

Four State Dairy Nutrition & Management Conference

2025

Proceedings



Changes in Muscle Throughout a Dairy Cow Lactation

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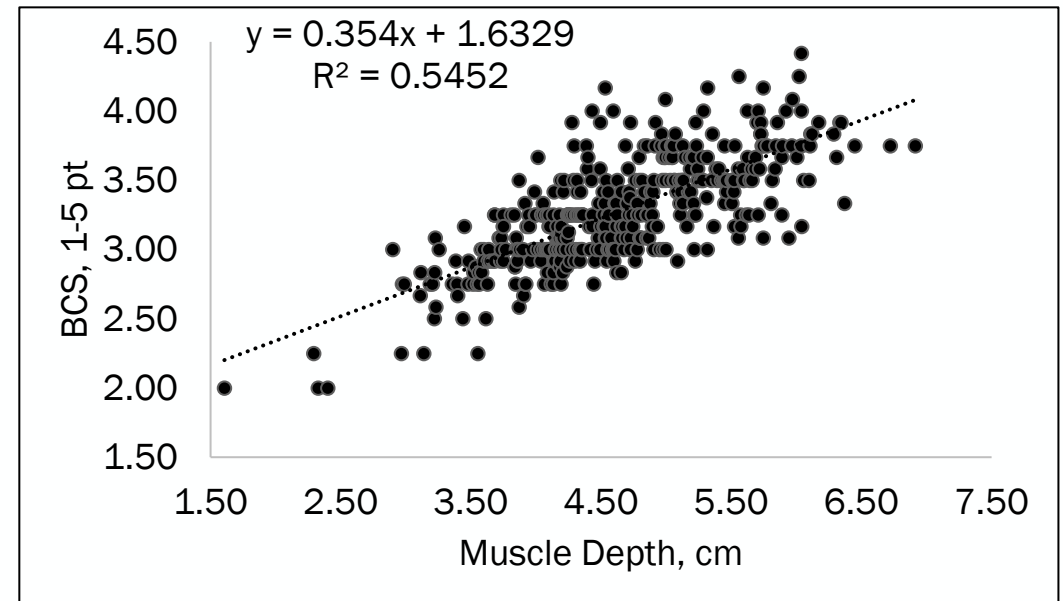


Metabolic Changes Associated with Onset of Lactation – Partial List

Biological Function	Metabolic Change	Tissues Involved
Milk synthesis	Increased use of nutrients	Mammary
Lipid metabolism	Increased lipolysis Decreased lipogenesis	Adipose tissue
Glucose metabolism	Increased gluconeogenesis Increased glycogenolysis Decreased use of glucose and increased use of lipid as energy source	Liver Body tissues in general
Protein metabolism	Mobilization of protein reserves	Muscle and other body tissues
Mineral metabolism	Increased absorption Increased reserve mobilization	Gut, bone, kidney and liver
Intake and digestion	Increased food consumption Hypertrophy of digestive tract Increased nutrient absorption capacity	Central nervous system All segments of the digestive tract
Immune function	Increased positive acute phase proteins Decreased negative acute phase proteins	Liver and other tissues Slide adapted from Dr. Dale Bauman

How Much Tissue Can Be Utilized

- Body composition
 - Protein – 90 to 125 kg
 - Can mobilize < 25%
 - Variation in protein mobilization
 - Adipose – < 100 to > 200 kg
 - Dependent on body condition score
 - Can mobilize in excess of 100 kg
- Subcutaneous fat is highly correlated to body condition score
- Subcutaneous fat is highly correlated to whole body fat ($r = 0.90$)
- Muscle depth and body condition score are moderately correlated ($r = 0.50$ to 0.60)



Data from Gouveia et al., 2024

Protein Balance Post Calving

- MP balance reaching nadir around 7 DIM
- By about 30 DIM positive protein balance
- Dependent on intake of CP, milk production and milk protein yield

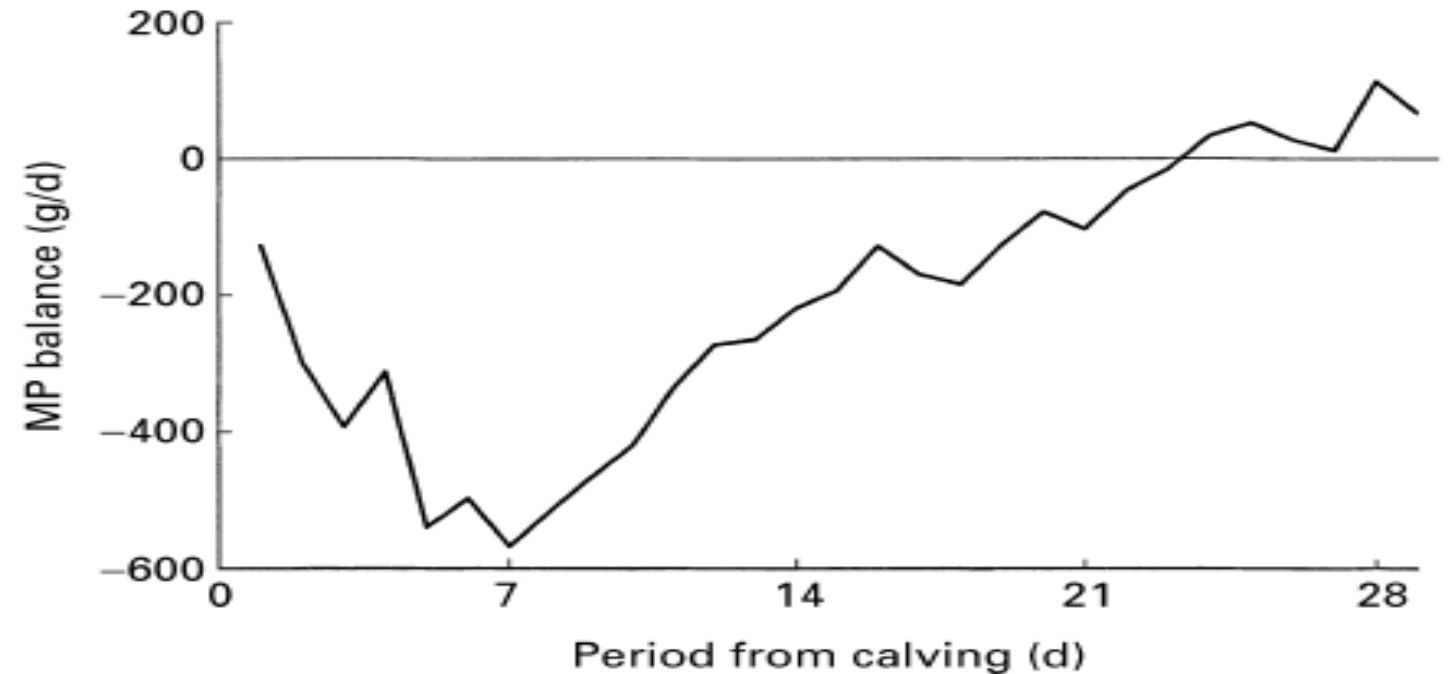
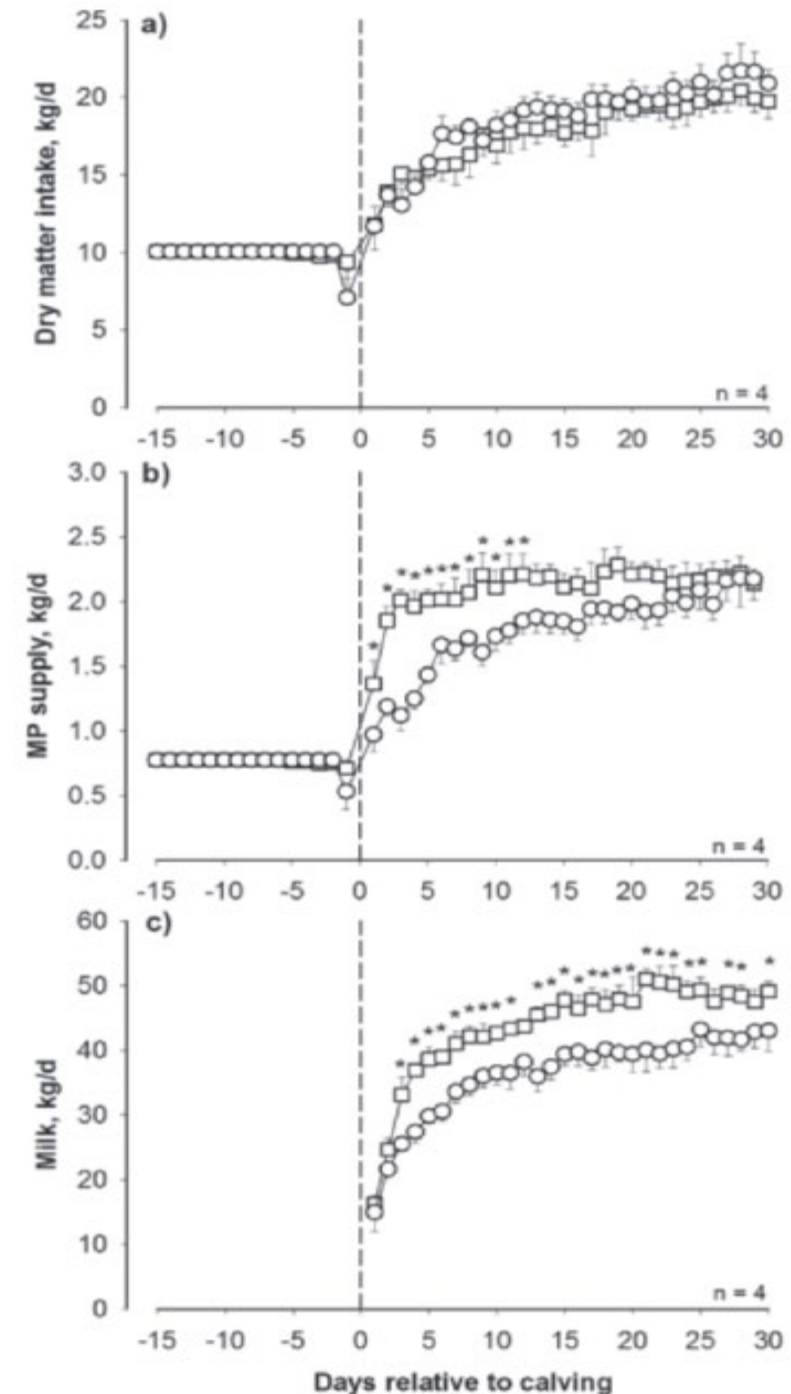


Fig. 1. Calculated metabolizable protein (MP) balance in post-parturient cows (n 80) fed on a ration containing (/kg DM) 178 g crude protein (nitrogen $\times$ 6.25) and 7.0 MJ net energy for lactation. Individual values were calculated from daily individual measurements of crude protein intake and milk yield, and weekly measurements of milk composition.

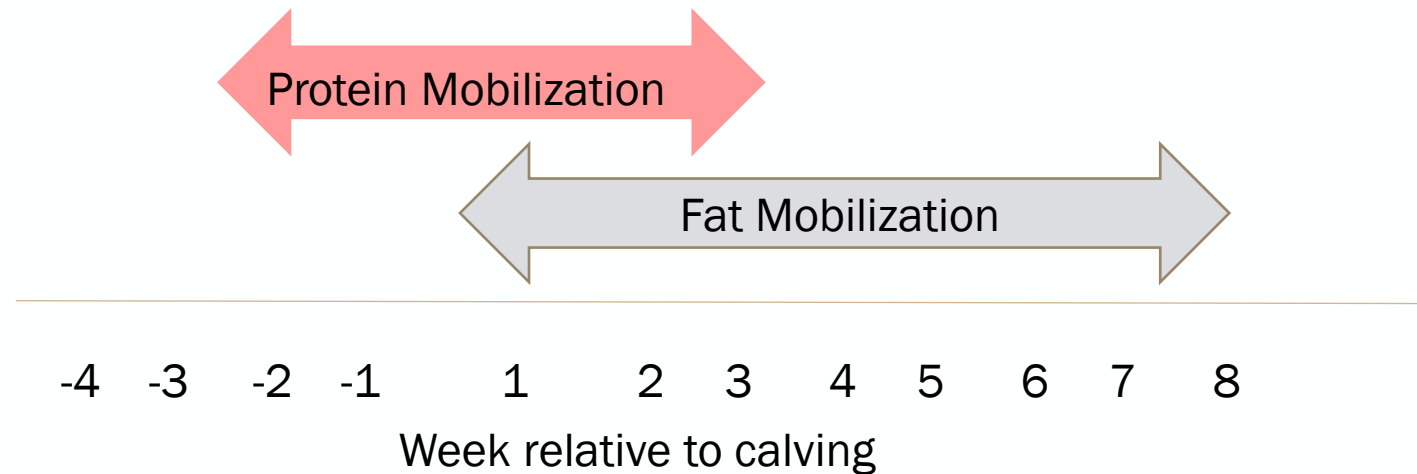
Infusions of Casein Studies

- Due to the negative MP balance observed in early lactation → abomasal infusions of AA of casein (Larsen et al., 2014) or similar in profile to casein (Larsen et al., 2015)
 - Supply of ~700g/d, ~500 or ~200 g/d at 4, 15, 29 DIM
 - No difference in intake
 - Milk yield was 7.2 kg/d greater from through 30 DIM
 - Milk protein yield greater earlier in lactation
- If we supply MP (with an AA profile that matches milk) it will preferentially go to the mammary gland in early lactation
- How does muscle mobilization contribute to production in early lactation?

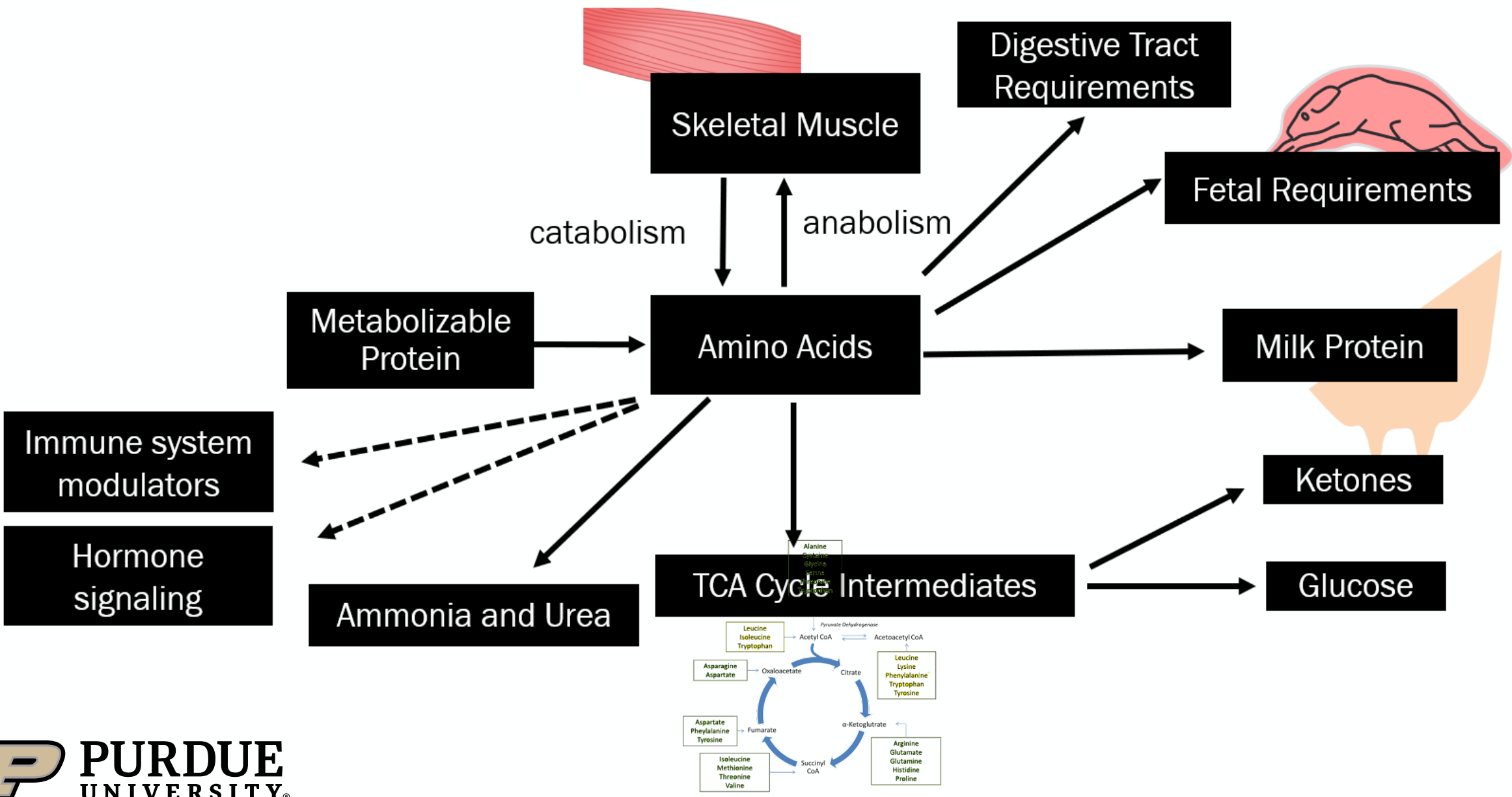


Mobilization of Tissue Stores

- 3 main stores of tissue to mobilize during the transition period
 - Glycogen – mobilized quickly, not a large reserve
 - Adipose – usually largest pool of tissue unless under-conditioned
 - Protein – mostly skeletal muscle and likely starts prior to calving

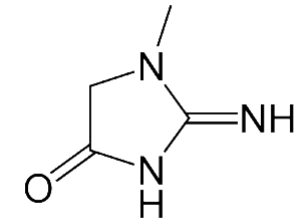
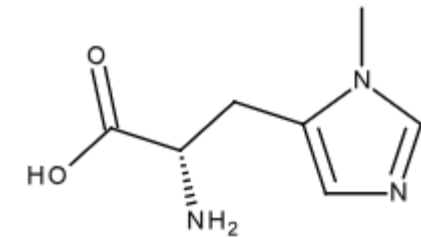
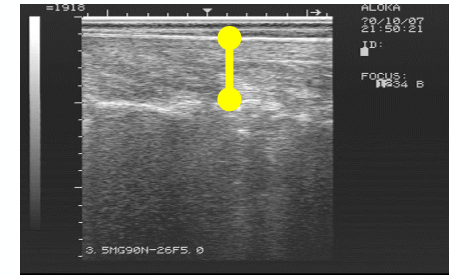


Uses for Amino Acids



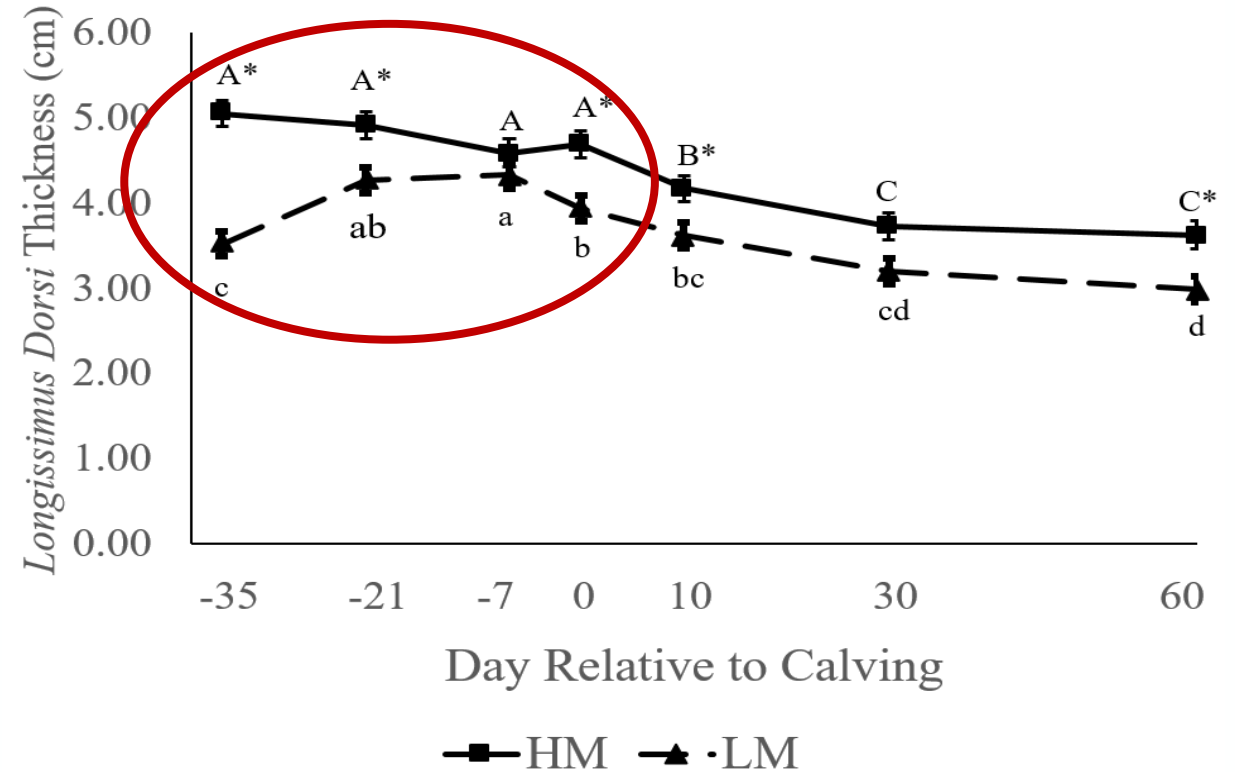
Measuring Protein Mobilization

- Serial ultrasound images to measure change in muscle depth
- 3-methylhistidine is released when muscle fiber (actin and myosin) is degraded and is not used for protein synthesis
- Creatinine is an indicator of muscle mass
- Ratio of 3-methylhistidine to creatinine would indicate muscle mobilization per unit of muscle mass
 - Higher → more muscle mobilization



How Dynamic is Muscle Amount in the Transition Period?

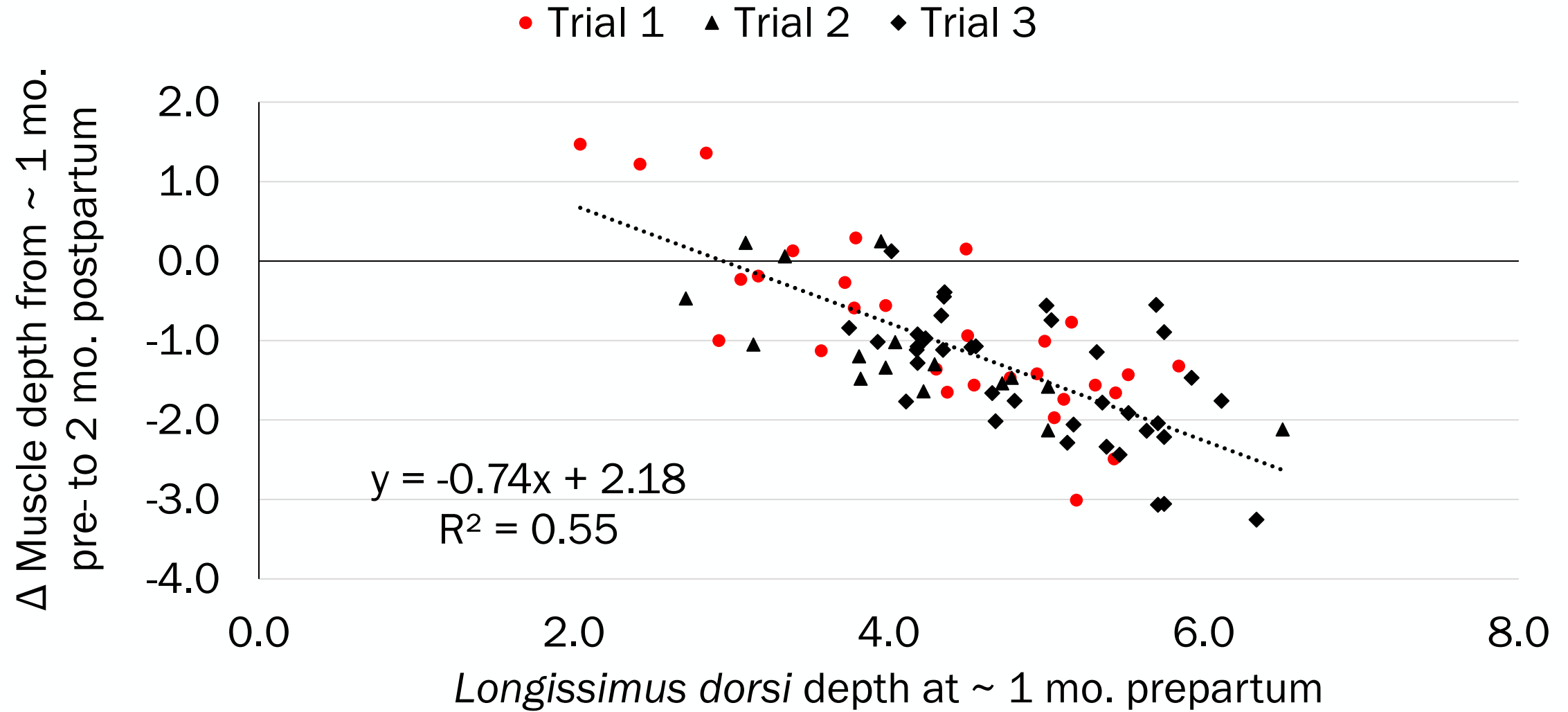
- Separated animals into low muscle and high muscle from 35 d before calving to 60 DIM based on *longissimus dorsi* thickness
- High muscle (HM) mobilized average 1.54 cm (n=20)
- Low muscle (LM) mobilized average of 0.52 cm (n=21)
 - Because gained muscle during prepartum period



Differences in uppercase letters indicate a difference between timepoints within HM, lowercase letters indicate a difference between days within LM, and an asterisk indicates a difference between groups within a day at $P < 0.05$.

McCabe et al., 2021

Relationship Between Prepartum Muscle Reserve and Muscle Depletion



High Muscle Cows Have Higher 3-MH and 3-MH:CRE

Item	2 DIM		7 DIM		14 DIM		21 DIM		SEM	<i>P</i> - Value Group
	HM	LM	HM	LM	HM	LM	HM	LM		
Insulin (ng/mL)	0.21	0.37	0.18	0.41	0.15	0.31	0.31	0.24	0.10	0.26
Glucose (mg/dL)	68.1	69.8	70.8	64.6	66.3	64.8	69.6	68.8	2.2	0.32
BHB (mmol/L)	0.97	1.04	1.15	1.11	1.08	0.99	0.95	0.87	0.17	0.80
NEFA (mmol/L)	0.64	0.54	0.72	0.62	0.63	0.63	0.75	0.51	0.09	0.15
CRE (ng/mL)	3,588	3,477	3,398	3,407	3,173	3,178	3,196	2,994	125	0.57
3-MH (ng/mL)	493 ^{abc}	437 ^{cd}	538 ^a	414 ^d	581 ^a	471 ^c	520 ^{ab}	428 ^{cd}	34	0.02
3-MH:CRE	0.137 ^c	0.122 ^c	0.163 ^b	0.118 ^c	0.188 ^a	0.143 ^{bc}	0.167 ^b	0.141 ^{bc}	0.010	<0.01

High Muscle Cows Produce Calves with Greater Birthweight

Item	HM	LM	SEM	Group <i>P</i> -value
Calf Birthweight (kg)	45.2	41.8	0.7	<0.01
Milk Yield (kg/d)	38.8	41.6	0.8	0.02
Fat %	4.33	4.05	0.12	0.09
Protein %	2.83	2.88	0.03	0.28
Lactose %	4.75	4.71	0.04	0.42
Fat Yield (g)	1703	1612	66	0.32
Protein Yield (g)	1102	1160	34	0.21
Lactose Yield (g)	1843	1918	57	0.35
Milk Urea Nitrogen (mg/dL)	7.44	8.08	0.30	0.12

Prepartum Muscle Depth Results

48 multiparous cows
High Muscle (HM) > 4.6 cm
Low Muscle (LM) ≤ 4.6 cm

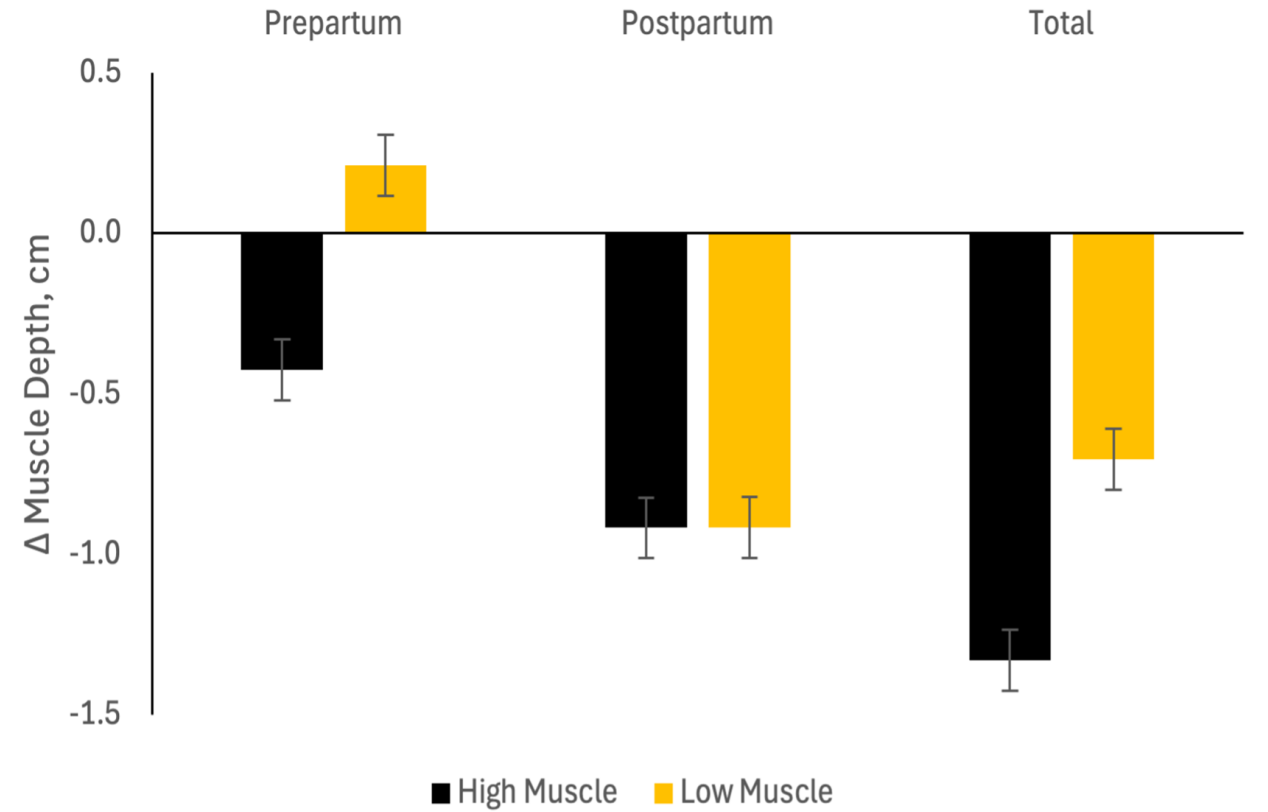
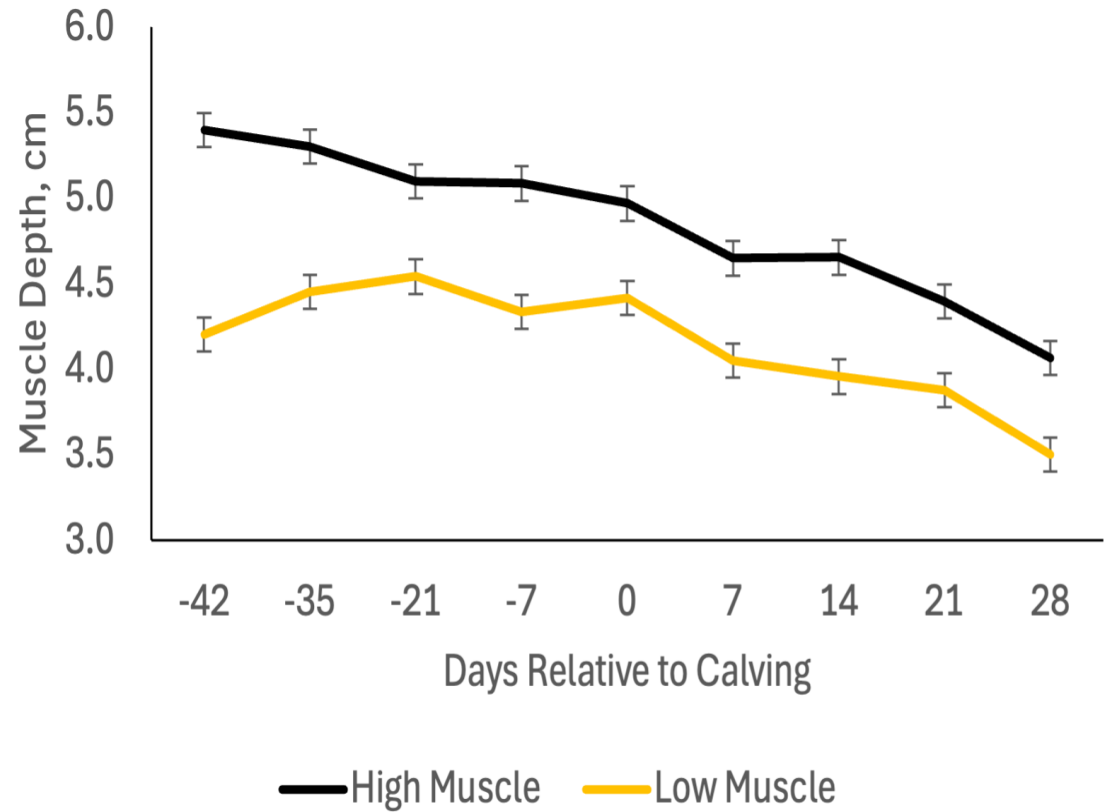
	High Muscle	Low Muscle	SEM	<i>P</i> -values
DMI, kg/d	13.7	13.3	0.47	0.52
BW, kg	789	762	22.3	0.38
BCS, 1-5 scale	3.61	3.29	0.06	<0.01
Glucose, mg/dL	78.6	76.8	0.89	0.16
BHB, mmol/L	0.61	0.60	0.02	0.76
Insulin, ng/mL	0.54	0.66	0.11	0.26

Prepartum Dam Muscle Depth - Calf Results

	High Muscle	Low Muscle	SEM	P-values
Birthweight, kg	48.8	45.2	1.04	0.01
Muscle metabolic activity, fluor g-1 h-1/1000	2,846	2,253	187	0.02
Creatinine, ng/μL	10.2	8.81	0.59	0.10
3-methylhistinine, ng/μL	3.78	3.13	0.38	0.21

- This effect does not appear to be the same in primiparous cows. No difference in calf birthweight with different amounts of prepartum muscle of primiparous dams. – Becky Coombe, to be presented at ADSA, 2025

Muscle Accretion and Depletion During the Transition Period



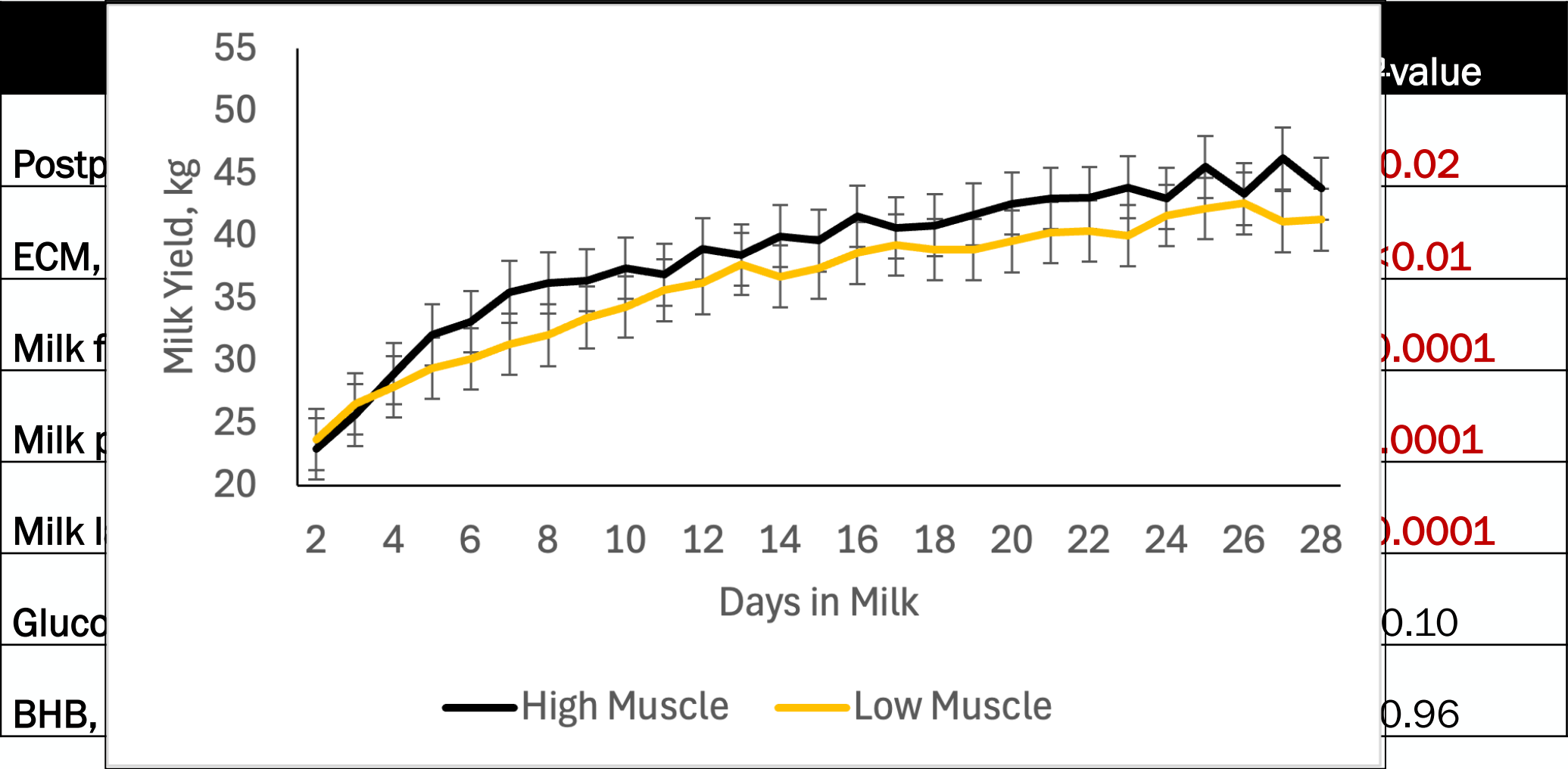
Production Results

14 lbs. of ECM based on muscle reserves

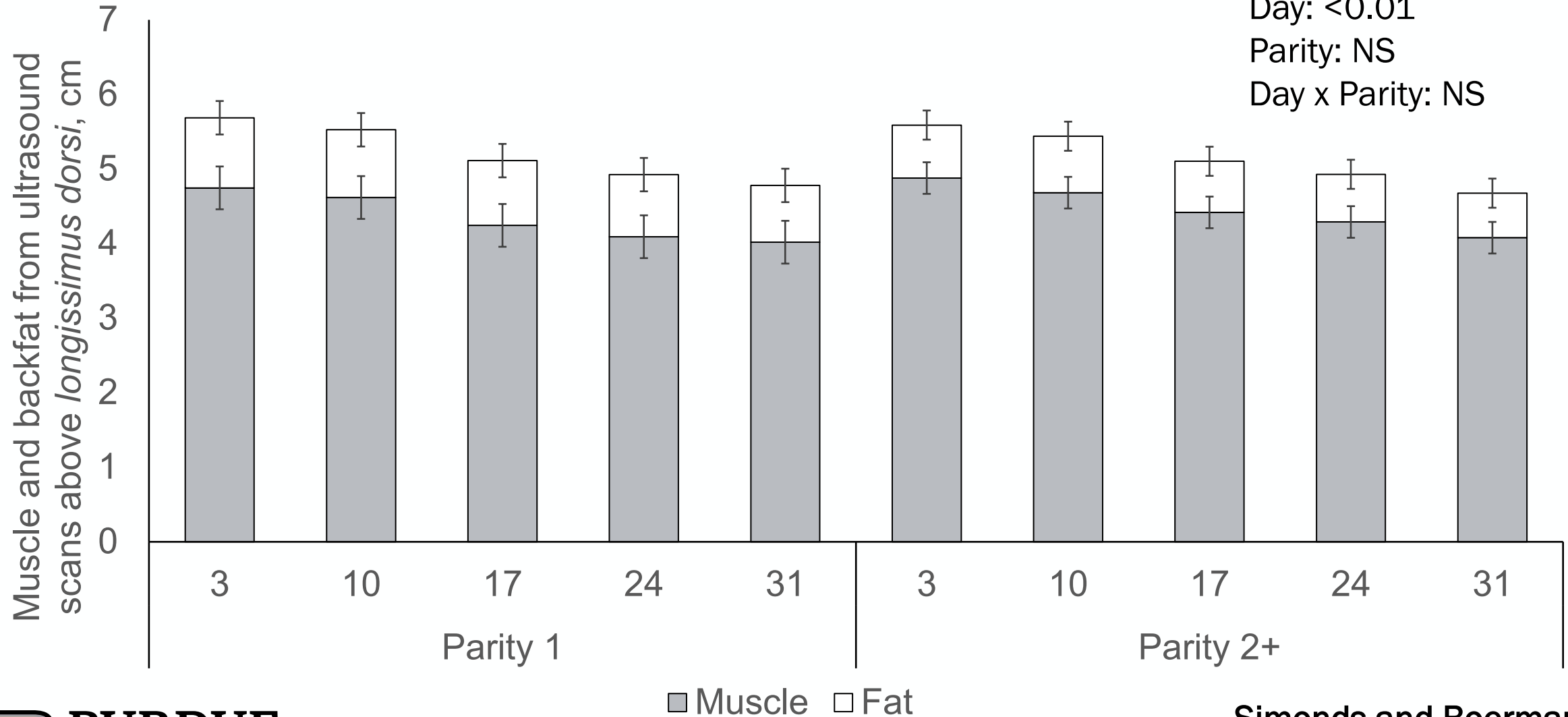
	High Muscle	Low Muscle	SEM	P-value
Postpartum DMI, kg/d	20.1	19.4	0.21	0.02
ECM, kg/d	47.8	41.4	1.06	<0.01
Milk fat, kg/d	1.90	1.63	0.05	<0.0001
Milk protein, kg/d	1.32	1.18	0.03	0.0001
Milk lactose, kg/d	2.04	1.76	0.05	<0.0001
Glucose, mg/dL	78.4	76.4	0.96	0.10
BHB, mmol/L	0.90	0.90	0.04	0.96

Production Results

14 lbs. of ECM based on muscle reserves



Parity Effects of Tissue Reserves After Calving



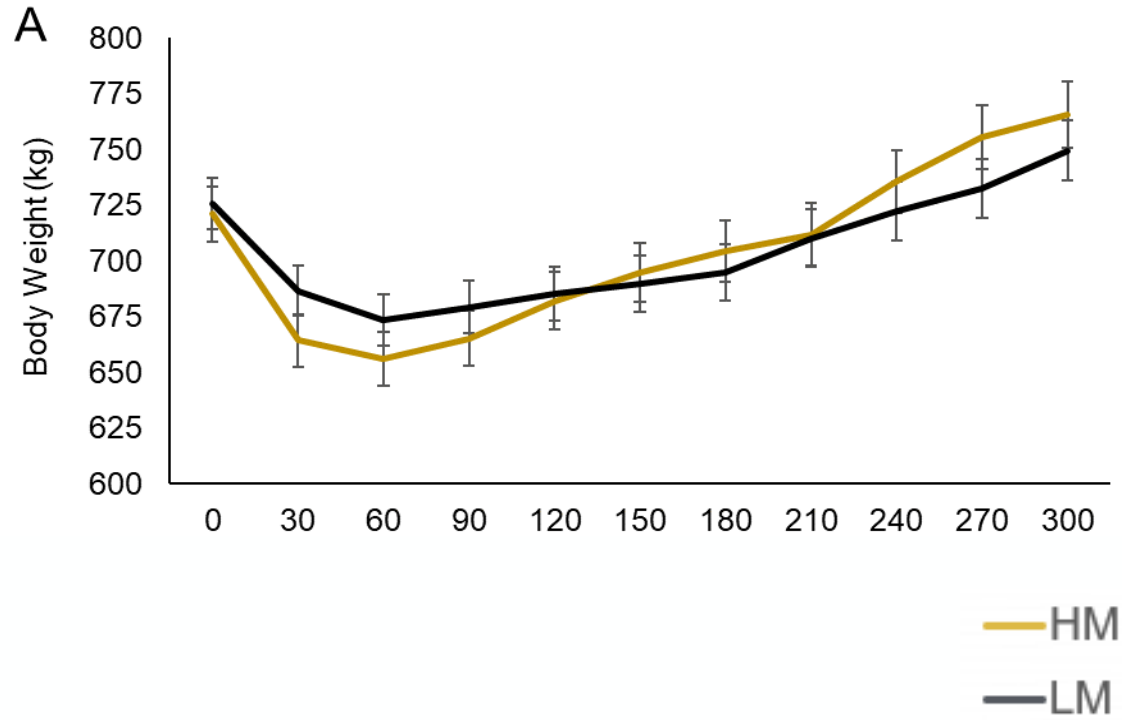
Simonds and Boerman,
preliminary data

Production and Body Composition Changes Across Lactation

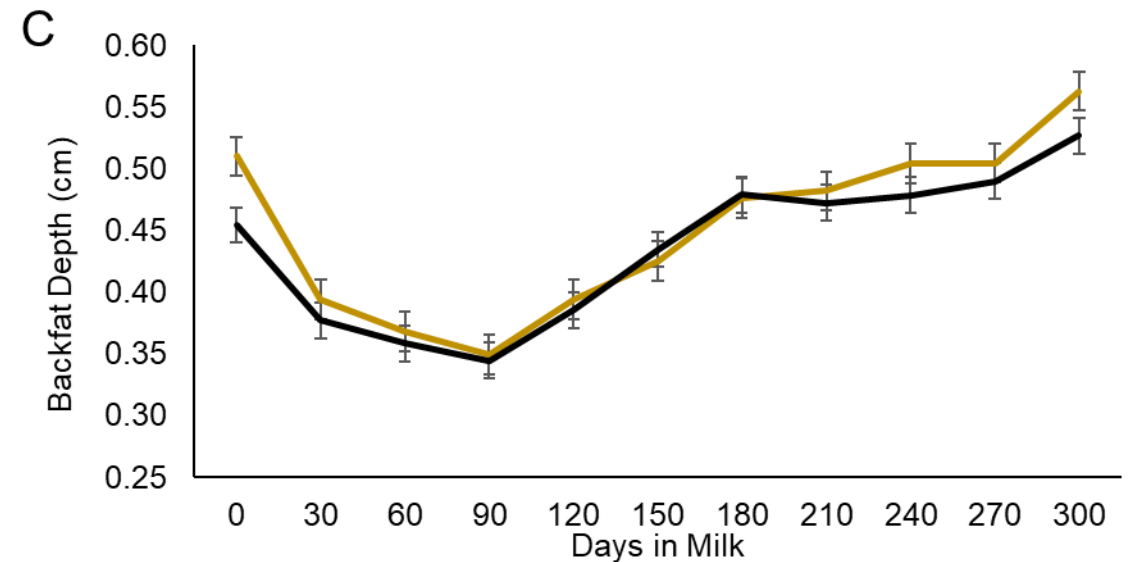
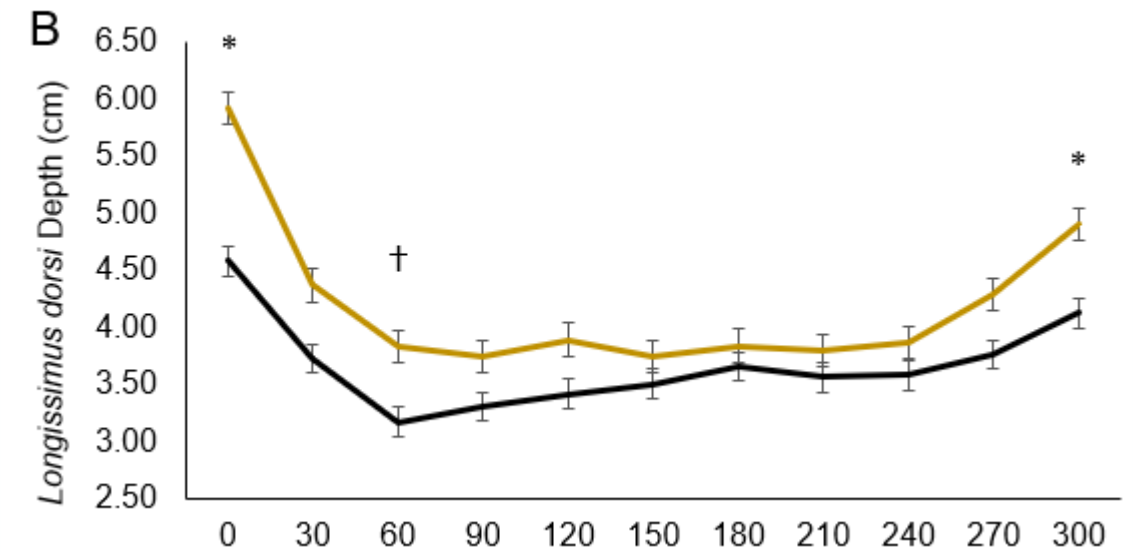
	0-60 DIM		60-240 DIM		240-300 DIM			P-values		
Variable	HM	LM	HM	LM	HM	LM	SEM	Muscle Group	Time	Muscle Group×Time
Milk Production										
Milk Yield (kg/d)	43.5	41.0	39.1	37.7	28.8	30.6	1.75	<0.01	<0.01	<0.01
Milk Fat (%)	4.15	3.84	4.21	4.00	4.04	4.11	0.11	0.05	0.50	0.12
Milk Protein (%)	3.03	3.09	3.29	3.31	3.48	3.52	0.05	0.23	<0.01	0.89
Absolute Change										
Δ Body Weight (kg)	-71.4	-45.8	65.1	61.5	26.3	29.5	8.70	0.20	<0.01	0.18
Δ Muscle Depth (cm)	-2.12	-1.42	0.01	0.41	1.04	0.54	0.16	0.09	<0.01	<0.01
Δ Backfat Depth (cm)	-0.15	-0.10	0.15	0.12	0.05	0.04	0.03	0.97	<0.01	0.17
Percent Change										
Δ Body Weight (%)	-9.0	-6.5	9.5	9.8	3.4	4.2	1.21	0.20	<0.01	0.60
Δ Muscle Depth (%)	-35.1	-30.8	2.8	13.9	26.7	15.2	3.85	0.65	<0.01	0.01
Δ Backfat Depth (%)	-28.4	-21.3	45.3	35.6	12.8	9.0	5.58	0.61	<0.01	0.27

