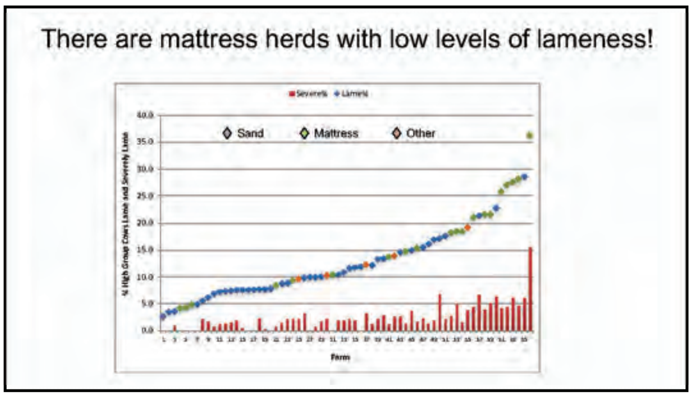

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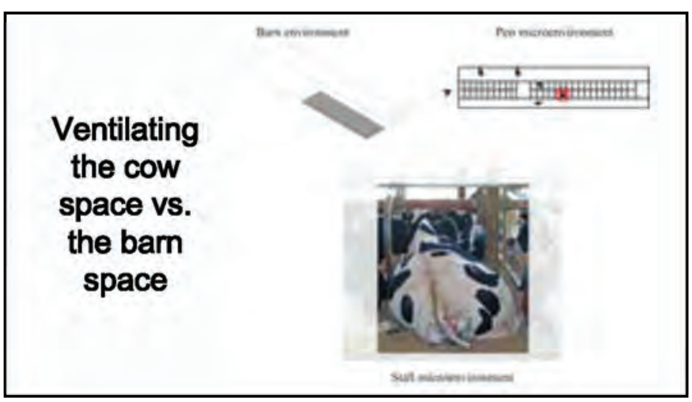
Mattress Herds and Lameness

- Equal pressure for new cases of lameness between mattress and sand herds
- Impact of sand is on reducing the chronicity of lameness!
- Mattress herd owners must:
  - Have excellent stall design
  - Identify new cases of lameness and treat effectively
  - Allow lame cows to recover on a bedded pack
  - Control infectious causes of lameness through effective footbathing
  - Use sufficient bedding to reduce hock injury …..

40



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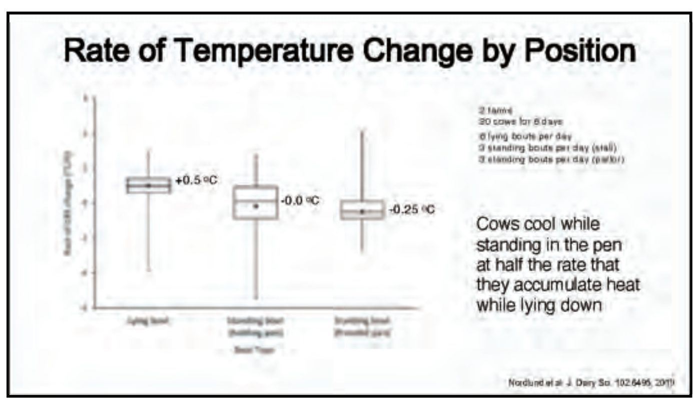

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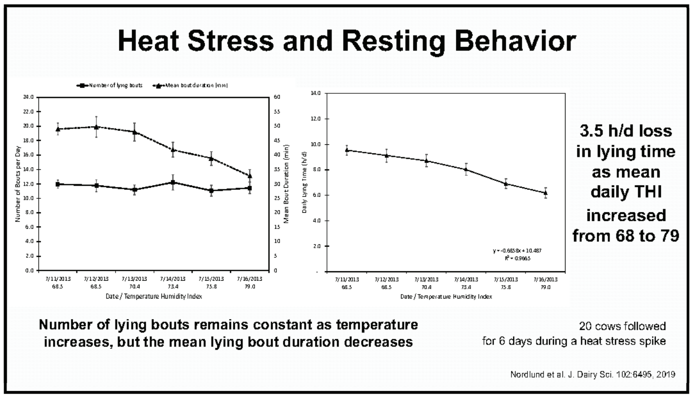

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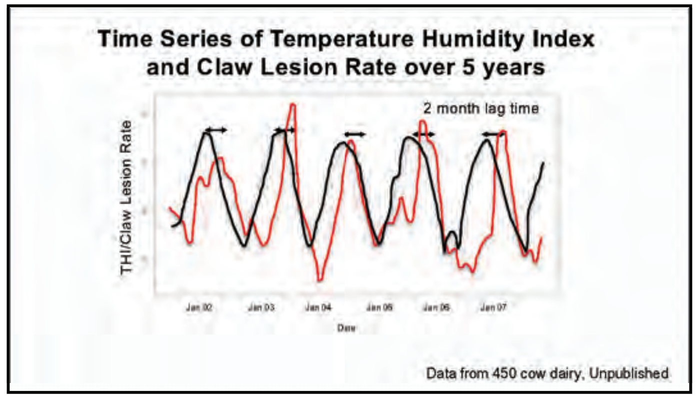

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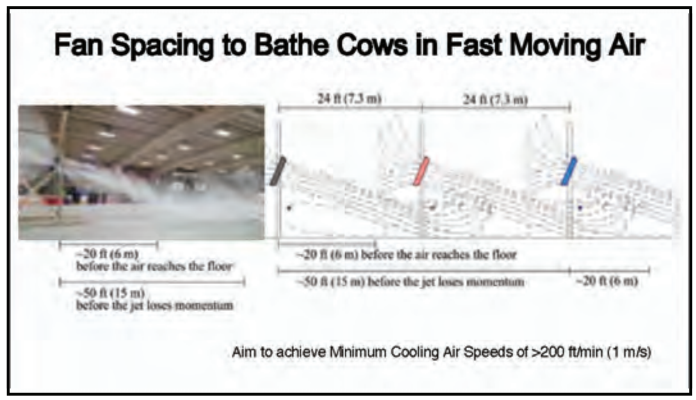

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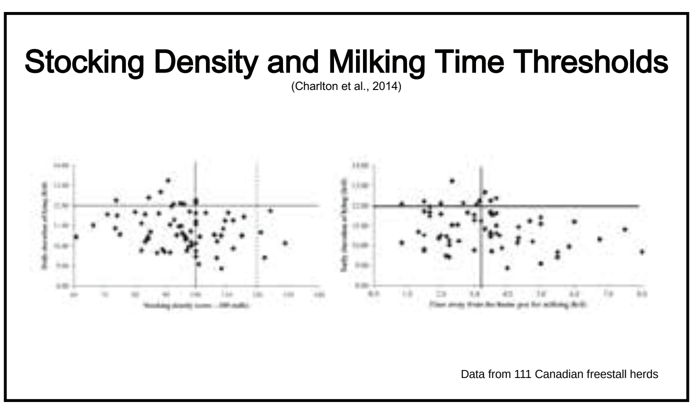

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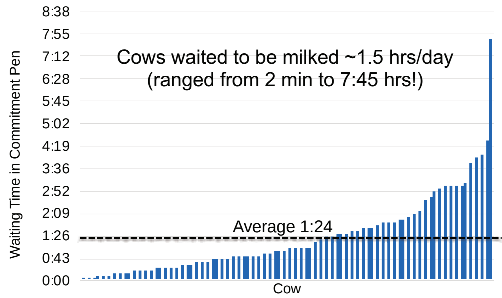
Daily waiting time to be milked in a guided-flow AMS



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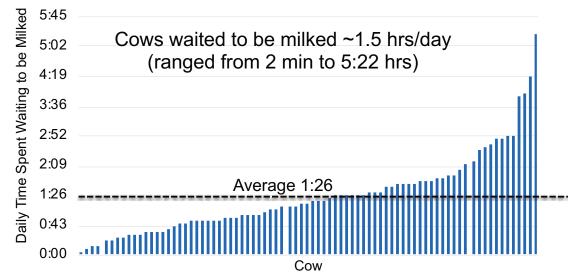
Daily waiting time to be milked in a free-flow AMS



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Surveys of Resting Behavior (453 Farms)

Study	Number of Cows	Number of herds	Mean herd lying time (h/d)	Mean number of lying bouts per d	Mean daily lying bout duration (h/bout)	Days recorded	Recording type
Ito et al., 2009	2,033	43	11.0	9.0	1.5	5	HOBO
Gomez and Cook, 2010	205	16	11.9	12.9	1.2	1-2	VIDEO
Thomsen et al., 2012	1,340	42	10.5	NR	1.2	2	ICETAG
Yunta et al., 2012	NR	10	12.0	9.8	1.4	10	HOBO
Deming et al., 2013	NR	13	10.8	9.3	1.3	4	HOBO
Charlton et al., 2014	NR	111	10.6	10.5	1.2	4	HOBO
Solano et al., 2016[2]	5,135	81	10.3	10.5	1.0	4	HOBO
		40	11.0	10.0	1.1	4	HOBO
		20	11.2	9.2	1.2	4	HOBO
King et al., 2016	1,230	41	11.5	9.3	1.3	6	HOBO
Westin et al., 2016	1,418	36	11.4	9.5	1.2	4	HOBO/ICETAG
Mean			11.1	10.0	1.2		

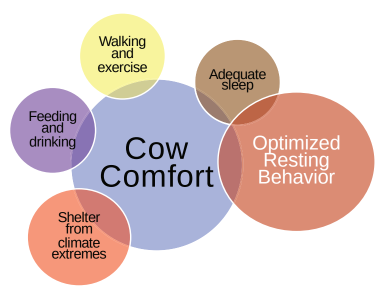
52

An Achievable Target for Rest

- Based upon:
  - Healthy, non-lame cows
  - Deep bedded comfortable freestalls
  - TMR fed
  - >21 h/d in the pen
  - 1 cow per stall
  - Favorable resting area microenvironment
- Aim for mean lying times of 11.5 to 12.5 h/d, with mean lying bout durations of 1.2 h

53

The Components of Cow Comfort



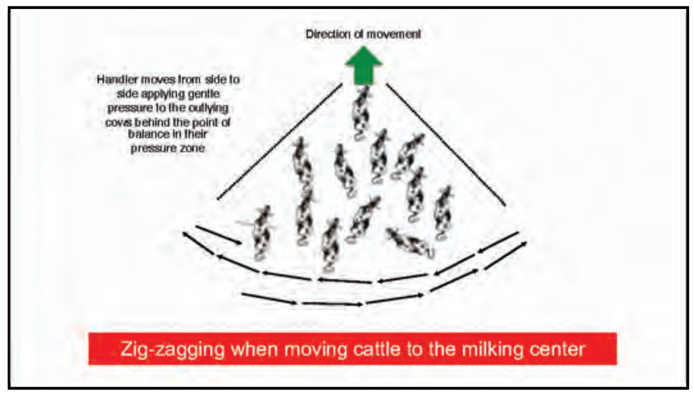
Definition: "Contented Well-being"

54

55

56

57



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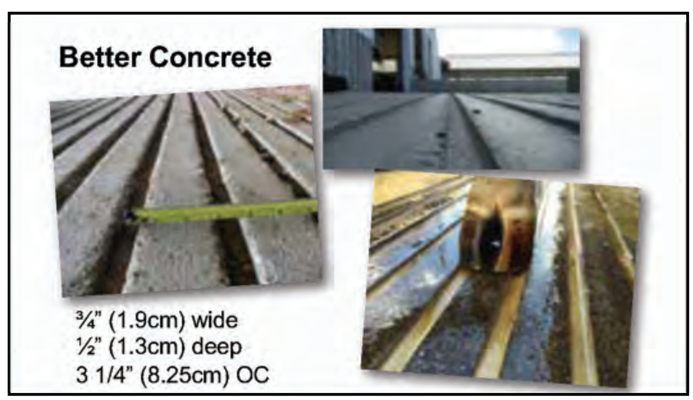

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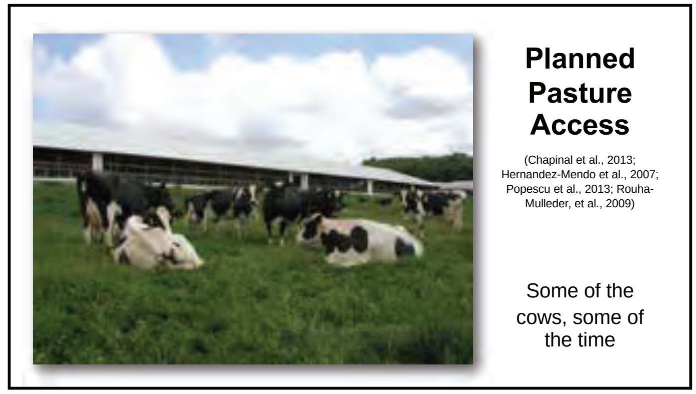

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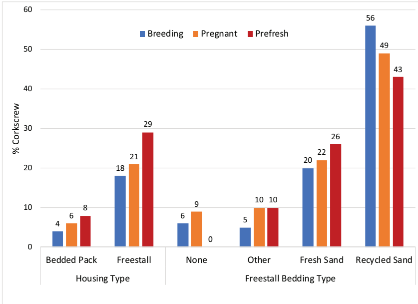
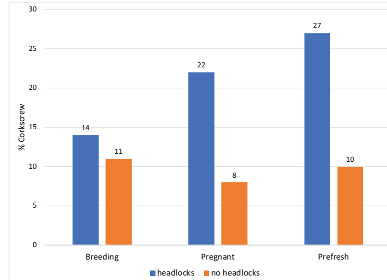
Type of Heifer Housing and Bedding



67

Use of Feed Bunk Headlocks



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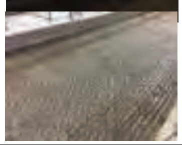
Pressure at the bunk



Creates hoof growth/wear issues during heifer development

69

Heifer Housing Recommendations (Different from Cows!)