Hanno et al., 2025

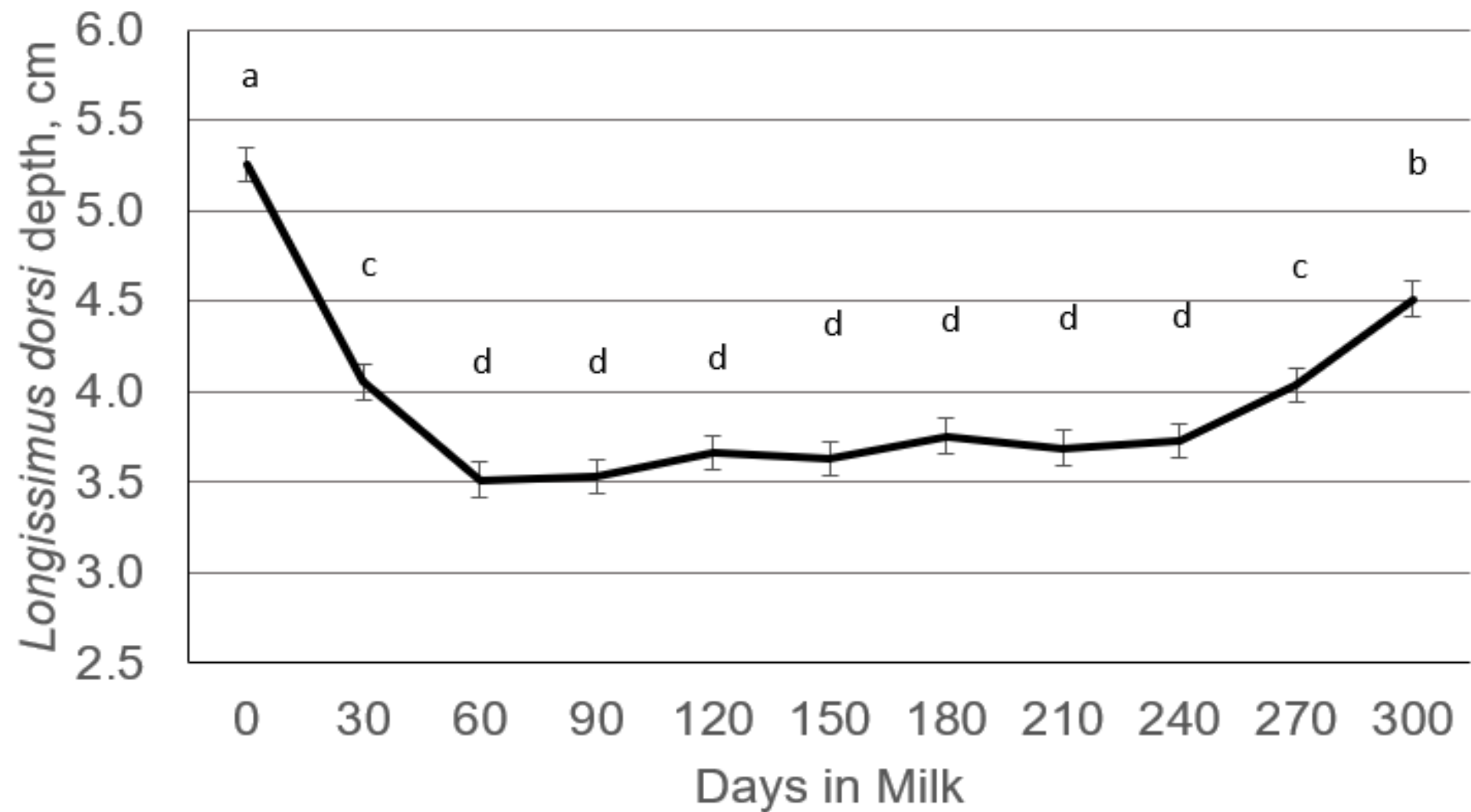
Body Composition Across Lactation



Hanno et al., 2025



Timing of Muscle Depletion and Accretion Throughout Lactation

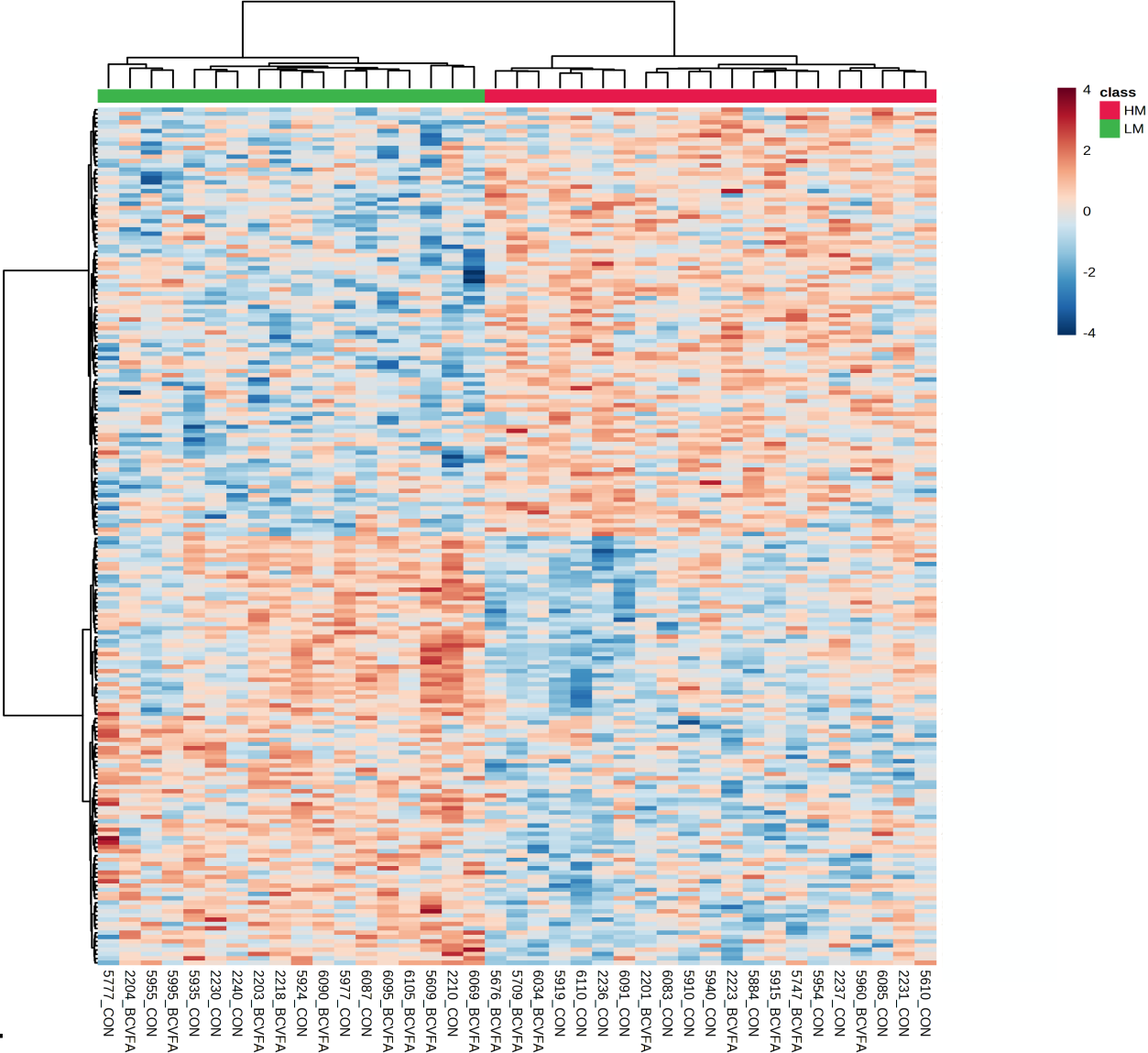
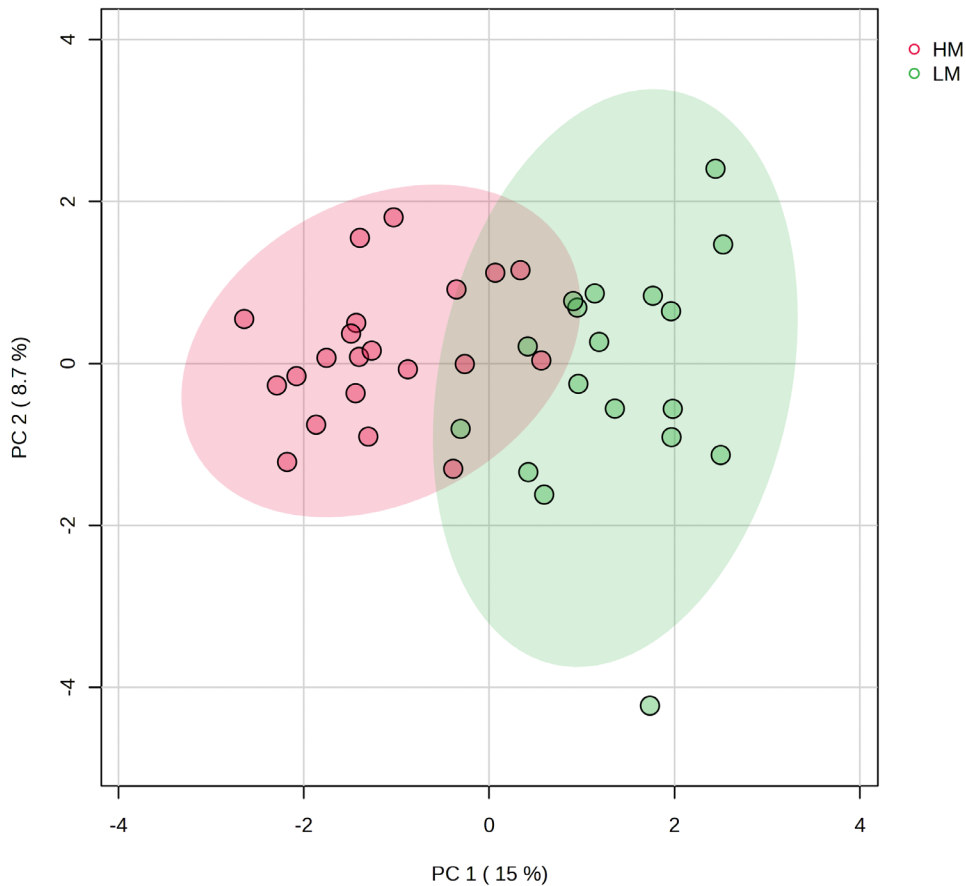


Tissue Accretion/Depletion Related Metabolites Across Lactation

Variable	7 DIM		150 DIM		300 DIM		SEM	<i>P</i> -values		
	HM	LM	HM	LM	HM	LM		Muscle Group	Time	Muscle Group×Time
3-MH (ng/μL)	2.09	1.86	2.16	1.78	0.99	0.97	0.18	0.19	<0.01	0.54
Creatinine (ng/μL)	5.95	5.75	4.43	4.43	5.97	5.80	0.27	0.60	<0.01	0.91
3-MH: Creatinine	0.35	0.33	0.49	0.46	0.17	0.17	0.04	0.60	<0.01	0.89
NEFA (mmol/L)	0.54	0.54	0.13	0.12	0.11	0.12	0.04	0.97	<0.01	0.99
Insulin (μIU/mL)	0.39	0.37	0.40	0.35	0.64	0.62	0.08	0.52	<0.01	0.97

Differentiation Between High and Low Muscle Cows (Prepartum)

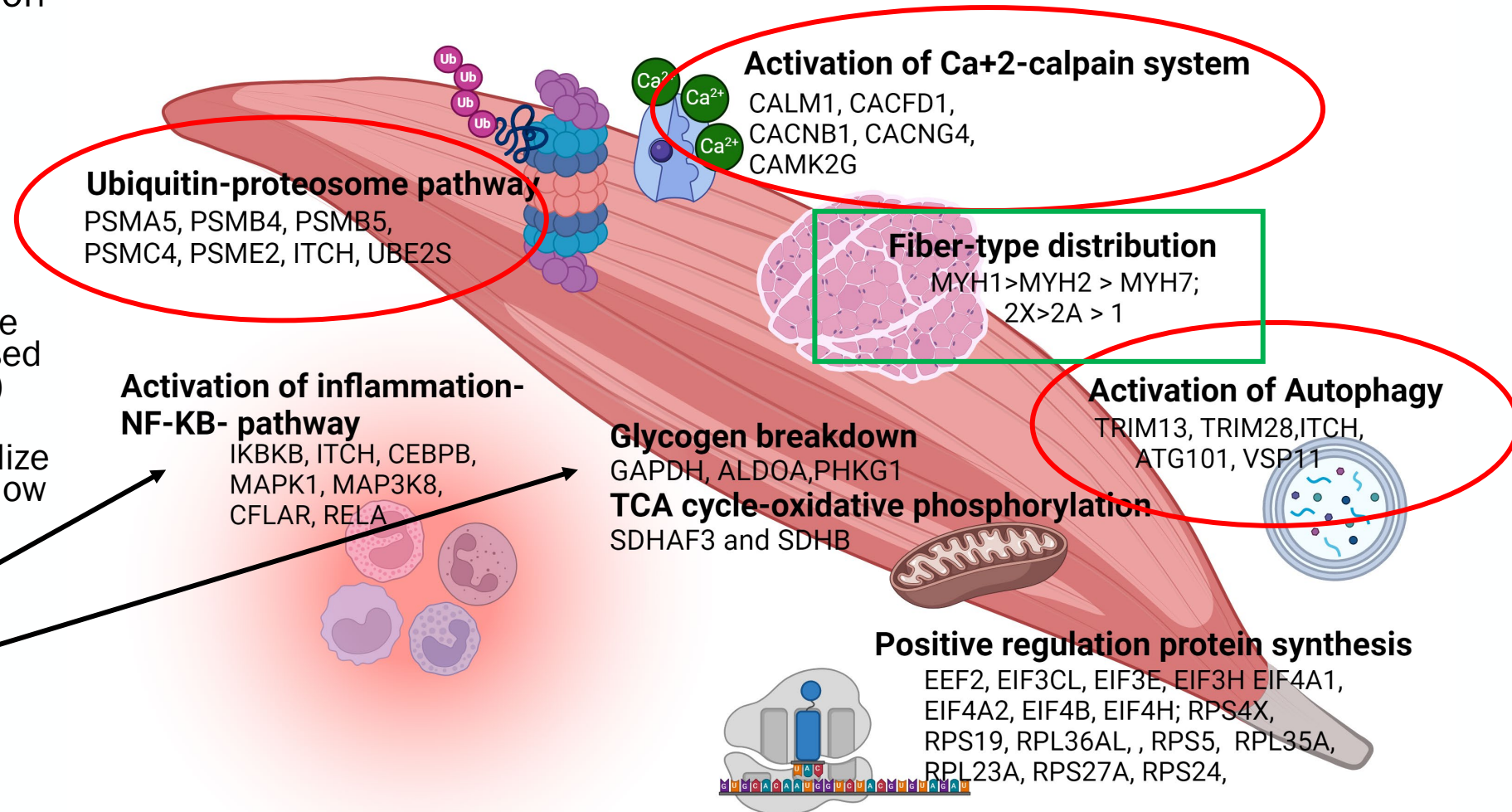
Scores Plot



Distinct Molecular Signatures Based on Prepartum Muscle

Transcriptional signature of low muscle cattle in late gestation

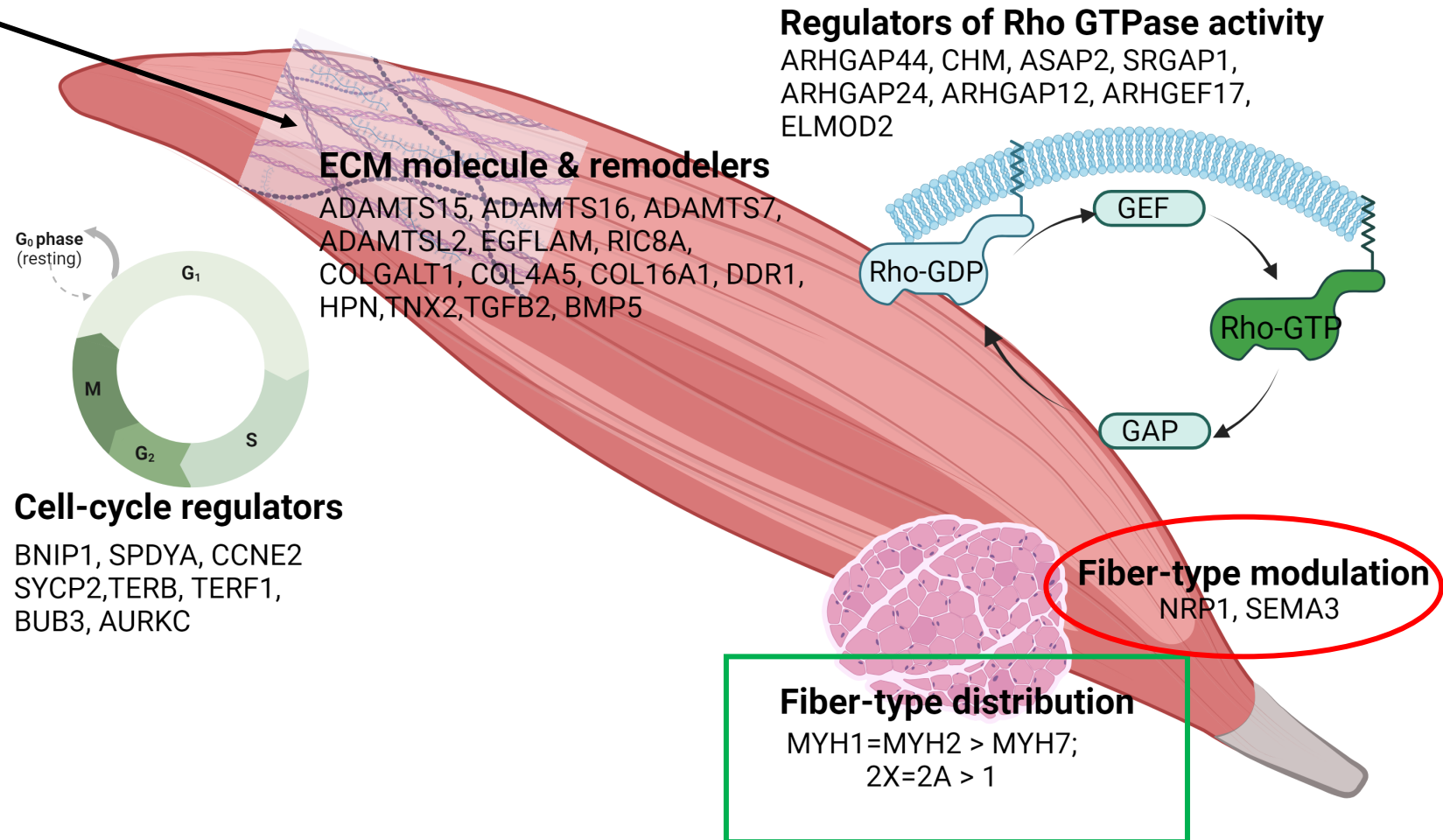
- Increased in all 3 pathways related to protein degradation
 - Ubiquitin-proteasome pathway
 - Ca²⁺-calpain system
 - Autophagy – lysosomal
- Myofiber Type IIx > IIa > I
 - Type IIx – primarily rely on anaerobic respiration, more glycogen storage – increased use of glucose (fast twitch)
 - Type I – primarily rely on aerobic respiration and utilize glucose more efficiently (slow twitch, endurance)
- Increased inflammation pathways
- Increased glycogen breakdown



Distinct Molecular Signatures Based on Prepartum Muscle

Transcriptional signature of high muscle cattle in late gestation

- Changes in extracellular matrix
- Different muscle fiber type distribution $IIx = IIa > I$
 - More Type IIa – more efficient use of glucose and more mitochondria compared to IIx
- Fiber type modulation potentially impacting myofiber switching
- Why could this matter → can be a metabolic adaptation to conserve more efficient muscle fibers



Casey et al., 2024

Summary

- Cows lose skeletal muscle postpartum but also can lose muscle prepartum, depending on muscle reserves
 - Mobilizing 30-35% of their muscle depth (not all protein)
- Cows accrete skeletal muscle at the end of lactation
 - Ended lactation with less muscle than at calving
- High muscle reserves → more higher calf birthweights and more milk yield (most of the time)
- There does not appear to be large parity effects for skeletal muscle
 - Cows continually accrete muscle and then deplete across lactations

Take Away Messages

- Considerable variation exists between cows for tissue mobilization, extent of mobilization was dependent on amount of tissue
- Muscle mobilization occurs prior to fat mobilization, need for AA at the end of gestation
- We are not accounting for muscle gain during the dry period in transition cows when it comes to MP requirements.
 - Cows with little muscle reserves can gain muscle during this time and can draw on it in early lactation
 - Cows with higher muscle reserves use this muscle in late gestation and early lactation

Acknowledgements

- Dr. Theresa Casey – Lactation Biologist
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 - Sam Hanno
 - Madi Simonds
 - Becky Coombe
- Postdoc – Dr. Linda Beckett
- Purdue Dairy Farm Staff and Undergraduates
- USDA – NIFA # 2022-67015-36317

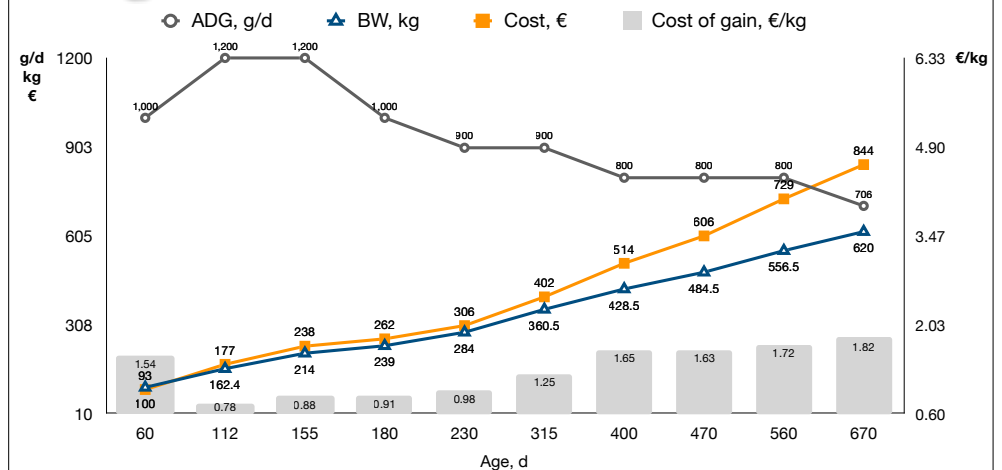


Getting the most out dairy replacements: Key nutrition and management aspects

Alex Bach



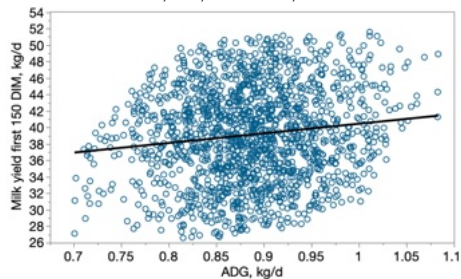
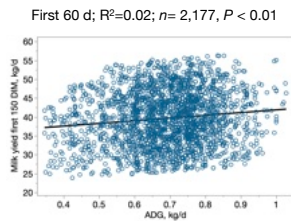
Targets



Setting the stage

- The weeks following weaning are the most interesting to promote BW accretion because of its economic returns (FE ~35%, a low feed cost)
- ADG during the post-weaning period has been positively correlated with future milk production (Shamay et al., 2005; Bach and Ahedo, 2008)

$n = 1,618$; $R^2 = 0.02$; $P < 0.01$

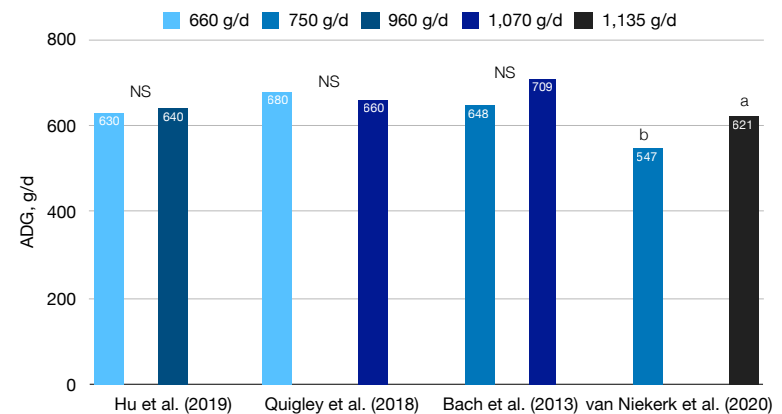


Bach et al. (2021)

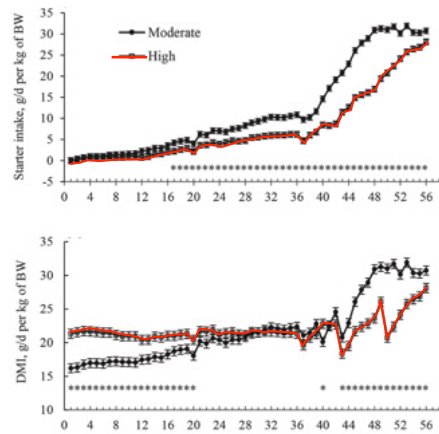
Pre-weaning

Milk replacer

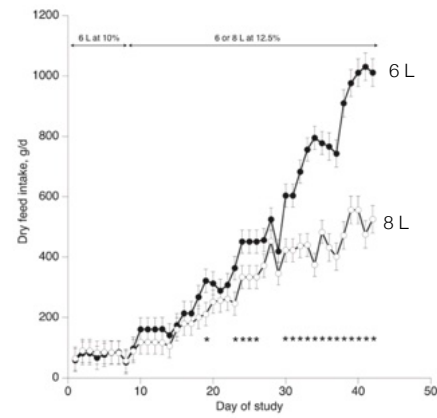
- Low or high MR allowances may result in equivalent total ADG and FE



Liquid feeding



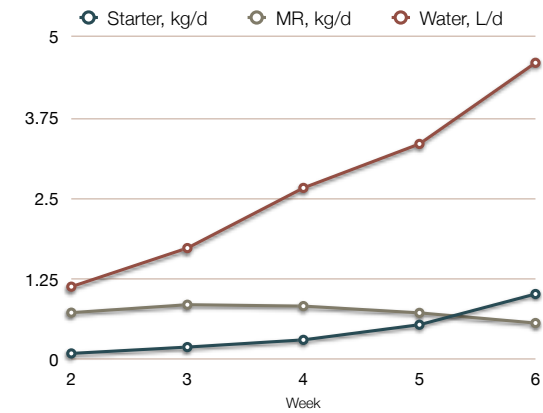
Hu et al. (2019)



Bach et al. (2013)

Liquid feeding

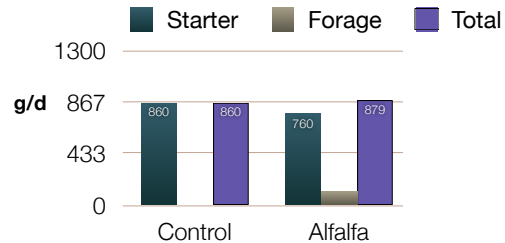
Water



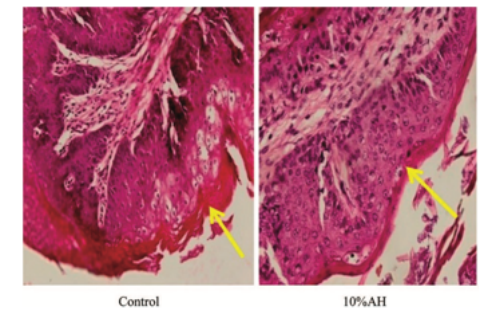
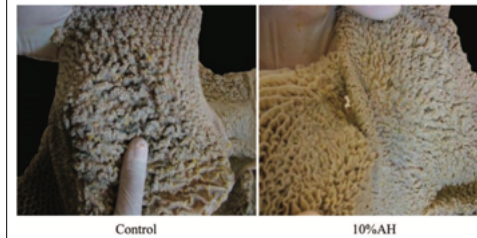
Ensuring a minimum ratio of 4.5 L of water:1 kg of starter intake (about 2.5 L/kg of DMI)

Solid feeding

- A common recommendation for feeding calves is to offer just starter and no forage before weaning (Quigley, 1996; Davis and Drackley, 1998, NRC, 2001)
- Castells et al., (2012) concluded that offering chopped forages (2 cm) may increase total intake



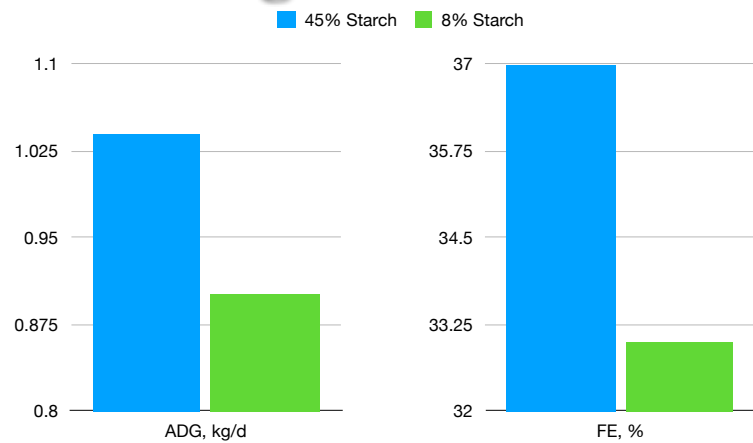
Solid feeding



Beiranvand et al. (2014)

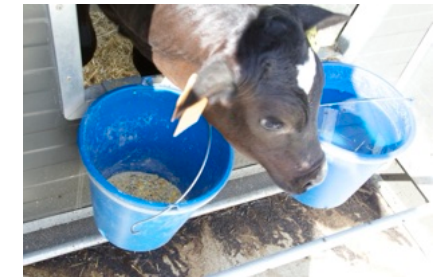
Pre-weaning

Solid feed

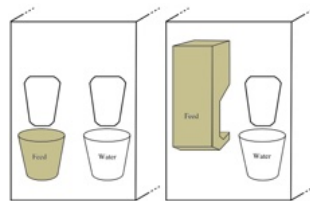


Aragona et al. (2020)

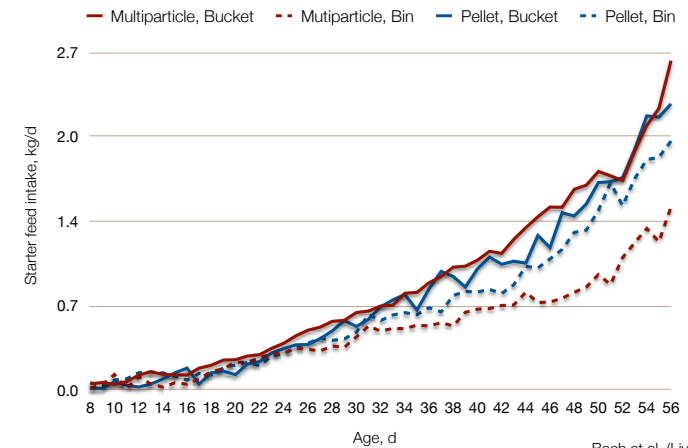
How the feed is offered matters



How the feed is offered matters



How the feed is offered matters



Bach et al. (Livestock Sci., 2010)

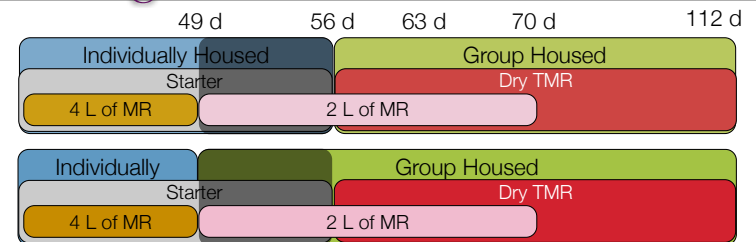
Solid feeding

Use palatable ingredients to foster solid feed intake

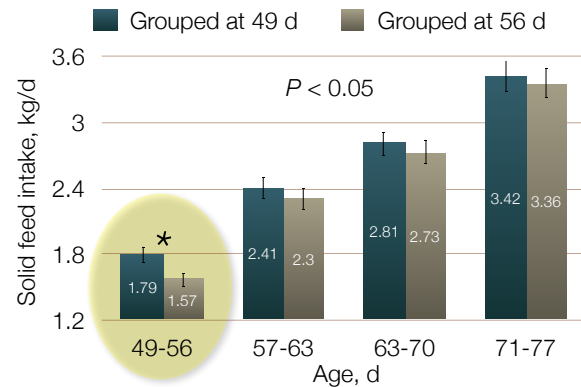
Wheat	Soybean meal
Sorghum	
Corn	
Barley	
Wheat midds	DDGs
Oats	Sunflower
Rice	Peas
Corn gluten feed	Rapeseed meal
	Corn gluten meal

Montoro et al., 2009

Calf Management



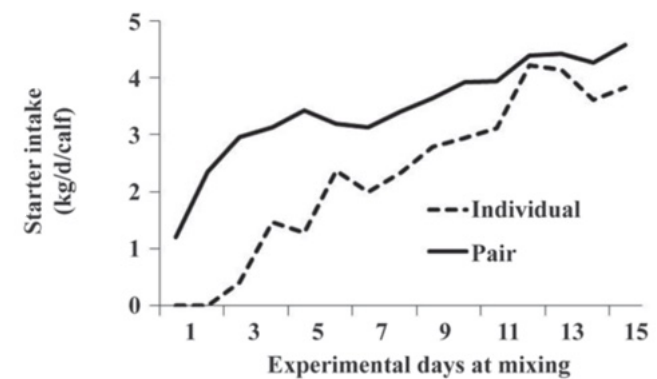
Calf Management



Grouped calves consumed more solid feed than those individually housed

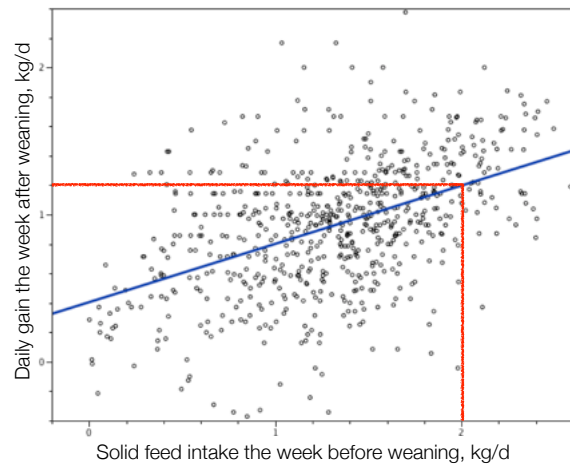
Bach et al. (2010)

Calf Management



de Paula Vieira et al. (2010)

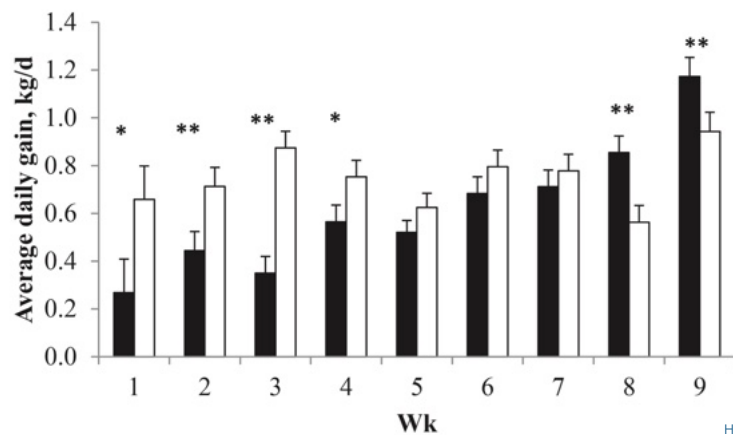
When to wean



Weaning methods

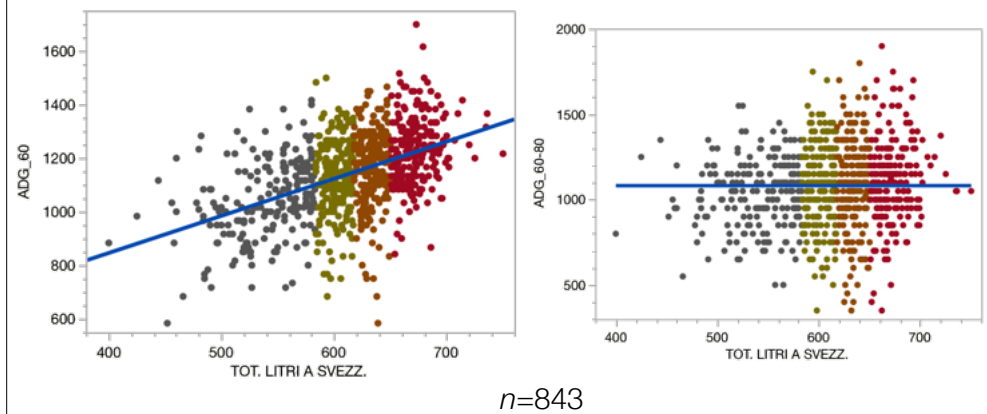
- Reduce the amount of milk at each milk offer (AM and PM) 3 or 2 weeks before weaning
- Reduce the frequency of milk offer the week before weaning

Achieving Growth Targets



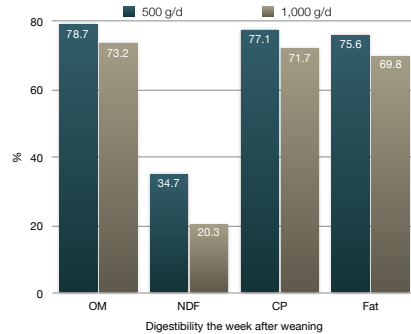
Haisan et al. (2019)

Achieving Growth Targets

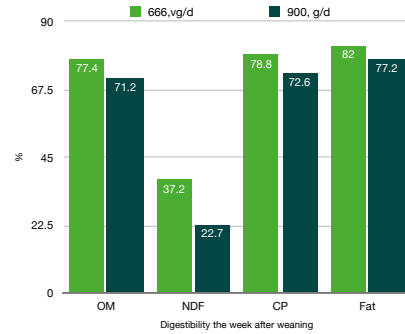


Post-weaning

- The Differences in FE, and ADG, are greatly influenced by the feeding strategy of calves during pre-weaning as well as feeding regimes offered after weaning

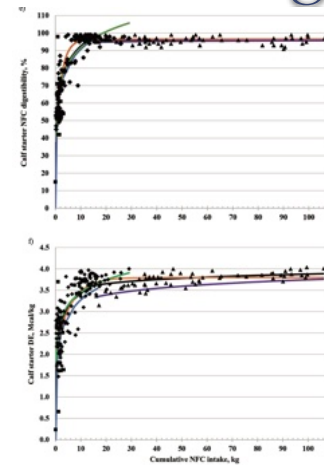


Terré et al. (2007)



Hu et al. (2019)

Post-weaning



- The cumulative NFC intake from starter (and not daily intake at any given time) explains a large proportion of the difference in digestibility

Quigley et al. (2019)

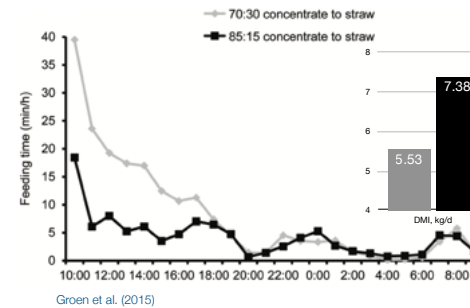
Health

- Most research studies and producers feed right after weaning 5-10% of forage (chopped or long)
- 'Magically', when MR is removed calf seem to gain the ability of digesting forage... (??)

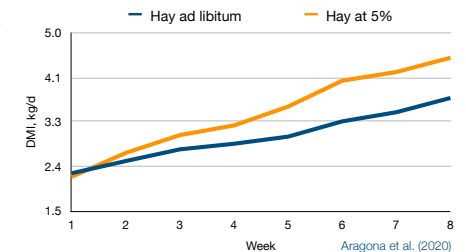


Post-weaning

- Providing excessive amounts of forage during post-weaning will limit intake, even if chopped



Groen et al. (2015)

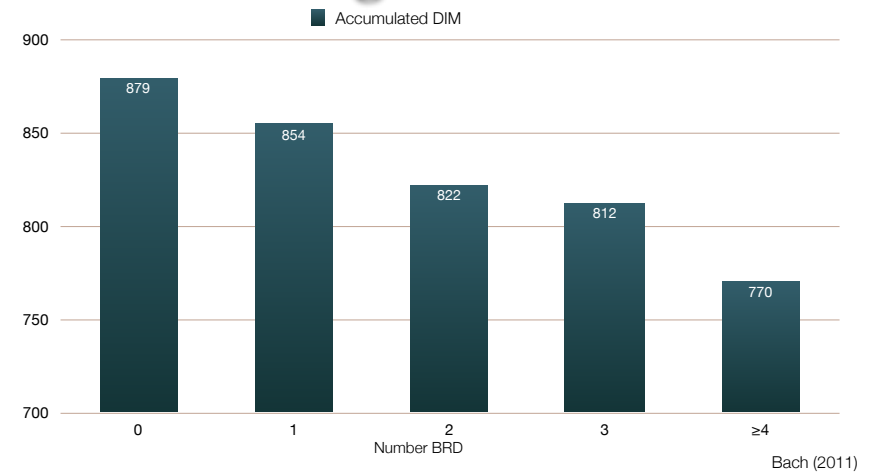


Aragona et al. (2020)

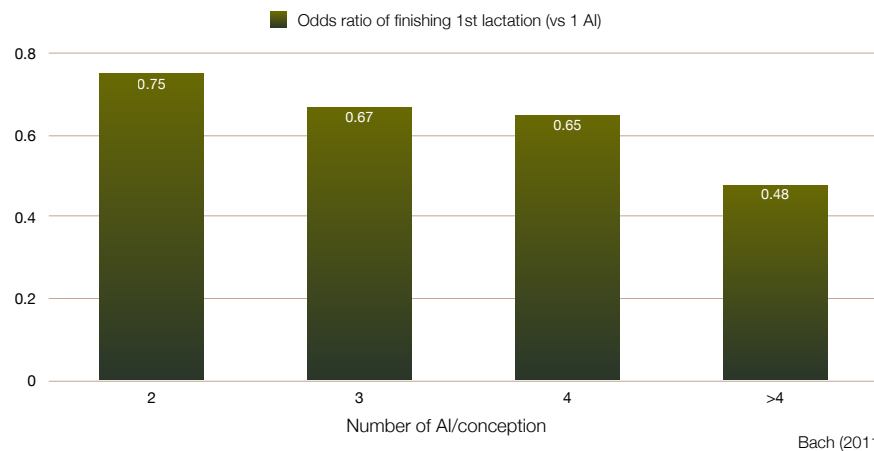
Post-weaning

70-100 d	100-180 d	180-240 d
20% CP	19% CP	18.5% CP
17% NDF	19% NDF	20% NDF
3.2 Mcal of ME	3.1 Mcal of ME	2.8 Mcal of ME
8% forage	8-10% forage	12-15% forage

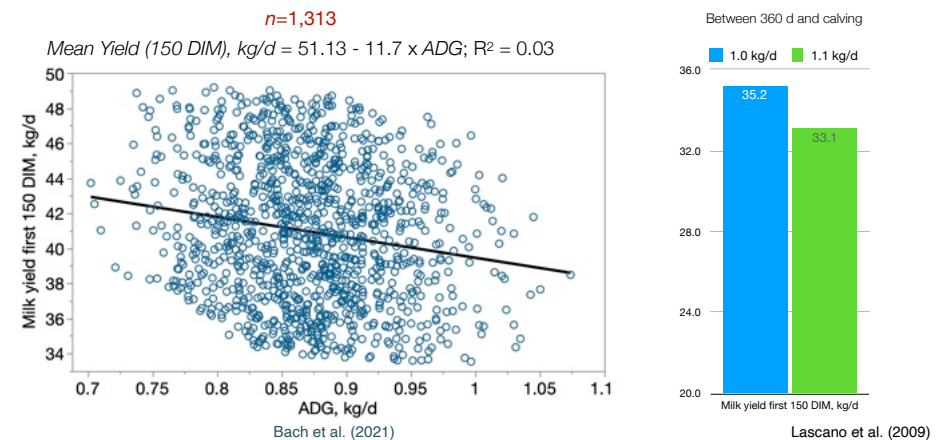
Pro-Active Mangement



Management Aspects



Breeding and Pregnancy

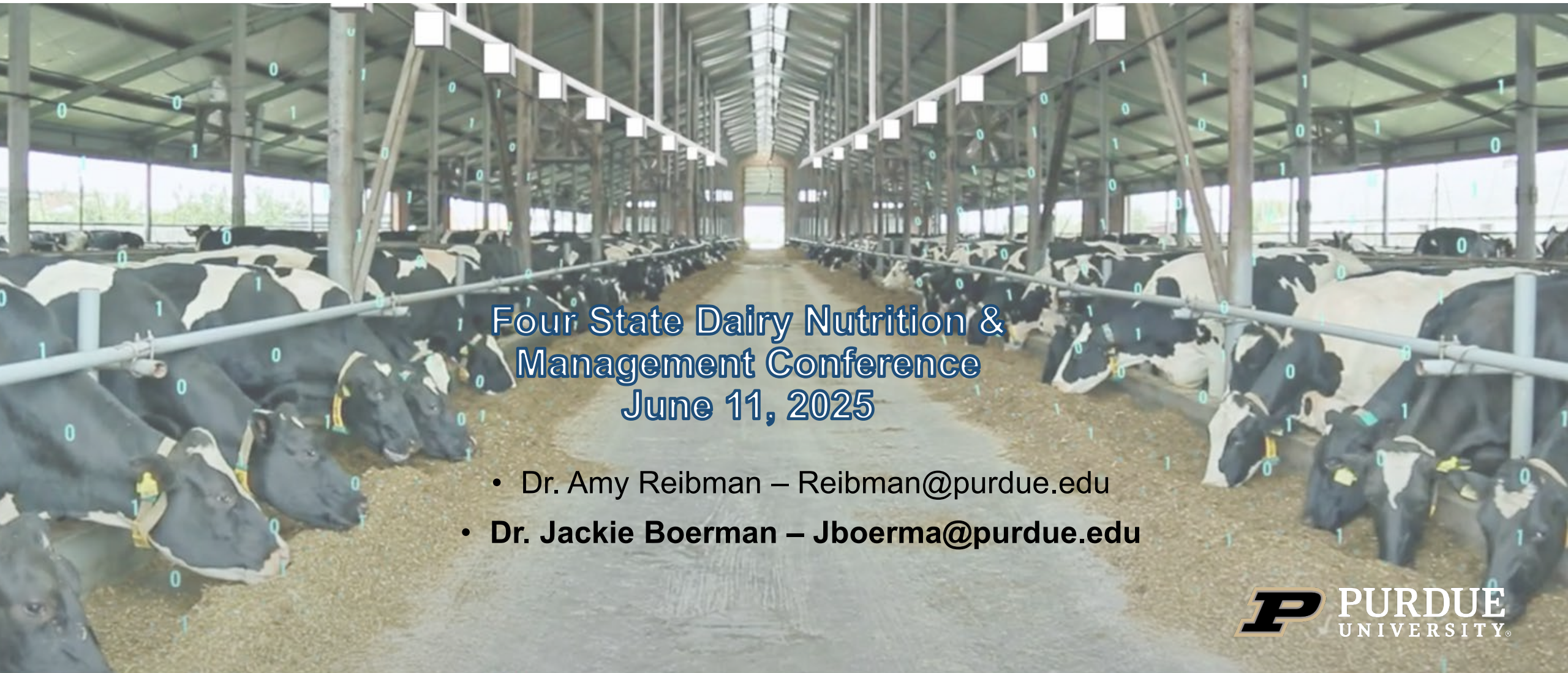


Conclusions

- Ensuring rapid growths early in life reduces rearing costs and improves performance at adulthood
- Find the right balance between solid and liquid feed
- There is not such a thing as “digestible fiber” to calves
- Group calves early
- Wean progressively
- Limit forage post-weaning
- Grow slowly after breeding



Feed Video: What we can extract from video related to dairy nutrition



Four State Dairy Nutrition &
Management Conference
June 11, 2025

- Dr. Amy Reibman – Reibman@purdue.edu
- Dr. Jackie Boerman – Jboerma@purdue.edu

Overall Project Goals



To design a video system to measure diet uniformity of TMR



To design a video system to measure individual intake of group housed animals



To integrate data across technologies to measure feed efficiency (milk or components per cow / DMI) of cows in a group housed setting



To implement potential end users input to improve the development of the systems



What is Video Analytics

- Video analytics – automatically extract usable, actionable information from video
 - Anything you can see visually (and sometimes things you can't see and infrared or hyperspectral) we can convert to information from video
- Precision livestock farming – use detailed knowledge/measurements of individual animals to optimize management decisions and management practices
 - Can include sensors and wearables that provide information about individual animal performance and also data extracted from video



Video Applications on Dairy Farms

- Commercial applications
 - Cainthus – feedbunk management
 - Viking Genetics – estimating intake of cows
 - Cattle Eye – lameness detection
 - Maternity Warden – video monitoring of calving pens
- Research applications we are pursuing at Purdue University
 - Feed consistency
 - Feed intake
 - Body weight estimation
 - Lameness detection



Feed and Diet Uniformity Background

- Feed costs are largest expense for dairy farms
 - Dairy industry spending over \$25 billion annually for lactating cows
- Video for feeding management
 - 3 diets on the farm (formulated, **delivered, consumed**)
- Existing feed management software exists
 - Provide information about ingredient order, amounts, and mixing time
- Nutritionists and consultants have been performing TMR audits for years to assess diet uniformity
 - Have provided insight on how to improve diet uniformity and the value of diet uniformity
 - **What is missing is automatic measurements of diet uniformity**



Videos of Feed Mixing

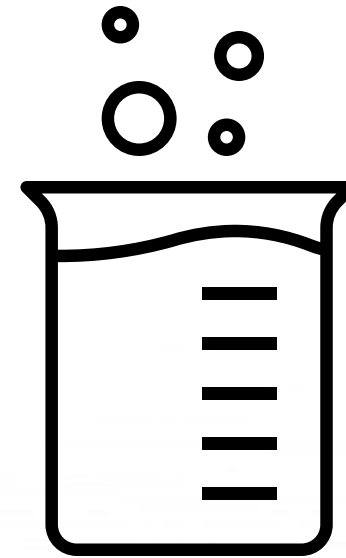


Current Methods to Assess Diet Uniformity

Particle size distribution



Nutrient content distribution

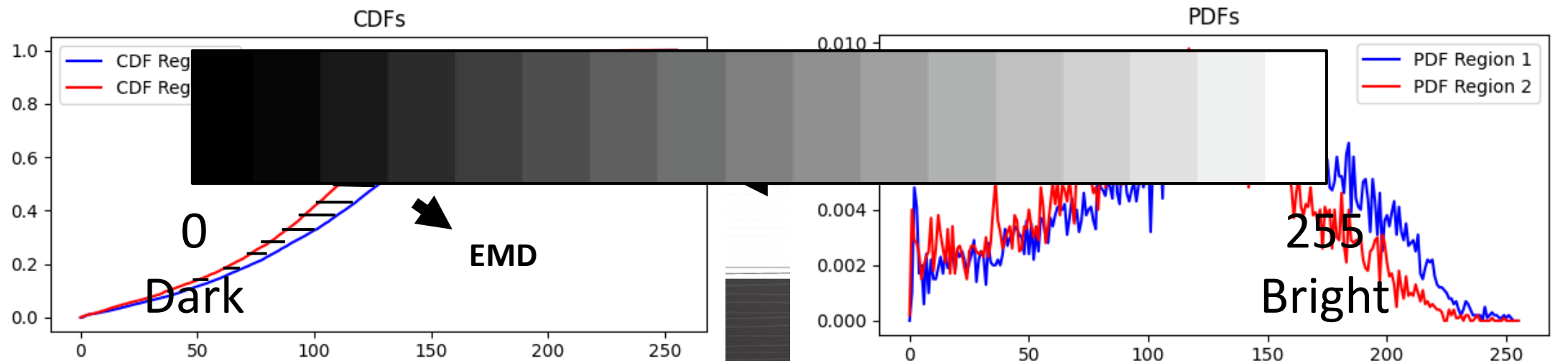


Coefficient of variation (CV) along the bunk



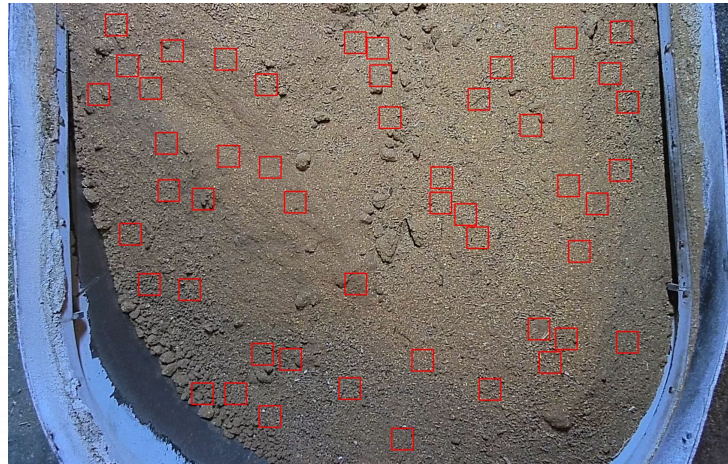
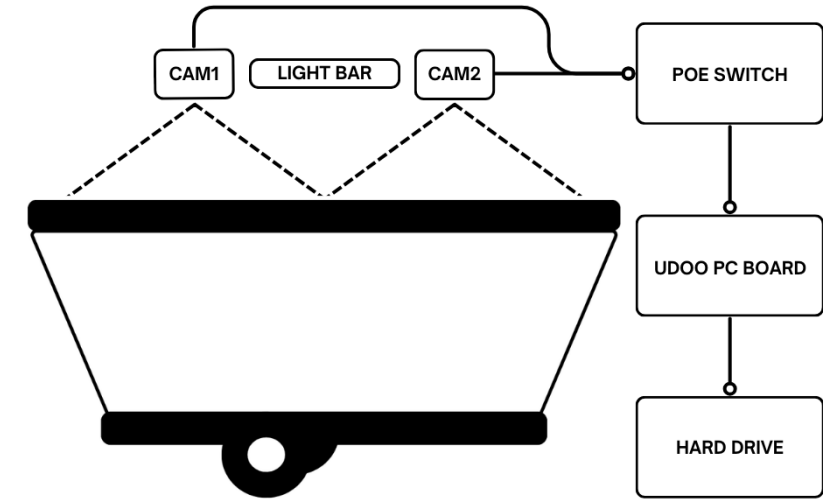
Methods – Software Functionality

PhD work of Isabela Santos



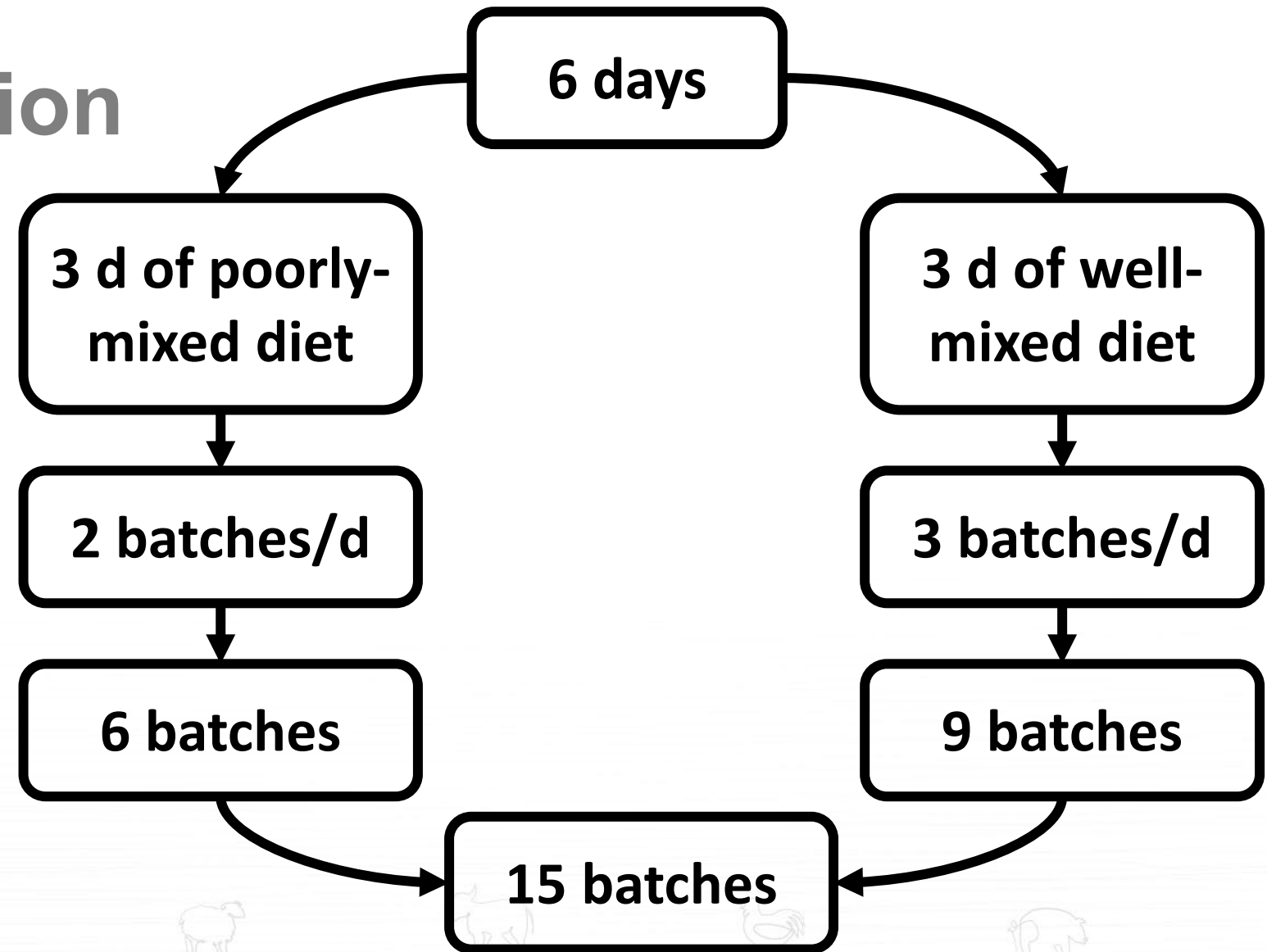
Methods – Data Collection

- Cameras mounted above the mixer wagon
- Observing feed during the mixing process
- Comparing 100 regions across the mixer for 4,950 pairwise comparisons per frame

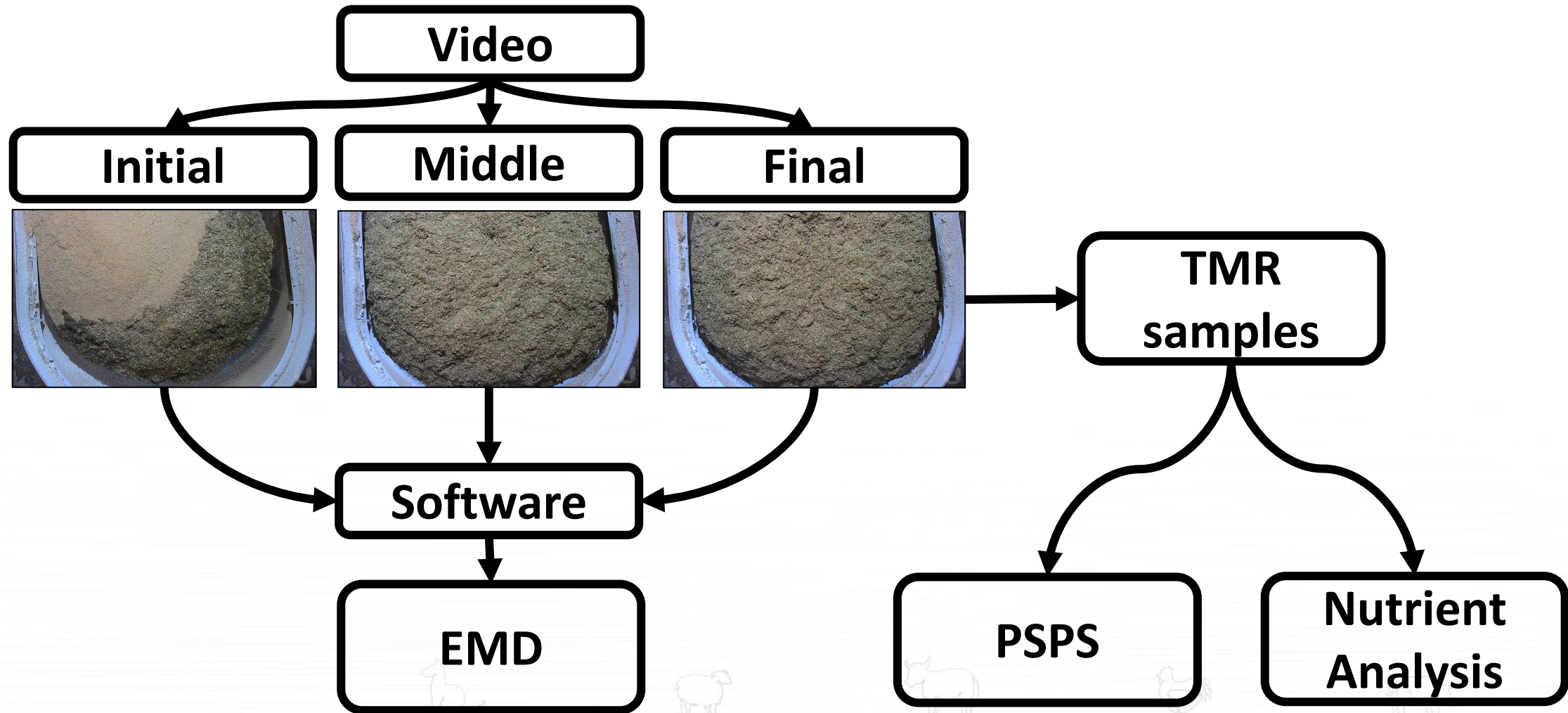


Data Collection

- Penta 4430 Hurricane – 440 cubic ft capacity
- Poorly-mixed diet
 - 9,600 lbs. mixed for 3 minutes
- Well-mixed diet
 - 6,280 lbs. mixed for 10 minutes



Methods – Data Collection



Comparing Poorly-Mixed and Well-Mixed Diets

Variable	Poorly-Mixed Diet		Well-Mixed Diet	
	Mean	CV	Mean	CV
Dry matter, %	49.0	5.89	46.1	0.97
Protein, %	17.6	8.32	18.0	3.61
Fat, %	3.45	5.80	3.14	2.85
Ash, %	7.41	4.72	7.70	1.83
ADF, %	12.7	9.79	15.3	4.61
NDF, %	22.8	11.3	25.5	4.98
Mn, ppm	74.7	14.6	69.5	3.83
Zn, ppm	95.6	16.7	88.8	6.31
Penn State Particle Separator				
Upper sieve, %	1.64	36.3	1.64	20.4
Middle sieve, %	49.7	11.2	43.0	2.92
Lower sieve, %	15.1	4.9	15.8	3.21
Bottom pan, %	33.5	18.3	39.6	2.83
Mean particle size, mm	6.46	12.3	5.68	2.28

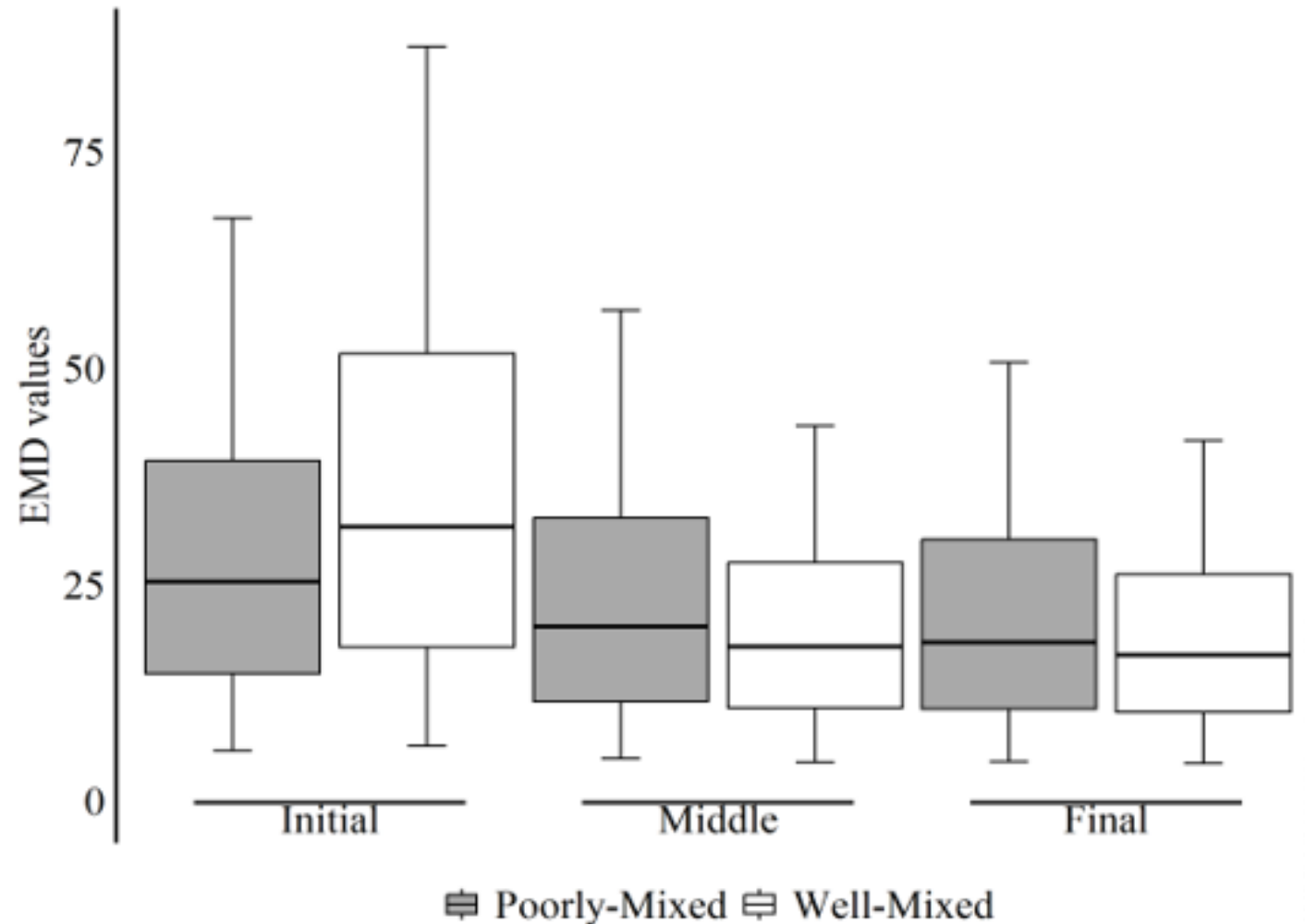


Results – Comparing Ground Truth Values

CV	Mn, ppm	Zn, ppm	Upper sieve, %	Middle sieve, %	Lower sieve, %	Bottom pan, %	Mean particle size, mm
Mn, ppm	1						
Zn, ppm	0.95 (<0.01)	1					
Upper sieve, %	0.80 (<0.01)	0.83 (<0.01)	1				
Middle sieve, %	0.95 (<0.01)	0.96 (<0.01)	0.87 (<0.01)	1			
Lower sieve, %	0.43 (0.11)	0.53 (0.04)	0.64 (<0.01)	0.57 (0.03)	1		
Bottom pan, %	0.93 (<0.01)	0.94 (<0.01)	0.87 (<0.01)	0.99 (<0.01)	0.56 (0.03)	1	
Mean particle size, mm	0.95 (<0.01)	0.95 (<0.01)	0.87 (<0.01)	0.99 (<0.01)	0.56 (0.03)	0.99 (<0.01)	1

Video Results

- Reduction in EMD (median and confidence interval (CI)) from initial to final frame for both conditions
- Reduction in CI for well-mixed diet compared to poorly-mixed diet



Comparing Traditional Methods to Video

CV for mineral and particle size distribution	Earth mover's distance for frame evaluation
Mn, ppm	0.65 (<0.01)
Zn, ppm	0.64 (0.01)
Upper sieve, %	0.65 (<0.01)
Middle sieve, %	0.68 (<0.01)
Lower sieve, %	0.23 (0.40)
Bottom pan, %	0.65 (<0.01)
Mean particle size, mm	0.67 (<0.01)



Implications

- Monitor feed consistency for all batches in a daily-basis
 - Especially important in small batches
- Provide near real-time feedback while TMR is being mixed
 - Do not need to wait until TMR is fed (too late)
- Data-driven decision-making for farm management and performance tracking

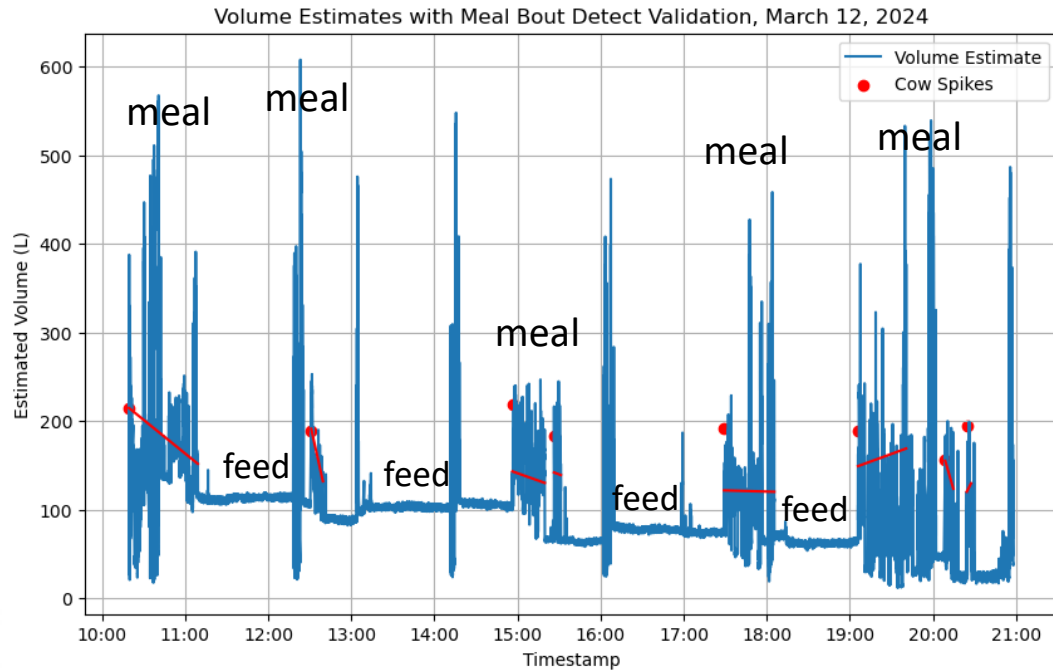


Estimating Feed Volume: Goals

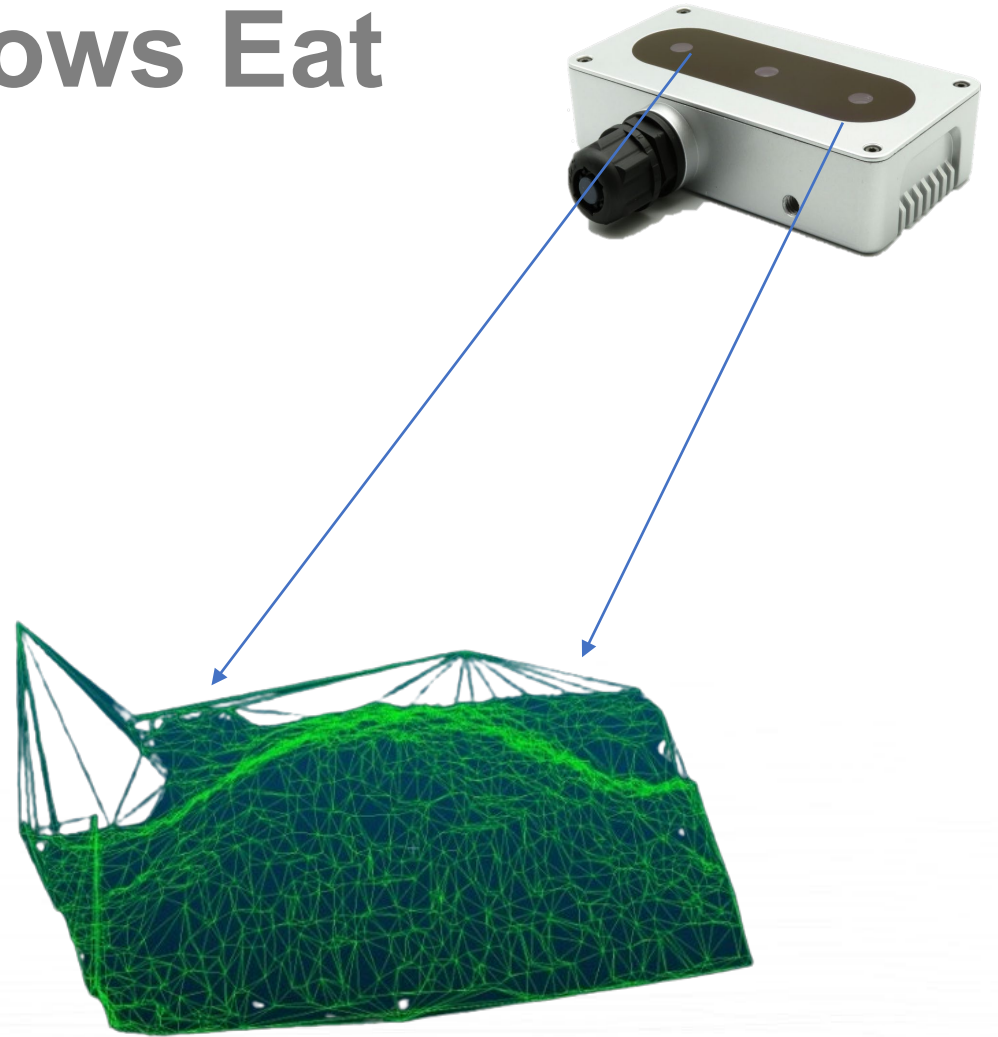
- Design and deploy a camera recording system that collects data from the feed bunk throughout the day
- Apply video analytics to measure volume of feed on offer
- Design automated system to estimate per-cow per-day feed intake
 - No modification to the daily routine of farmers or cows



Predicting How Much Cows Eat



- Cameras mounted above feed bunk
- Predict volume of feed available to cow before eating and after eating
- Differences between meals is intake



Next Steps for Predicting Individual Intake

- Connecting identity of the cow at meal bout with feed volume before and after meal
 - Fully automated system to learn new identities and track individuals both in the parlor and in the open barn with group housing
 - Integrating video observations and other data from multiple sources
- Expanding study into group housed environment with 2 diets that differ in density
 - Evaluating various conditions that may impact volume estimates

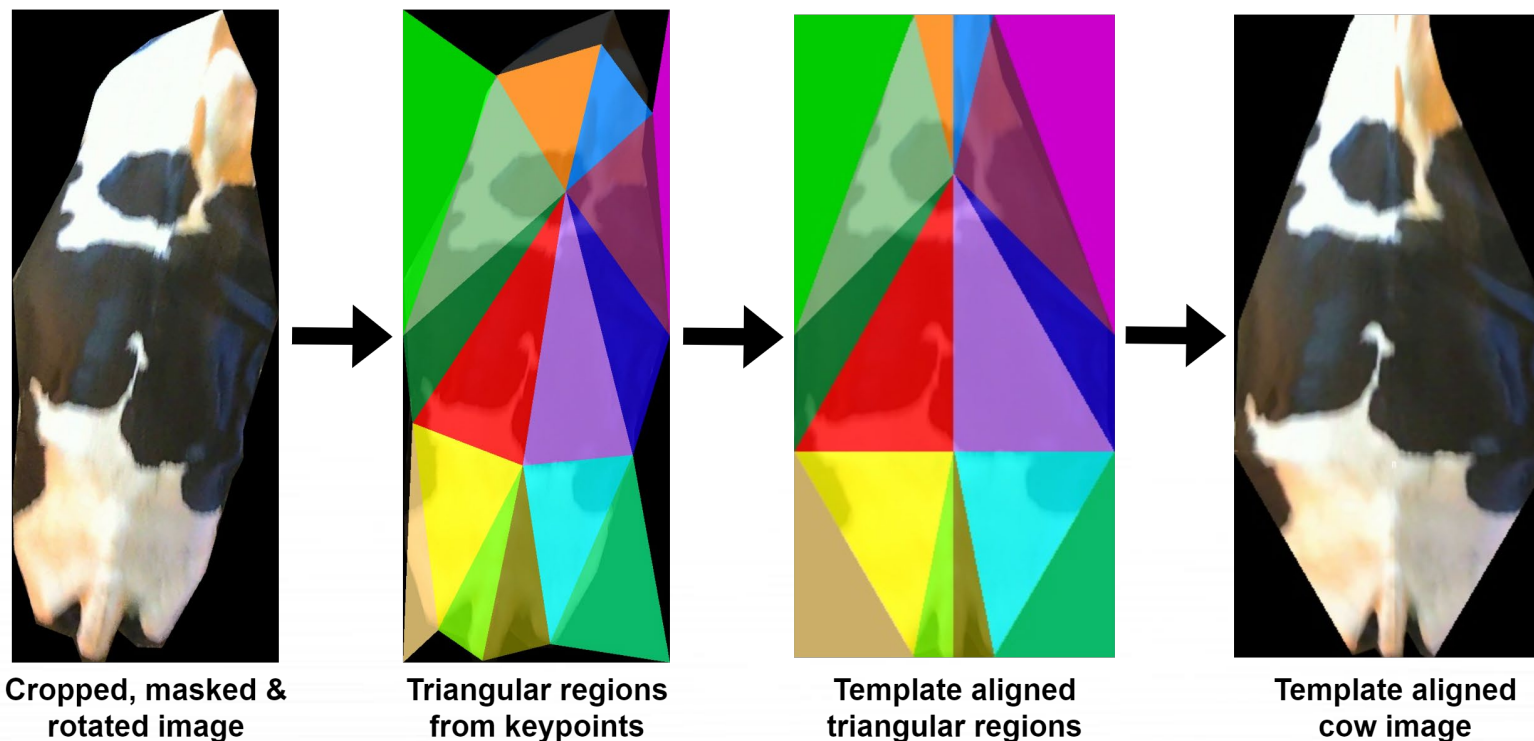


Identity from Different Camera Angles



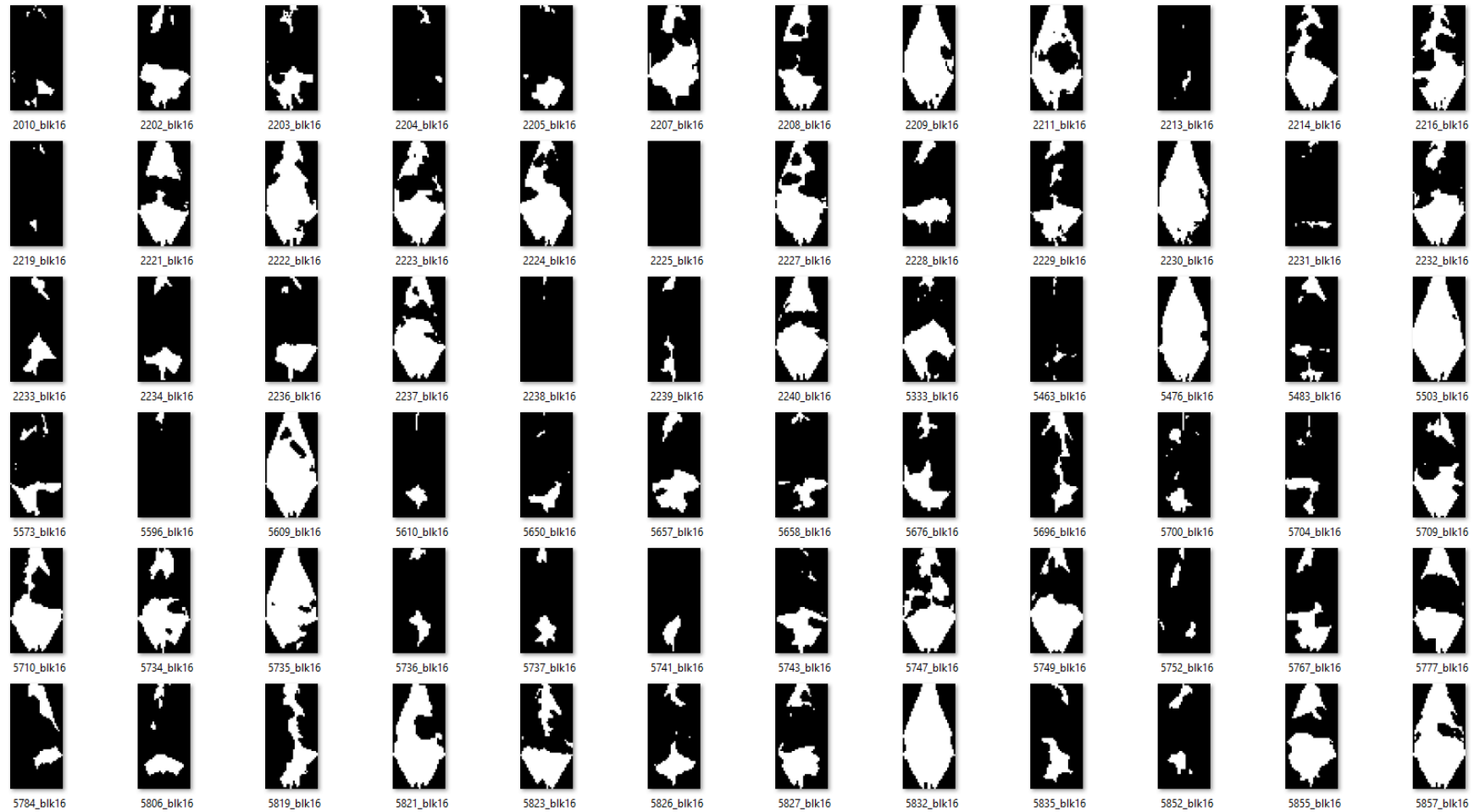
Aligning Keypoints to a Fixed Template

by affine morphing triangles



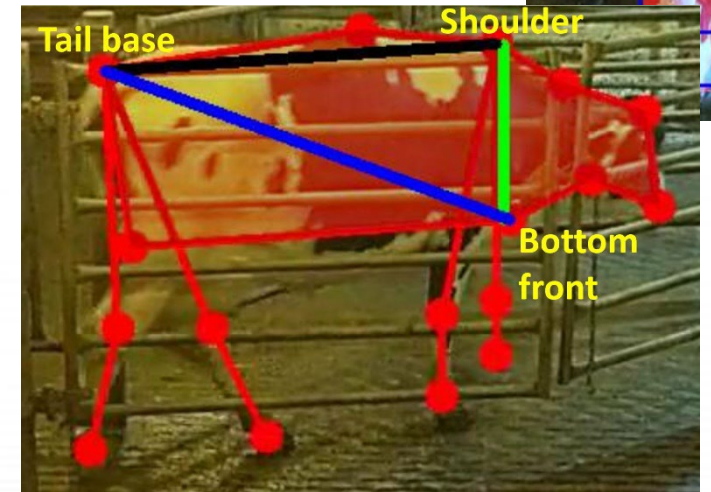
Template has fixed image size (256×512)px and fixed keypoint locations

The Digital Cattlog

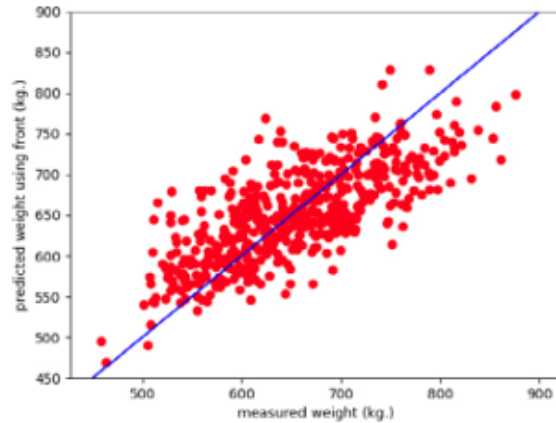


Application: Estimating Body Weight

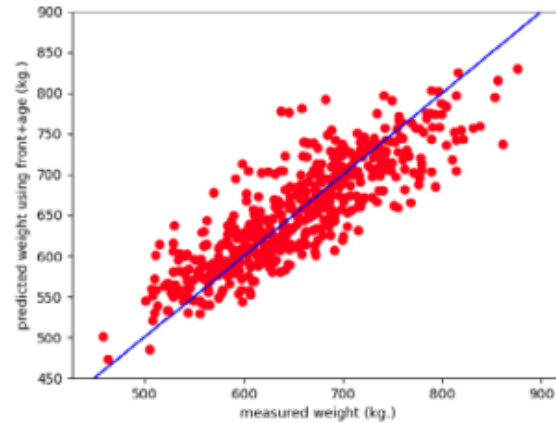
- Predict the cow weight automatically
 - Have BW for nutritionists, veterinarian, to see if cows are losing or gaining weight (health status, pen moves)
 - Inexpensive devices, no change to dairy workflow
- Proposed method:
 - Use both **front-view** and **side-view** videos from surveillance cameras
 - Extract visual features from two videos
 - Fit regression models to predict cow weight



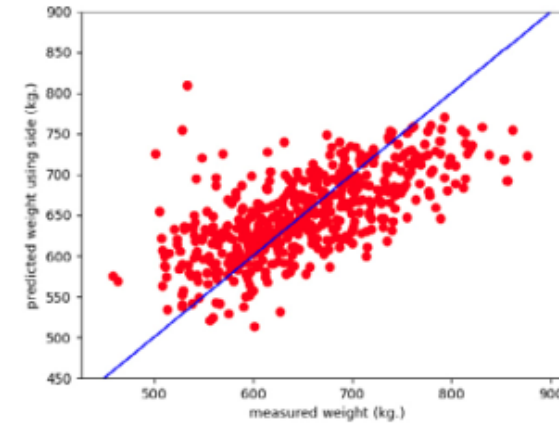
Variables to Predict Body Weight



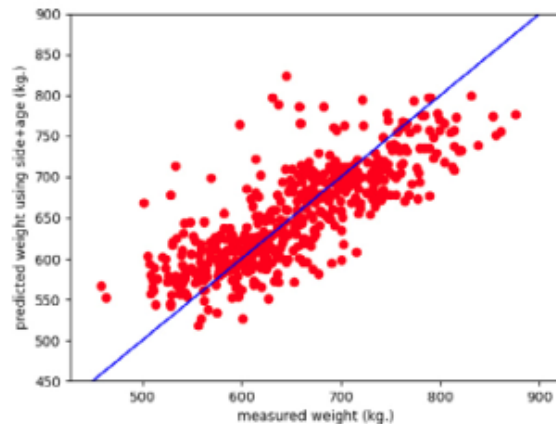
(a) Features: Front view



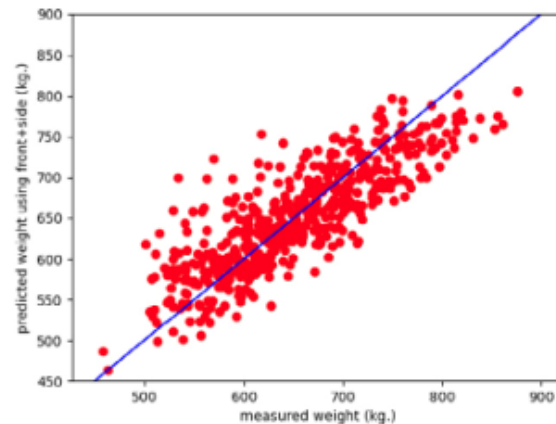
(b) Features: Front view plus age



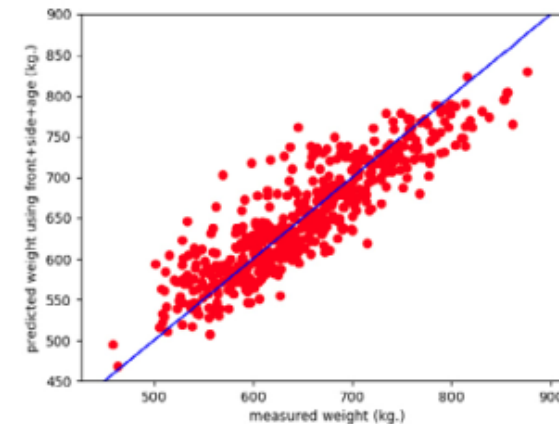
(c) Features: Side view



(d) Features: Side view plus age view



(e) Features: Front view and side



(f) Features: Front view and side view and age



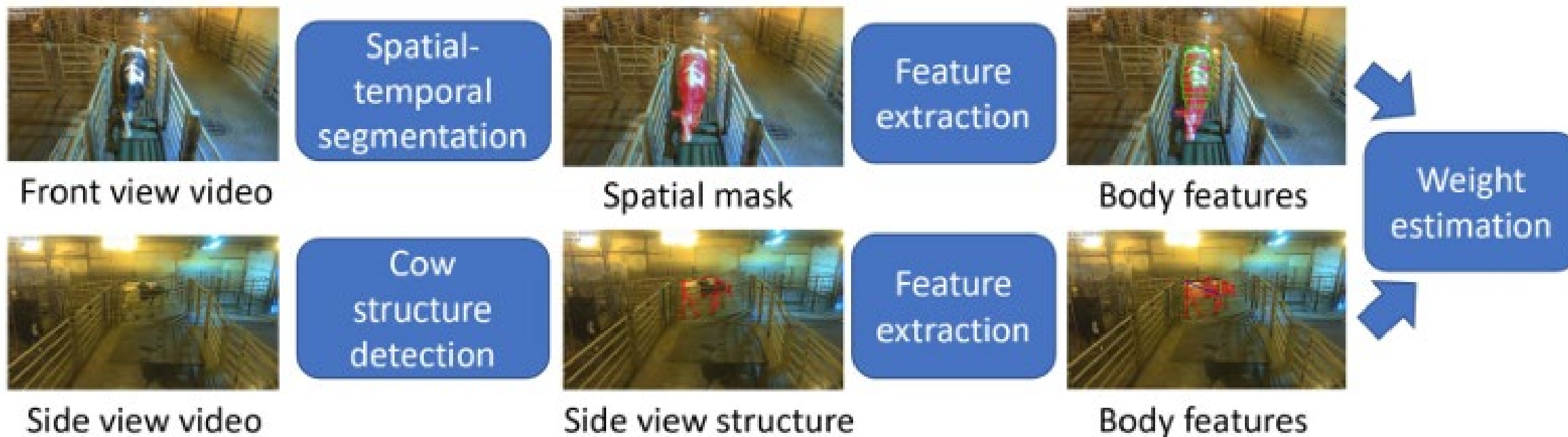


Table 2

Body weight prediction results using linear regression applied to combinations of features. RMSE is expressed in kg; MAPE are expressed in percentages. FV: front view; SV: Side view; A: age.