1. Bedded pack housing preferred where possible up to at least breeding age
2. Deep bed freestalls with organic bedding vs sand (avoid recycled sand!)
3. Mix slant bar and headlock feed bunks – reduce headlock exposure
4. Improve the design of flooring finishes to suit heifers – mini-grooves?
5. Provide outdoor access – feeding/pasture

70

Can we have high milk production and low levels of lameness?

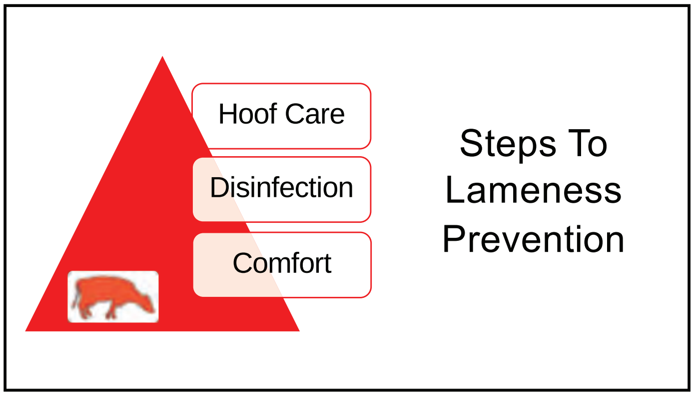
71

Select Housing and Management Characteristics of High Milk Production (90lb 41 kg) Herd Groups (n=44) with Lameness Prevalence of 13%

Management Characteristic	% Herds or Mean
Deep loose bedded stalls (sand)	70
Headlocks at the feedbunk	70
Solid floor (vs slats)	97
Manual manure removal from alleys (vs scraper)	69
Rubber freestall alley flooring	3
Fans over resting area	96
Feedline soakers in the pen	79
Trim cows feet at least once per lactation	83
Footbath frequency (mean times per week)	4.5

From Brotzman et al., 2015, Cook et al, JDS 99:5879, 2016

72


Hoof Care
Disinfection
Comfort
Steps To Lameness Prevention

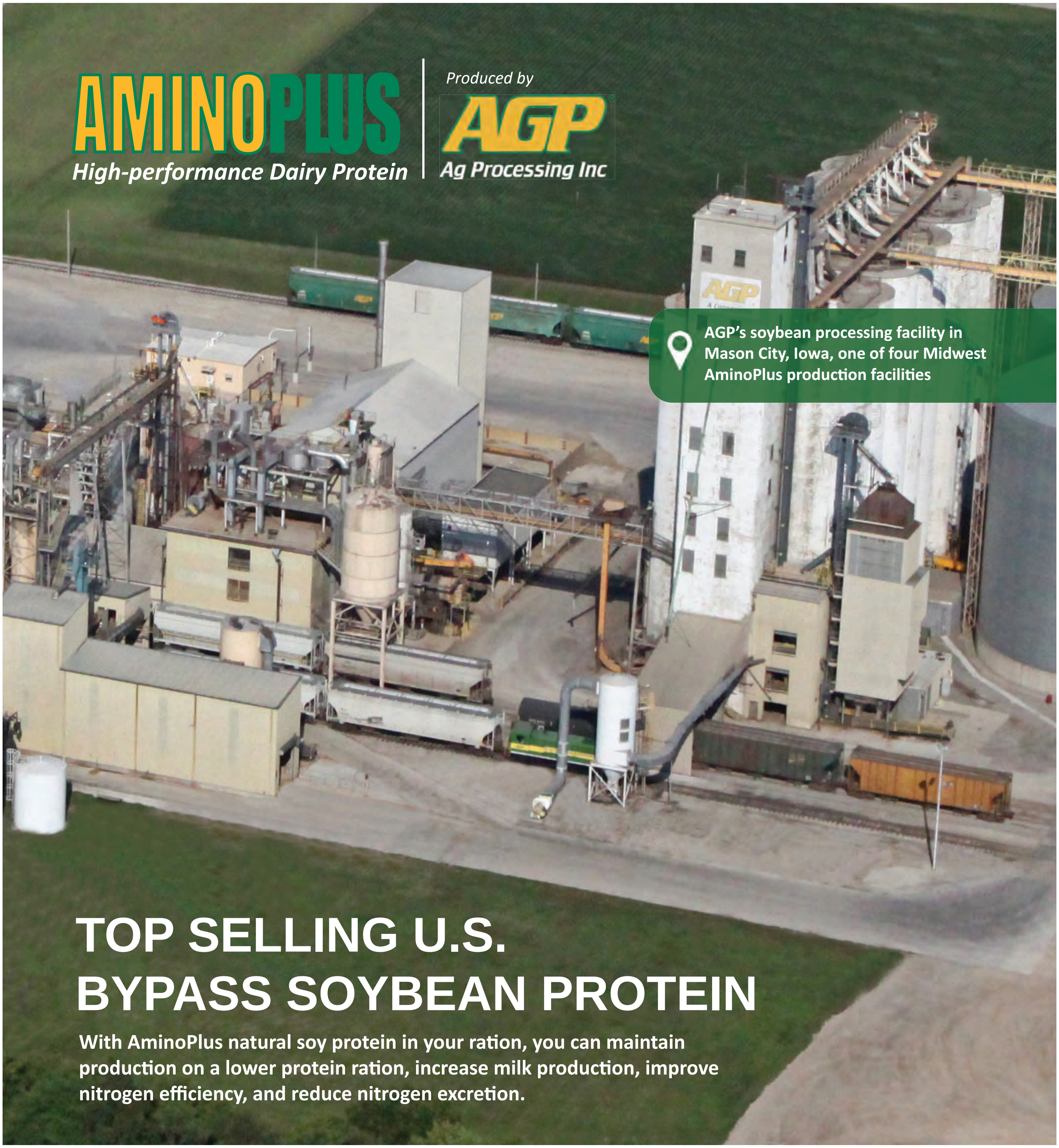
73


Dairyland Initiative
Sponsors
Mission
Saputo
Program
ZINPRO
DAIRYLAND HOOF CARE INSTITUTE
Workshop
Artex
McLanahan
Kestrel

74


DairylandInitiative
Dairyland Initiative
www.thedairylandinitiative.vetmed.wisc.edu
Thank you!

75



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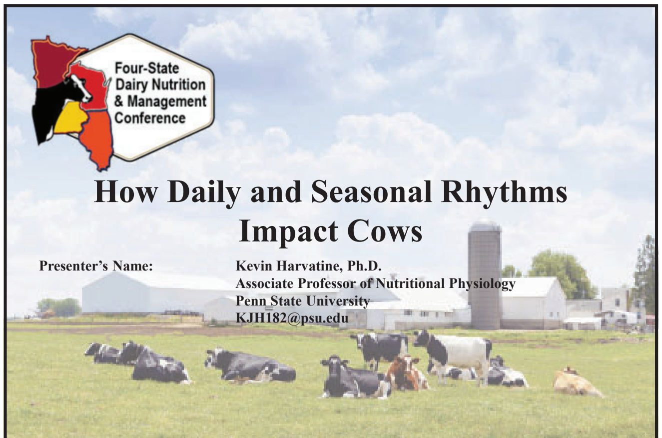
Four-State Dairy Nutrition & Management Conference

How Daily and Seasonal Rhythms Impact Cows

Kevin Harvatine, Ph.D.
Associate Professor of Nutritional Physiology
Penn State University
KJH182@psu.edu



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1

Milk fat and protein are affected by many factors

Nutritional Factors

Decreased by milk fat depression
- Unsaturated fat
- Fermentability
- Acidosis
- Feeding strategies
- Ionophores

Increase by additional substrate
- Acetate from forages
- Fat supplement
  - Palmitic acid

Milk fat

Non-nutritional Factors

Genetics

Season

Time of day

Stage of lactation

Parity

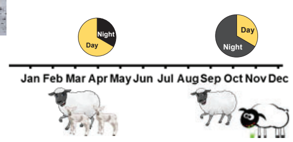
Milk protein also impacted by diet and other similar non-nutritional factors

2

Seasonal rhythms coordinate physiology (metabolism) with the environment: Amazing examples in nature!

Migration

Hibernation



Seasonal Breeding in Sheep

3

Daily rhythms coordinate metabolism with changes across the day

Most processes in the body follow a 24 h cycle
- Activity and Alertness
- Nutrient Metabolism
- **Milk Synthesis**
- **Intake**

Why??
Allows the animal to anticipate changes and adapt before they occur

4

Key Principles

- **There is a seasonal pattern of milk composition and yield driven by day length and change in day length**
- **There is a daily (circadian) pattern of intake that has a major impact on the rumen and there is a daily pattern of milk synthesis**
- **Considering seasonal and daily patterns provide additional avenues to optimize milk production and profitability**

5

How does the cow know what time of year and day it is?

Environmental Cues Light/Dark

Master Clock (SCN- Brain)

Other Environmental Cues e.g. Feeding Times

Peripheral Clocks

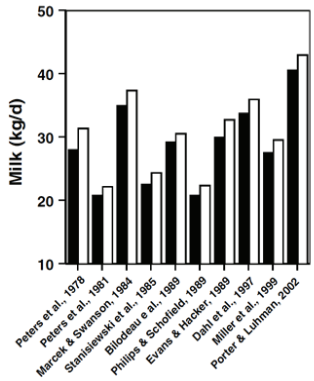
- **Main environmental cues:**
  - Light/Dark
  - Feeding Times
  - Milking Time?
- **A breakdown in the system creates jetlag!**
- **A disconnection between lighting and timing can cause metabolic issues in humans and rodents**

- Example is night shift work in humans

Asher, Schibler 2011

6

We know "Photoperiod" has a large impact on milk yield



Dahl and Petitclerc., 2003

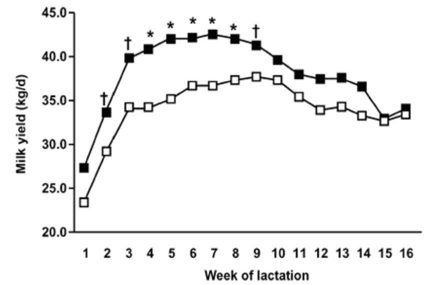
Constant 16 to 18 h vs. 8 to 10 h light

- ~5 to 10% increase in milk yield and no change in milk composition
- Additional effect of short days in dry period
- Eliminated by constant light

-Basic mechanism of photoperiod is through same signaling as circadian rhythms

7

Short photoperiod during dry period increases milk yield in the next lactation!