	ρ	RMSE	MAPE	% errors < 25 kg.
FV	0.738	52.2	6.41	38.8
FV+A	0.853	40.3	4.83	49.5
SV	0.668	57.6	6.94	35.4
SV+A	0.793	47.2	5.58	45.3
FV+SV	0.832	42.9	5.21	48.1
all	0.885	36.0	4.30	55.2

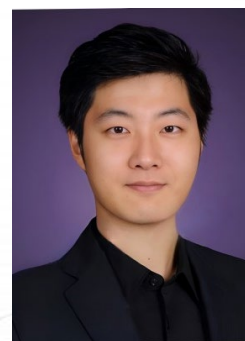
Considerations for Using Video Analytics on Farm

- Some commercial applications for video analytics already exist
 - Projected growth in precision dairy pertaining to feeding practices
- Need to consider data storage, privacy, and ownership prior to understanding if it is a fit on individual farms
- Video analytics can be used as a tool to help with decision making on farm if developed in a way that solves problems rather than creating new ones



Feed Video Team

- Thank you to:
 - USDA-NIFA-IDEAS grant # 2023-68014-39719
 - Diamond V Technical Service
- Please reach out if you have any thoughts to share:
JBoerma@purdue.edu



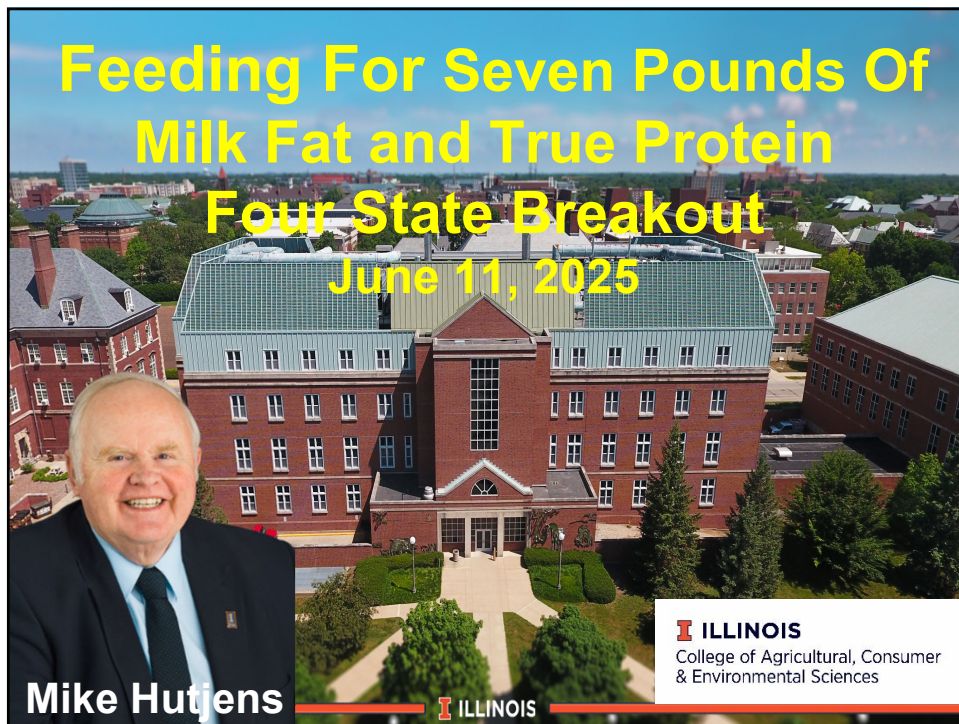
Help us understand what you want from this technology!

- Talk with us for 45 min – 1 hr about how this technology could fit on dairy farms.
- Phone or online interview
\$40.00 for your time

Call/Text to set up a time!

Hema: 317-969-7468





1

Importance of Milk Components

- Most dairy farmers (> 80%) are paid for pounds of milk fat and protein.
- Milk fat and protein yields reflect genetics, feeding, and management aspects.
- Milk component yields are driven by milk yield and milk component percentage.
- Herd health can be reflected in milk fat and milk protein test.

2

Value of Milk Components (April, 2025)

- Milk fat \$2.64 / lb. (5.81 / kg)
- Milk protein \$2.17 / lb. (4.77/ kg)
- Other solids \$0.31 / lb. (0.68 / kg)

Export Outlook (April 30, 2025 prices)

Product	U.S.	E.U.	NZ
	-----\$ / lb-----		
Cheese	1.72	2.42	2.23
Butter	2.23	3.76	3.40
Powder	1.19	1.23	1.27

Component Update—2025

(Hoards Dairyman, April 10, 2025)

- In 2024, average milk fat percent was 4.23 and true protein was 3.29 in the U.S.
- Cheese yield was 11.41 pounds per cwt in 2024; cheese yield was 10.14 pounds per cwt in 2010.
- Genetic PTA progress five years (Dechow, p 167)
 - Holstein increase was +45 pounds of milk fat
 - Holstein increase was +30 pounds of milk protein
 - Holstein genetic increase was +0.05% fat
 - Holstein genetic increase was +0.02 milk protein

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**Milk
Yield**



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Driving Milk Yield

- Peak milk sets the lactation curve and yield.
- Dry matter intake sustains milk yield and components.
- Feed efficiency is a tool to connect milk yield to dry matter intake (target > 1.6 lb 3.5% milk/lb DM).
- Body condition score can supply energy in early lactation (+) or reduce DMI (-)
- Transition management close-up and fresh cows.

Holstein Milk Production Profile

Lact #	Milk*	Peak Milk	Milk/Peak	Days in Milk			
				1 - 40	41 - 100	101 - 199	200 - 305
1	19,000	68	279	56	62	59	53
	23,000	79	291	63	72	70	64
	26,000	90	289	67	81	81	76
	30,000	98	306	70	87	91	85
2	19,000	84	226	72	76	67	55
	23,000	99	232	84	91	81	66
	26,000	114	228	94	104	95	78
	30,000	124	242	99	113	106	87
3+	19,000	90	211	75	81	71	57
	23,000	107	215	88	97	85	67
	26,000	123	211	97	111	100	80
	30,000	133	226	102	120	110	89

* 19,000 RHA n=1,014 herds, 23,000 RHA n=1,998 herds; 27,000 RHA n=1,022; 30,000 RHA n=292 herds

Milk Fat



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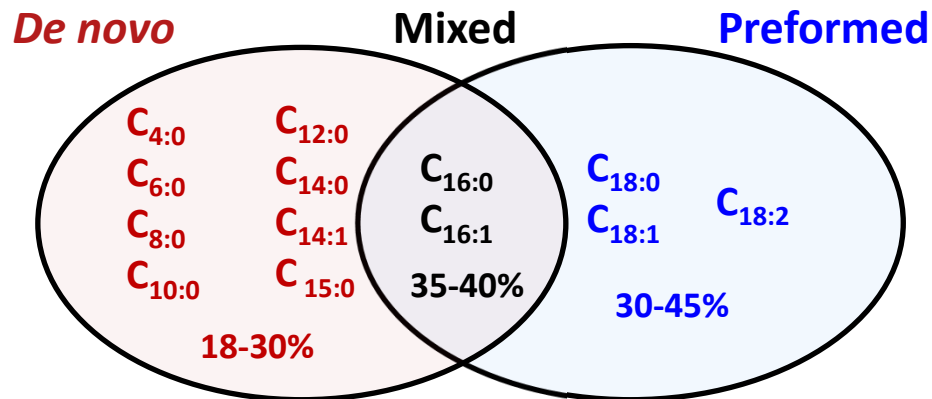
Milk Fat Sources

- **50% - VFA acetate and butyrate (de novo synthesis)**
 - C4 to C16 fatty acids
 - Acetate and butyrate precursors
- **50% - Blood lipids (fatty acids)**
 - C16 to C18 (saturated and unsaturated)
 - Dietary fat / oil (oilseeds and commercial sources)
 - Body fat mobilization (NEFA)
 - Liver and microbial synthesis

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Milk Fatty Acid Origin



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Proportion Fatty Acids (Dann, 2025)

- **Denova fatty acids:** 25% to 30%
- **Preformed fatty acids:** 40% to 45%
- **Mixed fatty acids:** Remaining
 - 50% from denova
 - 50% from preformed

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High Oleic Soybeans

- Oleic fatty acid is rumen friendly (75% oleic and 7% linoleic); conventional 23% oleic and 54% linoleic.
- Michigan State fed up to 24% DMI
- No yield reduction or higher cost seed
- Pioneer (Corteva) and Bayer (GMO)
- Recommend roasted soybeans (higher RUP and lysine)
- Reduce purchased protein sources



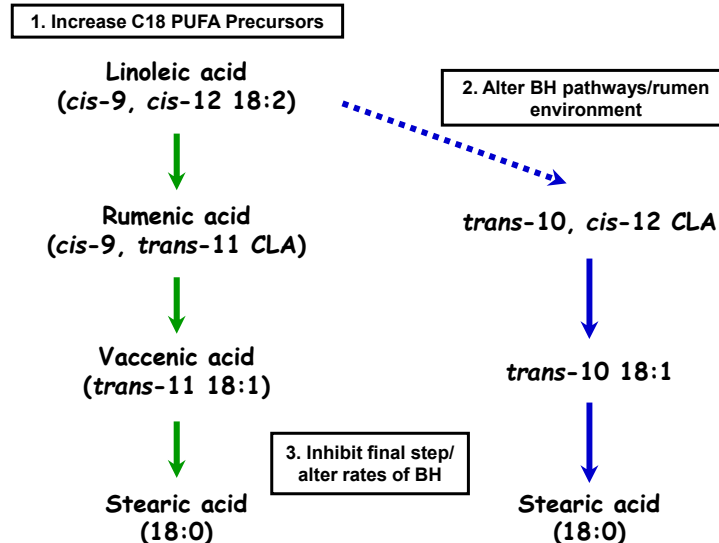
13

Feed Fatty Acid Composition

Feed Name	C14:0	C16:0	C16:1	C18:0	C18:1C	C18:2	C18:3
CrnSil6Cp60Ndf11LNdf	0.46	17.83	0.36	2.42	19.24	47.74	8.25
AlfSil17Cp43Ndf20LNdf	0.66	18.81	1.91	3.35	2.05	15.91	38.71
AlfHy17Cp46Ndf20LNdf	0.85	25.01	2.23	4.01	2.43	18.49	36.79
BakeryByProd	3.16	15.82	0.18	9.29	26.41	33.51	0.85
CornGrainGrndFine	2.33	13.21	0.12	1.99	24.09	55.70	1.62
CornHM22%Med	0.26	13.57	0.19	1.83	25.99	55.08	1.64
FatTallowBeef	3.00	24.43	3.79	17.92	41.62	1.09	0.53
FatCornOil	0.00	11.08	0.00	1.55	26.95	58.95	1.10
FatSoybeanOil	0.11	10.83	0.14	3.89	22.82	53.75	8.23
FatSoybeanOil PLENISH	0.04	6.26	0.10	3.87	75.71	6.71	1.61
Megalac	1.60	50.80	0.00	4.10	35.70	7.00	0.20
EnergyBooster	2.90	40.00	0.62	40.70	10.40	1.80	0.00
CornDistEthanol	0.14	14.05	0.13	2.39	24.57	56.11	1.68
CottonseedWhlwLint	0.69	23.91	0.55	2.33	15.24	56.48	0.19
SoybeanMealExtrd	0.07	11.55	0.09	3.71	18.13	54.77	9.52
ClvrSil17Cp53Ndf15LNdf	0.33	15.22	1.52	2.38	2.62	18.19	53.84
GrssSil7Cp72Ndf13LNdf	0.54	16.76	1.67	1.94	3.80	19.96	44.30
GrssHy16Cp55Ndf6LNdf	0.43	16.44	0.48	1.33	2.53	23.38	49.90

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Fatty Acids Impact MFD

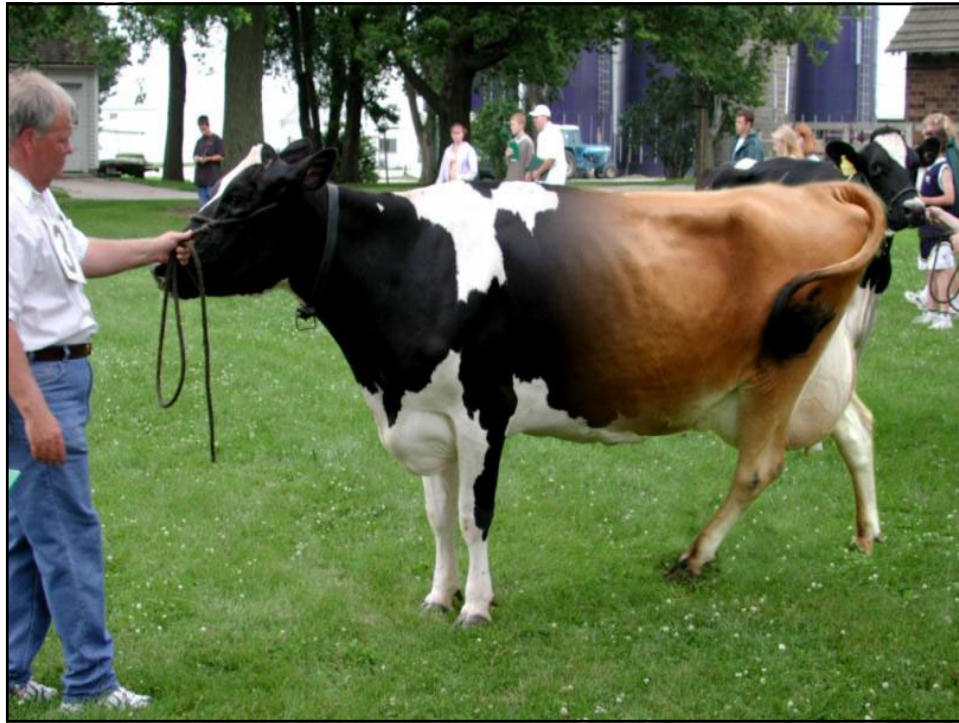


15

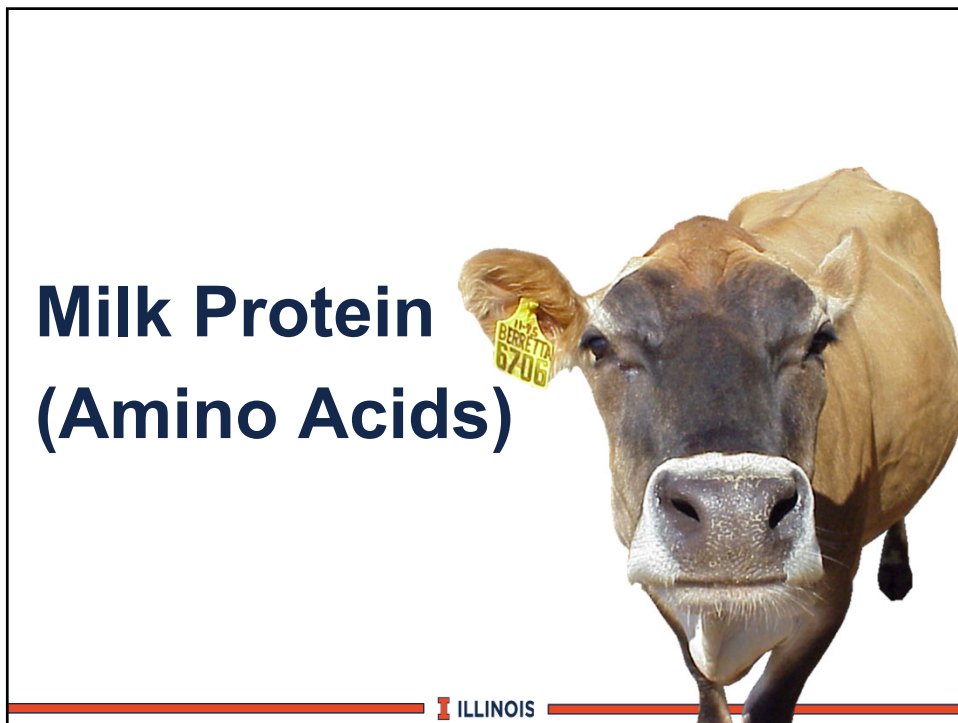
Sources Of Milk Fat Change

- **Genetics**—selecting for pounds of milk fat and milk protein (not percent)
- **Shifting to Jersey or crossbreeding**
- **High quality forages**—increase acetate production and higher dry matter intake
- **Improving rumen efficiency**
- **Feeding fat**—palm fatty acids, soybeans, commercial dry fats, or other oilseed sources

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Milk Protein (Amino Acids)

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Milk Protein Sources

1. Fermentable Carbohydrate (60-75%)

- **Rumen microbial protein**
- **24 to 28% starch, 5 to 7% sugar, and 10 to 12% soluble/fermentable fiber: these three values > 40% (rumen fermentable carbs)**

2. Protein Requirements (25 to 40)

- **Level (14% to 17% crude)**
- **Type (6% to 7% R.U.P.), 10-12% RDP (50% soluble of RDP)**
- **Quality (lysine / methionine / histidine)**



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The Ohio State University Trial

	LP	LP-AA
CP (%)	16.9	16.9
Milk (lb)	94.4	102.5
Protein (%)	2.99	3.09
MUN (mg/dl)	14.3	13.5

**LP-aa: HDCB plus balanced
lysine and methionine**



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Benefits Of Feeding Rumen-Protected Amino Acids

1. Milk protein increase

- About 0.1 percentage unit
- Usually occurs within 3 days
- Occurs when ruminally undegradable protein is low in methionine and / or lysine

2. Milk yield increase

- 0 to 5lb/cow/day
- Usually occurs only during early lactation

3. Milk fat increase

- 0 to 0.2 % unit when RPMet is fed
- Response may be restricted to RPMet products that are partially degraded in the rumen



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Rumen Protected Methionine

- Cost varies from 1.5 to 2.6 cents / gram of RP metabolizable methionine
- 15% of the herds in the 2024 Hoards survey are supplementing with RPMethionine
 - Smartamine (Adisseo) 48%
 - AminoShure-M (Balchem) 21%
 - MetaSmart (Adisseo) 14%
 - Mepron (Evonik) 13%
 - Alimet (Novus) 10%
 - MFP (Novus) 10%
 - Novimet (Innovad) 3%
 - Timet (VetAGro) 2%



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Rumen Protected Lysine

- Field cost varies from 1.5 to 2.2 cents per gram of RP metabolizable lysine
- Estimated that 15.6% of the herds in the 2024 Hoards survey are supplementing RPLy
 - USA Lysine (Kemin) 46%
 - Bovi-Lysine (Quali Tech) 35%
 - AjiPro-L (Alinomoto) 17%
 - MetaboLys (HJ Baker) 4%

Evaluating Amino Acid Balancing

- Use a rumen modelling program
 - Evaluate on herds for the “sweet spot”
 - Target 2.65 : 1 lysine to methionine ratio
- 41% balancing for amino acids (Hoards 2024 survey)
- Determine a cut point on protein yield (> 2.4 pounds of true protein)
- If milk protein test is low for your breed average or region

Milk Component Interpretations



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Milk Fat and Milk Protein Relationship

(Hoard's Dairyman—August, 2024)

	Fat %	Protein %	Protein vs Fat	Fat vs Protein
Ayrshire	3.89	3.15	81%	1.23
Brown Swiss	4.18	3.43	81.9%	1.212
Guernsey	4.58	3.36	73%	1.36
Holstein	4.11	3.17	77.2%	1.30
Jersey	5.01	3.76	74.9%	1.33

ILLINOIS

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Holstein Component Profiles

Lact #	Milk (lbs)	Fat %				Fat/Prot	Protein %				Milk (kg)
		1-40	41-100	101-199	200-305		1-40	41-100	101-199	200-305	
1	19,000	2.9%	3.0%	3.5%	3.7%	1.32	2.2%	2.4%	2.8%	3.0%	8,618
	23,000	3.4%	3.3%	3.6%	3.8%	1.36	2.5%	2.6%	3.0%	3.1%	10,433
	26,000	3.8%	3.5%	3.6%	3.9%	1.36	2.8%	2.8%	3.0%	3.2%	11,793
	30,000	3.9%	3.5%	3.6%	3.8%	1.34	2.9%	2.8%	3.0%	3.2%	13,608
2	19,000	2.9%	3.1%	3.5%	3.7%	1.26	2.3%	2.5%	2.9%	3.1%	8,618
	23,000	3.3%	3.3%	3.6%	3.8%	1.32	2.5%	2.6%	3.0%	3.2%	10,433
	26,000	3.7%	3.4%	3.6%	3.8%	1.32	2.8%	2.8%	3.0%	3.2%	11,793
	30,000	3.8%	3.4%	3.5%	3.8%	1.31	2.9%	2.8%	3.0%	3.2%	13,608
3+	19,000	3.5%	3.4%	3.6%	3.8%	1.35	2.6%	2.6%	2.9%	3.1%	8,618
	23,000	3.7%	3.4%	3.6%	3.8%	1.37	2.7%	2.7%	3.0%	3.2%	10,433
	26,000	3.9%	3.4%	3.6%	3.8%	1.39	2.8%	2.7%	3.0%	3.2%	11,793
	30,000	4.0%	3.4%	3.5%	3.7%	1.38	2.9%	2.8%	3.0%	3.2%	13,608

* 19,000 RHA n=1,014 herds, 23,000 RHA n=1,998 herds; 27,000 RHA n=1,022; 30,000 RHA n=292 herds



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Evaluating Your Herd

- **Milk fat inversions** are cows that are **0.2% milk protein above milk fat percent**. Example: Cows 3.2% milk protein and < 3.0% fat
- **Milk fat depressions** more than **1.0 fat percentage below the herd average**. Example: Cows under 3.0% when the herd average is 4.0%

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Milk Component Efficiency

(Pounds of Component / Pound DM)

- **55 lb. DM @ 7 lb. milk solids = 12.7%**
- **60 lb. DM @ 7 lb. milk solids = 11.7%**
- **55 lb. DM @ 6 lb. milk solids = 10.9%**
- **60 lb. DM @ 6 lb. milk solids = 10%**

Milk Protein Efficiency

90 lbs milk @ 3.2% protein = 2.88 lb of milk protein produced daily

- **55 lb dry matter @ 17% crude protein = 30.1%**
- **55 lb dry matter @ 16% crude protein = 32.7%**
- **55 lb dry matter @ 15% crude protein = 34.9%**
- **55 lb dry matter @ 14% crude protein = 37.4%**

Take Home Messages

- Milk component yield will continue to be important.
- Review your records to evaluate if lactation number and days in milk are below target values
- Use tools to measure your herd
 - Breed average vs. your herd
 - Ratio of milk protein to milk fat
 - Feed efficiency
 - MUN values

It Is Possible; Over 8+ Pounds

- Midwest Holstein herd
- 421 lactating cows
- Averaging 110 pounds of milk
- Producing 132 pounds of ECM
- 4.8% milk fat test
- 3.3% true protein test
- 173 days in milk
- 8.9 pounds of fat / protein



The Hidden Cost of Heat: Multigenerational Effects on Dairy Cattle



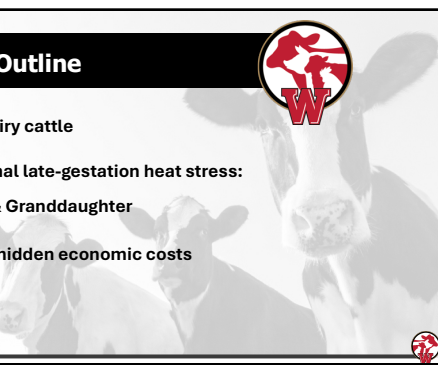
Four-State Dairy Nutrition & Management Conference

Jimena Laporta
Associate Professor
Mammary Gland Physiology

ANIMAL & DAIRY SCIENCES
University of Wisconsin-Madison

1

Presentation Outline



- Heat stress in dairy cattle
- Effects of maternal late-gestation heat stress:
Dam, Daughter & Granddaughter
- Deciphering the hidden economic costs

2

Heat stress & the dairy industry

- Global issue affecting highly populated dairy regions once considered low-risk
- One of the dairy industry's greatest challenges
- Threatens all aspects of sustainable milk production
 - **Cow** health, production, and welfare | **Crops** nutritional value, yield, and quality



GLOBAL Temperature Rise
2021 PROJECTIONS

2.75°C
3.58°C - 2.05°C

3

When do cattle experience heat stress?

Cattle are homeotherms

- Maintain internal temperature | despite the outside environment
- Behavioral and physiological mechanisms
- Heat load exceeds the ability to dissipate it ...
- Body heat accumulates → **cows become heat-stressed**

Hahn, 1998; West, 2003; Becker et al., 2020.

4

Heat stress: *lactating* cows

Causing immediate effects on production, health, well-being, and sustainability

Adoption of some form of heat mitigation (NAHMS)

- **Disrupts physiology** | energy shift towards heat dissipation
 - Increasing respiration, sweating & body temperature
- **Decreases feed intake** | nutrient utilization & metabolism
- **Impacts milk yield, reproduction/fertility, and health**

Significant financial losses

Kadzere et al., 2002; West et al., 2003; St Pierre et al., 2003

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Heat Stress: “*non-lactating*” herd

Historically received less attention | not a priority for mitigation 🤔

- 1 More heat-tolerant and don't require cooling
 - Not lactating, thus generating less heat
- 2 Assumption: the cost of cooling outweighs the benefits
 - Lack of infrastructure | high setup costs: a major barrier

Dry cows **Calves** **Heifers**

6

Heat Stress: “non-lactating” herd

Historically received less attention | not a priority for mitigation 🤔



3 Lack of immediate production outcomes affecting revenue

- Heat stress effects are less visible in the short term

4 Underestimation/lack of evidence of long-term effects

- Limited research in dairy cattle



Dry cows



Calves



Heifers

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Heat Stress: “non-lactating” herd



LAPORTA
LABORATORY
WWW.LAPORTA.LAB

Vulnerable to summer heat, but the negative effects often emerge later in life -- years after exposure!

- Leads to programming effects “beyond the heat of summer”
- Generates less productive and less resilient cows
- Economic consequences can be costly to manage over their lifetime



Dry



Calves



Heifers

8

Why is it important to focus on the dry-pregnant cow?

Three “programming events” represented in a dry-pregnant cow



F₀ Dry cow

Mammary “regeneration” during the dry period

F₁ Daughter

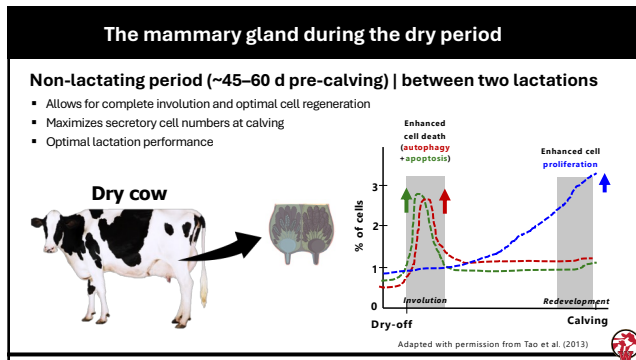
Undergoing the last-trimester of gestation in utero

F₂ Granddaughter

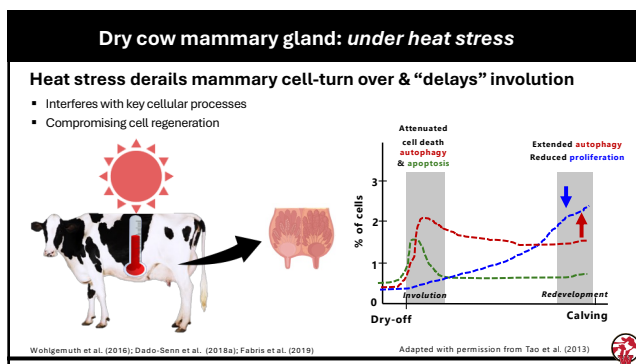
The development of the germline in the fetal daughter (that will give rise to the F₂) take place in utero



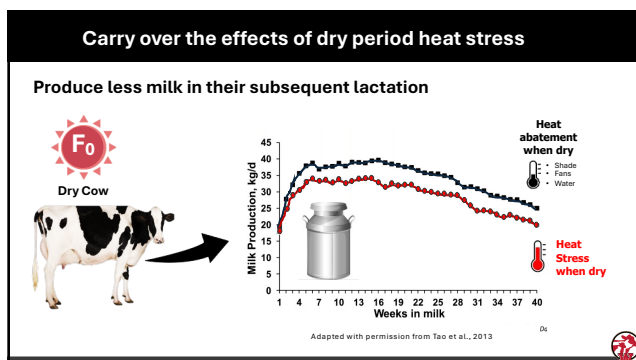
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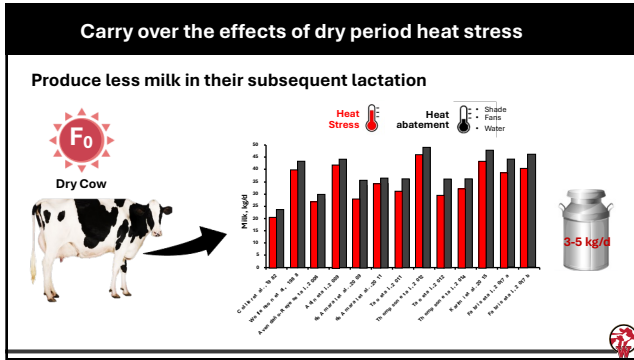
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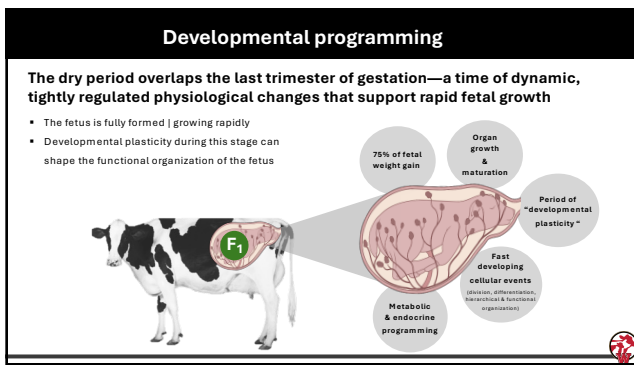
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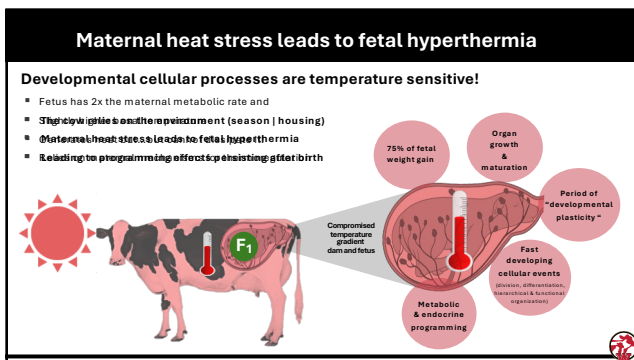
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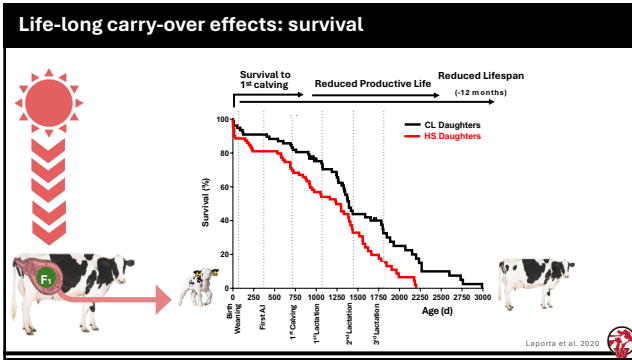
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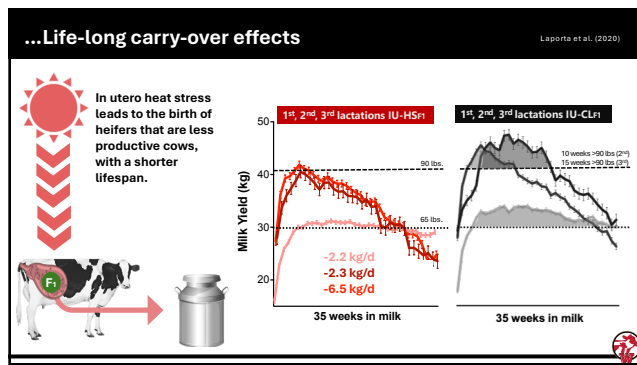
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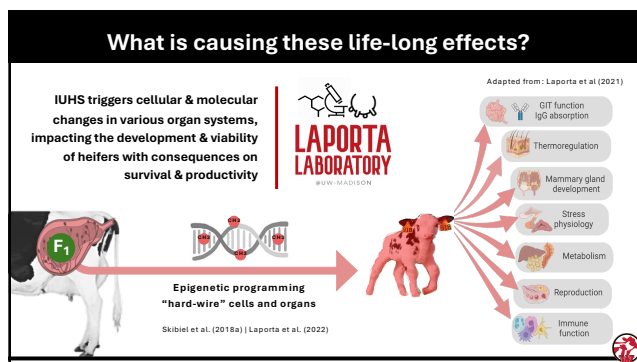
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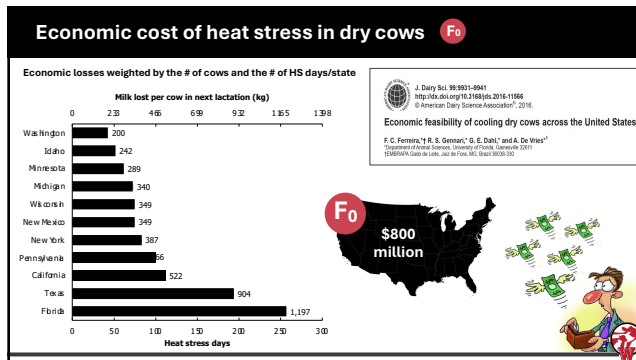
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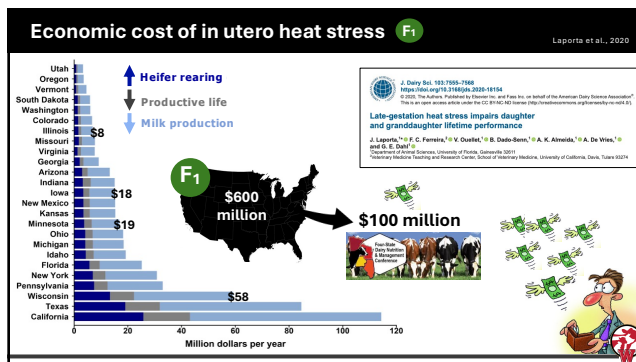
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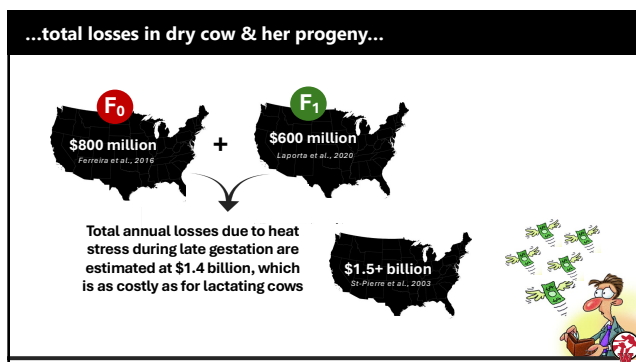
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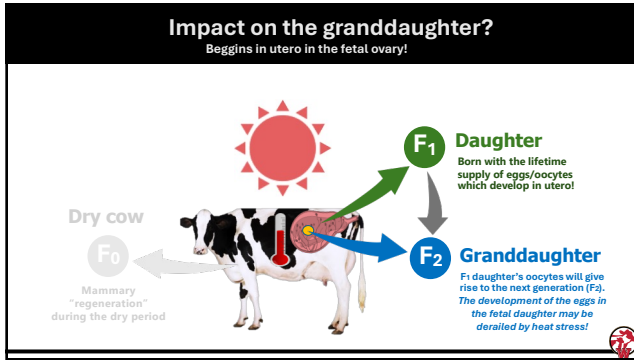
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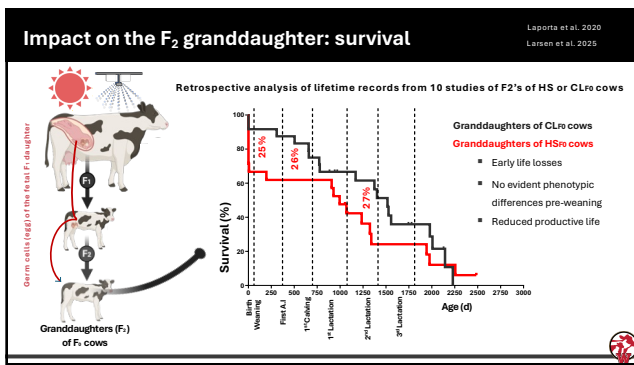
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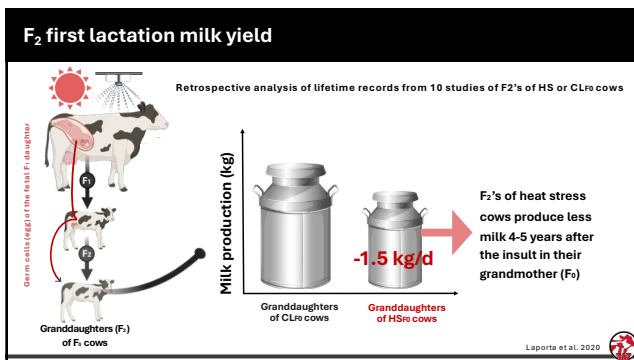
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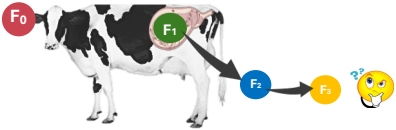
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Summary and take-away points





Heat stress impacts extend beyond “lactating cows”
Its effects reach further than “just the summer months”
Generational consequences: daughters and granddaughters
leave heerd and exhibit lower productivity
Economic losses escalate!



25

University of Florida
Dr. Geoffrey Dahl
Dr. Amy Skibiel





2019-67015 | # 2022-08036



WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON
Vilas Award | CALS

26



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SSOY

Four State Dairy Nutrition & Management Conference

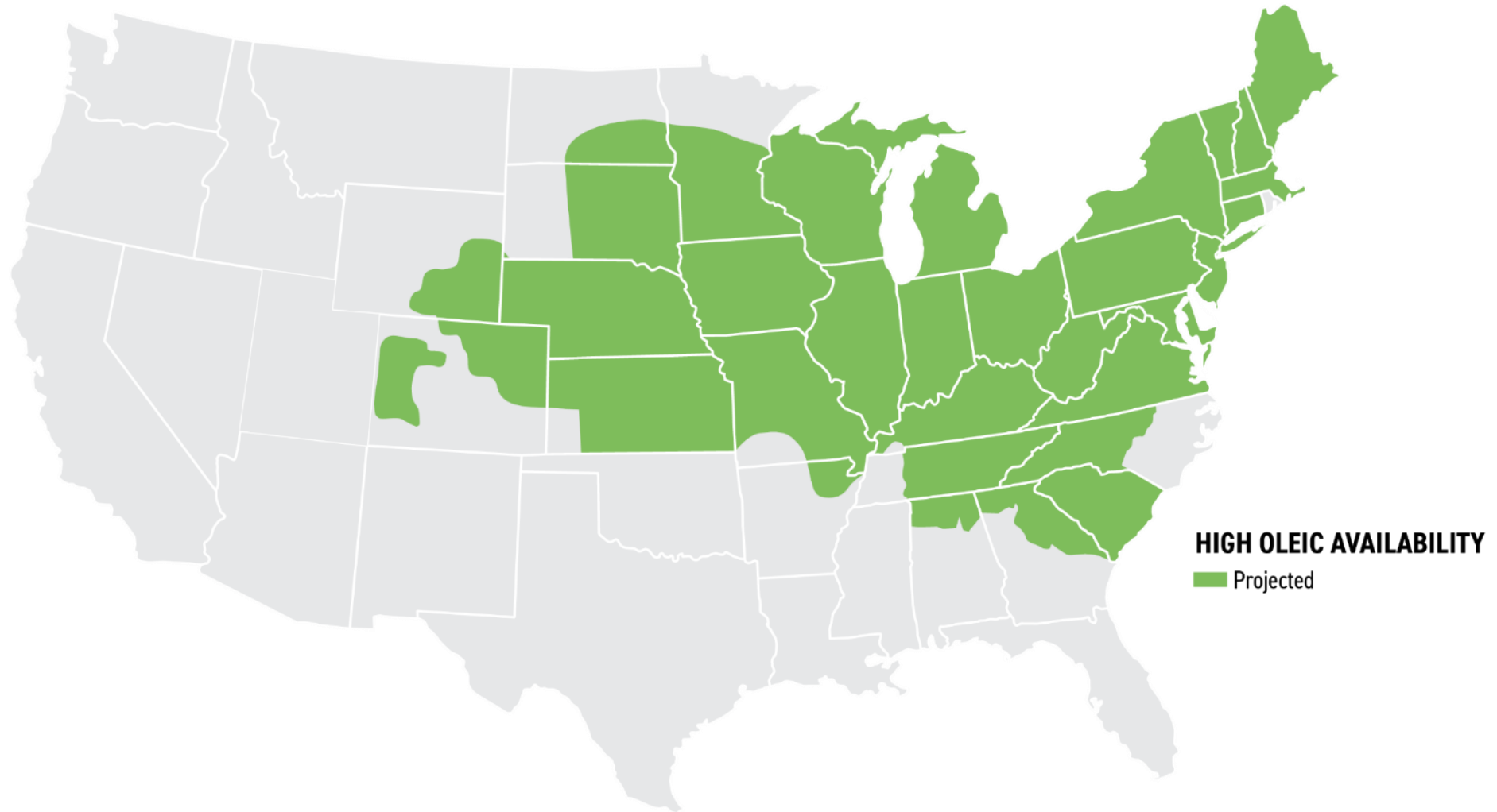
JUNE 12, 2025



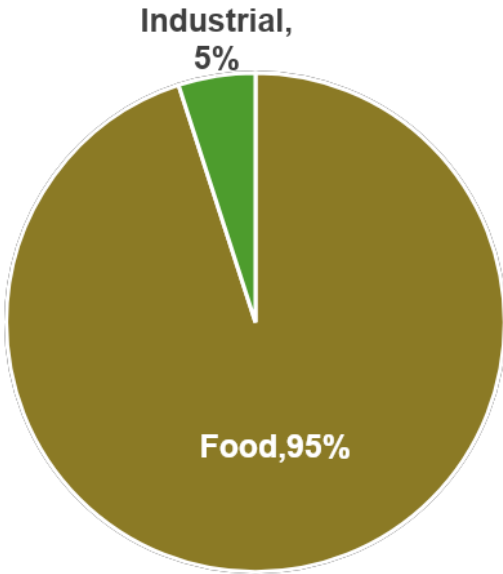
Utilizing High Oleic Soy in Dairy Cow Diets

- Secure impactful and long-lasting demand for high oleic soy
- Deliver heat-treated high oleic soy with consistent quality
- Support dairy nutritionists in strategically and confidently advising dairy farmers on product quality control and nutritional value

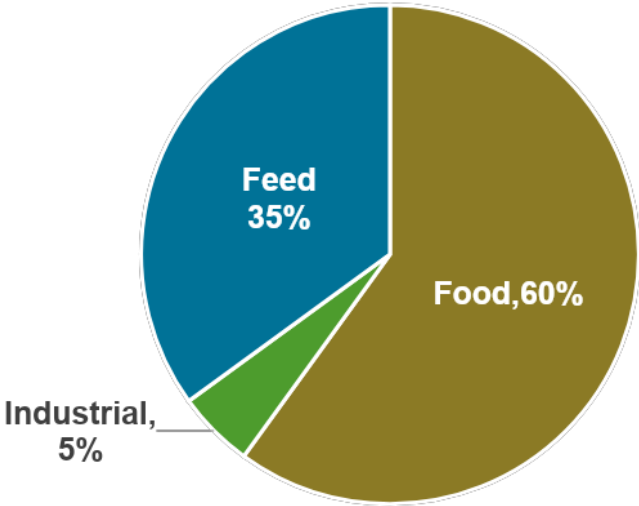




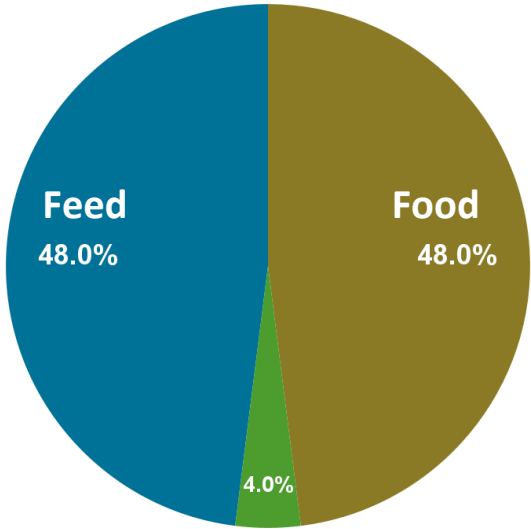
HIGH OLEIC DEMAND BY SEGMENT



2010-2023



2024



Industrial

Projected
2025-2030

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Chuck Nicholson
University of Wisconsin



Adam Lock
Michigan State



Kevin Harvatine
Penn State

THANK YOU



High Oleic Soy in Dairy Rations

Frequently Asked Questions

For Dairy Nutritionists and Dairy Producers

This document was funded by the National Soybean Checkoff and is based on research plus real-world commercial experience. It represents the collective and collaborative efforts of the following dairy-industry leaders:

- Corwin Holtz, MSc., Holtz Nelson Dairy Consultants
- Lynn Davis, Ph.D., Quality Roasting, Inc., Nutrition
- Professionals Inc., Breeze Dairy Group, LLC
- Jim Barmore, MSc., PAS, Five Star Dairy Consulting
- Stacy Nichols, MSc., Vita Plus Corporation
- Chuck Nicholson, Ph.D., University of Wisconsin
- Adam Lock, Ph.D., Michigan State University
- Kevin Harvatine, Ph.D., Pennsylvania State University



Purpose

The goal of this document is to bring awareness to key considerations when evaluating high oleic soy as an ingredient for dairy cow rations.