Auchtung et al., 2005

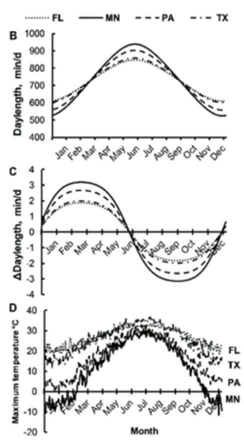
- Spring calving cows would normally be dry during short days
- Likely driven by increased mammary development so more milk secreting cells

8

Seasonal rhythms are common in many animals

- **Patterns that repeat every year**
- **Mostly driven by**
  - **- day length**
  - **- lengthening/shortening days**
  - **- change in day length**
- **Regulated through the same molecular system as circadian rhythms**

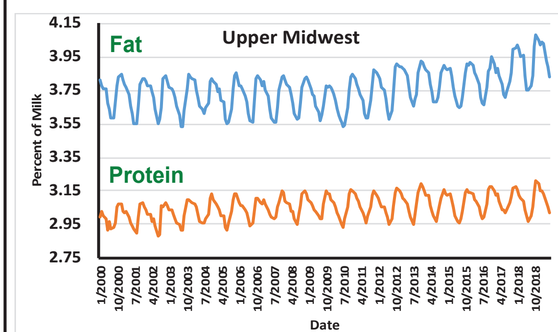
Some Amazing Examples in Biology



9

Seasonal Pattern of Milk Fat & Protein:

Upper Midwest US Milk Market



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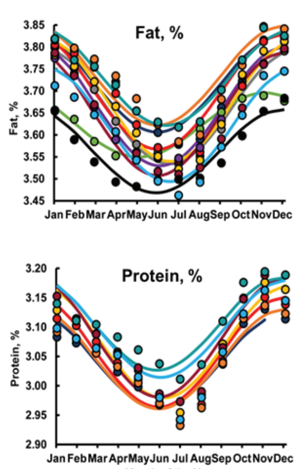


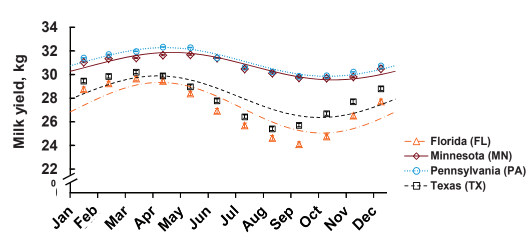
The annual rhythms occurs in all US milk Markets. Percent fat has a larger amplitude in north and smaller in south

- All milk markets fit a cosine function with a very good fit

Salfer et al. 2019

11

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

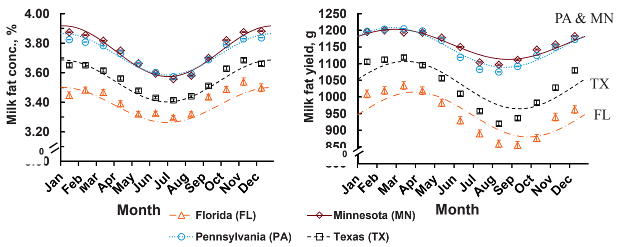


State	Range, lb	Acrophase
MN	5.3[a]	Apr 22
PA	5.3[b]	Apr 15
TX	7.9[c]	April 7
FL	9.2[d]	April 9

Salfer et al. 2020

12

Milk fat percent peaks at end of year, but milk fat yield peaks in March and differ by region



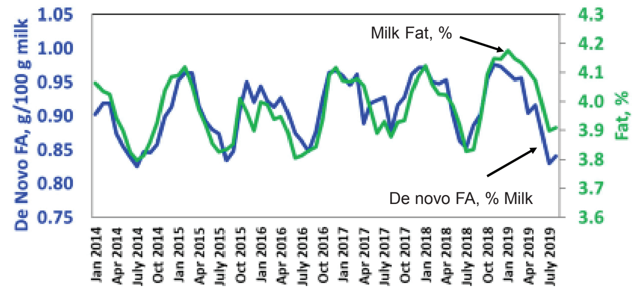
State	Range, %	Peak
PA	0.28	Jan 4
MN	0.34	Jan 5
TX	0.28	Jan 3
FL	0.24	Jan 2

State	Range, lb	Peak
PA	0.26	Feb 23
MN	0.20	Feb 27
TX	0.31	March 13
FL	0.29	March 31

Salfer et al. 2020

13

Most of the seasonal variation in milk fat is due to de novo synthesis <16 C FA (40 herds)



40 St. Albans Coop herds

Dann 2019 PSU Dairy Nutr. Workshop

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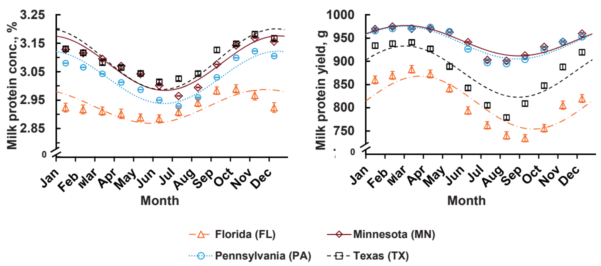
There is an annual pattern to milk protein!

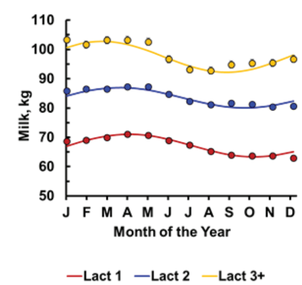


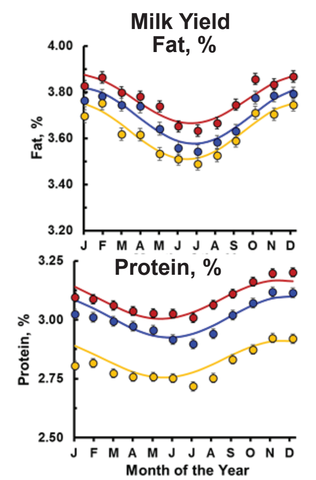
State	Range, %	Peak
PA	0.18	Dec. 21
MN	0.20	Dec. 22
TX	0.22	Dec. 17
FL	0.12	Dec. 1

State	Peak
MN	Feb 24[a]
PA	Mar 2[b]
TX	Mar 6[c]
FL	Mar 19[d]

15

The seasonal pattern is consistent by parity





16

What does heat stress do to milk yield and composition?

Reference	MY, kg	Fat, %	Prot, %
Rungruang et al. 2014	-3.4	0.20	-0.10
Baumgard et al. 2011	-6.2	0.28	-0.12
Zimbelman et al. 2010	-0.1	-0.17	0.13
Wheelock et al. 2010	-9.6	0.60	-0.27
Rhoads et al. 2009	-10.6	0.34	-0.13
Schwartz et al. 2009	-10.1	0.06	-0.22

- Generally a decrease in milk yield and milk protein percent and an increase in fat percent

17

What do I think is going on?

Two seasonal time-keepers:

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

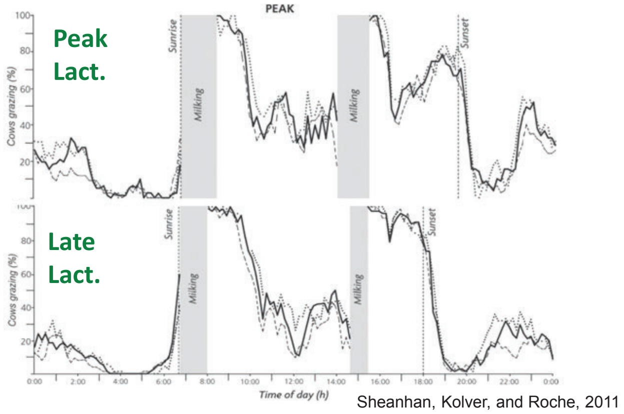
Constant long days appears to be setting physiology of the spring equinox (increased milk yield and no change in composition)

- No data on how to manage out of this. Managing photoperiod probably best chance

18

Is there a daily pattern of feed intake?

Pasture Fed Cows

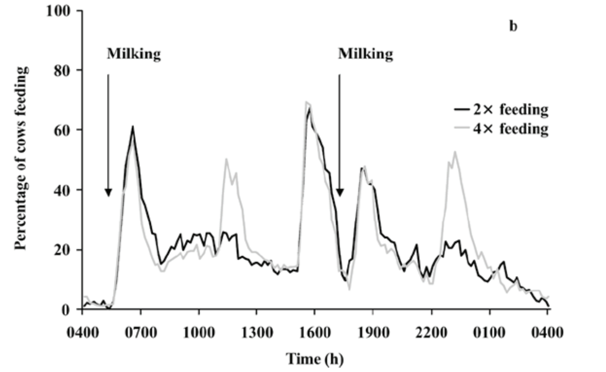


Sheanhan, Kolver, and Roche, 2011

19

TMR fed cows: Feeding time is most important

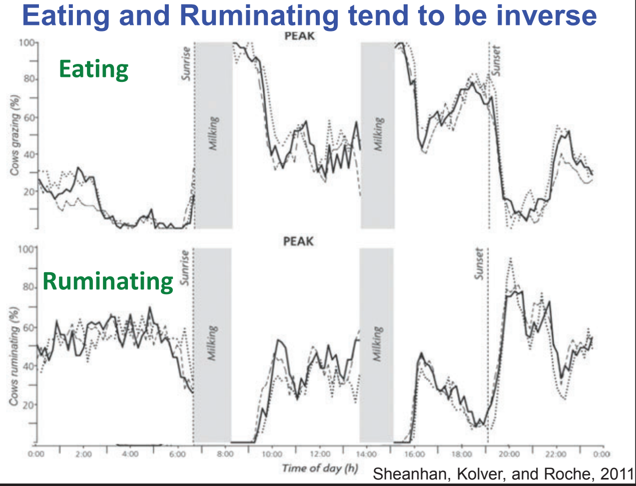
Feeding and milking commonly both near dawn & dusk



DeVries et al. 2005

20

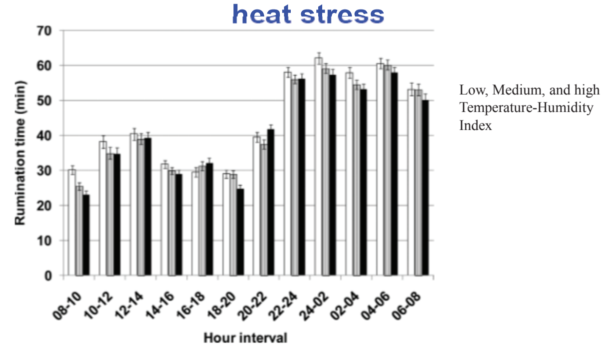
Eating and Ruminating tend to be inverse



Sheanhan, Kolver, and Roche, 2011

21

Rumination pattern is maintained even during heat stress

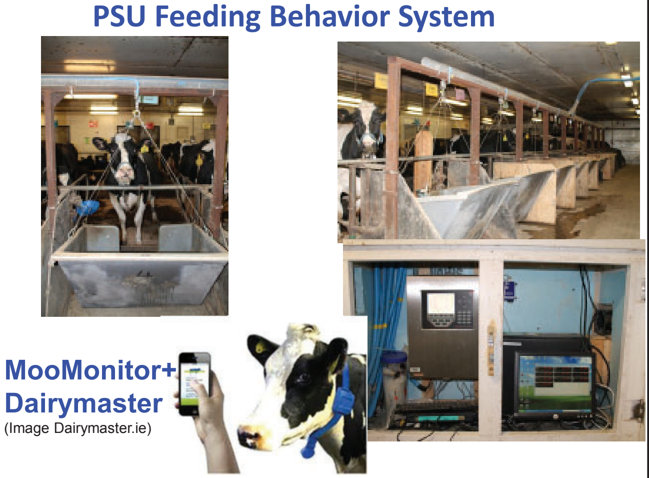


Daily pattern of rumination time expressed in minutes per 2 h in 3 levels of daily maximum temperature-humidity index (THI).
White bars = THI <80; bars with vertical lines = THI from 80 to 85; black bars = THI >85.

Soriani et al. JDS 2014

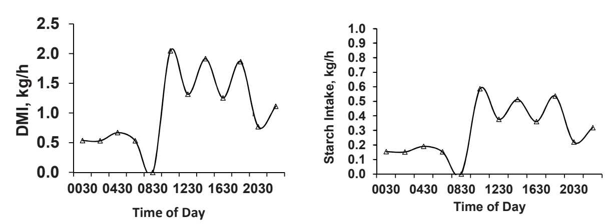
22

PSU Feeding Behavior System



23

Rate of feed intake is variable over the day



Ying et al. 2015

24

What is the impact of the daily pattern of intake?

Intake =

Entrance of fermentable feed into the rumen for microbes to digest

Fermentable feed =

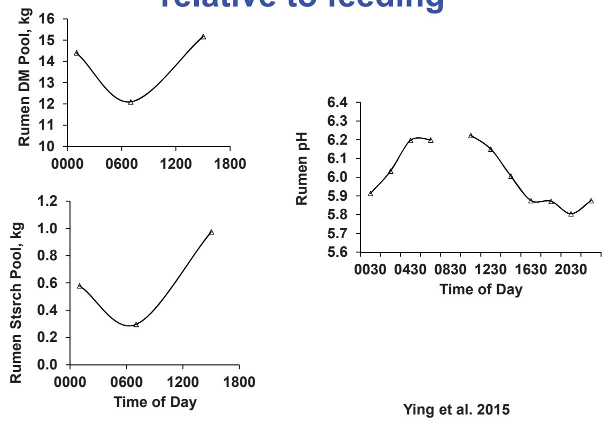
Synthesis of VFA's (acids) & microbial protein

VFA's =

Acid load for rumen
Nutrient supply for cow

25

What is in the rumen changes relative to feeding



Ying et al. 2015

26

How flexible is the daily pattern of feed intake?

- **Feeding stimulates intake, but what is the impact of feeding time**
- **Fed TMR:**
  - **1x/d at 0830 h (AM)**
  - **1x/d at 2030h (PM)**
  - **2x/d at 0830 and 2030 h (AMPM)**

27

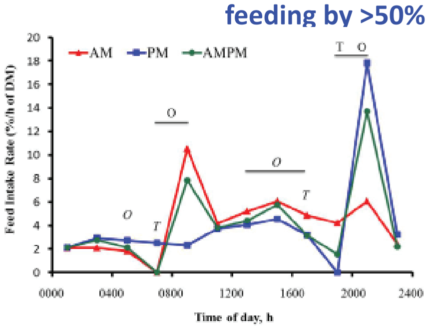
AM vs PM feeding had no effect of DMI or milk production

	Treatment Means				*P*-value		
						-----Contrasts-----	
Item	AM	PM	AMPM	SE	Trt	AM vs. PM	AM vs. AMPM
Yield, lbs/d							
Milk	110.0	111.1	111.8	5.7	**0.69**	**0.59**	**0.40**
Milk fat	3.78	3.78	3.85	0.09	**0.84**	**0.99**	**0.62**
Milk protein	3.26	3.28	3.30	0.13	**0.77**	**0.78**	**0.48**
Milk composition, %							
Fat	3.51	3.49	3.48	0.15	**0.90**	**0.83**	**0.66**
Protein	2.97	2.95	2.96	0.07	**0.80**	**0.52**	**0.69**
DMI, lbs/d	71.7	69.1	70.2	2.0	**0.40**	**0.18**	**0.44**
Feed Efficiency	1.54	1.58	1.57	0.05	**0.43**	**0.21**	**0.37**

- **Also no difference in milk FA profile**

28

Evening feed delivery increased feed intake after feeding by >50%!



➢ ANOVA

Effect	*P*-value
Treatment	0.78
Time	<0.01
Treatment x Time	<0.01

➢ Circadian Parameters

Treatment	Phase/h	Amplitude	*P*-value
AM	1654	2.0	<0.01
PM	1638*	0.6*	<0.01
AMPM	1448*	1.1*	<0.01

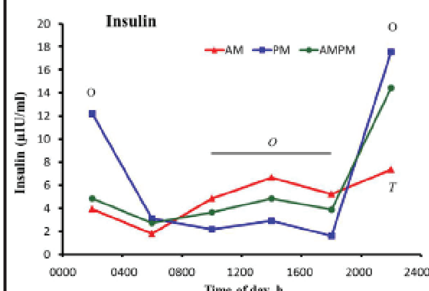
*Significantly ($P < 0.05$) different from AM

❖AM vs.PM (^{O} = $P < 0.01$, and ^{O} = $P < 0.05$); AM vs. AMPM (^{T} $P < 0.01$, and ^{T} $P < 0.05$)

- Conditional meals were larger at the evening feeding
- Modestly higher intake rate in the early afternoon for AM

29

Increase intake in the evening spikes insulin



➢ ANOVA

Effect	*P*-value
Treatment	0.76
Time	<0.01
Treatment x Time	<0.01

➢ Circadian Parameters

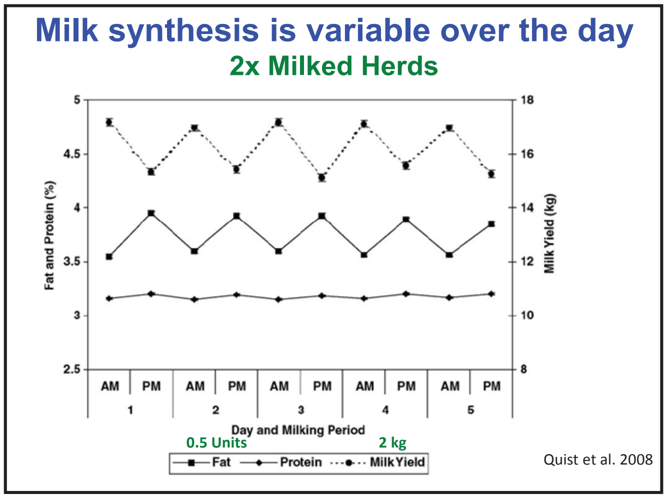
Treatment	Phase/h	Amplitude	*P*-value
AM	1844	1.8	0.07
PM	0031*	8.3*	<0.01
AMPM	2220*	4.8*	<0.01

*Significantly ($P < 0.05$) different from AM

❖AM vs.PM (^{O} = $P < 0.01$, and ^{O} = $P < 0.05$); AM vs. AMPM (^{T} $P < 0.01$, and ^{T} $P < 0.05$)

- Fresh feed delivery at night resulted in greater insulin secretion
- Morning feeding moderately increased insulin in the early afternoon

30



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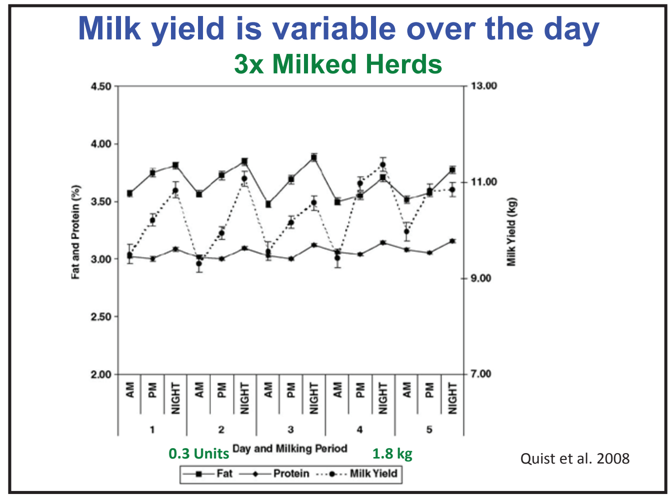

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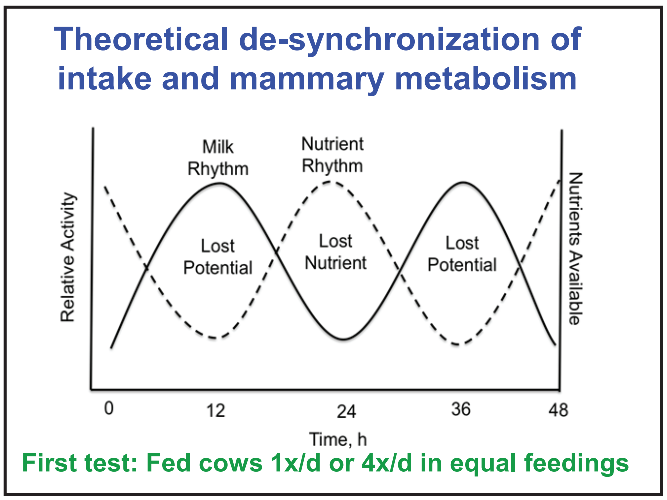

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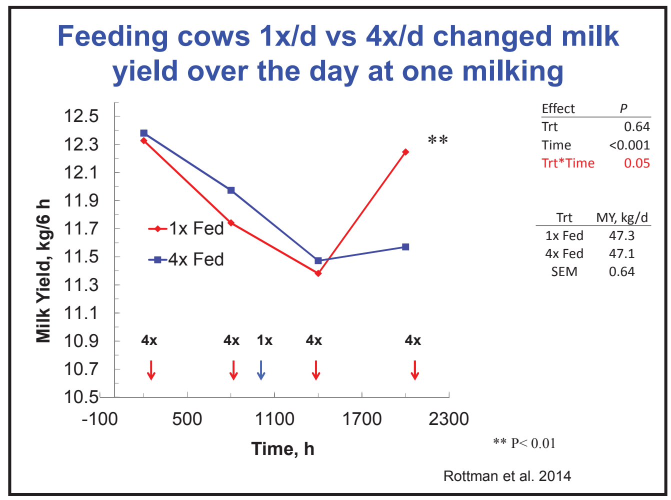

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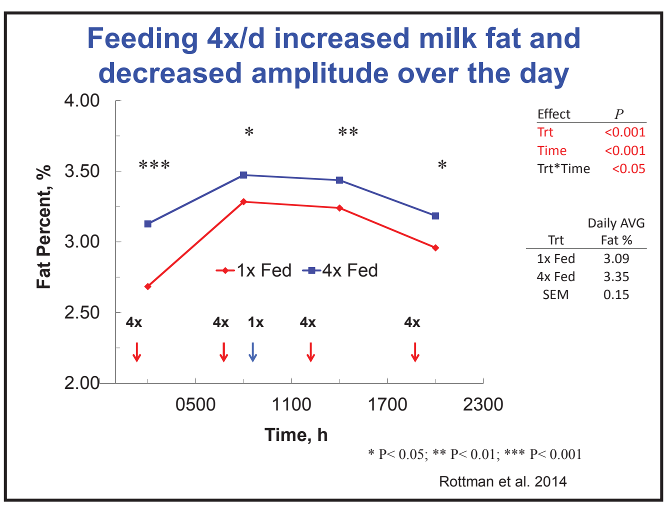

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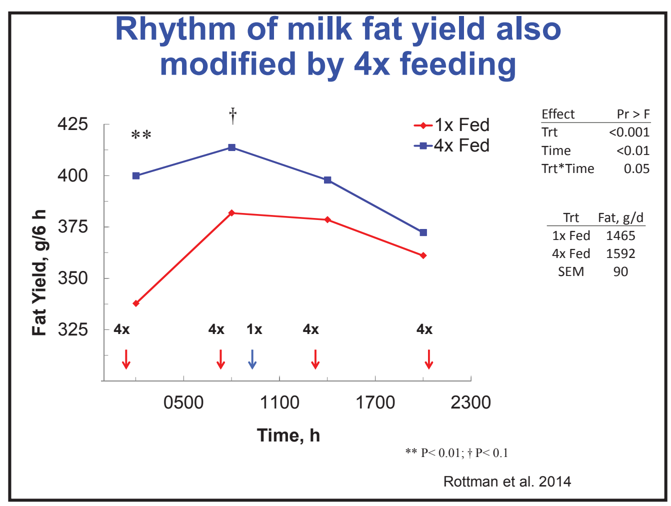

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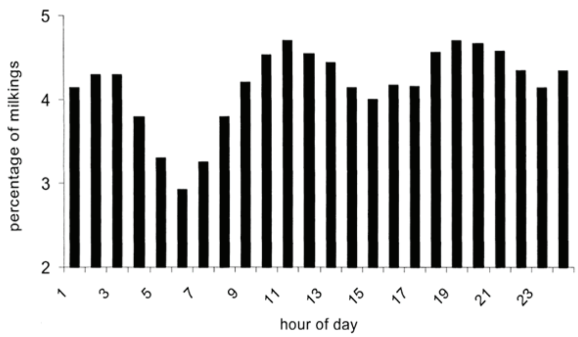
When do cows prefer to be milked??

Automated Milking System



Hogeveen et al., 2001

37

How Can We Use This Information??

Think not just about the diet we are feeding, but how we are feeding it and how the cows are eating it!

We need to watch the cows and see what they are doing!

38

1st… Think of the rumen

- **Can we stabilize the amount of fermentable feed entering the rumen over the day?**
  - **Take out some of the slugs and fill in during some of the low points**

39

How do we do this?

- Feed delivery is a strong signal for feeding which can be used to increase intake during low intake periods of the day
- Make sure feed is available when return from parlor………, but
  - Delivery of feed 2-3 h before or after milking may spread intake more across the day??

40

What else can we do?

- **Feeding different diets across the day might also work**
  - **Feed same ration to entire herd in morning**
  - **Return to "top-off" high groups**

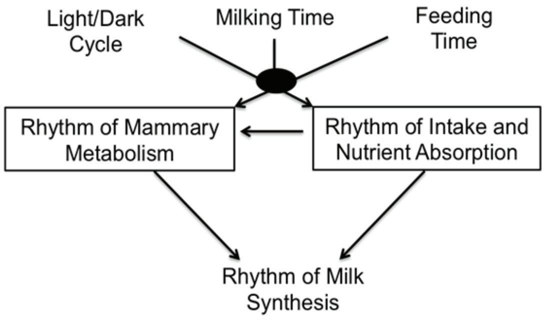
41

Interesting Call From the Field

- One pen of cows on a large farm consistently 0.3 to 0.5 units lower in milk fat than peer pen in another barn fed same diet
- Moved fifteen cows from the pen to another pen and they increased milk fat
- Normal MFD troubleshooting turned up no clues
- Cows being fed later in the day (11:30 AM)
- Switched milking and feeding order so feed delivered earlier and before milking.
- Milk fat increased equal to peer pen

42

Must Consider Multiple Factors That Have an Impact on Behavior



43

Key Principles

- There is a daily (circadian) pattern of intake that has a major impact on the rumen
- There is a daily pattern of milk synthesis
- We need to manage the daily pattern of intake and our best tools for this are through feeding and milking schedules
- Don't be afraid to feed multiple diets per day, but be careful with late afternoon and evening feedings (early morning may be safer)

44

Lab Members:

Cesar Matamoros, Beckie Bomberger, Alanna Staffin, Reilly Pierce, Ahmed Elzennary, and Rachel Walker.