High oleic soybeans are a variety of soybean high in oleic acid, at least 70%. Conventional soybeans contain about 22–28% oleic acid. The fatty acid profile, specifically the high oleic acid content, makes high oleic soybeans a unique feed ingredient.

Heat-treated high oleic soy offers both fat and bypass protein, improving the energy density of the diet. However, the benefits of the bypass protein are dependent on the control and consistency of heat treatment.

There are many factors and considerations when evaluating heat-treated high oleic soy from growing to processing through feeding. High oleic soy has the opportunity to be a valuable feed ingredient included in dairy cow rations, and understanding how to successfully implement it is key.

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Feeding High Oleic Soybeans

■ Q1. I've heard HO soybeans increase milk fat? What kind of increase can I expect to see?

A1. In controlled studies, the level of response in the milk fat has been about 0.10% or greater.¹ There are many ration factors that impact milk fat and the response will partly depend on what is replaced in the diet. Compared to conventional soybeans and other ingredients high in linoleic acid (18:2), high oleic soybeans have a reduced risk for milk fat depression. This may result in increased milk fat or the opportunity to reduce the cost of supplemental fat compared to dry fat supplements. High oleic soybeans can increase the fat content of the ration, proving beneficial for both milk fat and energy-corrected milk (ECM) production.

■ Q2. Do high oleic soybeans increase energy-corrected milk (ECM)?

A2. When both milk yield and milk fat increases, ECM increases. In commercial diets balanced for bypass protein and fatty acids, the expected milk fat increase is 0.10%.¹ In turn, a Holstein producing 90 lbs of milk would have an additional 1.3 lbs of ECM per day. However, depending on the diet comparison, the response may be higher. In two high producing cow studies at Michigan State University (2024)²⁻³, when roasted high oleic soybeans replaced conventional soybean meal and hulls, the average response was 8.1 lbs ECM when compared to control diets without supplemental fat.

■ Q3. If I feed high oleic soybeans raw, what nutritional factors would I miss out on?

A3. Feeding heat-treated soybeans delivers both high quality protein and fatty acids to the cow. Raw soybeans have the same composition of fatty acids as heat-treated soybeans, yet deliver less metabolizable protein, which is key to higher production. Raw soybeans are more rumen available and have lower rumen undegradable protein (RUP). They also have higher levels of antinutritional factors (e.g., trypsin inhibitor), which may reduce protein digestion and absorption in the small intestine. Grinding has been shown to predispose soybeans to a shorter shelf life, especially when they are raw.

■ Q4. What is the minimum oleic acid content I should expect to see in high oleic soybeans?

A4. With today's varieties, oleic acid value typically ranges between 68%–80%. Testing for oleic acid in a commercial laboratory is recommended to verify successful segregation occurred from conventional soybeans while accounting for any geographical or genetic differences in total fat content. As genetics of high oleic soybeans continue to progress, the level of oleic fatty acid may also change. Certified commercial laboratories now offer fatty acid analysis by NIR analysis which reduces the cost and time required to obtain an accurate analysis, further encouraging that regular laboratory testing be done with oleic soybeans.

TODAY'S AGENDA



Alycia Bales, Ph.D.

Technical Support
Caledonia Farmers Elevator

“Turning High Oleic Soy Research into
Practical Nutrition Advice”



Kyle Taysom

CEO
Dairyland Laboratories

“Why and How Best to Test High Oleic Soy”

Q&A

10 minutes of Question and Answer

TURNING HIGH OLEIC RESEARCH INTO PRACTICAL NUTRITION ADVICE

Alycia Bales, Ph.D.
Animal Nutrition Technical Support at Caledonia Farmers Elevator

In conjunction with Dr. Adam L. Lock at Michigan State University

HIGH OLEIC SOY

- Processing methods
- Importance of fatty acid profile differences in soybean varieties

HIGH OLEIC SOY RESEARCH

- High oleic soybean (HOSB) trials
- High oleic expeller meal (HOEM) trial

RATION BALANCING

- Level of HOSB inclusion
- Fatty acid supplements?
- IOFC with HOSB inclusion

OTHER CONSIDERATIONS

- Grind size
- Heat treatment and fatty acid profile of HOSB

Soybean Processing

ROASTING

- Goal internal temperature: 295-300°F
 - Roasters: electric and flame
 - Time: varies on roaster type and speed
- Steep for 30 minutes
 - Cool after steeping is complete
- Increases undegradable protein and reduces anti-nutritional factors
- Whole soybean with ~20% total FA
- Further processing:
 - Grinding
 - Rolling
 - Cracking

**HIGH OLEIC
SOYBEAN
(HOSB)**

EXTRUDING

- Mechanical processing (grinding or crushing) at temperatures between 265 – 285°F with high pressure
- Increases undegradable protein and reduces anti-nutritional factors
- A meal containing ~20% total FA

EXPELLING

- The removal of a portion of the oil after extruding via pressing
- 6-8 % total FA

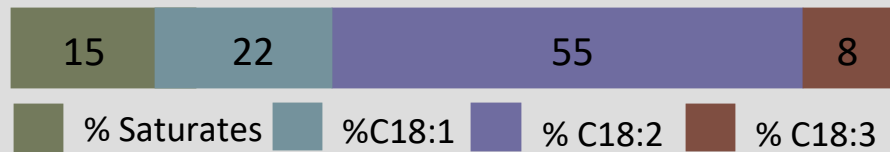
**HIGH OLEIC EXPELLER
MEAL
(HOEM)**

Soybean Variety

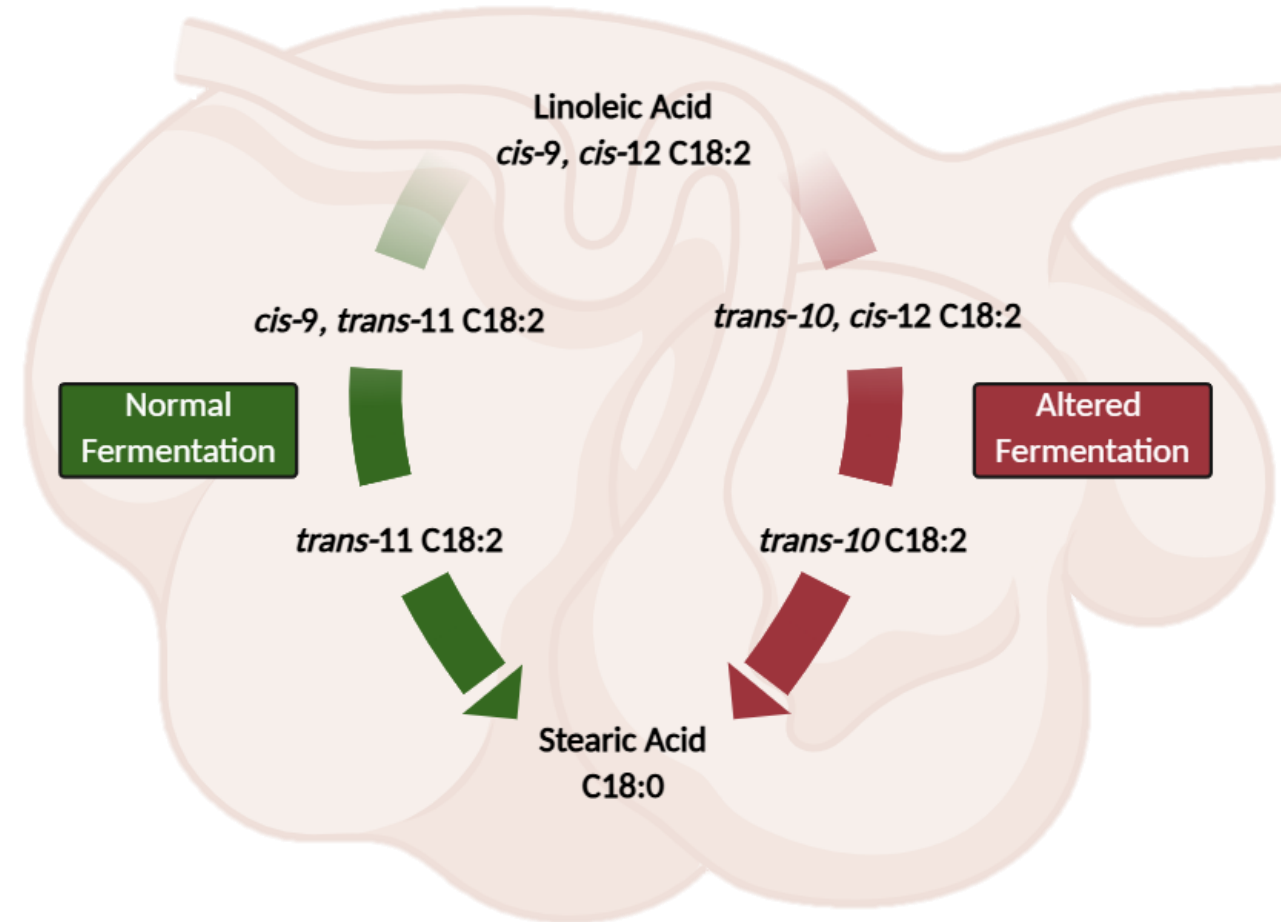
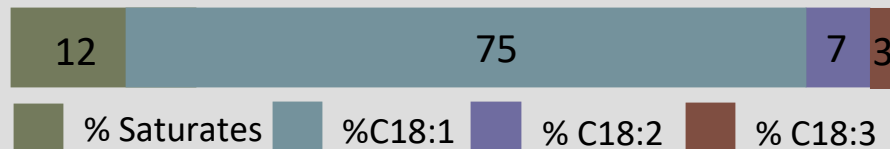
Soybean Variety



Conventional soybean



HOSB

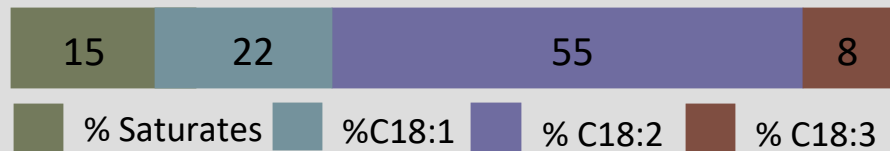


Soybean Variety

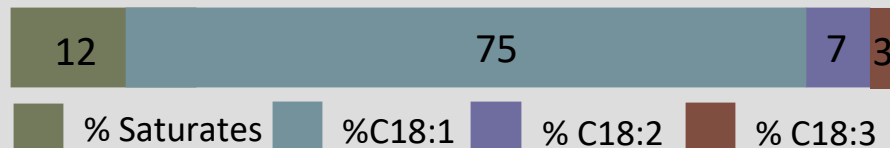
Soybean Variety



Conventional soybean



HOSB

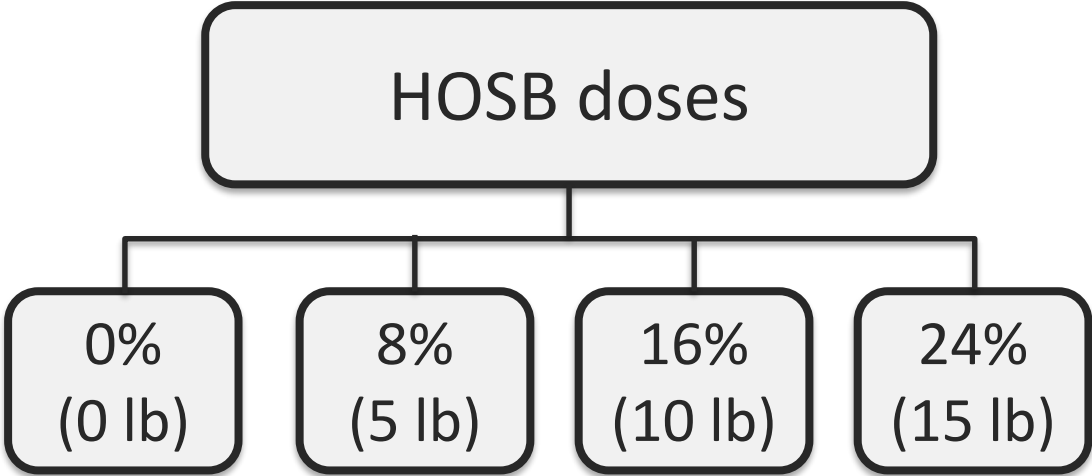


Variable	Treatment ¹				
	LF	GC	GP	WC	WP
DMI (kg/d)	26.5	26.3	26.3	26.7	26.6
Milk (kg/d)	48.0	48.8	47.2	48.5	46.8
Fat (%)	3.25	3.09	3.50	3.40	3.53
Protein (%)	3.18	3.09	3.18	3.08	3.13
Lactose (%)	4.96	5.00	5.07	5.00	5.01
Fat (kg/d)	1.54	1.49	1.64	1.64	1.63
Protein (kg/d)	1.51	1.50	1.49	1.49	1.40
Lactose (kg/d)	2.37	2.43	2.37	2.42	2.34
Milk (Mcal/d)	32.2	31.9	33.0	33.0	32.6

- W = Whole; G = Ground; C = Conventional; P = Plenish
 - Used raw soybeans
- Ground Plenish increased milk fat production (both $P=0.01$) but milk protein yield was not affected

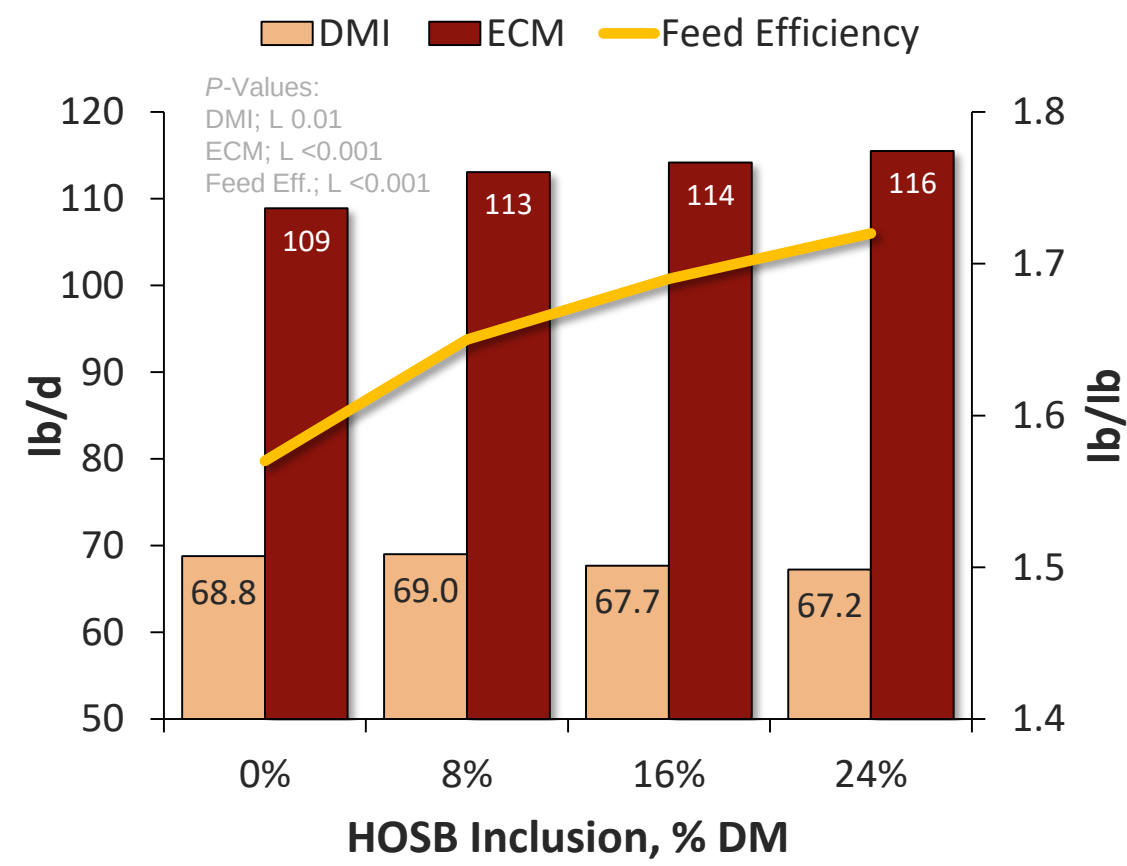
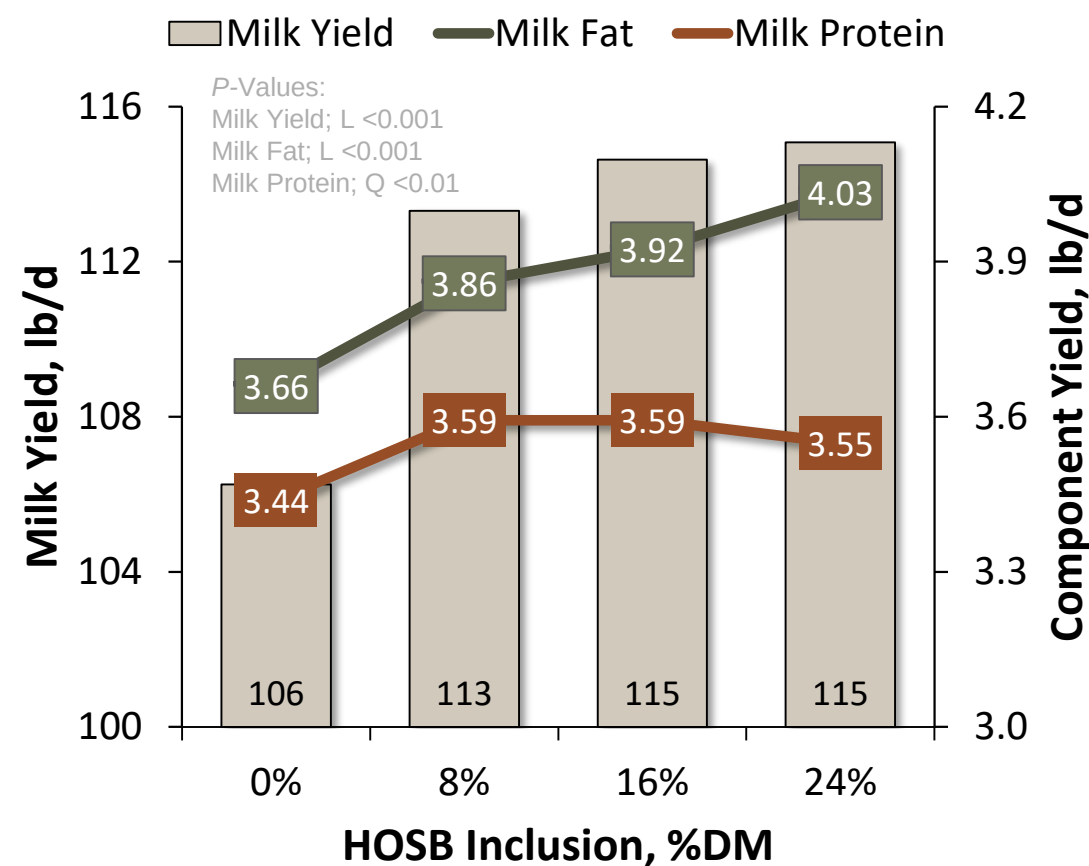
Exp. 1: HOSB Dose-Response

- 24 multiparous cows
 - Avg. 112 lb/d milk yield
 - 122 ± 57 DIM
- Four, 21-day feeding periods



Ingredient, % DM	Treatment			
	0%	8%	16%	24%
Corn Silage	45.6	45.4	45.4	45.4
Alfalfa Silage	8.11	8.08	8.08	8.09
Ground Corn	15.2	15.1	15.1	15.1
Mineral Mix	1.98	1.97	1.97	1.97
Lactation Mix	2.72	2.71	2.71	2.71
Soybean Meal	18.5	12.6	6.49	0.46
Soyhulls	7.47	5.46	3.54	1.31
Ground, roasted HOSB	0.0	8.23	16.2	24.4

Exp. 1: HOSB Dose-Response



Feeding HOSB increased pounds of milk, milk fat, and milk protein produced by using less feed

Exp. 2: HOSB Roasted vs Raw

- 36 multiparous cows
 - Avg. 102 lb/d milk yield
 - 110 ± 61 DIM
- Two, 35-day feeding periods



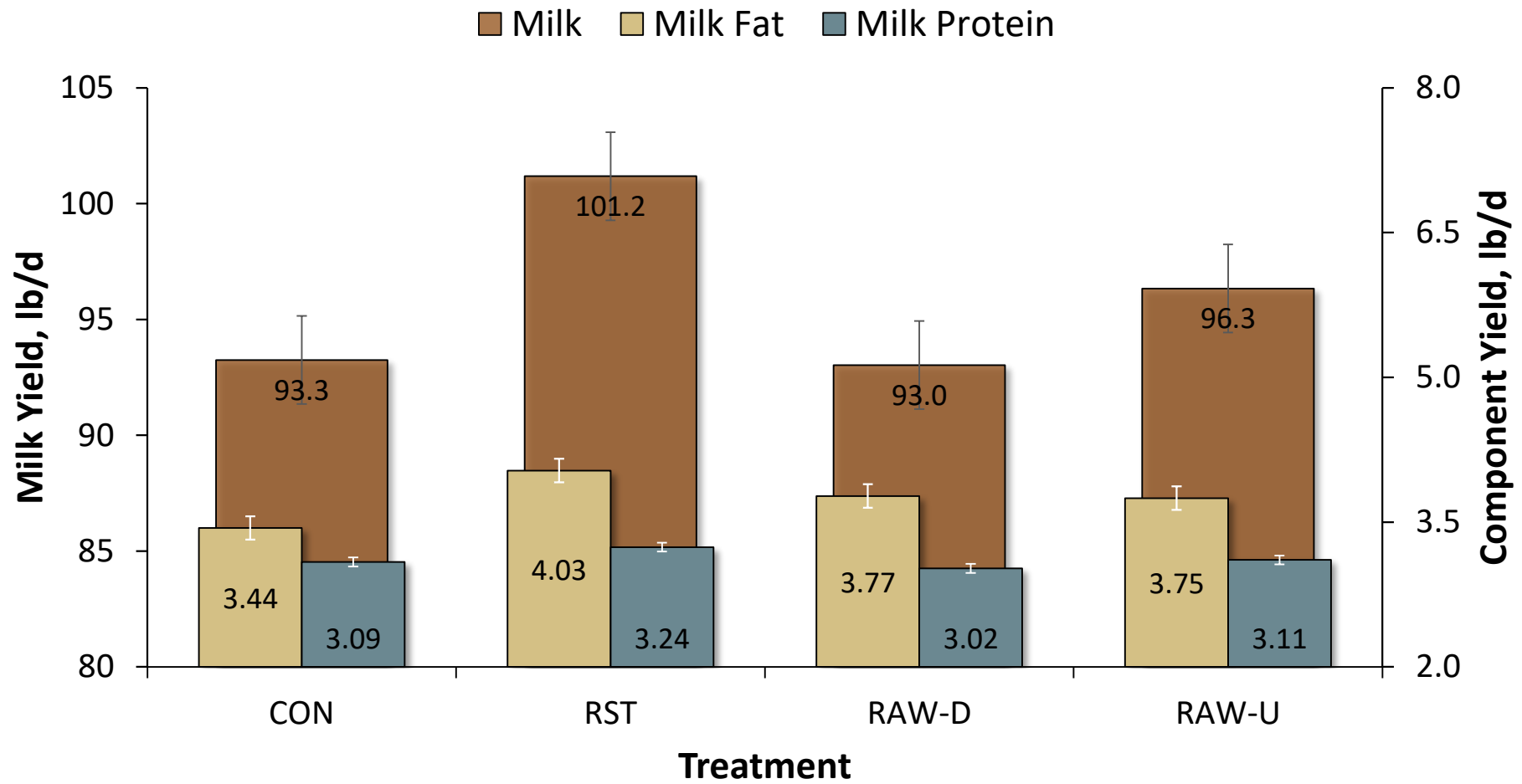
Ingredient, % DM	Treatment			
	CON	RST	RAW-D	RAW-U
Corn Silage	45.1	44.8	44.6	44.7
Alfalfa Silage	8.06	8.02	7.98	8.0
Ground Corn	11.3	11.2	11.2	11.2
Vitamin and Mineral Mix	2.0	1.99	1.98	1.99
High Cow Lactation Mix	4.17	4.14	4.13	4.13
DCAD	0.43	0.43	0.43	0.43
Roasted, ground HOSB	0.0	16.7	0.0	0.0
Raw, ground HOSB	0.0	0.0	16.9	16.8
Soybean Meal	18.6	6.12	6.32	0.0
Soyhulls	10.4	6.51	6.43	6.48
Amino Plus	0.0	0.0	0.0	6.24

Exp. 2: HOSB Roasted vs Raw

CON vs HOSB P-Values:
Milk Yield: <0.01
Milk Fat: <0.01
Milk Protein: NS

RAW vs RST P-Values:
Milk Yield: <0.001
Milk Fat: <0.001
Milk Protein: <0.001

Protein Source P-Values:
Milk Yield: <0.001
Milk Fat: NS
Milk Protein: 0.07



Roasting HOSB increased yields of milk, milk fat, and milk protein; Protein source impacted milk production responses

Exp. 3: HOSB + C16:0 Supplement

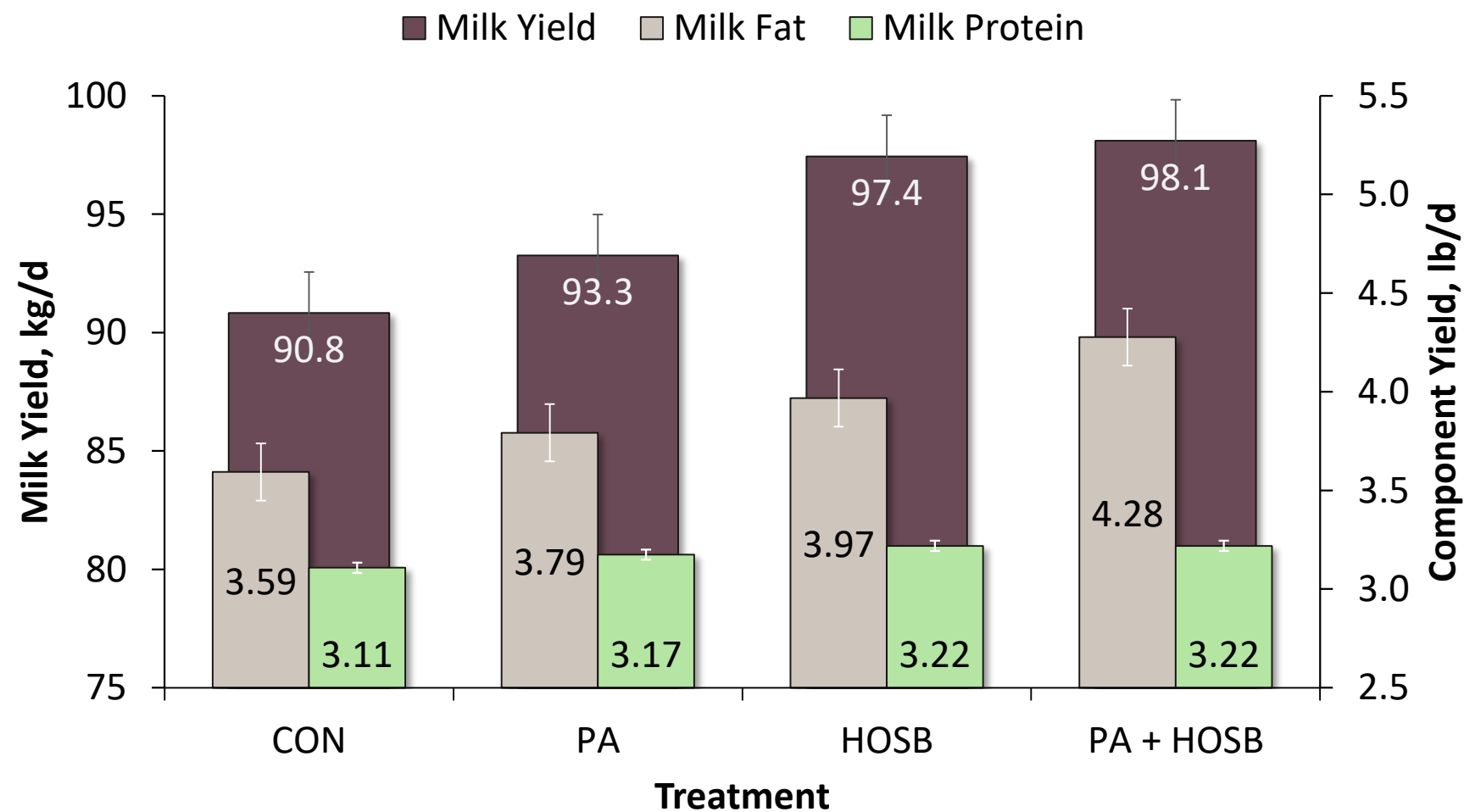
- 20 multiparous cows
 - Avg. 101 lb/d milk yield
 - 136 ± 18 DIM
- Four, 14-day feeding periods



Ingredient, % DM	Treatment			
	CON	PA	HOSB	PA + HOSB
Corn Silage	43.0	43.0	43.0	43.0
Alfalfa Silage	10.0	10.0	10.0	10.0
Alfalfa Hay	1.8	1.8	1.8	1.8
Ground Corn	12.1	12.1	12.1	12.1
Lactating Cow Mix	3.8	3.8	3.8	3.8
Vitamin and Mineral Mix	2.0	2.0	2.0	2.0
DCAD	0.5	0.5	0.5	0.5
Roasted, Ground HOSB	0.0	0.0	15.5	15.4
Amino Plus	10.7	10.7	0.0	0.0
Soybean Meal	7.0	6.9	5.8	5.7
Soyhulls	9.0	7.8	8.0	4.3
C16:0 Supplement	0.0	1.4	0.0	1.4

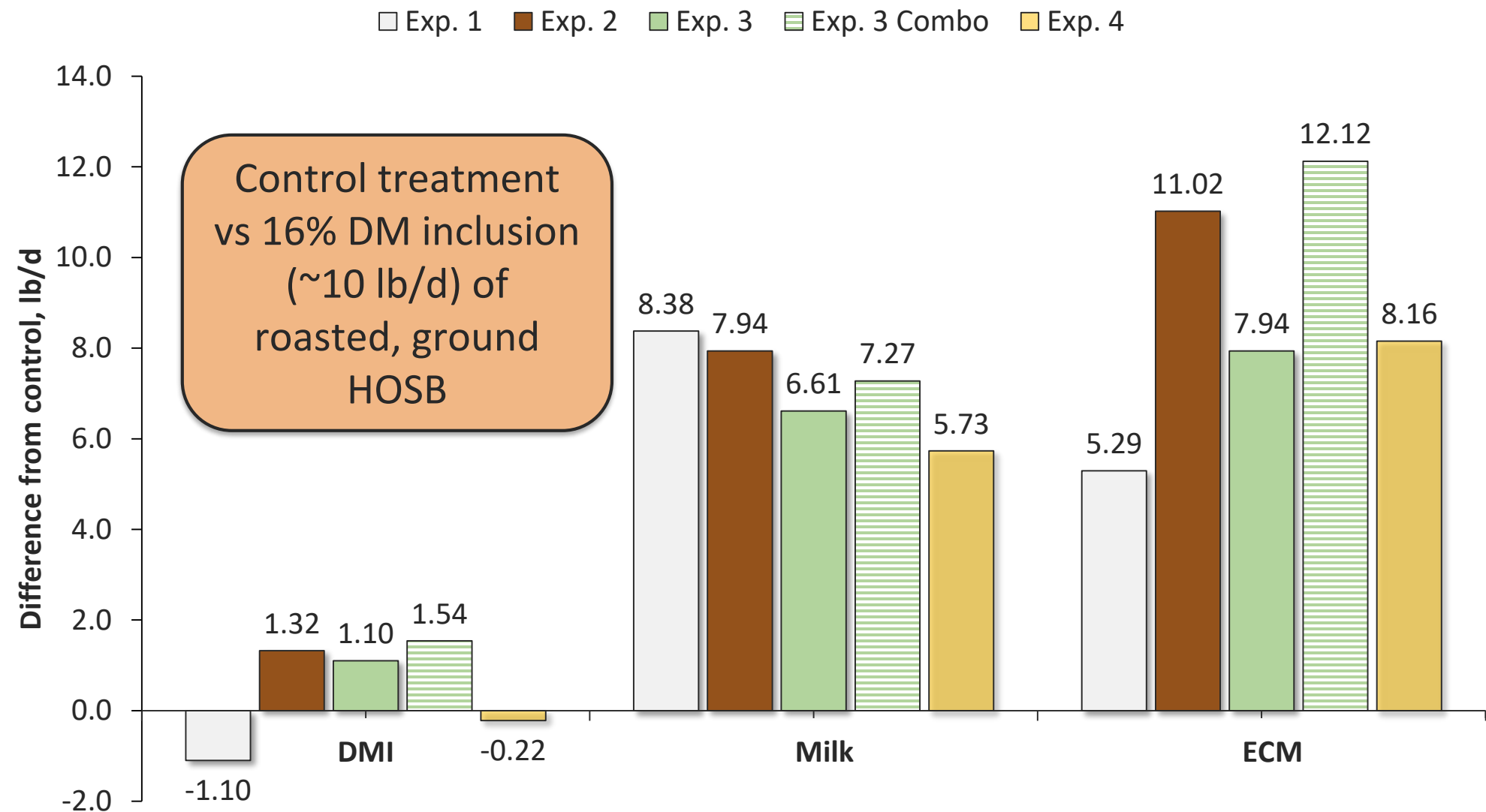
Exp. 3: HOSB + C16:0 Supplement

HOSB P-Values:
Milk Yield; <0.001
Milk Fat; <0.001
Milk Protein; <0.01



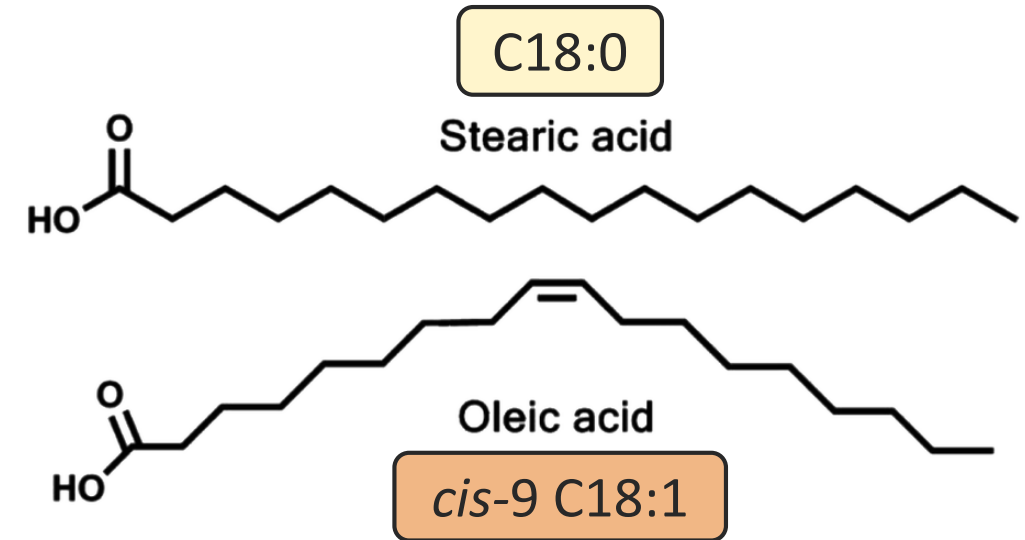
The addition of HOSB to diets increased DMI and increased yields of milk, milk fat, and milk protein

HOSB Consistent Production Responses



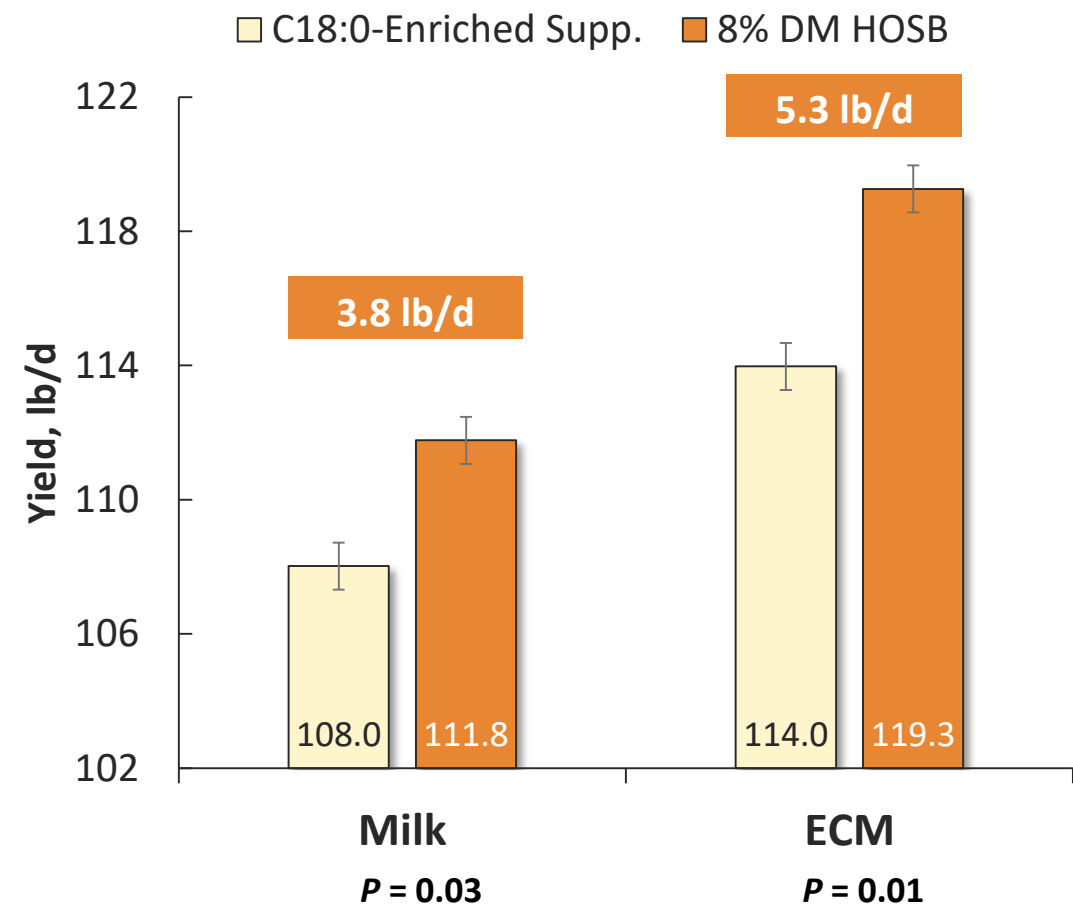
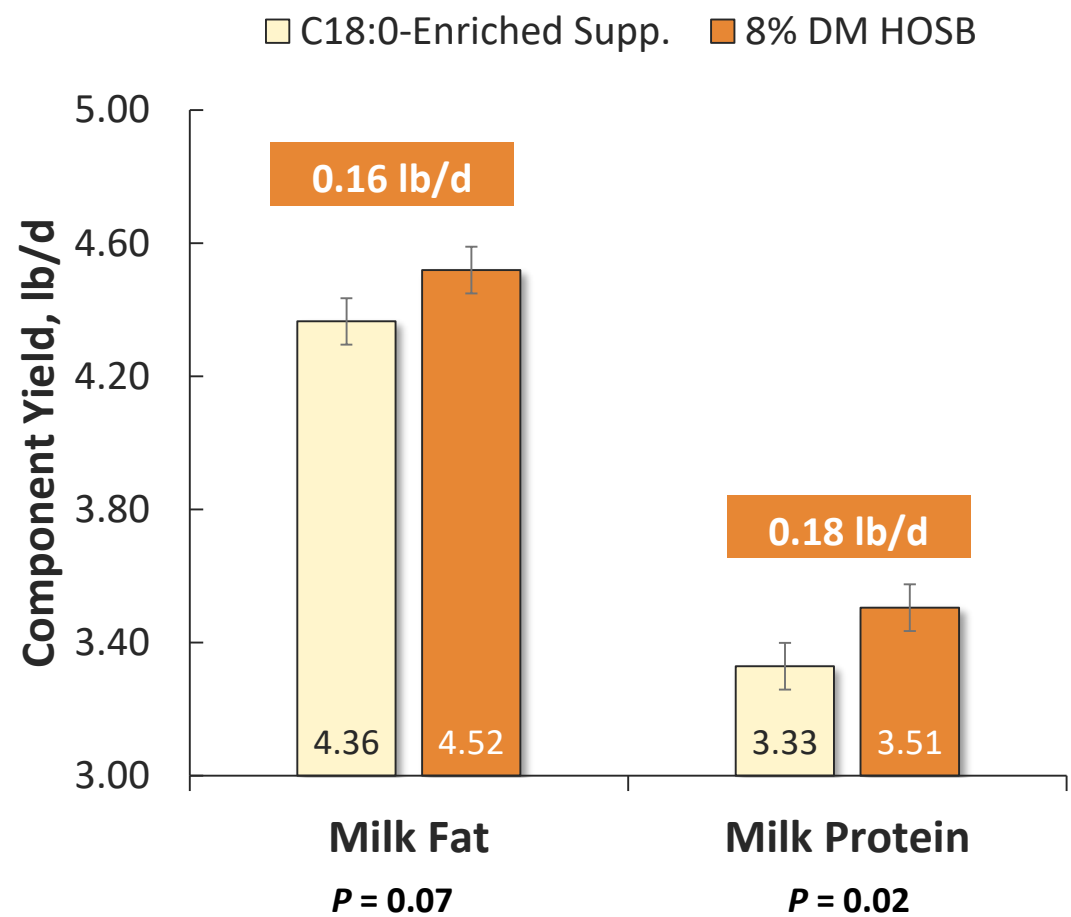
Are 18-Carbon FA's the Same?

Ingredient, % DM	Treatment	
	EB 100	HOSB
Corn Silage	43.3	43.3
Alfalfa Silage	11.6	11.6
Ground Corn	15.0	15.0
Vitamin and Mineral Mix	2.0	2.0
Lactating Cow Mix	7.2	7.2
DCAD	0.3	0.3
Soybean Meal	5.0	5.5
Soyhulls	6.2	6.0
Amino Plus	7.3	0.0
HOSB, roasted and ground	0.0	8.3
C16:0-enriched prill	0.0	0.7
C18:0-enriched prill	2.0	0.0



Nutrient Composition	Treatment	
	EB 100	HOSB
Total FA, %DM	4.47	4.34
C16:0, %FA	23.5	23.8
C18:0, %FA	24.3	2.94
C18:1, %FA	13.4	36.8
Total 18-C FA, %FA	70.6	73.3

HOSB vs C18:0-Enriched Supplement



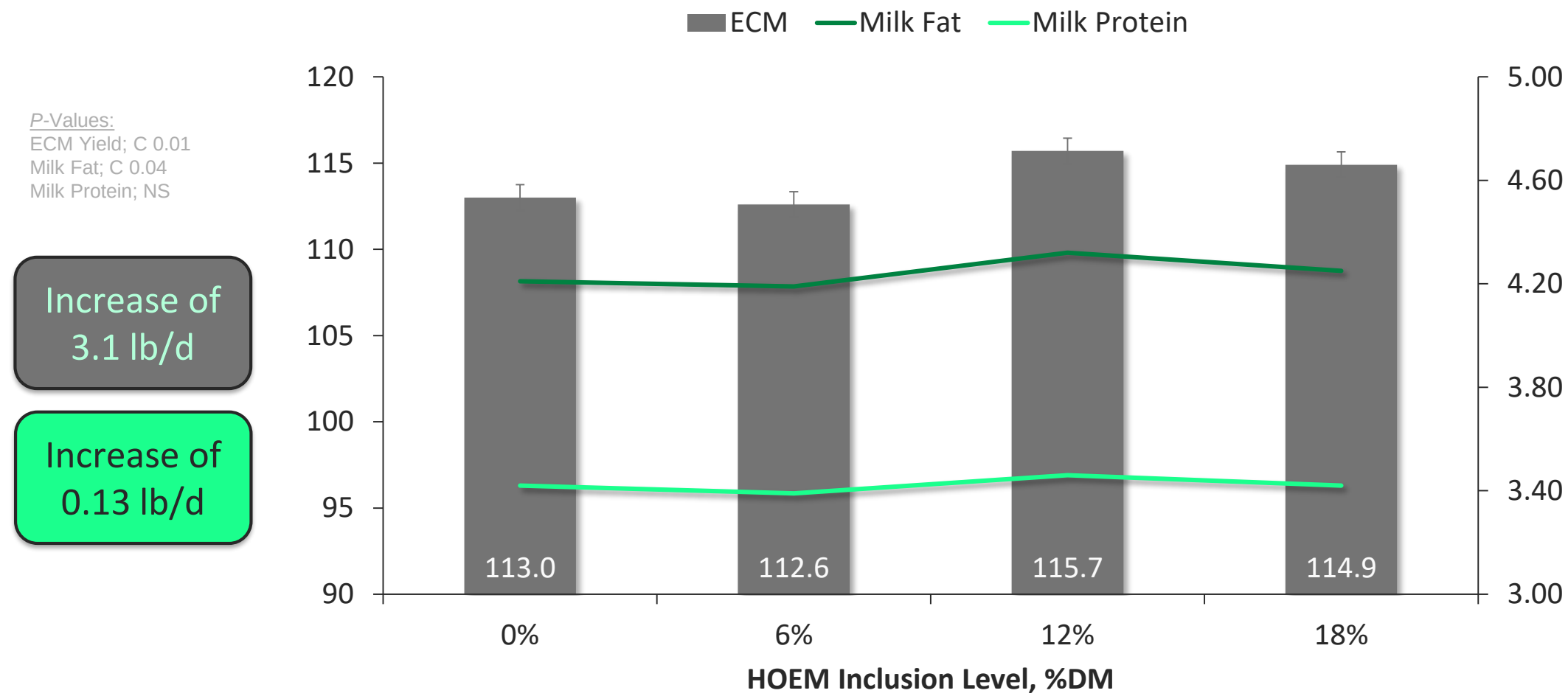
HOSB increased milk production compared with C18:0-enriched prill – not all 18-C are the same!