Previous Lab Members:

Chengmin Li, Elle Andreen, Dr. Isaac Salfer, Dr. Daniel Rico, Dr. Michel Baldin, L. Whitney Rottman, Mutian Niu, Dr. Natalie Urrutia, Richie Shepardson, Andrew Clark, Dr. Liying Ma, Elaine Brown, and Jackie Ying

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

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Thank You

45


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*The increased rate of fiber digestion, extent of digestion and crude protein data was developed from replicated research and on-farm testing. During the 2015 growing season at West Salem, WI and Woodland, CA, the following commercial dormant, semi-dormant and non-dormant alfalfa varieties were compared head-to-head with Alforex varieties with Hi-Gest alfalfa technology for rate of digestion, extent of digestion and percent crude protein: America's Alfalfa Brand AmeriStand 427TQ; Croplan Brands LegenDairy XHD and Artesia Sunrise; Fertizona Brand Fertilac; S&W Seed Brands SW6330, SW7410 and SW10; and W-L Brands WL 319HQ and WL 354HQ. Also, during the 2015 growing season, 32 on-farm Alforex varieties with Hi-Gest alfalfa technology hay and silage samples were submitted to Rock River Laboratory, Inc., for forage analysis. The results for rate of digestion, extent of digestion and percent crude protein were averaged and compared to the 60-day and four-year running averages for alfalfa in the Rock River database which included approximately 1,700 alfalfa hay and 3,800 silage 60-day test results and 23,000 hay and 62,000 silage tests results in the four-year average.
**Crude protein=60-day running averages and uNDF240=four-year running average
[1]Combs, D. 2015. Relationship of NDF digestibility to animal performance. Tri-State Dairy Nutrition Conference, 101-112. Retrieved from https://pdfs.semanticscholar.org/5350/f0a2cb916e74edf5f69cdb73f091e1c8280b.pdf.
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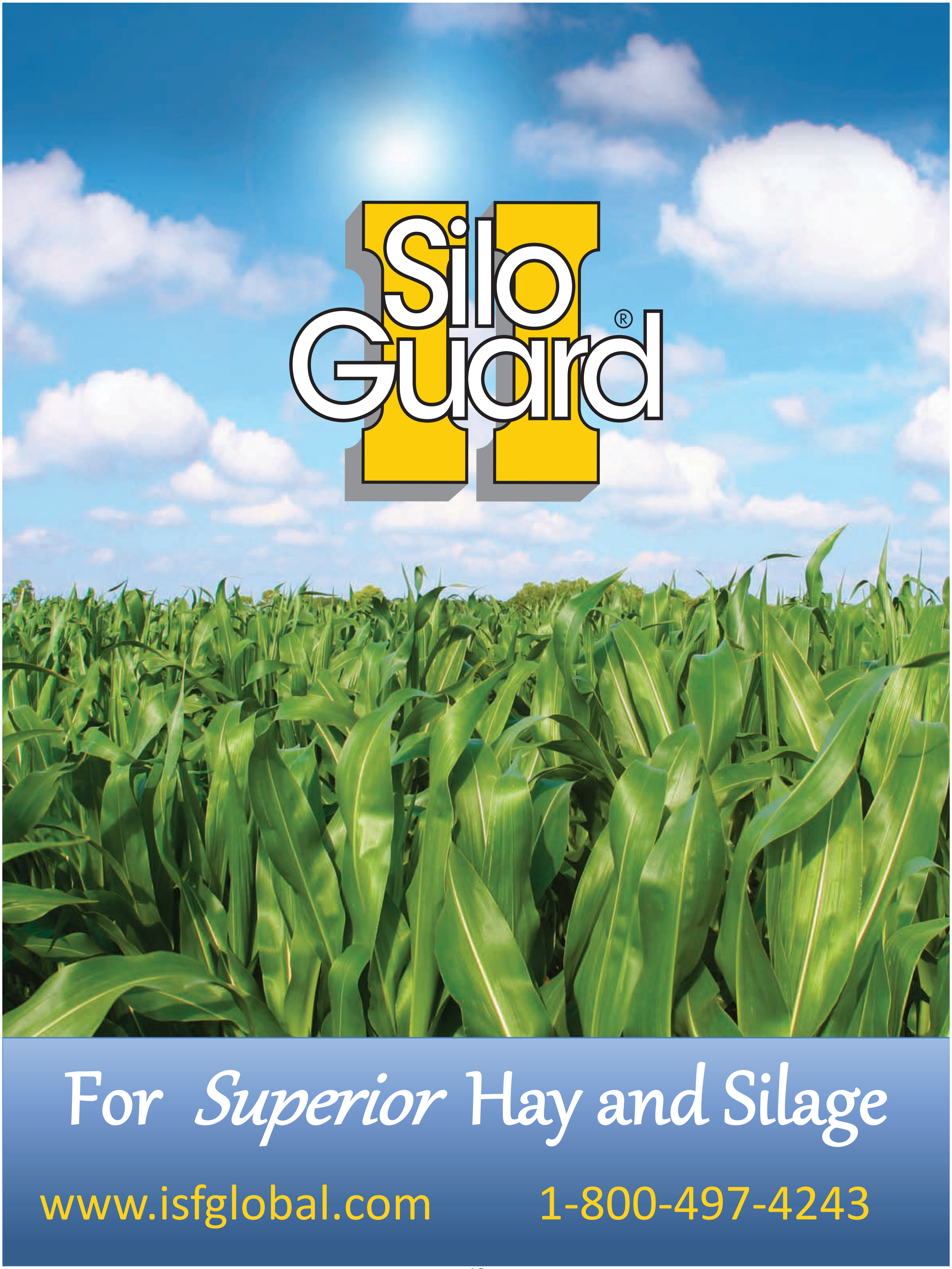
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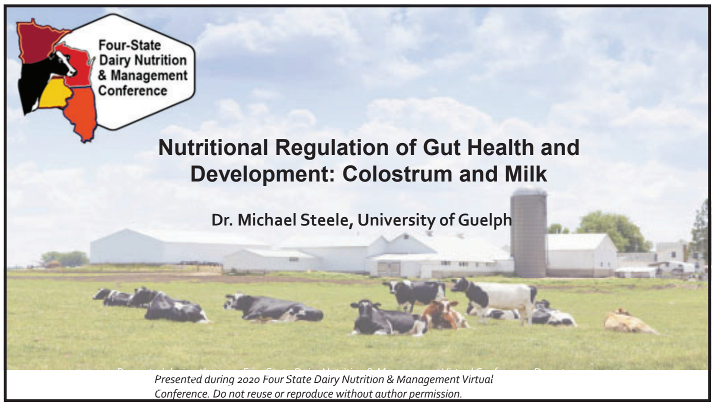
Nutritional Regulation of Gut Health and Development: Colostrum and Milk

Dr. Michael Steele
University of Guelph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Dr. Michael Steele, University of Guelph
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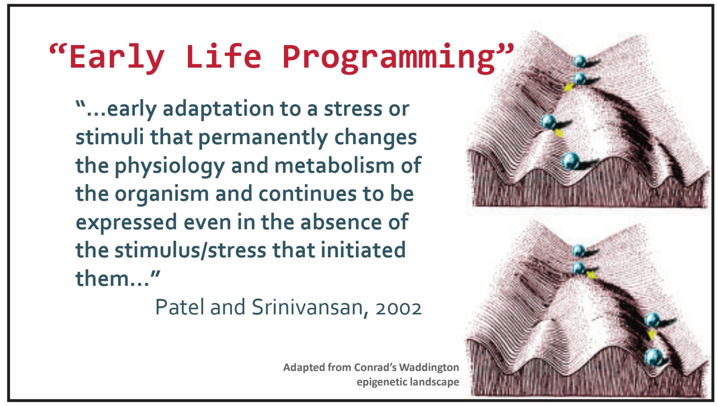
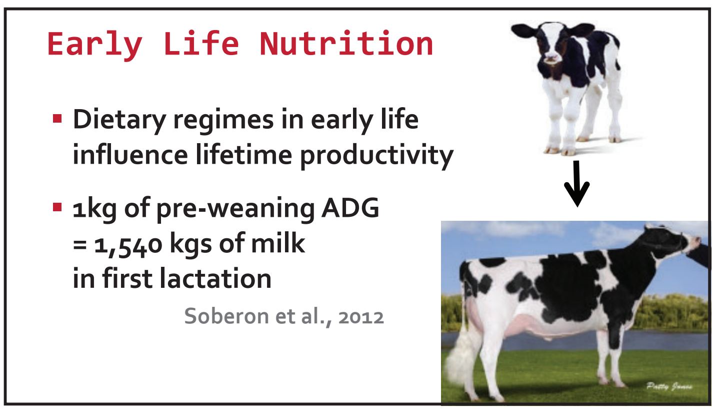
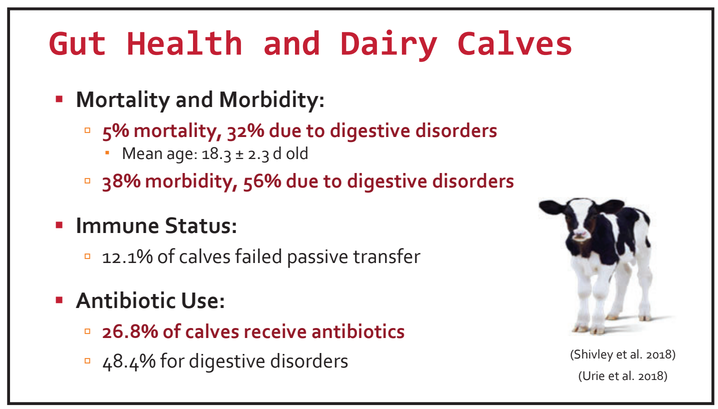
1


"Early Life Programming"
"…early adaptation to a stress or stimuli that permanently changes the physiology and metabolism of the organism and continues to be expressed even in the absence of the stimulus/stress that initiated them…"
Patel and Srinivansan, 2002
Adapted from Conrad's Waddington epigenetic landscape

2

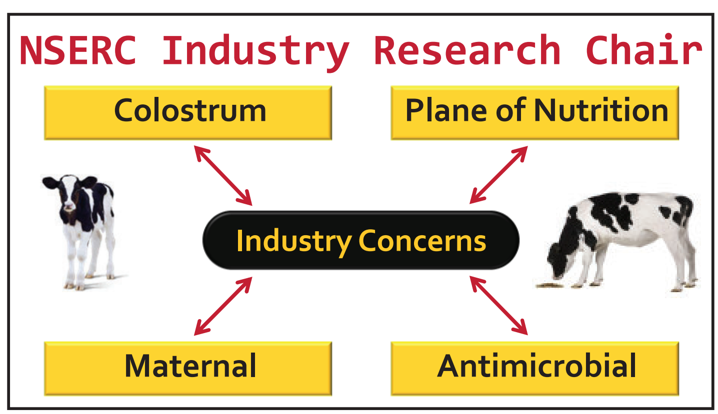

Early Life Nutrition
Dietary regimes in early life influence lifetime productivity
1kg of pre-weaning ADG = 1,540 kgs of milk in first lactation
Soberon et al., 2012

3


Gut Health and Dairy Calves
Mortality and Morbidity:
5% mortality, 32% due to digestive disorders
Mean age: 18.3 ± 2.3 d old
38% morbidity, 56% due to digestive disorders
Immune Status:
12.1% of calves failed passive transfer
Antibiotic Use:
26.8% of calves receive antibiotics
48.4% for digestive disorders
(Shivley et al. 2018)
(Urie et al. 2018)

4

5


NSERC Industry Research Chair
Colostrum
Plane of Nutrition
Industry Concerns
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6

Colostrum Intake

	2 L colostrum	4 L colostrum
n	37	31
ADG, kg	0.80	1.03 *
Age at conception, (months)	14.0	13.5 ns
Survival through 2nd lact., (%)	75.7	87.1 *
Milk yield through 2nd lact., (kg)	16,015	17,042 *

*P<0.05; ns P>0.1

Inadaquate colostrum intake reduces lifetime production

Faber et al., 2005

7

Failure in passive immune transfer...