HOEM Dose Response

- 24 multiparous cows
 - Avg. 112 lb/d milk yield
 - 107 ± 25 DIM
- Four, 21-day feeding periods

Ingredient, % DM	Treatment			
	0%	6%	12%	18%
Corn Silage	41.7	41.7	41.7	41.7
Alfalfa Silage	10.0	10.0	10.0	10.0
Alfalfa Hay	1.7	1.7	1.7	1.7
Ground Corn	16.0	16.0	16.0	16.0
Lactating Cow Mix	3.3	3.3	3.3	3.3
Vitamin and Mineral Mix	2.0	2.0	2.0	2.0
DCAD	0.5	0.5	0.5	0.5
C16:0 Supplement	1.0	1.0	1.0	1.0
High Oleic Exceller Pro	0.0	6.0	12.0	18.0
Amino Plus	16.5	11.0	5.6	0.0
Soyhulls	7.3	6.8	6.3	5.8

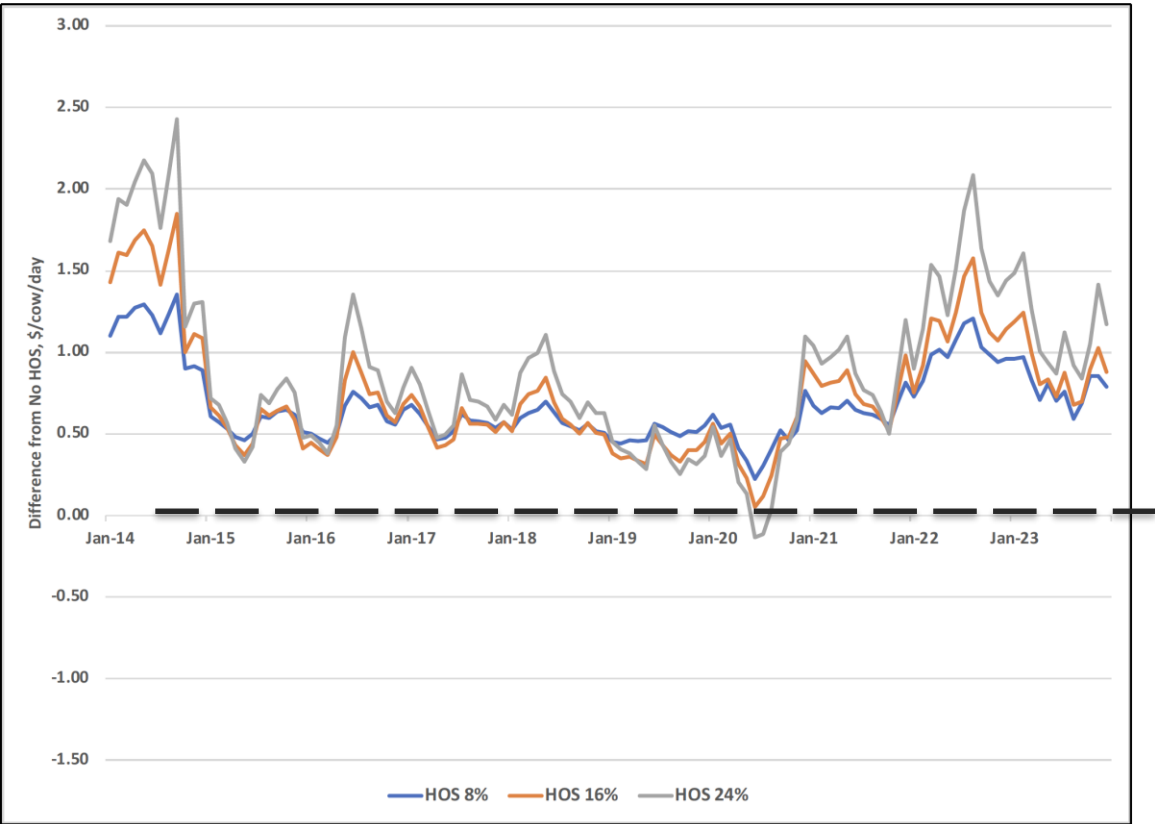
HOEM Dose Response



Increasing High Oleic Exceller Pro inclusion increased ECM yield but did not have a large impact on milk protein

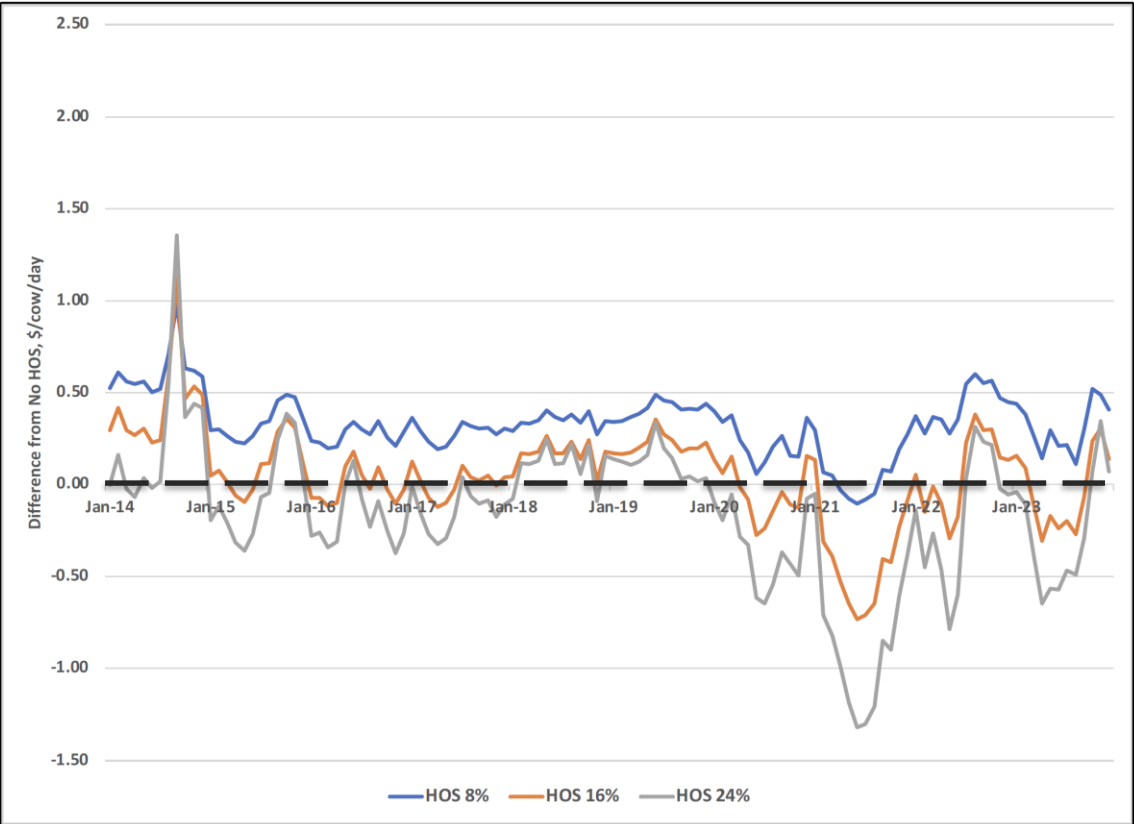
Economic Feasibility of HOSB

Homegrown Scenario



Revenue Less Feed Costs at HOS Production Costs Compared to Treatment without HOS, January 2014 to December 2023

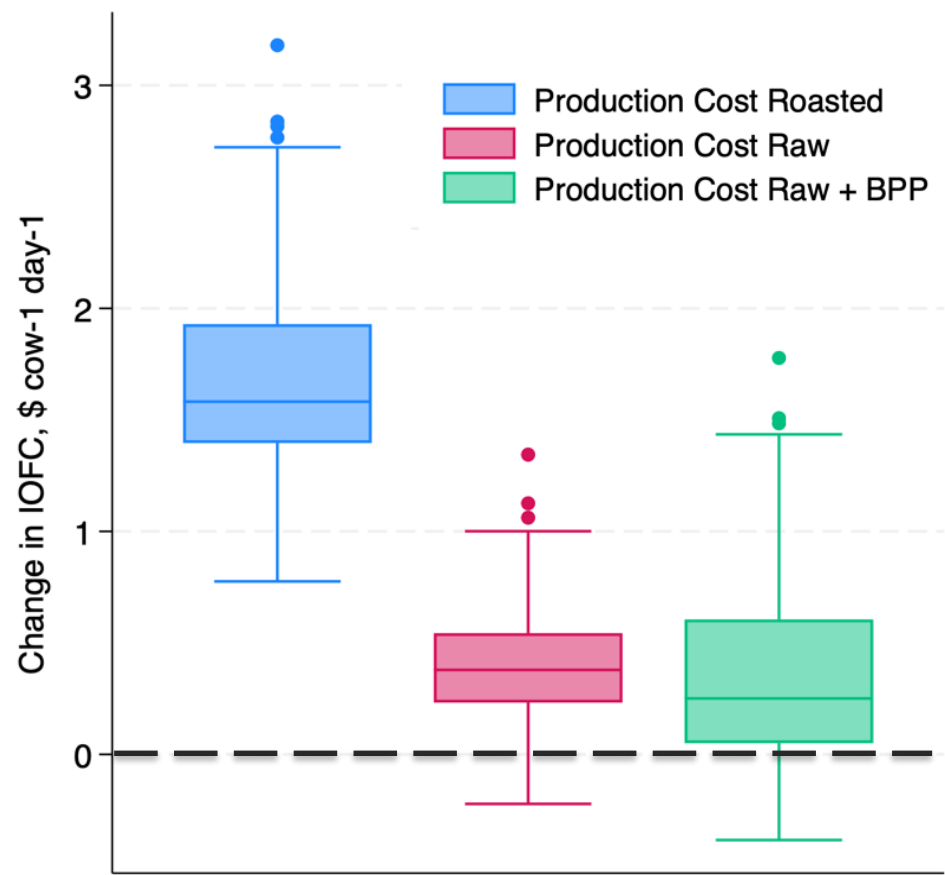
Purchased Scenario (transport + premium)



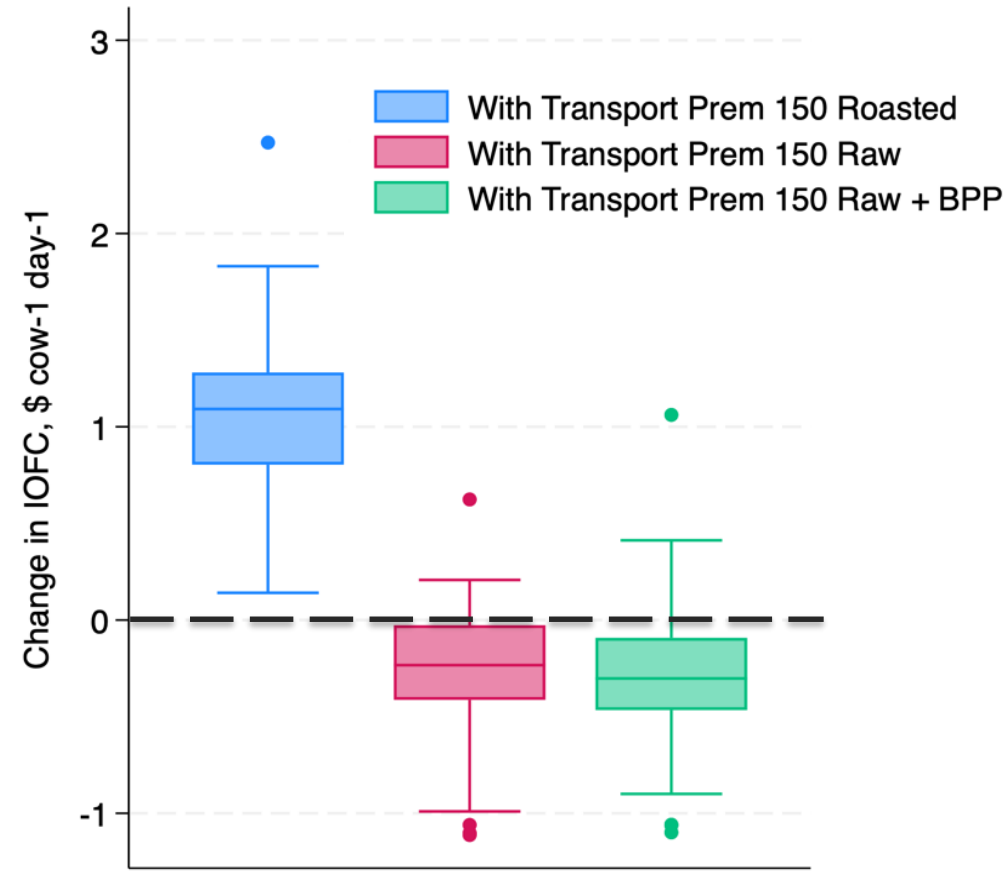
Milk Revenue Less Feed Costs With Transportation Costs and HOS Premium of \$1.50/bu Compared to Treatment without HOS, January 2014 to December 2023

Economic Feasibility of HOSB

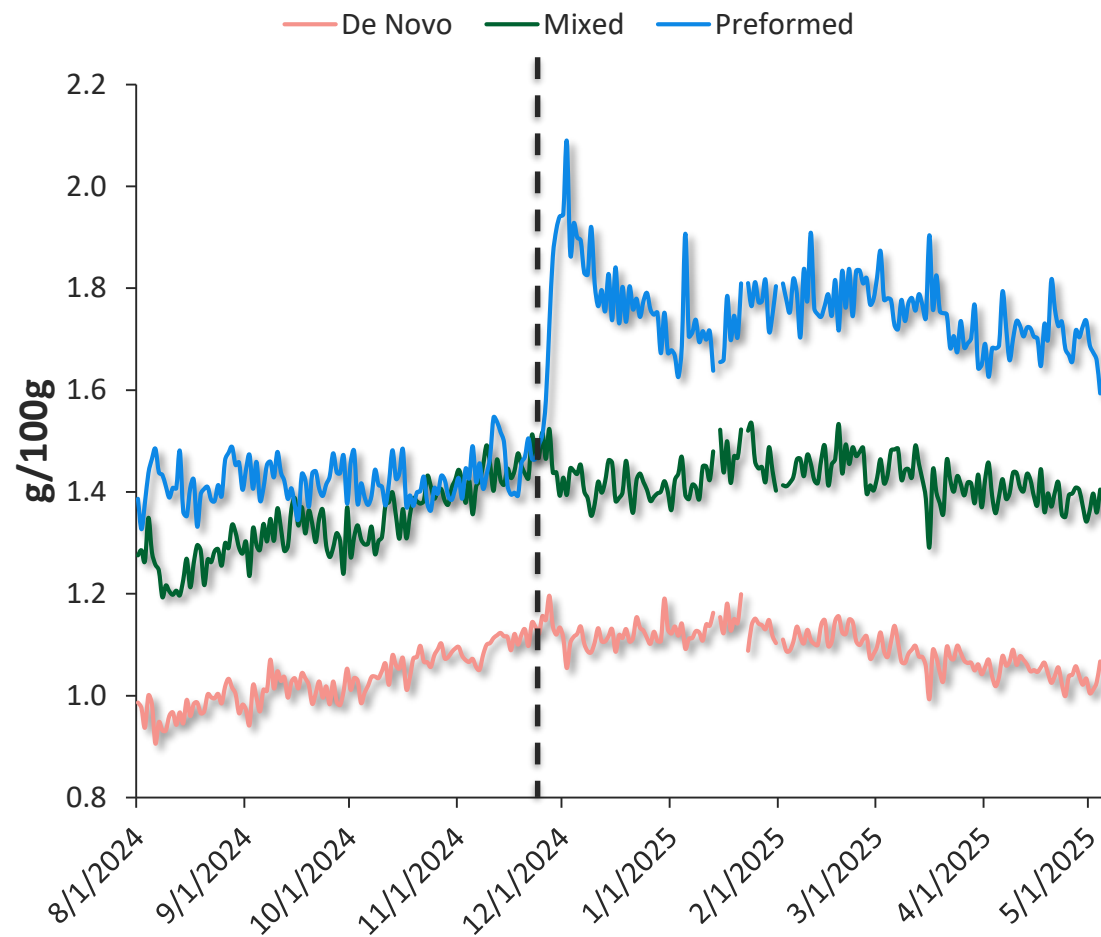
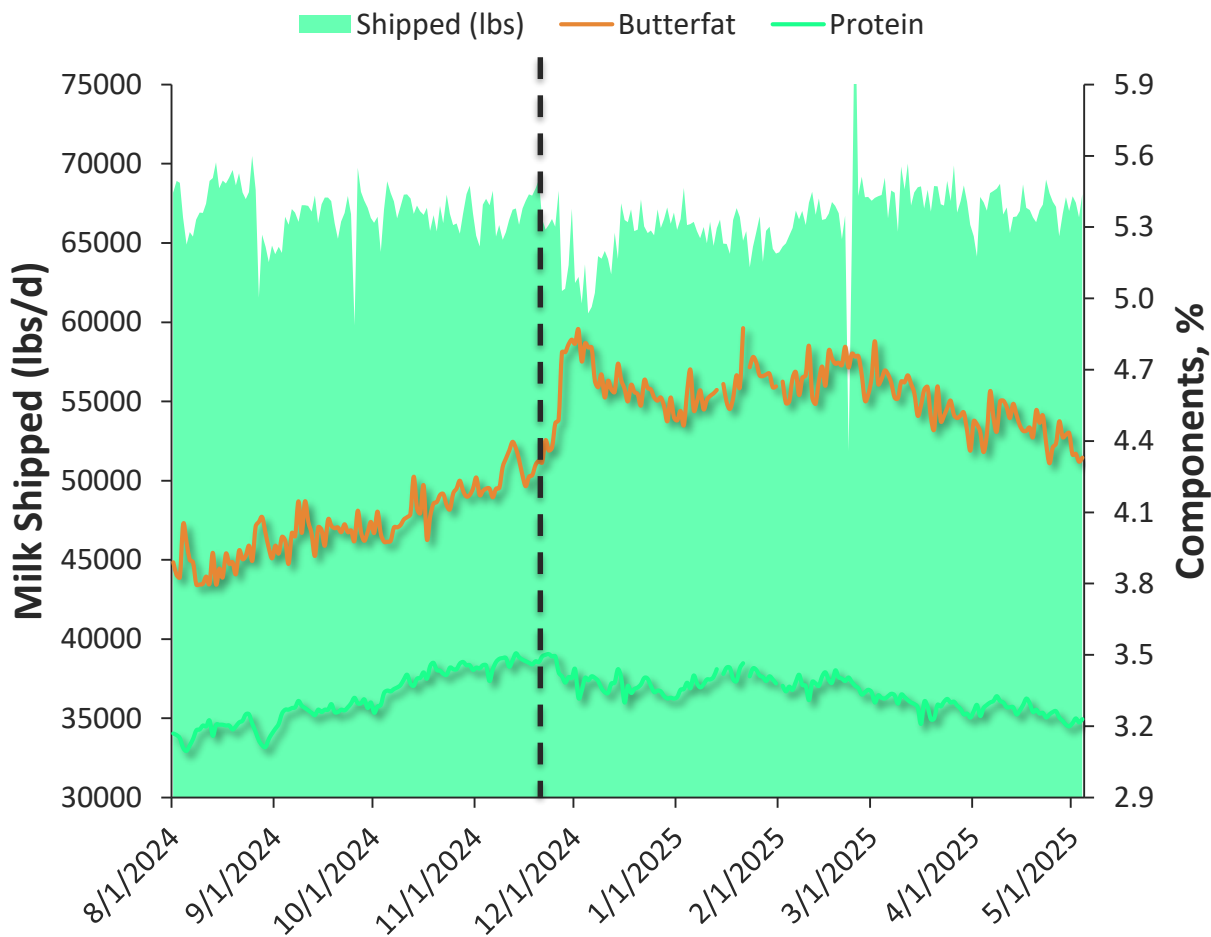
Homegrown Scenario



Purchased Scenario (transport + premium)



Farm Example 1 – 950 cows



Farm Example 1 – 950 cows

Ingredient, % DM	Before	After
Corn Silage	31.9	33.1*
Alfalfa Silage	16.3	15.5
Ground Corn	22.9	22.9
Vitamin and Mineral Mix	0.3	0.3
Molasses	0.5	0.5
Corn Gluten Feed (wet)	0.02	0.02
Lactating Cow Mix 1	10.1	0.0
Lactating Cow Mix 2	0.0	7.5
HOSB, ground and roasted	0.0	10.8
Soybean Meal	8.5	0.0

Homegrown HOSB +
roaster and grinder on site

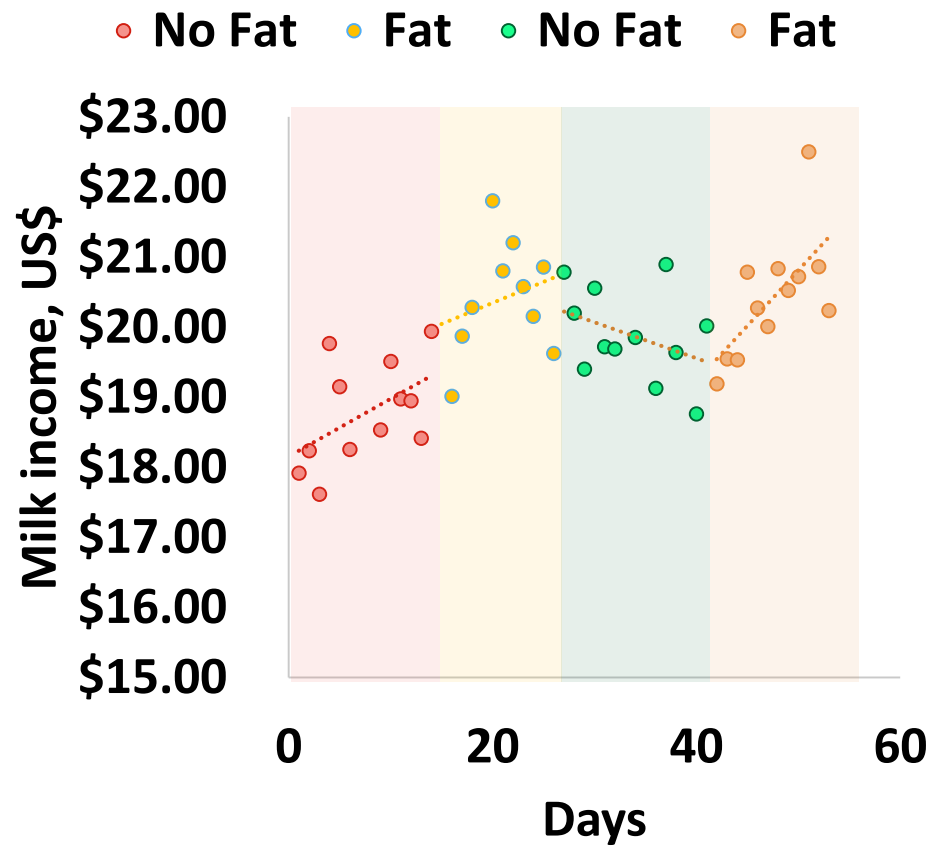
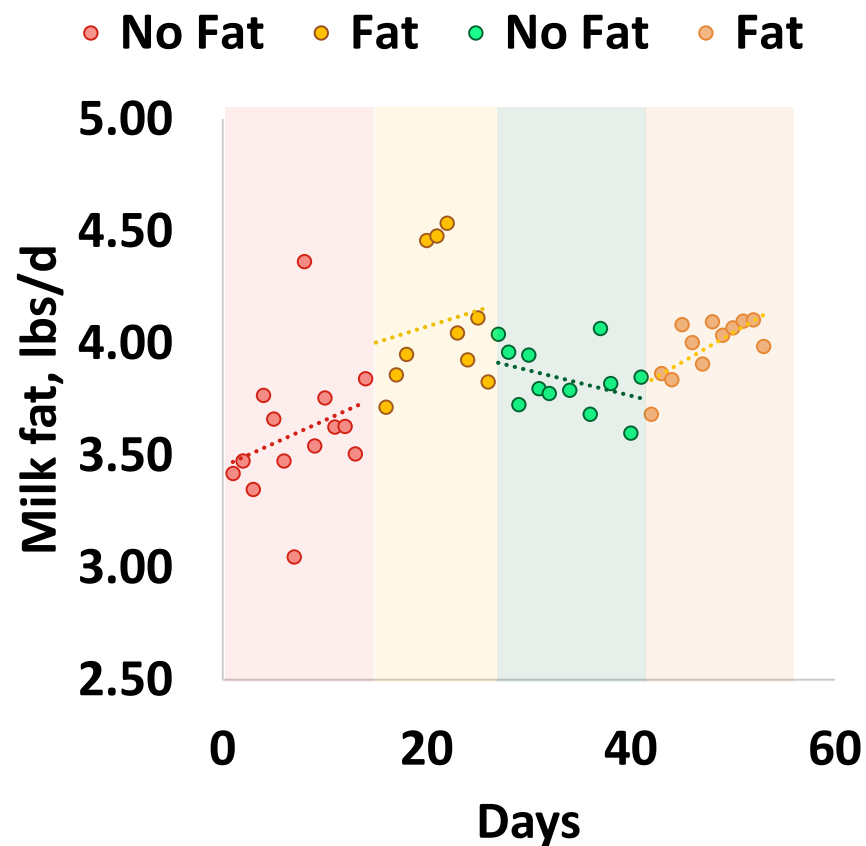
IOFC increase
of \$1.70

Nutrient Comp., % DM	Before	After
DM	51.5	52.9
NDF	24.9	24.9
Forage NDF	18.7	19.5
Starch	29.8	29.7
Sugar	6.05	6.97
CP	17.0	16.6
RUP (%CP)	41.5	41.7
Total FA	3.17	3.77

Farm Example 2

- 475 cows
- On-farm roaster and grinder
 - Farming their own HOSB since 2019
- Diet is corn silage, earlage, haylage, beans, dry corn, whey, and a 2lb mineral mix
- Due to diet dynamics, Spectrum Fusion was added directly on top (1.5% DM)
- Two weeks on, two weeks off
 - November – December 2024
- Daily tank weights, components, milk fatty acids and cow numbers

Farm Example 2



Period	Milk Fat Average	Milk Income
1	3.61	\$18.85
2	3.92	\$20.09
3	3.81	\$19.74
4	4.00	\$20.41

Ration Balancing

SOYBEAN INGREDIENTS

- Replacing soybean meal and heat-treated soybean meal (i.e. AminoPlus) with HOSB
 - In low haylage diets, some soybean meal will be needed for RDP requirements
- HOEM can replace heat-treated soybean meal
 - Main difference is the ~6-8% oil in expeller meal

ROASTING

- Roasted soybeans provide RUP and decrease antinutritional factors
 - Roasting temperature and time is crucial!
- Raw soybeans can be fed but will need additional undegradable protein ingredients
 - Use heat-treated soy and/or blood meal

PROTEIN INGREDIENTS

- Decreasing blood meal with addition of HOSB
 - Blood meal is an expensive protein source
 - High in Lysine – soybeans are too!
- Soybeans are low in Methionine
 - A Methionine product will still be needed

FAT SUPPLEMENTS

- Traditional Ca-salts can be removed
 - Have a C18:1 level of ~30-45%
- Keep the C16:0 prills in!!

INCLUSION RATE

- High Group – 6-12 lbs/hd
- Fresh Cows – 2-6 lbs/hd

Soybean Grind Size

Particle Size	
<600 µm	Lose digestibility
700 – 800 µm	Optimal
¼ - ½ cracked	Can work well for certain farms
Halves	
Whole	Less utilization



Roasted HOSB:
 $771 \pm 2.56 \mu\text{m}$
 $725 \pm 2.59 \mu\text{m}$



Raw HOSB:
 $794 \pm 2.52 \mu\text{m}$

Processing + Fatty Acid Profile

Individual Fatty Acid	WHOLE		GROUND	
	Raw	Roasted	Raw	Roasted
C14:0	0.05	0.05	0.03	0.03
C15:0	0.05	0.05	0.03	0.03
C16:0	6.15	6.20	5.55	5.62
C16:1 7c	-	-	0.02	0.02
C16:1 9c	0.11	0.11	0.09	0.08
C17:0	0.73	0.73	0.65	0.62
C18:0	3.87	3.95	3.87	3.58
C18:1 t	-	-	0.02	0.05
C18:1 9c	77.84	77.80	82.04	82.73
C18:1 11c	1.32	1.31	0.91	0.98
C18:2 9c,12c (n-6)	5.92	6.44	4.61	4.00

Analyzed by CVAS

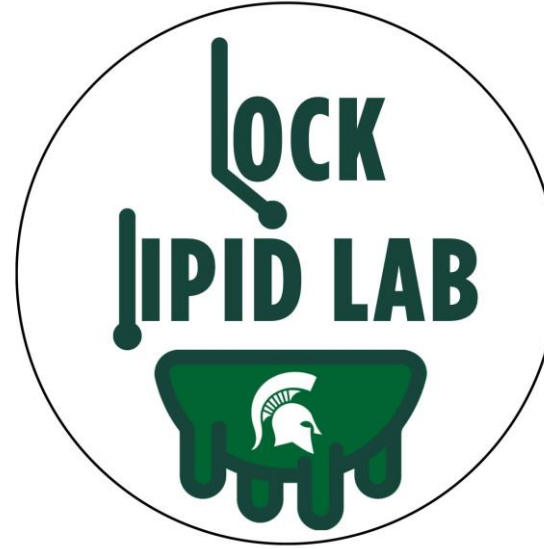
Analyzed by Lock Lipid Lab

Minimal changes
($<0.50\%$) in FA profile
within whole and
ground HOSB groups

Biggest difference
($\sim 0.5\% - 5.0\%$) is FA
profile between HOSB
batches

Acknowledgements

- Lock Lipid Lab – MSU
- Michigan Alliance for Animal Agriculture
- Michigan Milk Producers Association
- United Soybean Board
- Caledonia Farmers Elevator
- Perdue Agribusiness
- Pioneer
- Quality Roasting
- Chuck Nicholson – UW Madison



QUALITY
ROASTING



Thank You!



ALYCIA BALES, Ph.D.
ANIMAL NUTRITION TECHNICAL SUPPORT



 abales@cfeco.com

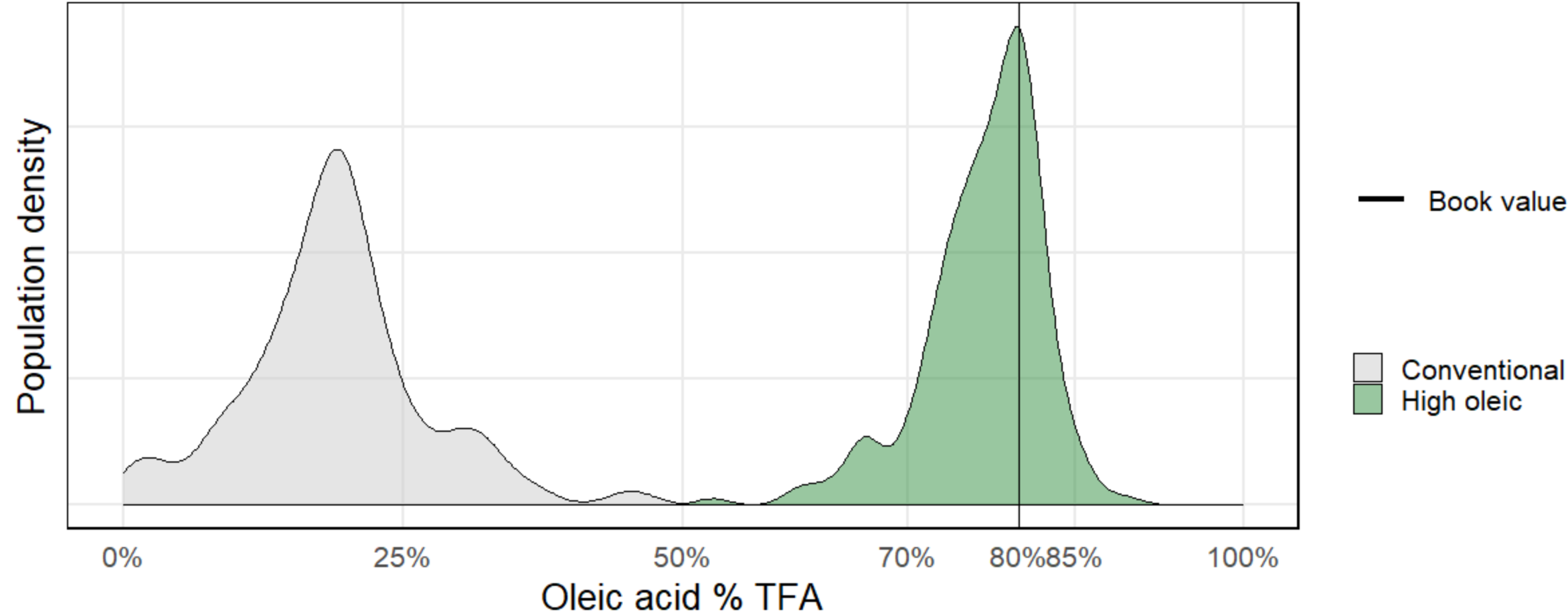
 (810)-543-1016

WHY AND HOW BEST TO TEST HIGH OLEIC SOY

Kyle Taysom
CEO at Dairyland Laboratories

Oleic acid distribution in soybeans

(>300 samples by chemistry)



Data source: Dairyland Laboratories Inc.



TESTING OPTIONS FOR OLEIC CONCENTRATION

Gas chromatography (chemistry)

- Gold standard method
- ~\$85/sample
- Use case: Research looking for small differences in treatments

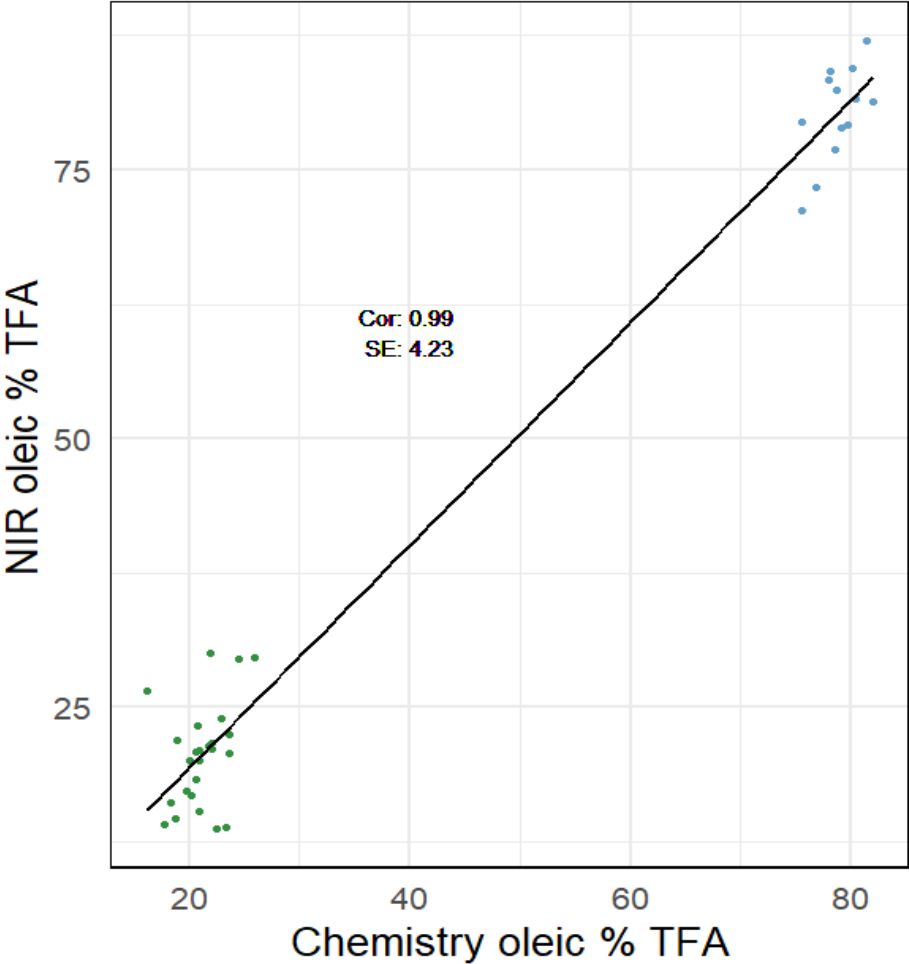
Lab based NIR

- Availability?
- Reliable classifier
- ~\$30/sample
- Use case: Downstream verification

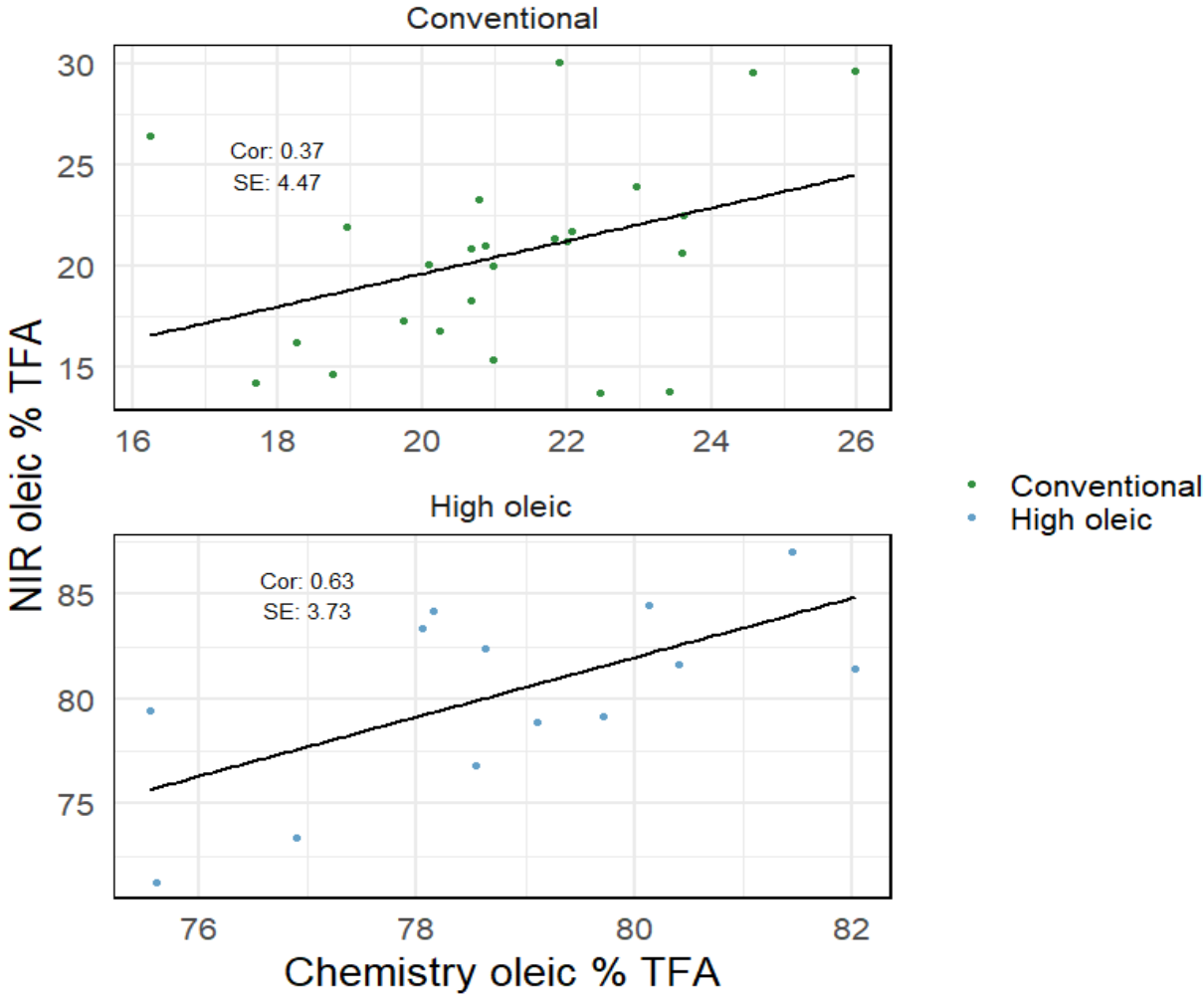
In-field NIR

- Identifying high oleic soybeans is easy
- Precise quantification is feasible, but requires attention to detail by the instrument vendor
- ~\$3k-5k/year?
- Use case: Screening of incoming ingredients

NIR is a reliable classifier
of high oleic soybeans



NIR may not be precise within group



Data source: Dairyland Laboratories Inc.



EVALUATING QUALITY OF ROASTING FOR DAIRY

Many methods are available

- In vitro rumen undegraded protein (RUP) & undigested protein (UCP)
- Protein dispersibility index (PDI)
- In situ RUP
- Potassium hydroxide solubility (KOH)
- Urease activity

All have demonstrated relationships to in vivo outcomes.

All can be used to “stay out of the ditches”.

None differentiate well within the normal ranges of roasting quality.

HSU AND SATTER, 1995

Conducted a thorough evaluation roasted soybeans methods and outcomes including:

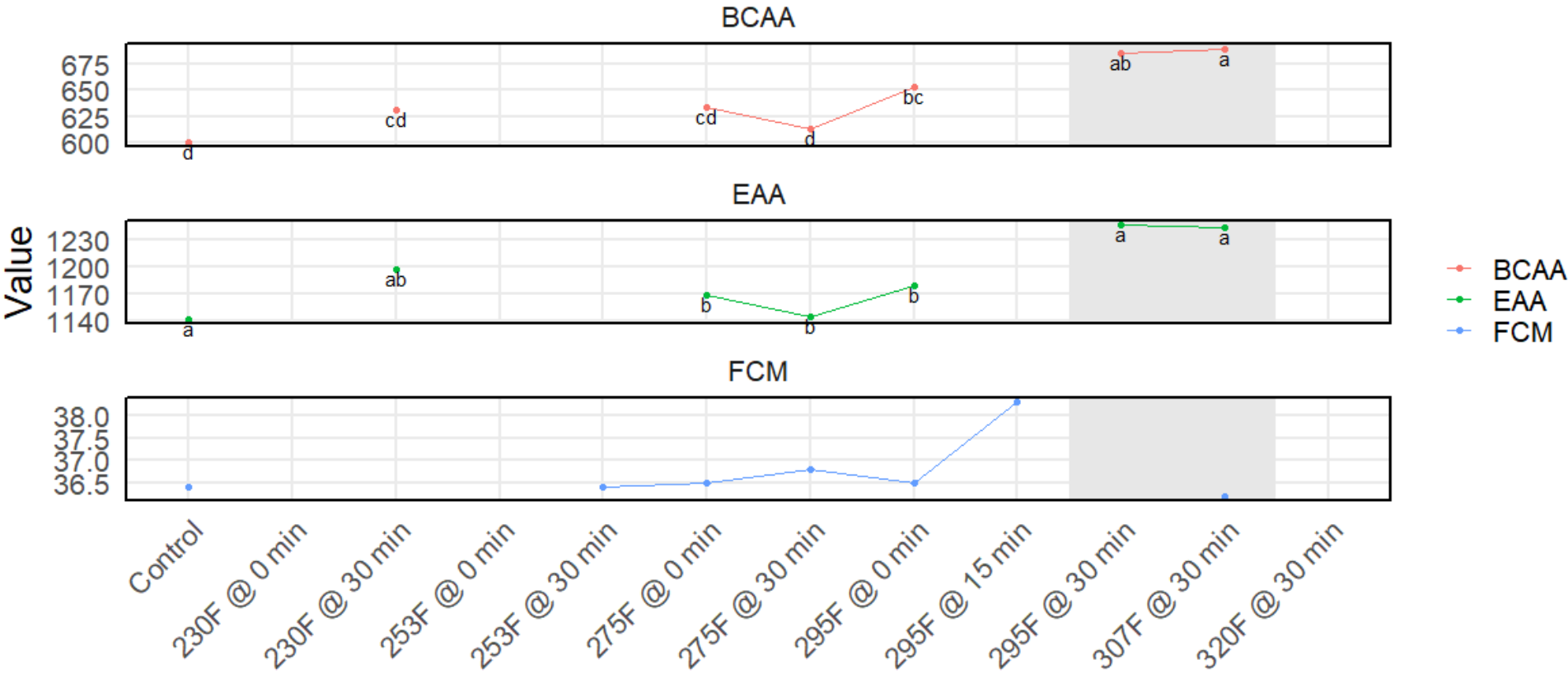
- 12 treatments or soybeans (temperature + steeping variation)
- Lactating cow trial
- Heifer feeding trial
 - Plasma concentration of lysine, branch chain amino acids (BCAA), essential amino acids (EAA), and total amino acids (TAA)
- PDI
- In situ RUP
 - 0,1, 2, 4, 8,16, 32, and 48 hr time points
 - 2 mm Wiley
 - Assumed passage rate of 7%/hr
- In vitro RUP
- Available lysine
 - Dinitrofluorobenzene method (AOAC 1984)
- Post ruminal available lysine (PRAL)
 - Calculated from in vitro RUP and available lysine measurements

HSU AND SATTER DIET

Fed in both the heifer trial and lactation trial

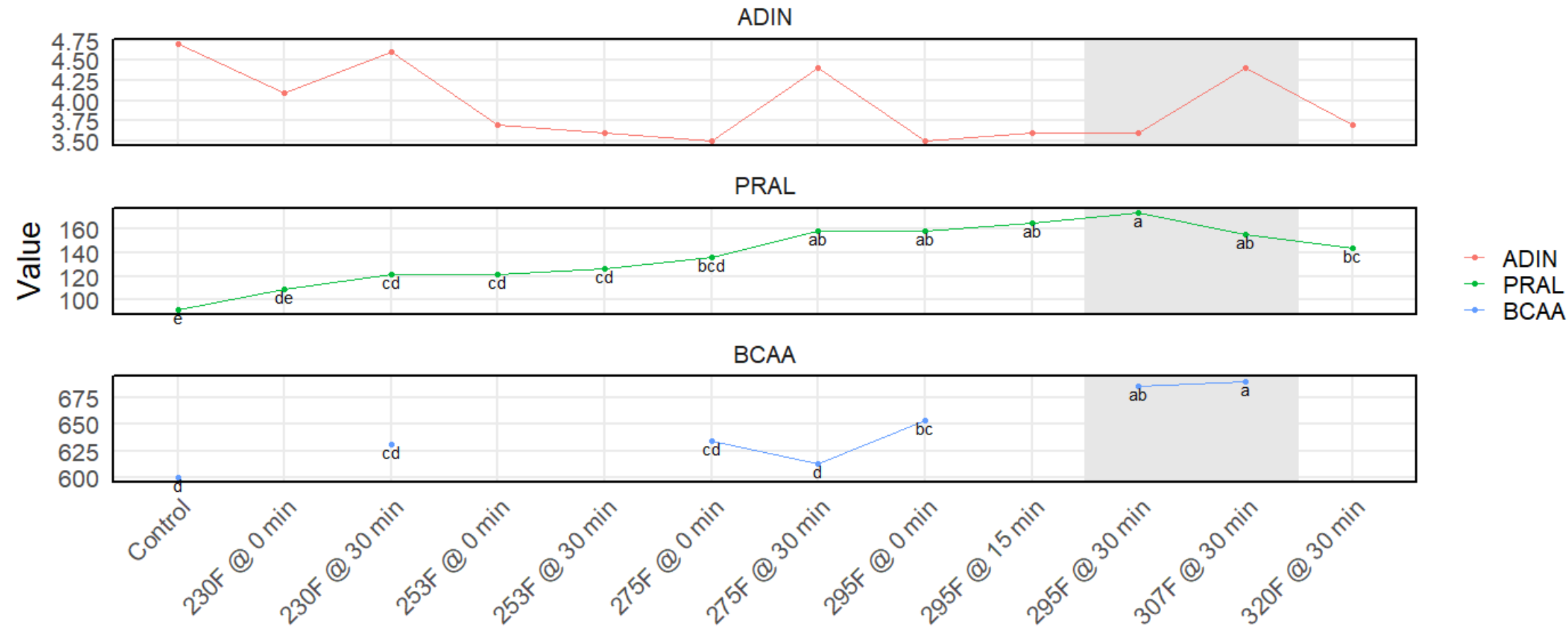
- 50% alfalfa silage
- 35.5% high moisture ear com
- 13% soybeans
- .5% dicalcium phosphate, .1% monosodium phosphate, .5% trace-mineralized salt, and .4% premix of vitamins A, D, and E. T