- **Delayed age at first calving**
  Waltner-Toews et al., 1986
- **Decreased milk and fat production at first lactation**
  Nocek et al., 1984; Robinson et al., 1988; Faber et al., 2005
- **Decreased average daily gain to 180 days**
  DeNise et al., 1989; Soberon et al., 2011
- **Negatively impacts feed efficiency**
  Soberon et al., 2011

8

Colostrum -Is it all the same?

	Colostrum Types		
	Fresh	Pasteurized	Dried
Pros	• Tailored for the calf • All bioactive molecules and cells	• Can assess the quality • Reduce bacterial load	• Convenient • Clean and consistent
Cons	• Opportunity for contamination • Difficult to test quality	• Destroys healthy bacterial and immune/developmental cells • Bioactive molecules may become less active (if not managed properly)	• Destroys healthy bacterial and immune/developmental cells • Bioactive molecules may become less active • Some products are missing major macronutrients

9

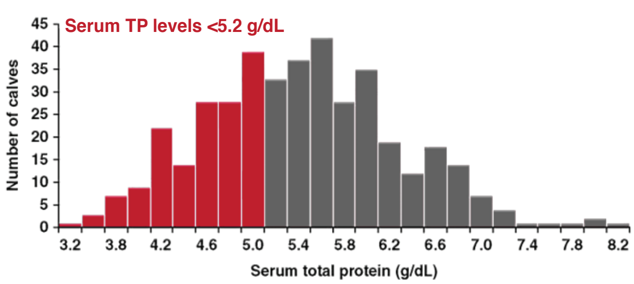
Evaluating colostrum absorption in calves

5.0 – 5.2 g/dl
Serum total protein = 5.0 – 5.2 g/dl ~
Serum IgG >10mg/ml

Brix refractometer is a good start but has limitations

10

Failure of Passive Transfer

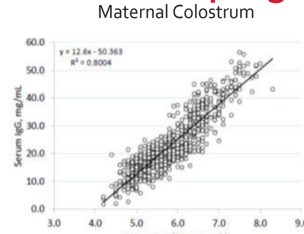


Trotz-Williams, 2008

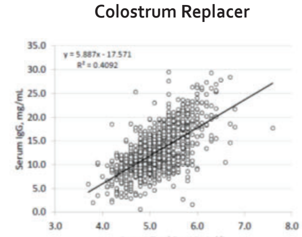
11

But is it accurate for all neonatal programs?

Maternal Colostrum



Colostrum Replacer



(Lopez et al., in review)

12

What's in colostrum?

Immunoglobulins	>100:1	immune function
Lactoferrin	>15:1	local immunity effect in gut
IGF-I	80:1	
IGF-II	20:1	
Epidermal growth factor	2:1	
Insulin	100:1	local gut effects
Interleukines	> 100:1	
Relaxin	19:1	reproductive development
Prolactin		little data
TGFα and TGFβ	> 100:1	
Leptin		hypotahlamic pituitary axis
Leucocytes		immune function

Slide Courtesy of Dr. VanAmburgh

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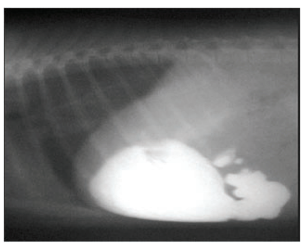
Components of Colostrum Management

Successful
Colostrum Feeding

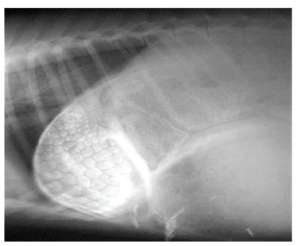
14

Colostrum Feeding Method

Bottle



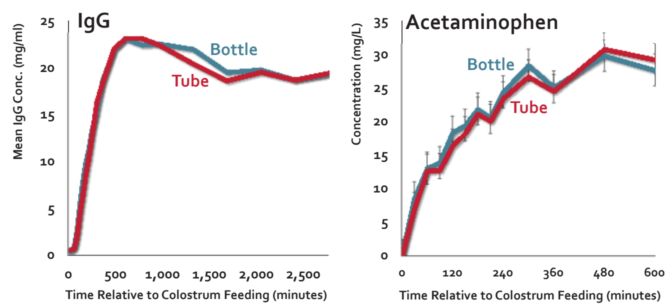
Tube



Sharifi et al., 2009

15

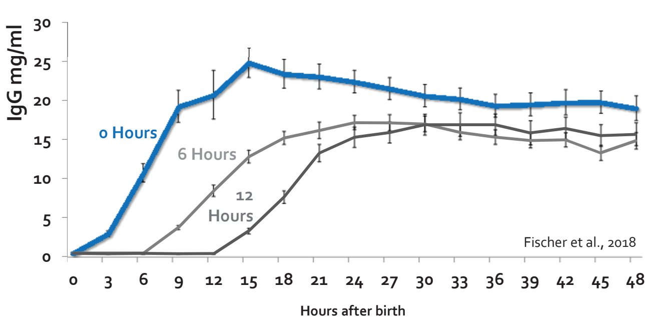
Colostrum Feeding Method



Desjardins-Morrissette et al., 2018

16

Delayed Colostrum Feeding



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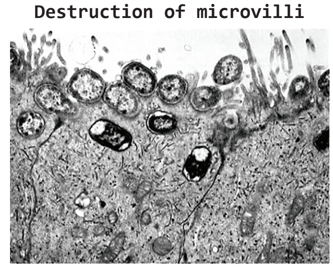
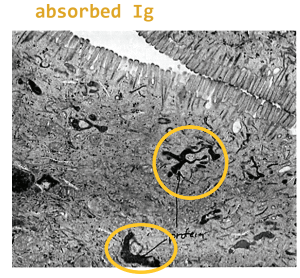
E. Coli entering intestine
epithelial cell
Destruction of microvilli



Colostrum deprived calf

Dark areas represent
absorbed Ig

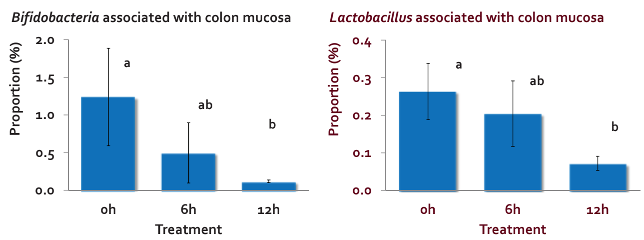


Colostrum fed calf

Slide Courtesy of Dr. James

18

Delayed Colostrum Feeding



Delaying the first colostrum meal may delay the colonization of beneficial bacteria to the calf intestine

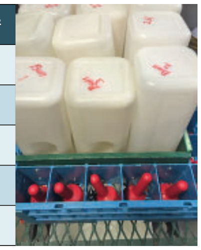
Fischer et al., 2018

19

Bacterial Contamination of Colostrum

Cut point is bacterial count < 100,000 cfu/ml

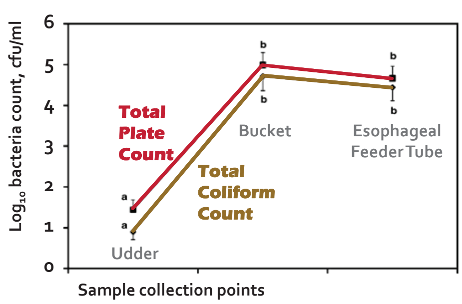
Total Bacterial Count	% of Samples[12]
< 100,000	54.8
100,000 - 300,000	12.1
300,000 - 500,000	6.3
500,000 - 1,000,000	9.9
>1,000,000	16.9



Morill, 2012

20

Cleanliness of colostrum handling equipment

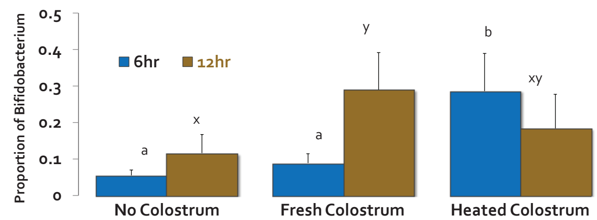


Mean log$_{10}$ total plate count and mean log$_{10}$ total coliform count for colostrum samples collected from the udder, milking bucket and esophageal feeder tube within bacteria type group.

Stewart et al., 2005

21

Heat Treatment of Colostrum

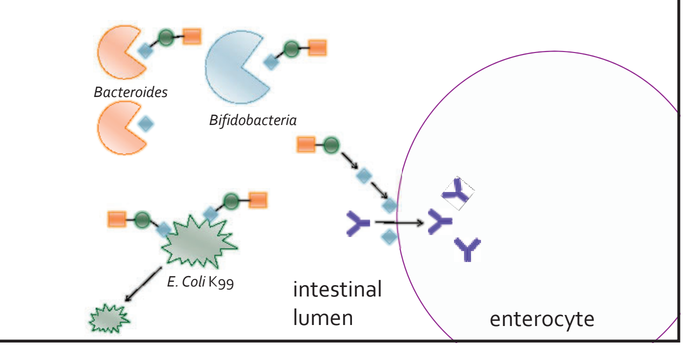


Heat-treated colostrum increases *Bifidobacterium* and reduced the colonization of *E. coli* in the small intestine

Malmuthuge et al., 2015

22

Colostrum Oligosaccharides



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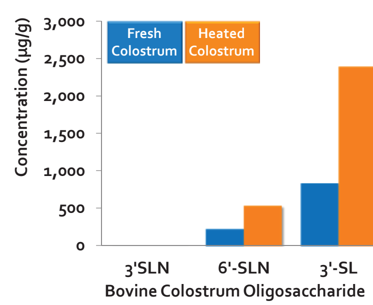
Heat Treatment of Colostrum

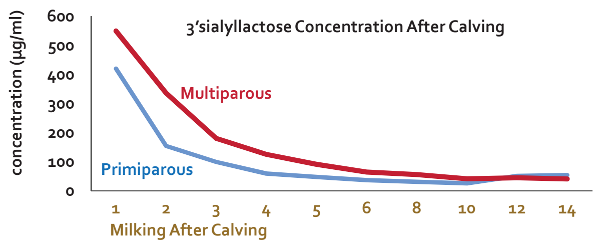


Heat-treatment may cleave prebiotic oligosaccharides from colostral proteins and lipids

Fischer et al., 2018

24

Oligosaccharides – Transition

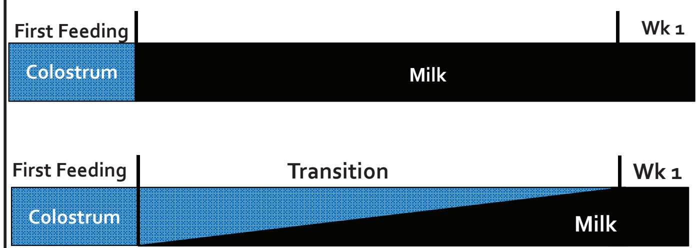


Bovine colostrum oligosaccharides (bCOs) produced in higher concentrations immediately after parturition

Fischer et al., 2020

25

From Colostrum to Milk



26

From Colostrum to Milk

	Unit	Colostrum Milking 1	2	3	4	5	Mature Milk
Dry Matter	%	24.5	19	16	15.5	15.3	12.2
Fat	%	6.4	5.6	4.6	5	5	3.9
Protein	%	13.3	8.5	6.2	5.4	4.8	3.2
Essential Amino Acids	mM	390	230	190	140	115	
Lactoferrin	g/L	1.84	0.86	0.46	0.36		
Insulin	µg/L	65	35	16	8	7	1
Growth Hormone	µg/L	1.5	0.5				
Insulin-like growth factor I	µg/L	310	195	105	62	49	

Improved health status in calves fed transition milk

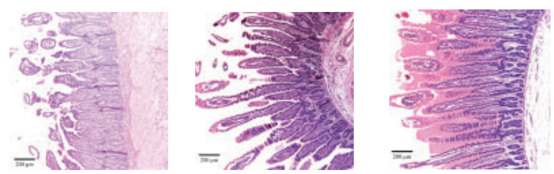
Conneely et al., 2014

27

From Colostrum to Milk

- **All calves fed one meal of colostrum followed by:**
  - Milk
  - 50% milk/ 50% colostrum (Transition)
  - Colostrum

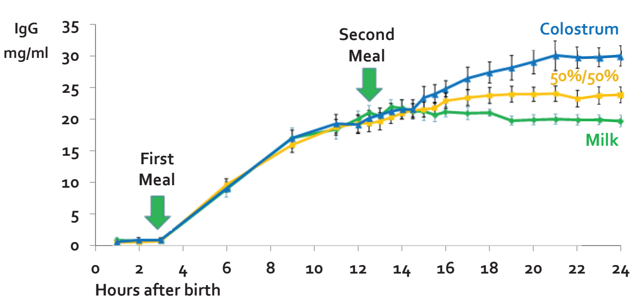
Pyo et al., 2020



Milk 50%/50% Colostrum

28

From Colostrum to Milk



Hare et al., in review

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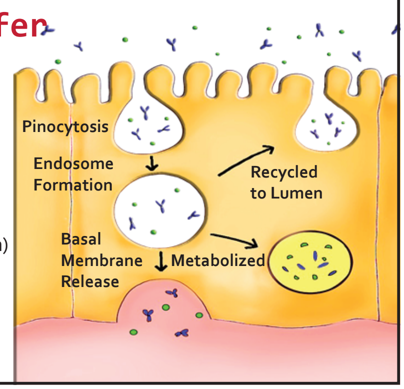
Passive Transfer

- **Trancytosis of immunoglobulins**
  Jochims et al., 1997
- **Receptor mediated and highly regulated**
  - Trancytosis (to blood)
  - Recycling (back to lumen)
  - Metabolism (endosome)
- **Regulation of these pathways in calves is unclear**



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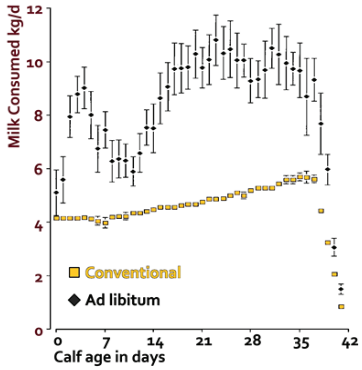
Normal Pre-Weaning Milk Intake



Jasper and Weary, 2002

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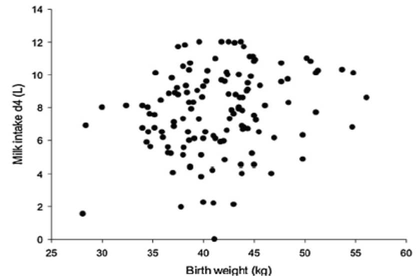
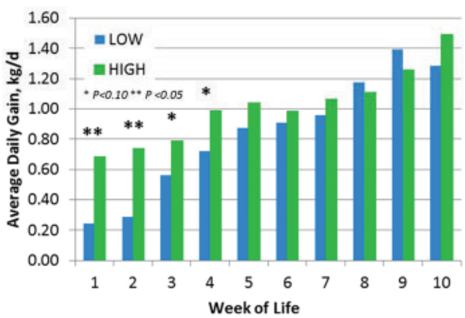
Normal Pre-Weaning Milk Intake



de Passille et al., 2016

32

5 (Low) vs 10L (High)



Haisan et al., 2018

33

Feeding Large Meals

- Calves typically nurse 6-12 times per day in the first weeks of life (Jensen, 2004)
- Larger meals fed less frequently increase the risk of:
  - Abomasal inflammation & lesions
  - Milk overflow into the rumen
  - Ruminal acidosis, decreased passage rate and digestion

Berends et al., 2012; 2015

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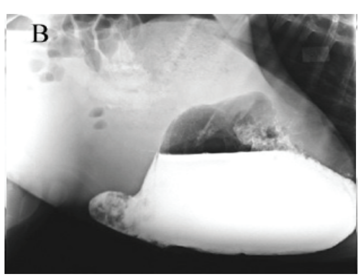
Abomasal Capacity

- Young calves fed 2 litres of milk per meal (3 x)
- Offered ad libitum meal of milk with barium sulfate
- Most calves drank more than 5 litres with no evidence or ruminal overflow



Ellingsen et al., 2016

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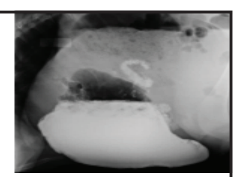
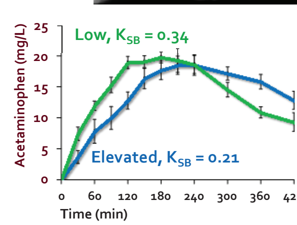
Larger Meal Size and Insulin Sensitivity



Compared calves fed elevated (8L/d) vs low (4L/d) plane of milk 2x per day

- No evidence of post-prandial hyperglycemia and hyperinsulinemia
- No difference in glucose tolerance
- Slower (41% reduction, P = 0.02) abomasal emptying rates during the pre-weaning phase

MacPherson et al., 2016



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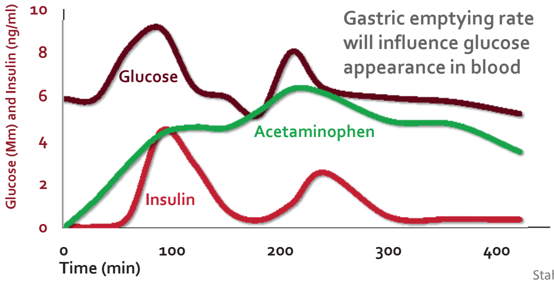
Gastric Emptying and Glucose-Insulin Dynamics



Stahel et al., 2016

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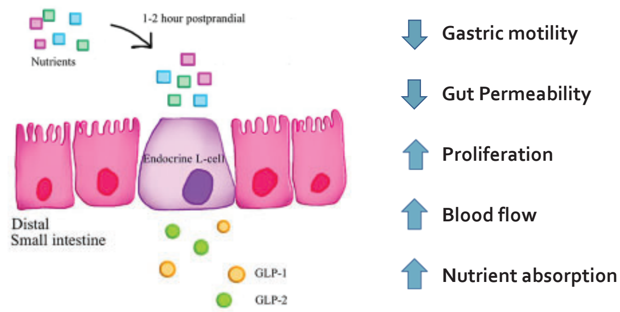
Gut Hormones



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Best innovation in calf feeding in recent years:

3-L and 4-L nursing bottles!

Allows us to design feeding system to meet calf requirements.

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Should intake be the same?

Slide Courtesy of Dr. VanAmburgh

40

Amount of Milk Replacer/Milk Dry Matter Required to Meet Maintenance Requirements (kg/d)

BW kg	Temperature, °C						
	20	10	0	-10	-15	-20	-30
27	0.27	0.36	0.41	0.45	0.5	0.54	0.64
36	0.36	0.41	0.5	0.59	0.64	0.68	0.77
45	0.45	0.5	0.59	0.73	0.77	0.82	0.91
55	0.5	0.59	0.68	0.77	0.86	0.91	1.05

Milk Replacer/Milk Dry Matter Required (kg/d)

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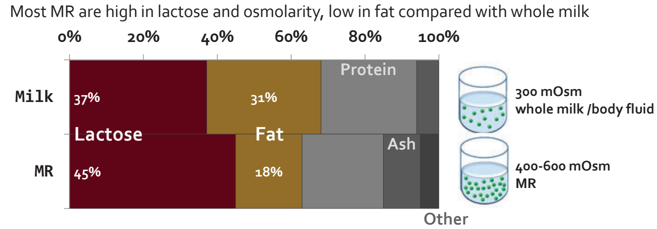
Milk Replacer vs Whole Milk

Most MR are high in lactose and osmolarity, low in fat compared with whole milk



Hypertonic MR increases gut permeability

Wilms et al., 2019

Higher lactose results in increased gastric emptying and lower glucose tolerance in the first week of life

Welboren et al., in review

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Take Home Messages

- There are still some basic concepts in calf biology and nutrition that we do not understand
- No difference between tube vs. bottle feeding colostrum for passive transfer
- Delaying colostrum by six hours can impact passive transfer and gut microbiology
- Pasteurizing colostrum may help to improve calf gut health if managed properly

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Take Home Messages

- An abrupt transition from colostrum to milk can compromise gut development
- Calves can consume large quantities of milk in early life when starter intake is depressed
- If feeding times per day is limited, the calf can regulate by decreasing abomasal emptying
- The environmental temperature has a large impact on milk feeding regimens

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Take Home Messages

- Some milk replacers are too high in lactose which may comprise calf health
- Using high quality ingredients and feeding consistency is key to promote gut health

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DAIRY at GUELPH

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Industry Collaborators

SCCL · milk · Bayer · Pancosma · trouw nutrition · GROBER · Cargill · Saskmilk · Dairy Farmers of Manitoba · WESTGEN · LALLEMAND

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Academic Collaborators

INRA · DairyNZ · University of Calgary Veterinary Medicine · University of Saskatchewan · UK · University of Guelph

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Colostrum and Milk Collaborators

- SCCL
- Alberta Milk
- Trouw Nutrition
- Alberta Agriculture
- NSERC
- Breevliet Ltd.

SCCL · milk · trouw nutrition · Alberta Agriculture and Forestry · NSERC CRSNG

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Thanks
to my Team
Alberta, 2017
Guelph, 2019

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DAIRY at GUELPH
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Realizing Full Value for Full- and Half-blood Holstein Steers

Dan Schaefer

Emeritus Professor

University of Wisconsin-Madison

Four-State Dairy Nutrition & Management Conference

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Departments of Animal Sciences & Dairy Science
UNIVERSITY OF WISCONSIN–MADISON

1

Outline

- Finishing Holstein steers
  - Management principles
  - Nutrition principles
- Characteristics of Holstein steers
  - Beef yield and quality
  - Attributes and limitations
- Dairy x native crossbred steers
  - Growth and nutrition principles

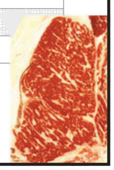

2

2

Significance of Holstein steers to U.S. beef production?

Assumptions	
Calving interval	13.1 months
Dairy calf component of U.S. calf crop	26%
Heifer component of dairy calf crop	53%
Dairy calf death loss	8.1%
Dairy feeder cattle deaths and realizers	3.77%
Holstein component of dairy cow herd	86%
Fed Holstein carcasses, USDA Prime	12.9%[1]
Results of Calculations	
Holstein steer component of fed steer & heifer supply	13.8%
Holstein steer component of USDA Prime carcasses	33%

[1] Native carcasses, 2.1% Prime (2016)

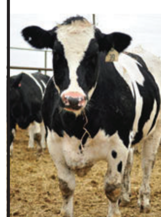


3

The Ideal Holstein Steer

"Really ideal type of steer. Live weight 1415 lbs, dressed yield estimate 61.5%, Y3, High Choice, Muscle score 1-2. The ideal kind of steer that is desired by both the dairy steer harvesters and native cattle packers alike."

Ron Mayer – JBS Packerland


4

Holstein Steer Packing Plants

- JBS – Green Bay, WI; Plainwell, MI; Tolleson, AZ; Omaha, NE; Grand Island, NE
- Cargill – Wyalusing, PA; Fresno, CA; Schuyler, NE
- American Foods Group – Green Bay, WI

5

5

Target for Marketing

- Only two competing Holstein steer harvesters in Upper Midwest
  - JBS
    - Prefers calf-fed steers up to 1550 lbs
  - American Foods Group
    - Prefers 1400 lbs and heavier
- Target finished weight for Holstein steers is 1400-1550 lbs for competitive bidding
  - 840-930 lb carcass
    - Discounts to cow beef price for stags, Standards (silage-fed), and dark cutters

6

Special Considerations for the Holstein Bull Calf

- Feed colostrum to bull calves as it is fed to heifer calves
- Purchase calves with colostrum feeding as a stipulation
- Castration
  - Stags: expensive to re-castrate, or steep carcass discounts
  - Simple math – count to two and then the job is done!
- Dehorn to prevent bruising

7

Weaning and Post-weaning

- Colostrum shortage, milk replacer, and housing environment are challenges to calf respiratory health
- Age at weaning? Typically, 7-8 wks.
  - "Wean early (28 to 42 d) and promote feed DM intake to take advantage of the efficient growth by young calf." – Hugh Chester-Jones, Univ. Minn.
- Growth target for the nursery phase is to double initial BW by 56 d of age with hip height growth of 4 inches or more
- Provide a high energy diet (60 Mcal NEg/cwt DM) with 18% crude protein

8

Grower Phase – Role for Forages?

- A grower phase is not needed for Holstein steers.
- Pastures, silage or hay can be included for middle weight (400-750 lb) steers to accommodate cropping system.
- Subsequently, reduce forage component to achieve ≥62 Mcal NEg/cwt DM

9

Short Transition to Finisher Phase

Conditions at a Midwest feedlot into which 300 lb Holstein steers were received. Upon arrival, the steers started at 56 Mcal NEg/cwt DM and were gradually incremented to 62 Mcal NEg/cwt DM. (Below Farms, Waseca, MN)

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Finisher Phase

- Start them on finishing diet (≥ 62 Mcal NEg/cwt DM) by 750 lbs
- Holstein steers need high-energy diets so they will finish at 1400-1450 lbs

11

Net Energy$_{gain}$ (NEg) Concentrations in Feedlot Diets

Equivalencies between corn silage:high-moisture corn ratios and net energy for gain concentrations[1, 2].