FEEDING TRIAL OUTCOMES

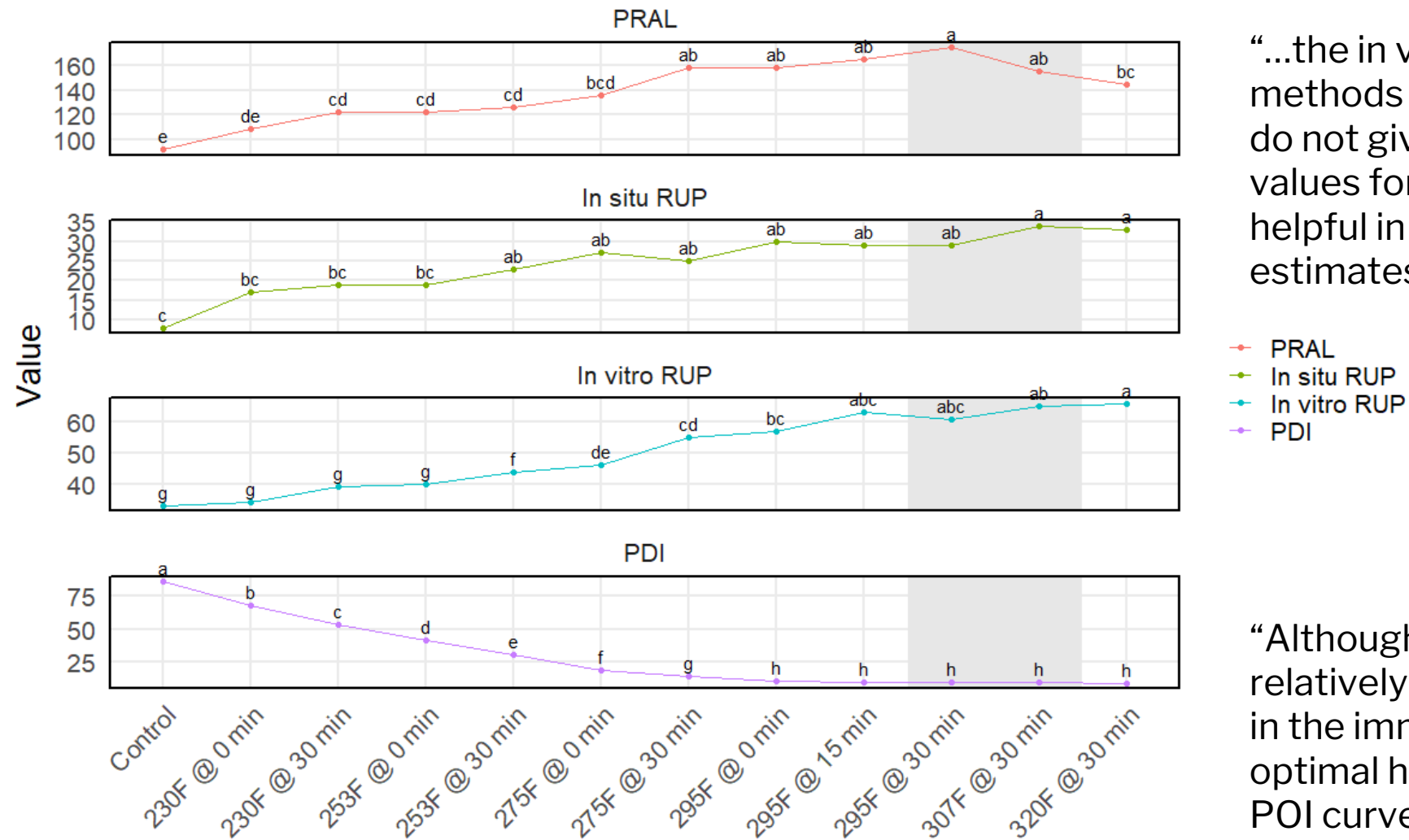


Adapted from Hsu and Satter, 1995 JDS

ADIN IS NOT USEFUL, PRAL INDICATES POINT OF OVERHEATING



Adapted from Hsu and Satter, 1995 JDS

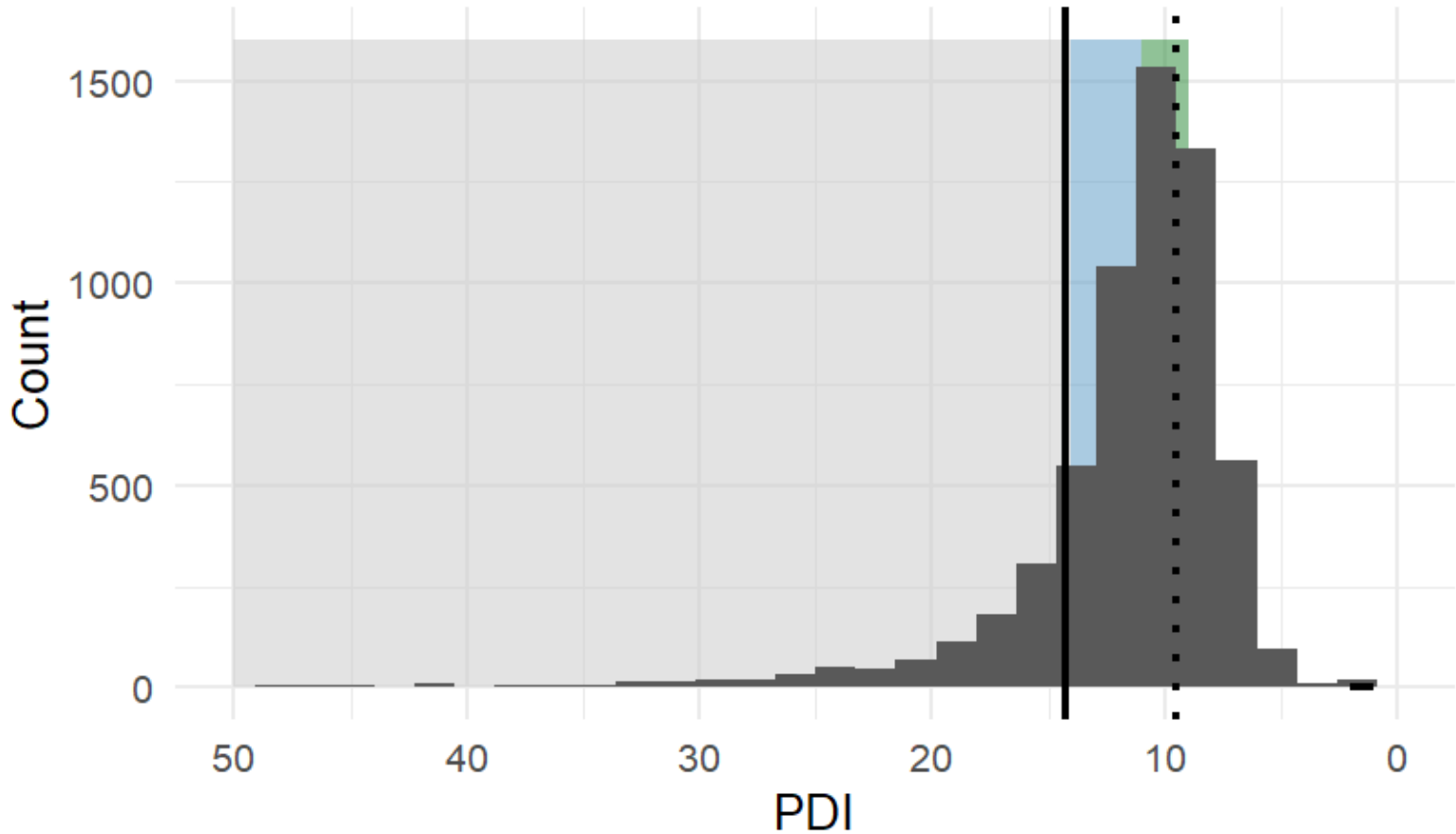


“...the in vitro and in situ methods of estimating RUP do not give reliable absolute values for RUP but are helpful in giving relative estimates of RUP.”

“Although the POI curve is relatively flat and insensitive in the immediate area of the optimal heat exposure, the POI curve clearly identifies the underheated soybeans.”

Adapted from Hsu and Satter, 1995 JDS

PDI in commercial soybean samples (>6,000 samples)



Data source: Dairyland Laboratories Inc.

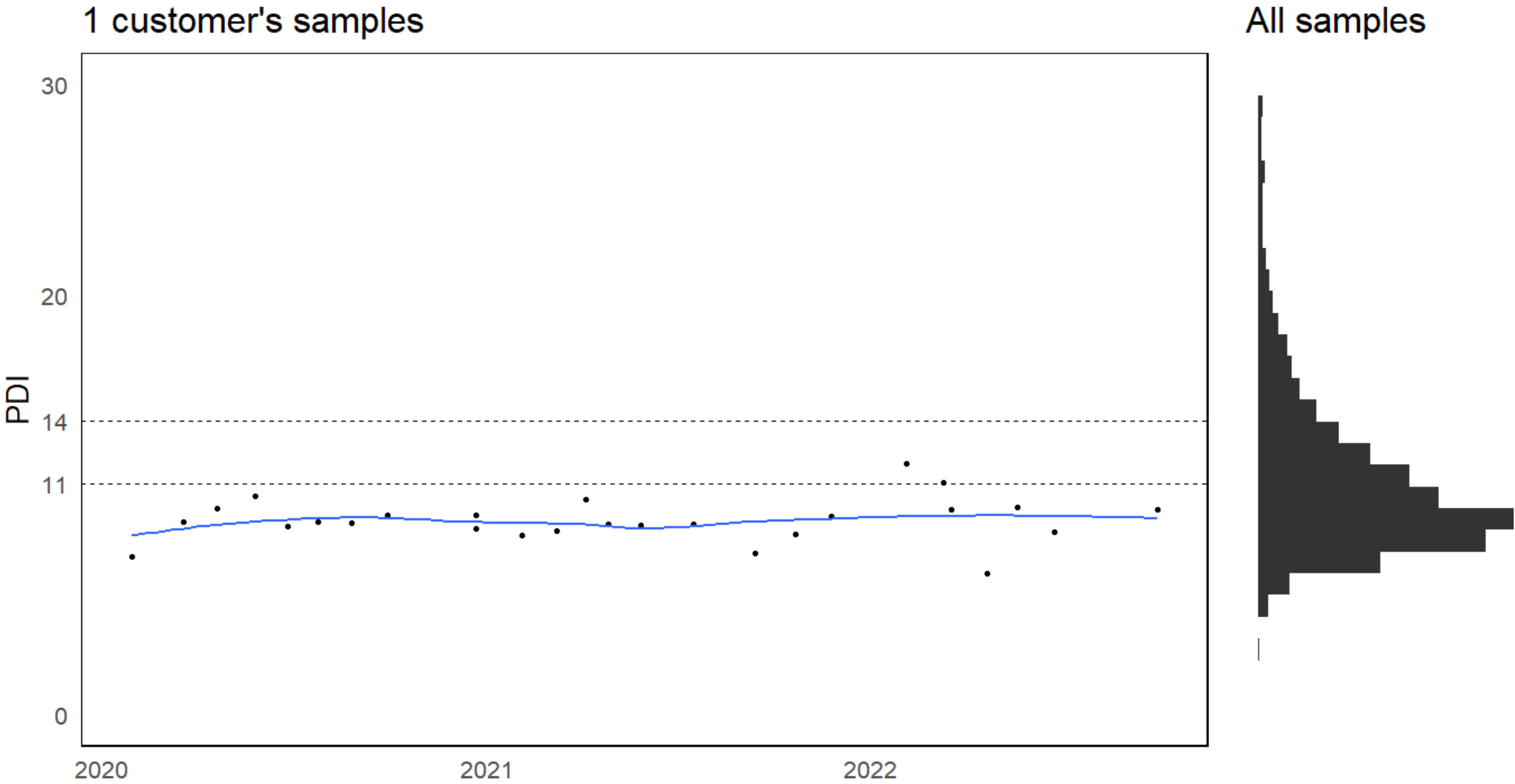
UDSA-FRC interpretations

- Underheated
- Slightly underheated
- Optimum

- Lowest treatment with statistical difference
- Optimum PRAL and feeding outcomes

Hsu & Satter, 1995





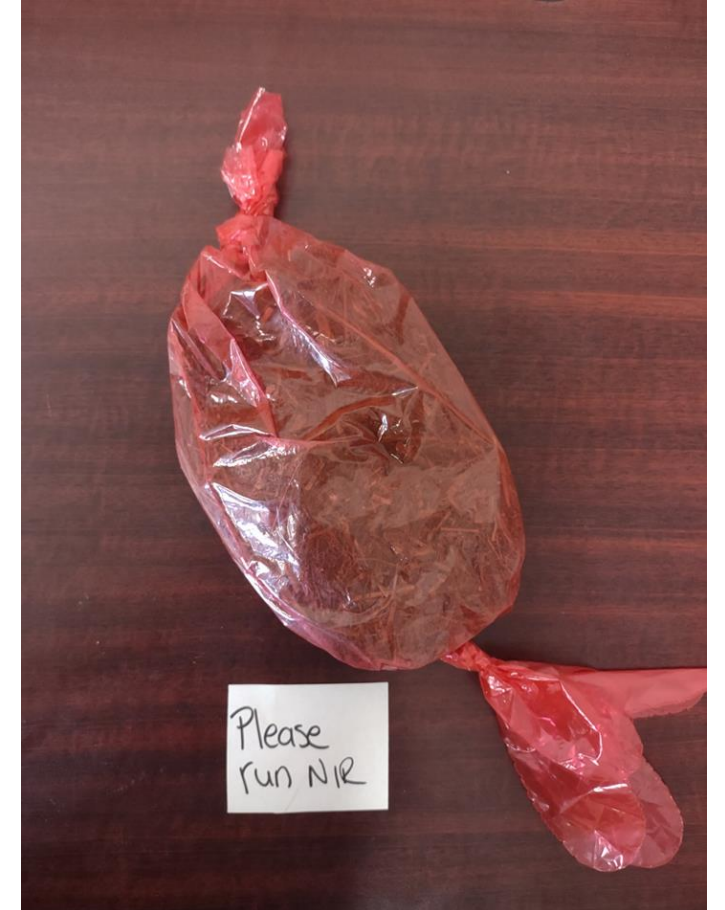
Data source: Dairyland Laboratories Inc.

HOW DO H.O. SOYBEANS COMPARE ON OTHER NUTRIENTS?

Dairyland customers do not:

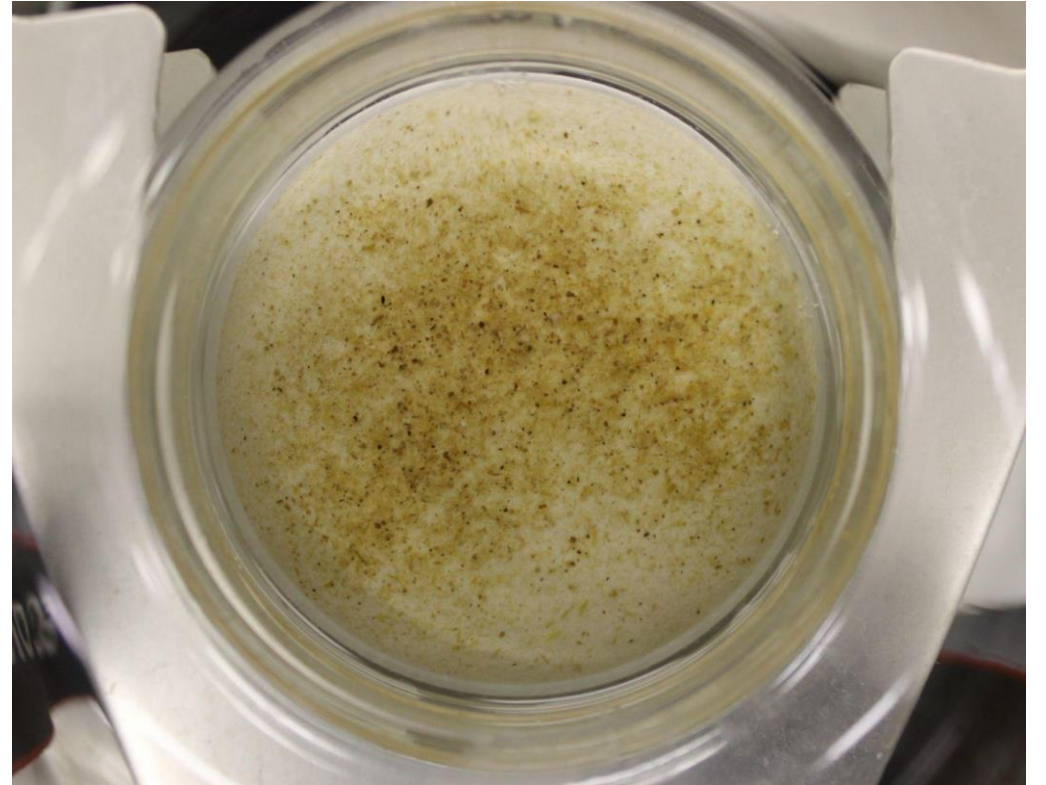
- 1) Provide descriptions like “high oleic”, “Plenish”, or “H.O.”
- 2) Order fatty acid profiles + other nutrients

Order counts	Identified by description or oleic measurement		
	Unknown	High oleic	Conventional
CP	2004	199	73
aNDF	709	33	0
ADICP	123	5	0
SP % CP	121	5	0
Ross UCP	99	14	0
NDICP	60	3	0



SUMMARY

- Chemistry, lab based NIR, and in-field NIR are available for high oleic verification
- Several methods can detect under-heated soybeans
- Current methods struggle to differentiate samples around optimum levels of roasting for bypass value



THANK YOU!

Kyle Taysom
CEO at Dairyland Laboratories

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608-409-7003



Q&A

Alycia Bales, Ph.D.
Animal Nutrition Technical Support at Caledonia Farmers Elevator

Kyle Taysom
CEO at Dairyland Laboratories

SSOY

Four State Dairy Nutrition & Management Conference

JUNE 12, 2025

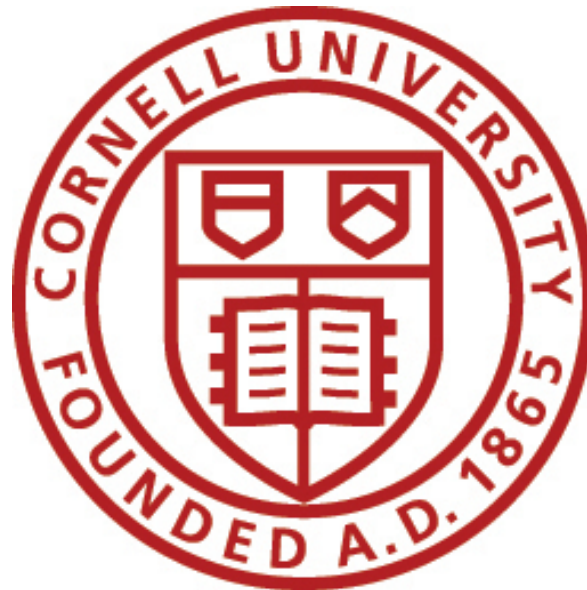


Improving Nitrogen Utilization While Reducing Urinary Nitrogen Excretion

Mike Van Amburgh, Alexandra Benoit, and Andrew LaPierre

Dept. of Animal Science

mev1@cornell.edu



Today's Talk

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

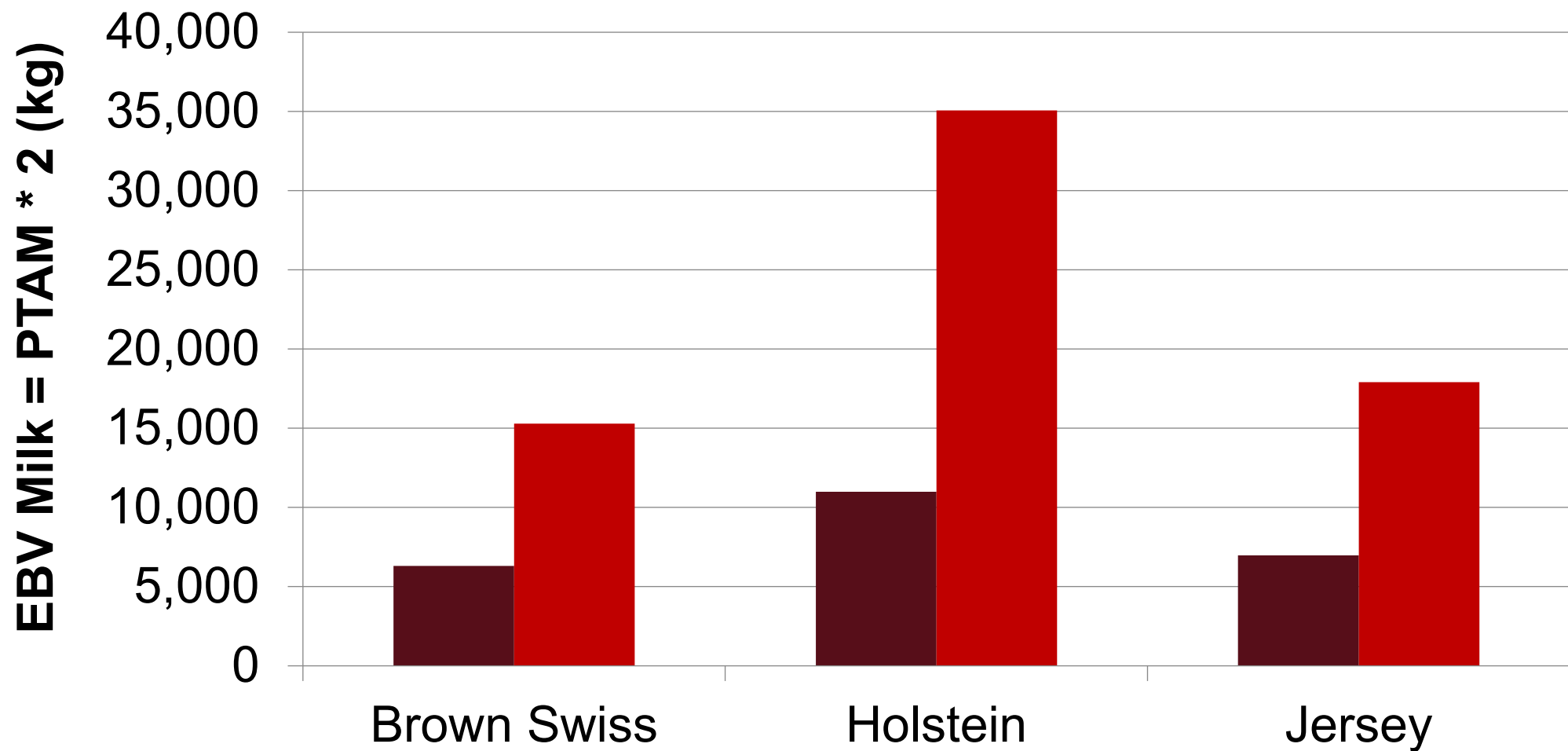
Nitrogen Emissions – Ammonia and Human Health

- Agriculture contributes over 81% of total NH_3 global emissions (Van Damme et al., 2021)
- Currently, NY air emissions are regulated at PM10 and PM2.5 (particulate matter @ 10 microns or 2.5 microns) (<https://dec.ny.gov/environmental-protection/air-quality/monitoring>)
- Higher ammonia emissions result in higher PM2.5 which results in greater health concerns for humans (Chronic Obstructive Pulmonary Disorder, lung cancer, and premature death)
- Eastern US is high in emissions – NY has this on its list of emissions to abate or reduce
- As an industry, we need to be conscious of this and outrun regulations by taking steps to reduce N emissions

Efficiency of Use of Intake Nitrogen

- This is a tough metric for ruminants since they require non-protein N for rumen function
- When this is described for non-ruminants the N-currency is amino acids
- Higgs and others determined a N efficiency of ~72-73% on a weighted average using just absorbed EAA
- Theoretical efficiency limit 40 to 45% in lactating dairy cattle (Van Vuuren and Meijs, 1987; Hvelplund and Madsen, 1995)
- Practical limit is ~38 to 40% (high cow groups are achieving this)
- Although it is an ambiguous metric, it can be useful if extended to whole body N metabolism

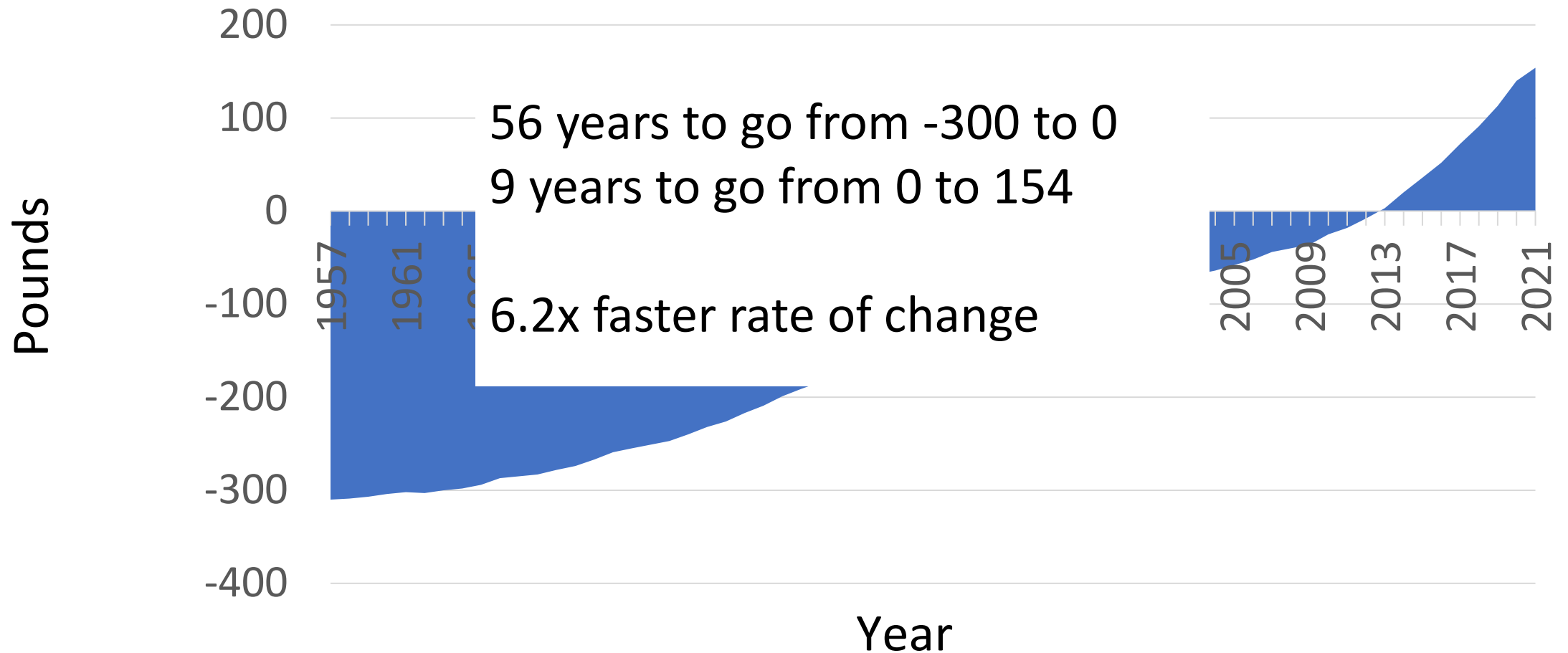
Genetic Potential: upper and lower bounds for Brown Swiss, Holstein and Jersey cattle



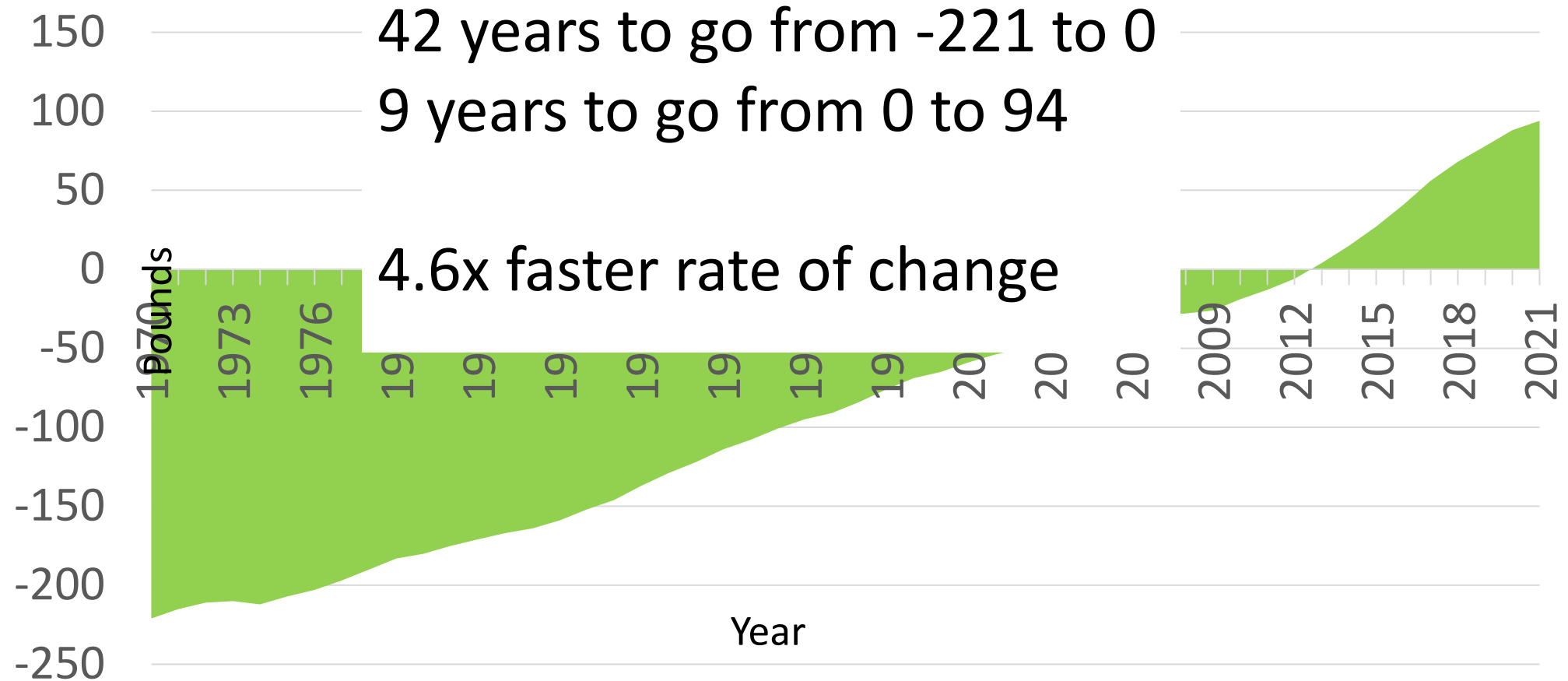
Perspective

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

US Sire Breeding Value for Fat 1957-2021



US Sire Protein Breeding Values over 51 years



DHIA on 6-17-2024

Top 5 cows Solids Produced.

DIM MILK (kg) Solids #

80 105.80 16.24

72 112.20 17.28

57 118.40 18.23

87 114.10 17.57

45 ~~105.60~~ 16.24

Average 68.2 111.22 kg 17.128 # of Solids

Milk @ 7% (3.8 - 3.20 Protein)

Five cows on this list are averaging 111 kg (246 lb) milk/d at 7.77 kg (17.13 lb) fat and protein

There are 10 other cows in the herd in this range

Not peak milk....

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

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

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

¹Minimum levels based on the NRC (2012) ingredient loading values.

²Minimum lysine levels considering a diet with 1,150 kcal NE/lb for growing pigs, 1,130 kcal NE/lb for gestating sows, and 1,160 kcal NE/lb for lactating sows.

³Minimum ratios to achieve approximately 95% of maximum growth performance. Minimum ratios of threonine, tryptophan, isoleucine, and valine can be greater depending on diet formulation.

⁴Data on amino acid requirements for contemporary sows is limited.

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

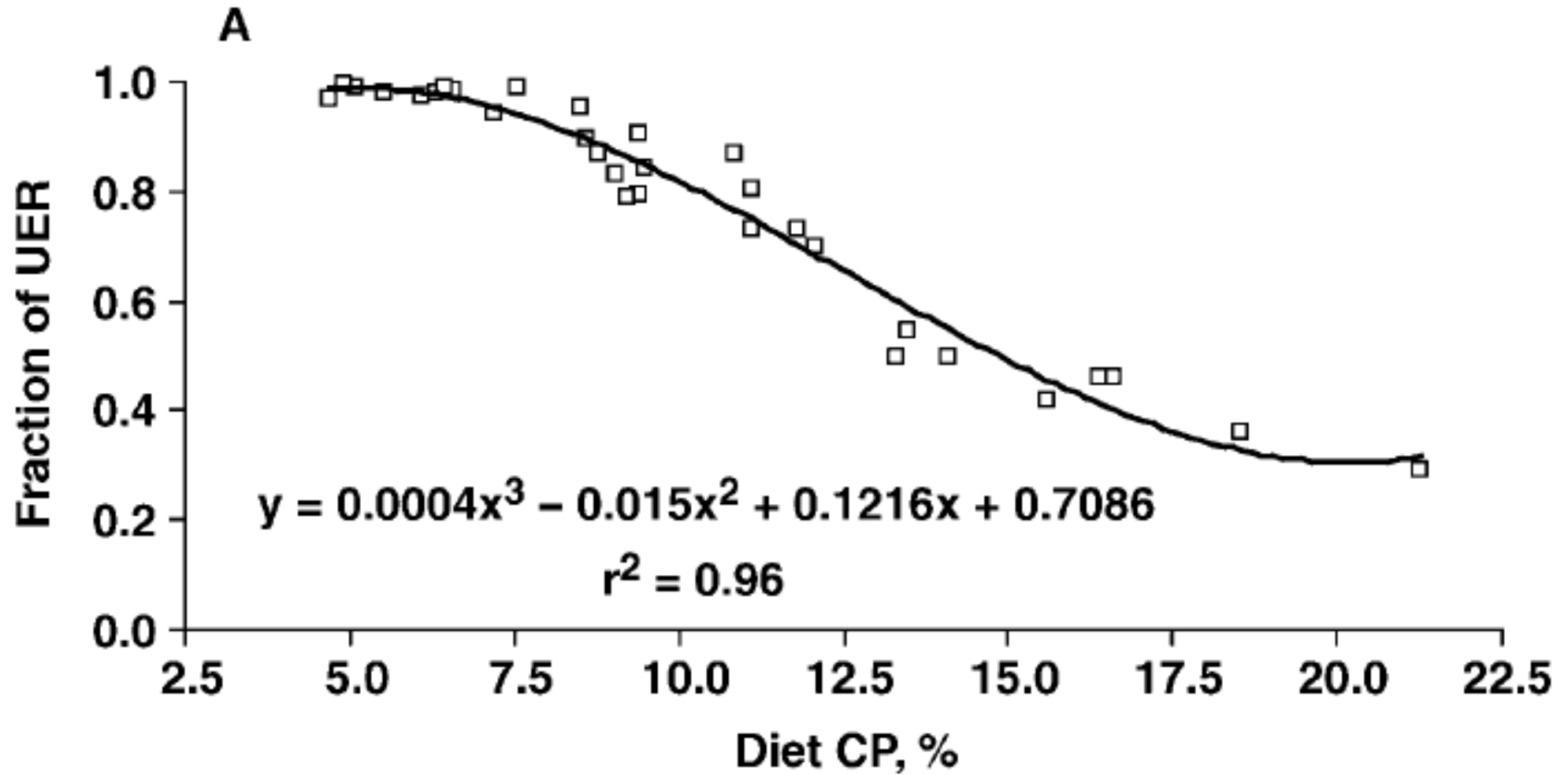
Two Somewhat Competing Objectives:

1. Partition as many nutrients to the mammary gland as possible
2. Reduce urinary N excretion by 30 to 50 grams per day

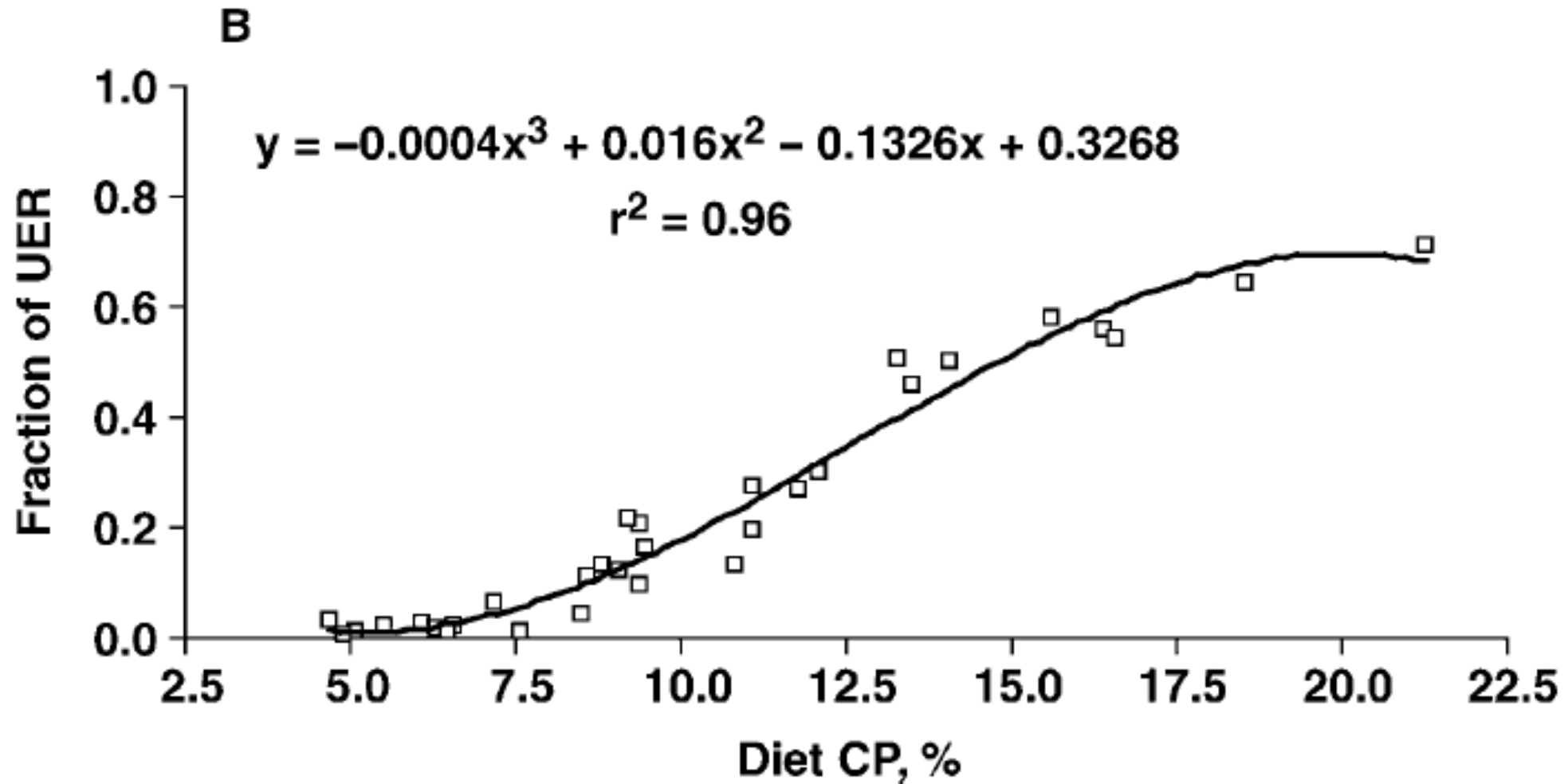
Steps to accomplish this:

1. Reduce, refine and modify the sources of nitrogen, carbohydrates and fatty acids in the diet to enhance nutrient signaling throughout the system
2. Optimize the capture of recycled Urea N and Endogenous N in the rumen
3. Formulate closer to the microbial N requirements of the rumen – consideration of BCVFA
4. Formulate closer to the EAA requirements of the cow

Urea entry rate to GIT



Urea entry rate that is excreted in urine/feces

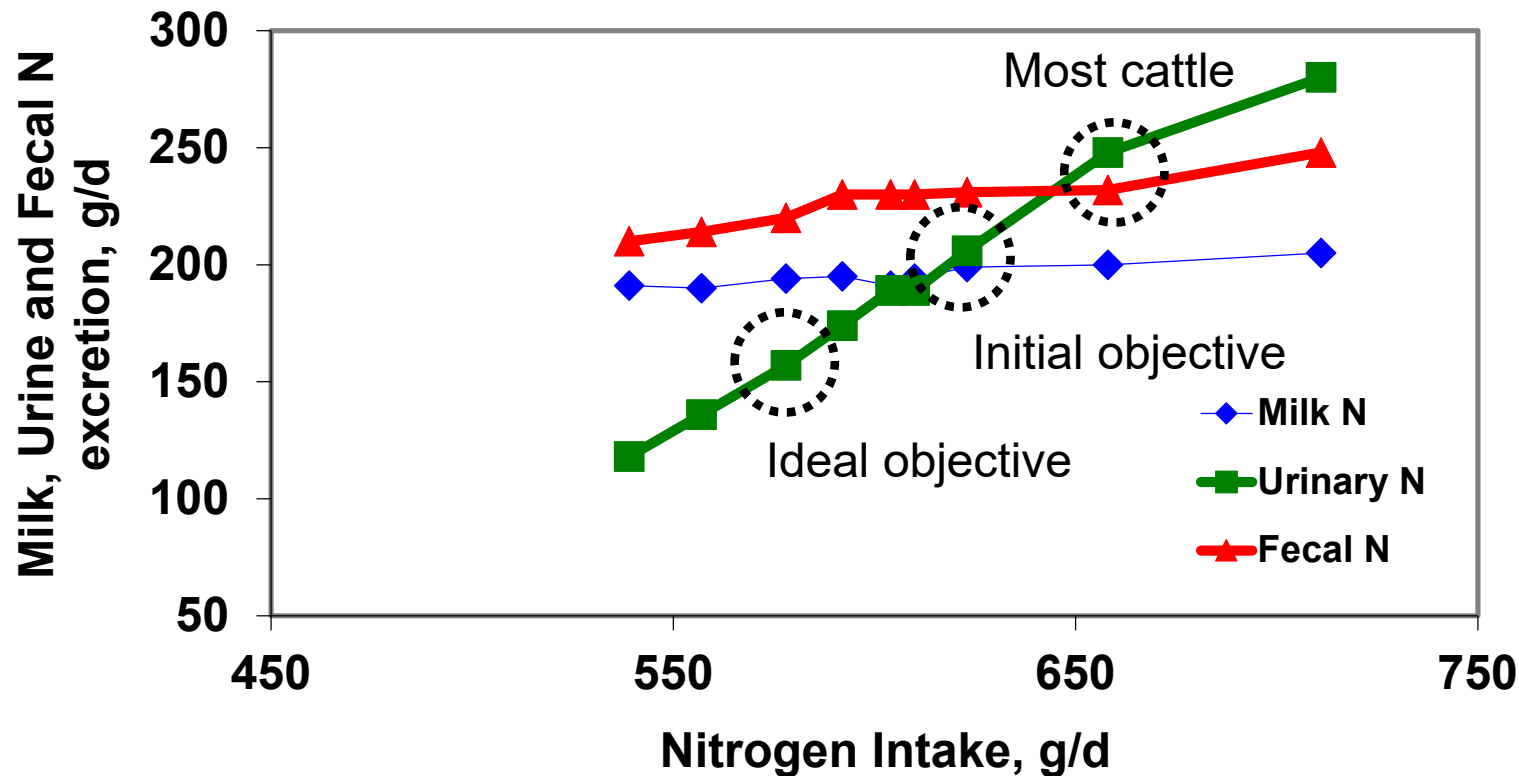


Efforts to reduce excessive protein feeding

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

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

Nitrogen excretion in diets varying in dietary nitrogen under conditions of energy limited diets



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

Urinary N:

Most Cattle: ~250 g

Initial Objective: ~200 g

Ideal Objective : ~150 g

Productive N:Urinary N

Most Cattle: 0.8

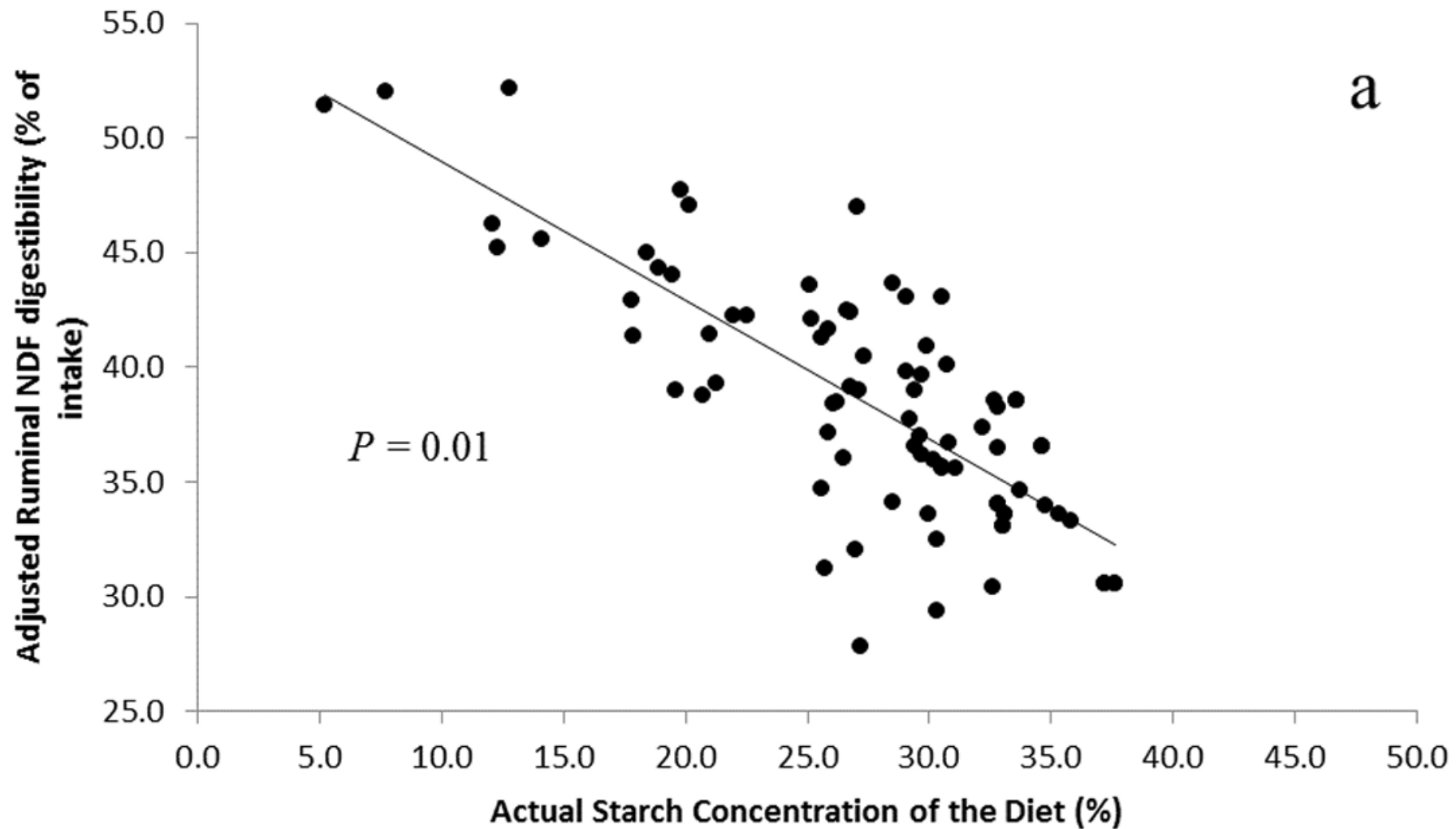
Initial Objective: 1.0

Ideal Objective : 1.3

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

Improving energetic efficiency through nitrogen reduction

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



dNDF decreased by 0.61%-units per %--unit increase in dietary starch content.