Corn silage	Corn, high-moisture	Net Energy$_{gain}$
Proportion (%)	Proportion (%)	Mcal/lb
10	60	0.65
15	55	0.64
20	50	0.63
25	45	0.61
30	40	0.60
40	30	0.57
50	20	0.54

[1] Based on diet DM formula as follows: corn silage proportion; high-moisture corn proportion; modified wet distillers grain with solubles, 25%; and supplement, 5%.
[2] NEg values for diet ingredients (NASEM, 2016) were corn silage, 0.44 Mcal/lb; high-moisture corn grain, 0.71 Mcal/lb; and modified wet corn distillers grain with solubles, 0.74 Mcal/lb. Supplement was considered to be only minerals, vitamins and additives with zero NEg value.

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Consistency of Holstein Steer Population

- Breed has an inbreeding coefficient of 6-7%
- Implications of this genetic homogeneity are both positive and negative.
- The following closeout results display consistency.

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Commercial Diets Self-fed (as-fed basis)

Ingredient	Diet 1	Diet 2
Corn, cracked, %	67	65
Corn gluten feed, pelleted %	12	-
Distillers grain, %	15	30
Balancer pellets, %	6	5

No inclusion of Tylan, Optaflexx, molasses, probiotics or other non-nutritional additives. No forage/roughage provided, except corn stalk bedding.

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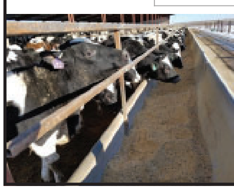
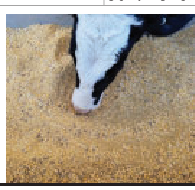
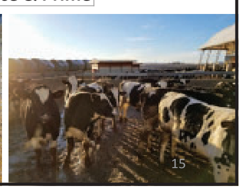
Summary across 25 Closeouts

Variable	Overall Ave
Head, Ave	346 (n=25)
Initial wt, lb	487
Harvest wt, lb	1437
Duration, d	321
DMI, lb/hd*d	**20.5**
ADG, lb/hd*d	**2.95**
DMI/ADG	**6.97**
Grade	**80+% Choice & Prime**







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Closeouts 1-5 with Self-feeders

	Group							
	1	2	3	4	5	**Mean**	S.dev.	**C.V.**
Head, n	294	390	114	360	534	**338**		
Implants[a]	E+FO	E+IS	E+FO	E+FO	E+FO			
Housing	Bedded Confine ment	Outside lots with sheds	Outside lots with sheds	Outside lots with sheds	Outside lots with sheds			
Begin wt, lb	565	593	594	610	541	**581**	27.4	**4.7%**
Kill wt, lb	1461	1458	1426	1440	1442	**1445**	14.3	**1.0%**
Duration, d	323.5	293	305	307	315	**309**	11	**3.7%**
DMI, lb/hd*d	20.7	21.0	21.8	20.9	21.0	**21.1**	0.4	**2.0%**
ADG, lb/hd*d	2.77	2.95	2.73	2.7	2.86	**2.80**	0.10	**3.7%**
DMI/ADG	7.48	7.11	8.00	7.76	7.34	**7.54**	0.35	**4.6%**
Death & Culls, %	4.85	2.74	5.0	2.7	2.9	**3.64**	1.18	**32%**
Choice & Prime, %	-	78.33	81.25	79.75	80.01	**79.84**	1.20	**1.5%**

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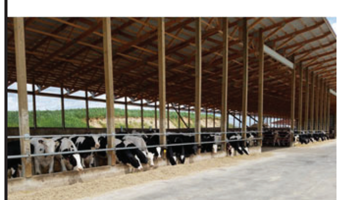
Consistent Holstein Steer Performance

- Note the consistency of DMI, ADG, DMI/ADG (feed conversion efficiency) and Choice/Prime percentage.
- Dead and culled steers are a greater percentage than one would expect from similar native steers, and this is probably due to early calfhood mgmt and inbreeding.

17

Aim for Dry, Draft-free Housing



Holstein steers are <u>more tolerant of elevated temperatures, but less tolerant of freezing temperatures</u> than native steers, which may be because of their thinner hide and diminished subcutaneous fat cover. Insulation provided by dry bedding is essential in cold conditions. (Ramthun Farms, West Bend, WI)

18

Yield Characteristics of Holstein Steer Carcasses

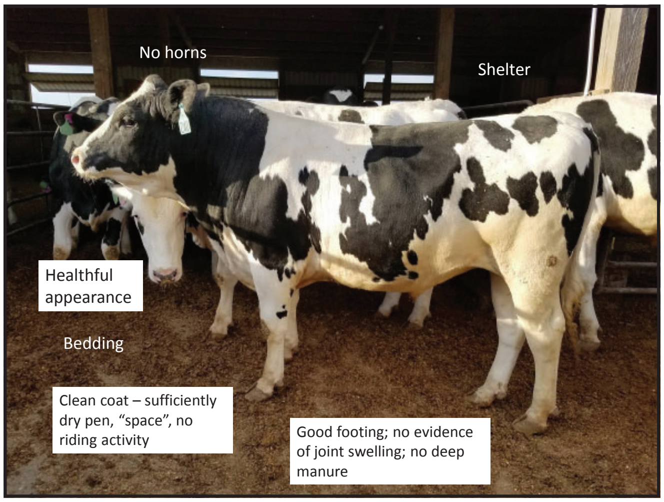
- Lower dressing percentage than native carcasses
  - Due to increased proportion of gut, reduced muscling score, less subcutaneous fat, increased liver size, increased proportion of abdominal fat
  - However, hide as proportion of body weight is less
- Lower muscle:bone ratio
  - Loin muscle of the Holstein is stretched over a longer skeleton, resulting in a smaller REA (Nour et al., 1981)

19

Quality of Holstein Beef

- Holstein steers have had higher marbling scores than the U.S. native fed cattle population
  - In recent years, there is less difference due to marked improvement in marbling scores within native population
- Holstein loin has greater drip loss but responds to vitamin E supplementation, if there is a large differential
- No breed difference in taste panel or tenderness attributes for Holstein vs Angus

20



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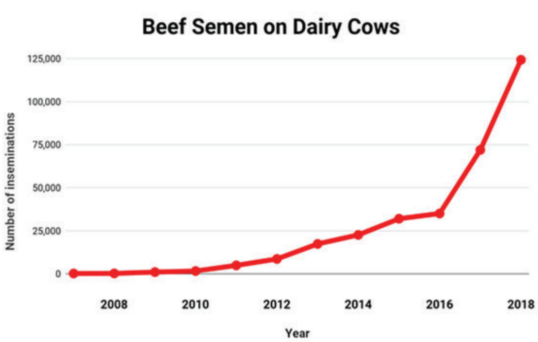
Finished Holstein Steer

Body wt	1388 lb
Dress	58.6%
Carcass	814 lb
Fat thickness	0.28 in
Loin muscle area	12.2 in^2
Kidney, pelvic, heart fat	3.0%
USDA Yield Grade	3.0
USDA Maturity	A
USDA Marbling	Modest[20]
USDA Quality Grade	Choice

22



Source: Agsource; Paul Fricke

23

What are the goals for half-blood dairy steers?

- Note the difference in frame size.

24

Beef Sire Selection for Dairy Matings

- Aim for more than simply a black calf
  - If it won't qualify for Certified Angus Beef, it's just a black Holstein or black Jersey
    - No reason to value greater than Holstein or Jersey bull calf
- F1 generation needs to meet CAB standards

Denise Schwab, Iowa State,
Extension Beef Specialist

25

Certified Angus Beef
(as stds apply to dairy-beef crossbreds)

- Predominantly (51%) solid black hair coat or AngusSource® genetic verification
- Modest or higher marbling (average and high Choice and Prime)
- Superior muscling (restricts influence of dairy cattle)
- 10- to 16-square-inch ribeye area
- 1,050-pound hot carcass weight or less

https://www.certifiedangusbeef.com/brand/specs.php

26

Traits of Importance

- Marbling
  - Highly heritable
- Muscling (muscle:bone ratio)
  - Medium to high heritability
- Respiratory health
- Hybrid vigor
  - Not a consideration for marbling or muscling
  - Possibly a benefit for respiratory health

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Beef Sire Selection Criteria for Holstein Matings

- Black hair coat – homozygous
- Polled – homozygous
- Frame size – 5 to 5.5 (on a scale of 1-9)
- Muscling – ribeye area in top 20% of breed; emphasize muscle to bone ratio
- Marbling – top 20% of breed
- Calving ease direct – top 50% of breed
- Conception rate – not known; beef = Holstein; sorted < non-sorted
- An index designed for these matings?

28

Beef Sire Selection Criteria for Jersey Matings

- Black hair coat – homozygous
- Polled – homozygous
- **Frame size – 6 to 6.5** (on a scale of 1-9)
- Muscling – ribeye area in top 20% of breed; emphasize muscle to bone ratio
- Marbling – top 20% of breed
- Calving ease direct – top 50% of breed
- Conception rate – not known; sorted < non-sorted
- There is no existing index designed for these matings

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Cattle Performance Estimates

Enterprise	ADG lb/d	Feed:Gain	Days on Feed
Holstein, birth to 400	2.0	3.5	150
Dairy x beef, birth to 400	2.0	3.5	150
Holstein 400- 1450	2.9	7.2	362
Dairy x beef 400-1400	3.2	6.9	312

There are no publicly available reports of half-blood Holstein steer feedlot performance.

30

Finishing Programs[1]

	Holstein	Half-Holstein	Native
Diet NEg (Mcal/cwt DM)	62-65	62-65	62-65
Start finishing by ____, lb	750	850	950
Harvest-ready, lb	1450	1375	1300
Daily gain, lb/day	2.9	3.2	3.5
Days to finish	240	165	100

[1] Assumes anabolic implant inserted as follows:
Holstein – Revalor XS (200 days)
Half-Holstein – Revalor S (last 100 days)
Native – Revalor S (last 100 days)

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Nutritional Recommendations

Nutrient	Growing	Finishing
	%, DM basis	
Crude protein	14	13
Calcium	0.65	
Phosphorus	0.30	
Potassium	0.60	
Sulfur	0.15-0.40	
Magnesium	0.10	
Salt	0.25	
Trace mineral pmx	0.05	
Vitamins	IU/lb DM	
A	1,000	
D	125	
E	15	

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Trace Mineral Premix[1,2]

Mineral	NRC Recomm.	TM Premix	Premix/Recomm.
	mg/kg	mg/kg	
Ca		230,000	
Fe	50	10,000	200
Mn	20	40,000	2,000
Zn	30	60,000	2,000
Co	0.15	300	2,000
Cu	10	20,000	2,000
I	0.5	1,000	2,000
Se	0.1	200	2,000

[1] Based on NASEM (2016)
[2] Add TM Premix as 0.05% of diet DM

33

Early Results are Encouraging

Black-coated, half-dairy crossbred heifers harvested in early January 2020 weighed 1250 lbs and dressed 61.3 % with 18% Prime and 77% Choice.

Note variation in frame size.

She's not pretty, but she's finished.

34

Summary

- Holstein steers have deficiencies
  - Respiratory health, growth rate, feed conversion, dressing percentage
  - Market understands these deficiencies and knows how to value them
  - Despite deficiencies, growth, carcass yield and quality are consistent
  - Supply of these cattle numbers hundreds of thousands
  - Mature market
- For Holstein x beef bull calf, easiest profit is realized by selling the 100-lb calf.
  - This market will become more discriminating as finishers and packers gain experience with these bull calves.
  - Immature market

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Market Comments

- The cash/auction market for feeder and finished cattle is not offering a profit incentive.
- The profit incentive is available for large volume forward contracts involving finished (and probably feeder) cattle.
  - Allows for better control of variability via mating, sorting and finishing decisions

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Interpretation

- Market for Holstein bull calves will persist as long as there is a
  - market demand
  - packer(s) with a market for Holstein beef
  - packer profit in the carcass cut-out value
- When the supply of Holstein bull calves shrinks relative to market demand,
  - market will induce more Holstein beef production
    - price incentive for forward-contracted Holstein steers & heifers
    - price incentive for newborn Holstein bull and heifer calves

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Take Home Message

- Health, growth, cost of production, and carcass value of Holstein steers have become consistently predictable.
- Much will need to be learned about dairy x native crossbreds so that the price premium in these commodity calves can be preserved.

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