Where do branched-chain volatile fatty acids (BCVFAs) fit in rumen ecology?

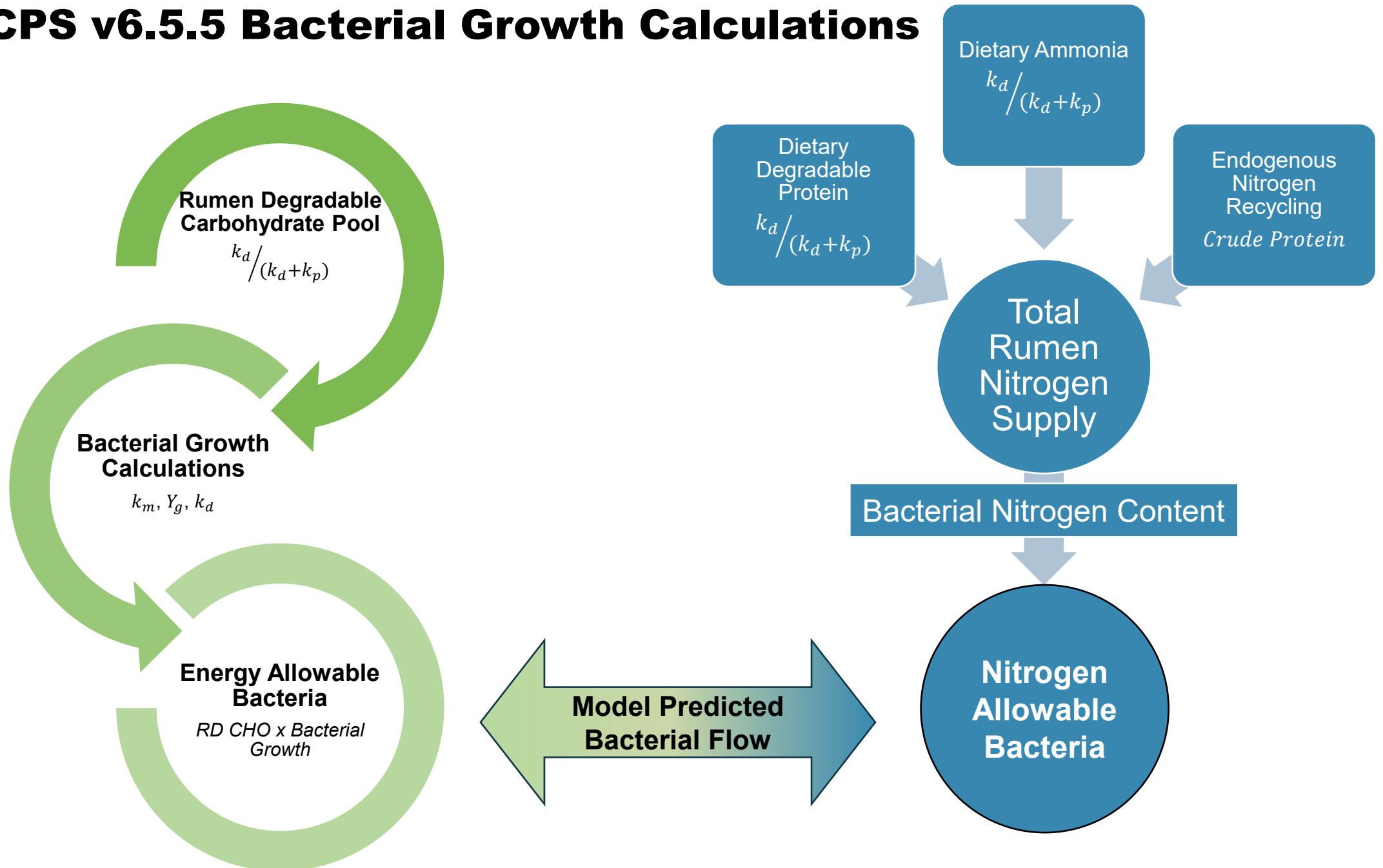
Fibrolytic bacteria, including the genus *Bacteriodes succinogenes* and *Ruminococcus* have known requirements for BCVFAs (Bryant and Robinson, 1960; Andries et al., 1987) and n-valerate to a varying degree.

- Most fibrolytic bacteria rely on ammonia as their primary source of nitrogen (Bryant and Robinson, 1961)
- BCVFAs provide the means for:
 - BCAAs synthesis → isopropyl malate and reductive carboxylation pathways.
 - BCFAs synthesis → membrane fluidity and invoke bacterial growth (Hauser et al., 1979 & Vlaeminck et al., 2006).
- Requirements of BCVFAs primarily met through decarboxylation of dietary BCAAs and fermentation of carbohydrates from amylolytic bacteria (Firkins, 2010)

In vitro results suggest improved bacterial growth when BCVFAs supplemented

- Improved ammonia utilization, protein synthesis and plant cell wall digestibility (Russell and Sniffen, 1983; Cummins and Papas, 1985)

CNCPS v6.5.5 Bacterial Growth Calculations



Determining bacterial yield in the CNCPS

Carbohydrate fermentation needs to be supported by sufficient ruminal nitrogen.

Nitrogen sources considered:

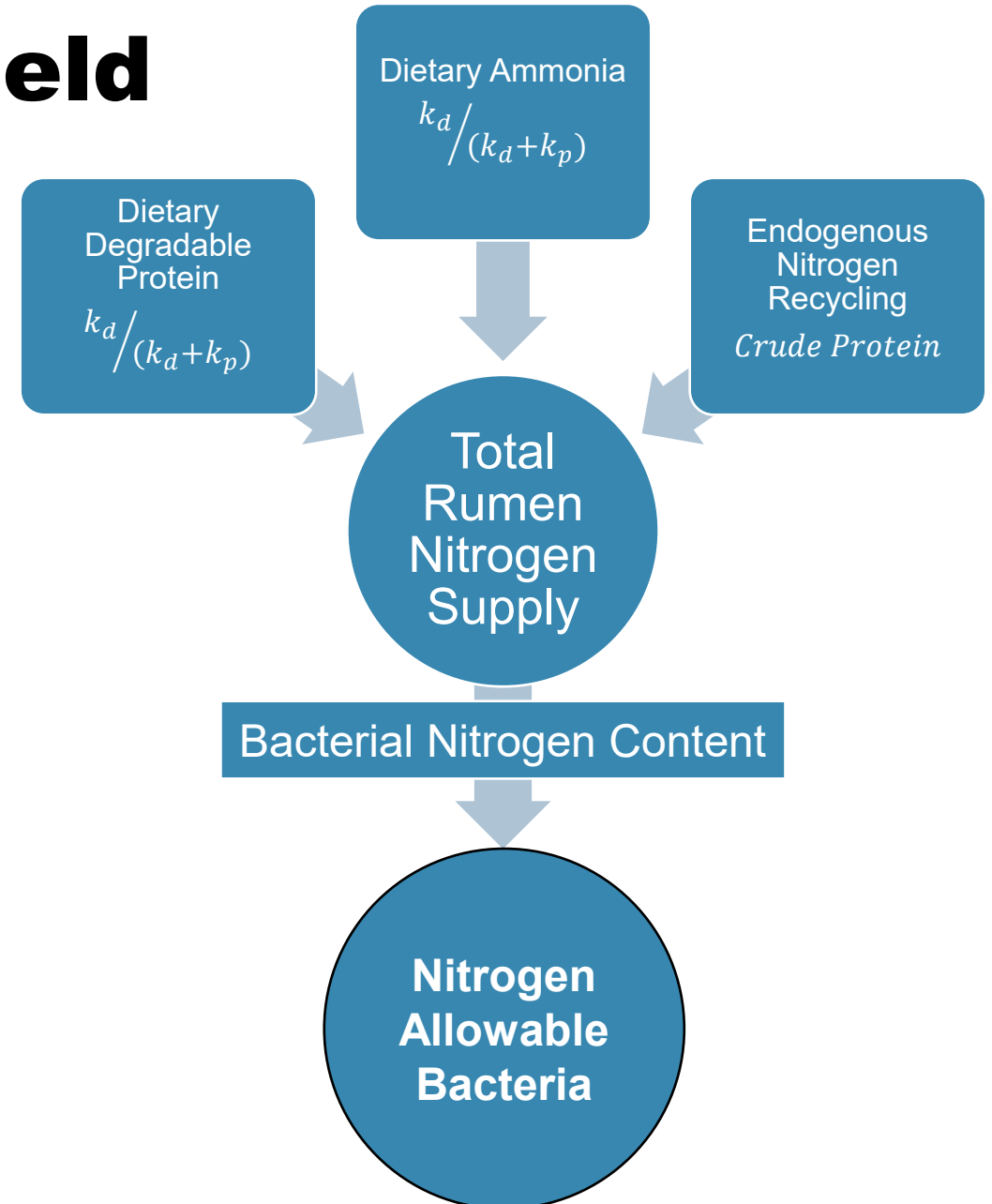
- Amino-N → Sourced from Diet
- Ammonia-N → Sourced from Diet & Animal

NFC Bacteria take up Amino-N for their requirement

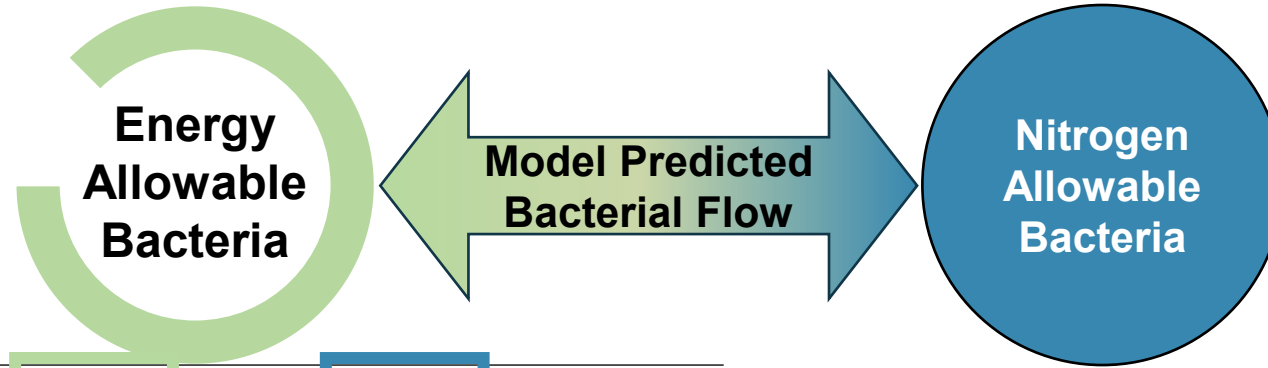
- 2/3 of requirement from Amino-N
- 1/3 of requirement from Ammonia-N

FC Bacteria take up Ammonia-N for their requirement

- Considered after the requirements of NFC Bacteria are satisfied



Assessing Energy and Nitrogen Allowable Bacteria in the Rumen



Ingredient Name	Dry Matter Intake, kg	EA Bact, g	EA Bact Ratio	NA Bact, g	NA Bact Reduct, g
Corn Silage	9.72	1892.4	44.9%	2412.0	0
Corn Grain	6.01	1103.3	26.2%	1406.3	0
Alfalfa Silage	3.97	542.3	12.9%	691.2	0
Clover Silage	2.51	306.0	7.3%	390.1	0
Soybean Meal	1.59	164.2	3.9%	209.3	0
Soybean Hulls	0.816	101.8	2.4%	129.8	0
Heat Treated Soy	1.27	100.1	2.4%	127.6	0
Linseed Meal	0.104	4.2	0.1%	5.4	0
Molasses Beet	0.018	4.1	0.1%	5.3	0
Rumen Protected Lysine	0.023	0.1	0.0%	0.1	0
Palm Fat Product	0.136	0.0	0.0%	0.0	0
Liquid Methionine	0.029	0.0	0.0%	0.0	0
Urea	0.086	0.0	0.0%	0.0	0
Min Vit	0.826	0.0	0.0%	0.0	0
Total	27.1	4218.7	100%	5377.0	0

Energy Allowable < Nitrogen Allowable

↓
Sufficient nitrogen to ferment carbohydrates.

Energy Allowable > Nitrogen Allowable

↓
Reduced bacterial growth to a level that nitrogen supports → FC Bacteria reduced

↓
Reduced fiber degradation

Advanced Rumen Values Report

AMT_S

AMTS Pro

Farm: Dairy Farm Example FBW: 667 kg DIM: 150
Cattle Group Name: High Cows BCS (1-5): 3.00 Milk: 45.35 kg/day Input DMI: 27.7 kg
Barn/Lot: Barn 1 High Cows ADG: 0.232 kg/day Milk Fat: 4.40% Predicted DMI: 27.0 kg
Milk Prt: 3.30% (True) 3.55% (Crude)

kp Forage	0.02
kp Conc	0.08
kp Liquid	0.14
Total RDCA1 (g)	0.00
Total RDCA2 (g)	155.18
Total RDCA3 (g)	0.00
Total RDCA4 (g)	940.51
Total RDCB1 (g)	6159.63
Total RDCB2 (g)	1347.71
Total RDCB3 (g)	3442.31
Total RDCC (g)	0.00
Total RDPA1 (g)	420.97
Total RDPA2 (g)	779.24
Total RDPB1 (g)	1287.29
Total RDPB2 (g)	103.27
Total RDPC (g)	0.00
Total Energy Allowable - FC Bact (g)	951.41
Total Energy Allowable - NFC Bact (g)	3326.00

N Intake (g)	820.00
Dietary NH3 (g)	67.35
Recycled NH3 (g)	84.24
Peptide NH3 (g)	125.43
NH3 Supply (g)	277.03
FC Bact - NH3 Available (g)	166.17
FC Bact - NH3 Required (g)	95.14
NFC Bact - NH3 Required (g)	110.87
N Allowable Bact (g)	4987.66
Total Rumen N Available (g)	498.77
Total Rumen N Required (g)	427.74
Total FC Bacterial Yield (g)	951.41
Total NFC Bacterial Yield (g)	3326.00
Bacterial NFC N Yield (g)	332.60
Total Bacterial N Yield (g)	427.74
Rumen CHO Degraded (g)	12045.34
Rumen Protein Degraded (g)	2590.77
Rumen CHO Escape (g)	7693.05
Rumen Protein Escape (g)	2007.71
MP - MET (g)	89.08
MP - LYS (g)	229.59
MP - HIS (g)	88.74
MP - THR (g)	154.84

Rumen Degradable Carbohydrate Pool

$$k_d / (k_d + k_p)$$

Bacterial Growth Calculations

$$k_m, Y_g, k_d$$

Energy Allowable Bacteria

$$RD\ CHO \times \text{Bacterial Growth}$$

Dietary Ammonia

$$k_d / (k_d + k_p)$$

Dietary Degradable Protein

$$k_d / (k_d + k_p)$$

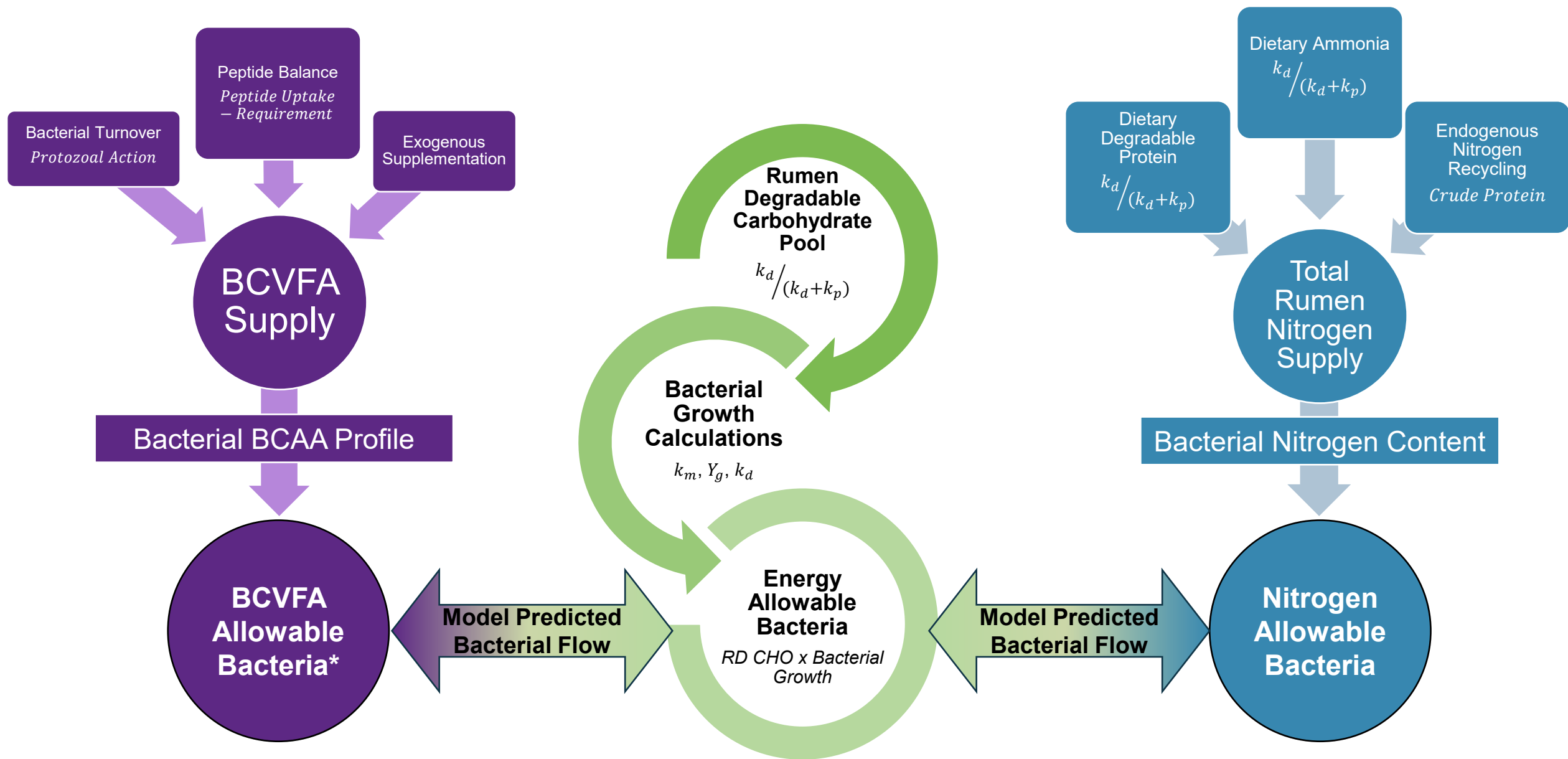
Endogenous Nitrogen Recycling
Crude Protein

Total Rumen Nitrogen Supply

Bacterial Nitrogen Content

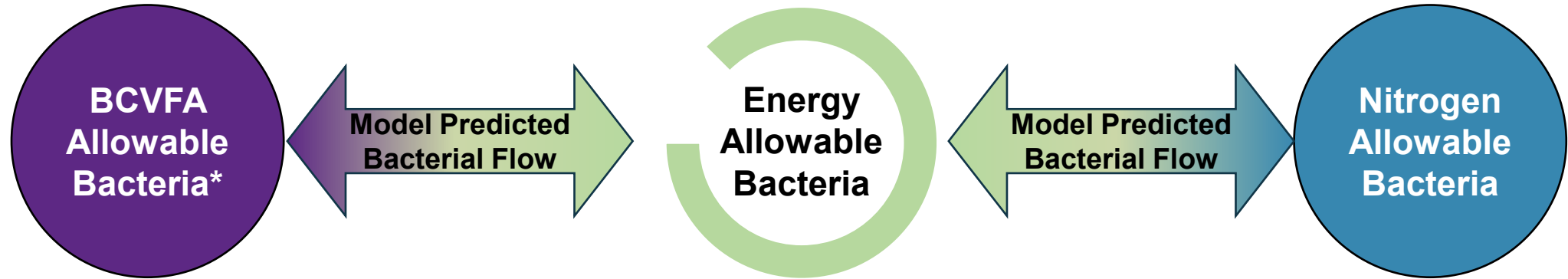
Nitrogen Allowable Bacteria

CNCPS v6.5.6 Bacterial Growth Calculations



*FC Bacteria growth considered.

Assessing Energy, Nitrogen and BCVFA Allowable Bacteria in the Rumen



Ingredient Name	Dry Matter Intake, kg	EA Bact, g	EA Bact Ratio	NA Bact, g	NA Bact Reduct, g
Corn Silage	9.72	1892.4	44.9%	2412.0	0
Corn Grain	6.01	1103.3	26.2%	1406.3	0
Alfalfa Silage	3.97	542.3	12.9%	691.2	0
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Soybean Hulls	0.816	101.8	2.4%	129.8	0
Heat Treated Soy	1.27	100.1	2.4%	127.6	0
Linseed Meal	0.104	4.2	0.1%	5.4	0
Molasses Beet	0.018	4.1	0.1%	5.3	0
Rumen Protected Lysine	0.023	0.1	0.0%	0.1	0
Palm Fat Product	0.136	0.0	0.0%	0.0	0
Liquid Methionine	0.029	0.0	0.0%	0.0	0
Urea	0.086	0.0	0.0%	0.0	0
Min Vit	0.826	0.0	0.0%	0.0	0
Total	27.1	4218.7	100%	5377.0	0

What CNCPS dietary parameters likely indicate an isoacid deficiency...

High Rumen Fermentable Carbohydrate load

- Diets $\geq 14\%$ DM fermentable NDF can have appreciable BCVFAs requirements
- Diets $\geq 42\%$ DM fermentable carbohydrates can limit isoacid supply $\rightarrow$ less BCVFA cross-feeding to FC Bacteria from NFC Bacteria

Degradable protein/nitrogen status

- Appropriate degradable PRO profile (PRO A2, PRO B1, PRO B2) to fermentable CHO profiles
 - True RDP (Total RDP – RDP PRO A1) $\geq 9.0\%$ DM
- Rumen NH_3 % requirement $\rightarrow \geq 125\%$ of Rumen requirement
- Reconcile BCAA/BCVFA balances by evaluating degradable AA in rumen
g tRDP/kg fCHO $\rightarrow 185 - 215$ OR g tRDP/lb fCHO $\rightarrow 84 - 98$

What CNCPS dietary parameters make diets a good candidate for BCVFA?

Parameter	Isoacid Preferred*	Range in EU Herds	Dietary Ranges Observed in US
Crude Protein, % DM	< 17	14 – 18	14 – 18
True RDP (Total RDP w/o PRO A1), % DM	< 10.2	8.5 – 11	8.5 – 11
NH3-N, % Req	125 [†] – 145		115 – 200
Sugar (ESC; CHO A4), % DM	> 4.0	4.0 – 8.0	3.0 – 12
Starch (CHO B1), % DM	> 22	18 – 28	22 – 35
Sugar & Starch, % DM	26 – 34	22 – 34	31 – 39
Rumen fermentable CHO (fCHO), % DM	> 40		36 – 48
Rumen fermentable aNDFom, % DM	14		10 – 17
g tRDP/kg fCHO	185 [‡] – 215		160 – 250

* Diets within the range for each parameter increases the likelihood of elucidating an isoacid deficiency.

[†] Diets with lower predicted Rumen NH3-N minimize exogenous isoacid efficacy, as ammonia nitrogen is needed for BCAA production.

[‡] If g true RDP per kilogram of fermentable carbohydrate is less than 185, consider elevating dietary degradable protein to optimize microbial growth.



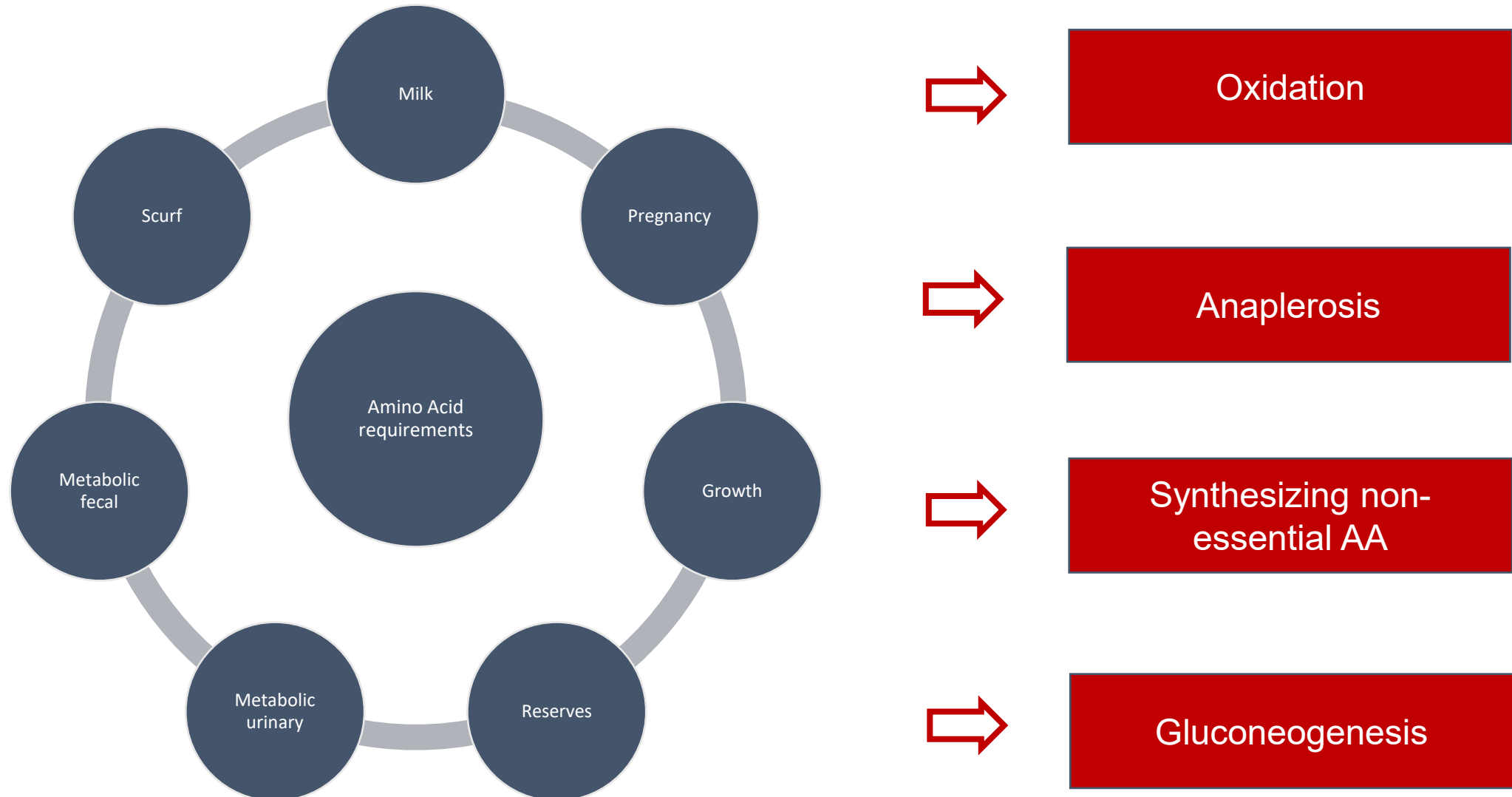
Ingredient, kg/d	Base diet	Balanced for AA and N efficiency	Balanced for reduced urinary N
Corn silage	10.0	9.30	9.80
Grass silage	5.60	5.20	5.40
Ground Corn	4.54	4.81	5.05
Soybean meal	2.14	1.82	0.50
SoyPass	1.07	1.56	1.60
Citrus pulp	0.00	1.20	1.24
Wheat middlings	2.06	1.20	1.40
Dextrose	0.00	0.42	0.44
Bloodmeal	0.00	0.27	0.28
Bergafat F100	0.15	0.16	0.17
Energy Booster 100	0.15	0.16	0.17
Sodium bicarbonate	0.12	0.11	0.12
Ground limestone	0.16	0.14	0.15
Smartamine M	0.03	0.03	0.03
Smartamine ML	0.00	0.03	0.05
White salt	0.08	0.07	0.07
Vitamin and mineral mix	0.18	0.18	0.18
Magnesium oxide	0.03	0.03	0.03
Levucell SC	0.01	0.01	0.01
Urea	0.06	0.00	0.00
Rumensin 90	0.00	0.002	0.002
Total Intake	26.4	26.7	26.7

IsoAcids were added to the diet balanced for reduced urinary N to meet the requirements for fiber digesting bacteria

Input/Output variables	<u>Diet 1</u>	<u>Diet 2</u>	<u>Diet 3</u>
	Base Diet	Balanced for EAA and N efficiency	Balanced for reduced urinary N excretion
DMI, kg/d	26.4	26.7	26.6
Milk, kg/d	41.7	39.6	39.6
ECM, kg/d	44.4	46.1	45.9
Milk fat, %	4.10	4.72	4.70
Milk protein, %	3.10	3.37	3.35
ME Allow milk, kg	43.0	43.6	43.6
MP Allow. Milk, kg	43.4	47.3	45.4
Carbohydrate allowable bacteria, g	4,021	4,184	4,210
N allowable bacteria, g	5,019	4,646	4,668
N intake, g/d	684.9	683.5	668.9
Rumen NH ₃ balance, %	146	121	125
Rumen Degradable Protein, % DM	10.5	9.0	9.0
True RDP/Fermentable CHO, g/kg	199	188	178

Input/Output variables	<u>Diet 1</u>	<u>Diet 2</u>	<u>Diet 3</u>
	Base Diet	Balanced for Amino Acids and N efficiency	Balanced for reduced urinary N excretion
Productive N, g/d	219	223	223.1
Urine N, g/d	221	215	192.6
Fecal N, g/d	257	258	256.1
Manure N, g/d	478	473	448.7
Productive N/Total N, %	32.0	32.6	33.5
Productive N/Urinary N, %	99.1	103.7	116.1
MP Supply, g/d	2888	3214	3131
MP Required, g/d	2820	2825	2840
MP Met, g/d	78.9	85.0	84.9
MP Met, g/Mcal	1.13	1.18	1.17
MP Lys, g/d	191.0	222.4	221.1
MP Lys, g/Mcal	2.74	3.20	3.05
MP His, g/d	76.0	88.9	86.7
MP His, g/Mcal	1.08	1.19	1.20

'Efficiency' Of Essential AA Use (Additional Requirements)



Higgs, 2014 from Loble, 2006

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

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

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

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

Redescribing AA balancing with more precision for higher milk yields and metabolic demand

- This approach has been evaluated in several research studies and is being applied in diet formulation through the CNCPS v6.5 (NDS, AMTS, Fabermatica, Dalex) for fresh and early lactation cows
- As milk and component yields increase the precision needed for diet formulation also needs to increase
- This is true for amino acids and will be true for fatty acids once we better understand the requirements

Review of recent experiment evaluating nutrient use efficiency

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

192 cows were used in a replicated pen study

16 cows per pen, milked 3x per day

Prior to the experiment, the cows were producing 42 kg, 4.0% fat and 3.1% true protein

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

Rumen modifier study diet chemistry – formulated

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

Diet formulation characteristics – consistent with high levels of production and high levels of milk components

- 54% forage diet – formulated to achieve the lowest uNDF for the highest aNDFom digestible pool for the available forages
- Dry ground corn from the farm – moderate starch
- Sugar added to enhance rumen fermentation, increase microbial flow (bacteria and protozoa) and fiber digestion - older data from Hoover indicating that 5-7% sugar in TMR diets is beneficial for component yields

Diet/Intake related information – Methionine and Lysine levels

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

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

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

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

Meeting the requirements should improve energetic efficiency and milk component yields

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

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

Van Amburgh et al., unpublished

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

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

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

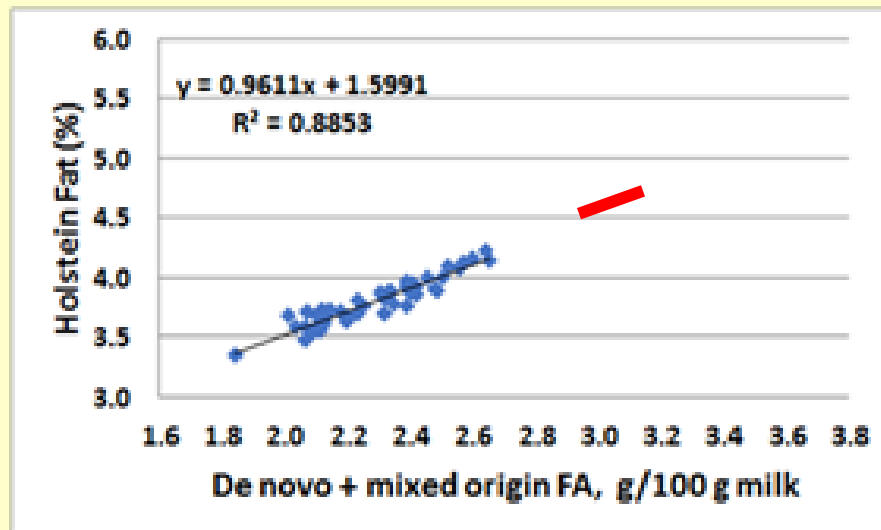
	Treatment					
Item	0	11g	14.5g	18g	SEM	P-Value
De novo fatty acid, g/100g	1.131	1.157	1.168	1.156	0.01	0.03
De novo fatty acid, kg	0.44	0.45	0.46	0.46	0.005	0.32
Mixed fatty acid, g/100g	1.856	1.881	1.918	1.897	0.02	0.02
Mixed fatty acid, kg	0.73	0.74	0.75	0.75	0.009	0.39
Preformed fatty acid, g/100g	1.34	1.33	1.38	1.85	0.02	0.23
Preformed fatty acid, kg	0.52	0.52	0.54	0.53	0.007	0.29
Fatty acid chain length	14.6	14.5	14.5	14.5	0.01	0.83
Double Bonds	0.23	0.23	0.23	0.23	0.002	0.42
C16:0, %	1.81	1.80	1.85	1.84	0.02	0.17
C16:0, kg	0.70	0.71	0.72	0.72	0.009	0.37
C18:0, %	0.36	0.36	0.38	0.36	0.005	0.08
C18:0, kg	0.14	0.14	0.15	0.14	0.002	0.15
C18:1, %	0.79	0.78	0.80	0.79	0.009	0.30
C18:1, kg	0.30	0.31	0.31	0.31	0.003	0.53

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

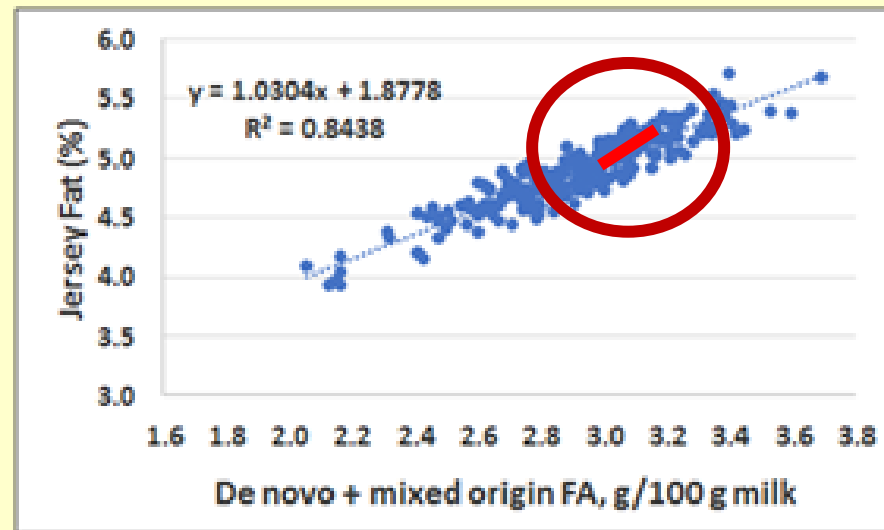
Holstein vs. Jersey Farms 2019

De novo + mixed origin fatty acids and bulk tank milk fat

Holstein



Jersey



Similar slope and high R^2 for the strong relationship between de novo + mixed origin fatty acid concentration and bulk tank milk fat concentration for Jersey and Holstein bulk tank milk. (herd average days in milk 150 to 200 days)

Calculations around Nitrogen and Energetic Efficiency

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

More importantly, the change in energetic efficiency was 8.1%
(43 kg to 46.8 kg ECM)

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



Methionine prototype dose titration study objectives

- The objective of this study was to evaluate a newly developed rumen-protected Methionine product (RPMet) when Lysine and Histidine were not considered co-limiting.
- A second objective was to further evaluate the AA requirement approach developed for CNCPS v7 (Higgs, 2014; Higgs et al., 2023)

Table 1. Amino acid formulation levels by treatment.

	RP Met g / Mcal ME	Lys g / Mcal ME	Hist g / Mcal ME
Treatment 1	0.86	3.2	1.19
Treatment 2	1.05	3.2	1.19
Treatment 3	1.19	3.2	1.19

Study Design

- 144 Holstein dairy cows assigned to a replicated pen study
 - 16 cows per pen, 3 pens per treatment
 - Diets fed once per day to 5% refusals
 - Sand bedded stalls, one stall per cow, free-choice water
 - Cows milked 3 times per day
- Cows were randomly assigned to treatment based on BW, milk yield, DIM and parity. (12 multiparous and 4 primiparous cattle per pen)
- Covariate period was 14 days, with sampling the last three milkings of the period
- Treatment period was 70 days for 84 total days of the experiment
- Milk sampled every 7 days, 3 contiguous milkings, all analyzed individually
- Pen level DMI measured daily
- BW and BCS measured/observed weekly

Composition of grain mix for cattle fed varying levels of methionine.

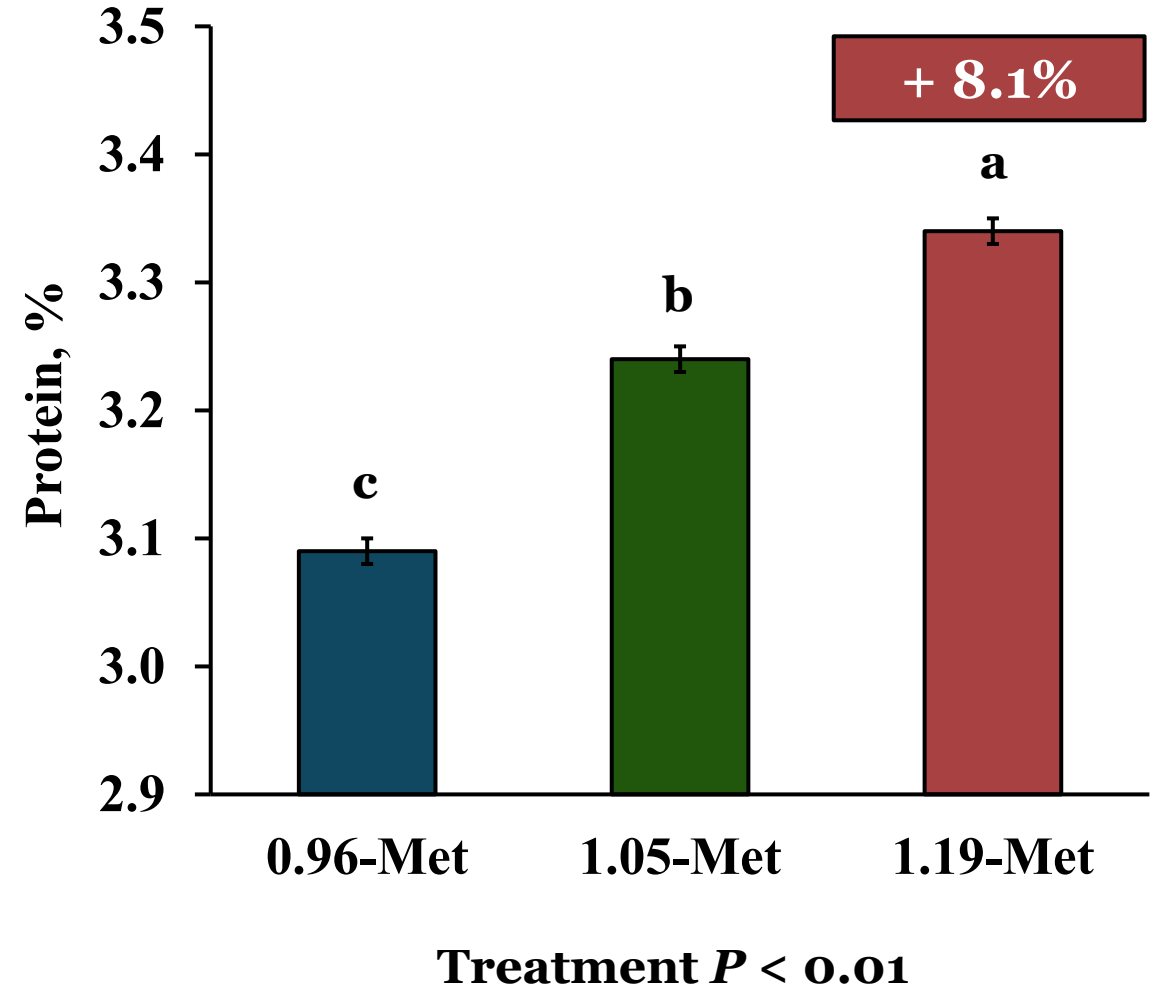
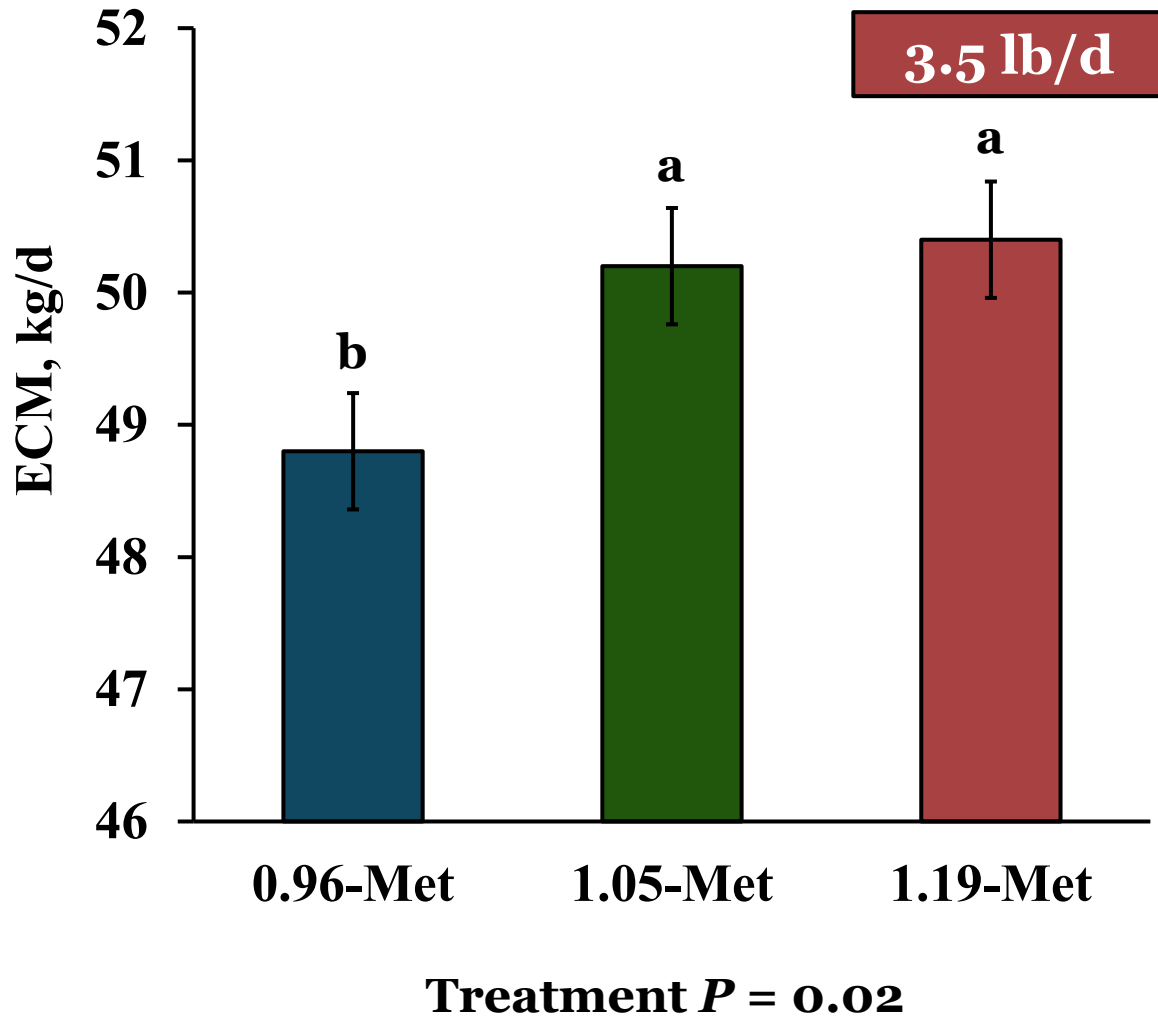
Ingredients, % DM	Gram of Metab. Met/Mcal ME		
	0.86	1.05	1.19
Grain Mix	4.96	4.99	5.02
Wheat middlings		2.08	
Sugar (sucrose)		0.79	
Soybean hulls		0.42	
Blood meal blend		0.42	
SoyPlus		0.28	
AjiPro L v3		0.08	
Energy Booster 100		0.07	
Urea		0.07	
Palmit 80		0.05	
Levucell SC		0.01	
Rumensin, 90 g/lb		0.002	
Minerals and vitamins		0.69	
RPMet Actus Prototype		0.02	0.04



Results – 144 cows, replicated pen study, 48 cows/trt

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

Effect of Increasing Methionine on ECM and Protein





Results

Diet, g Metabolizable Met/Mcal ME					
Parameter	0.86	1.05	1.19	SEM	Treatment
Milk fat, g/100g milk					
Denovo	1.14^a	1.17^b	1.20^b	0.010	< 0.01
Mixed	1.65^x	1.67^{xy}	1.70^y	0.015	0.07
Preformed	1.16	1.15	1.19	0.013	0.20
Milk fat, % Total fat					
Denovo	28.79^a	29.33^b	29.34^b	0.09	< 0.01
Mixed	41.83	41.61	41.56	0.15	0.40
Preformed	29.33	29.08	29.07	0.17	0.43



Results

Parameter	Diet, g Metabolizable Met/Mcal ME			SEM	P value
	0.86	1.05	1.19		
N intake, g	669	671	673	5.9	0.91
Productive N, g	235^a	241^b	250^c	1.7	< 0.01
Urinary N, g	193 ^y	189 ^{xy}	181 ^x	3.6	0.09
Productive:Urinary N	1.22	1.28	1.38		

- At the 1.19 supplementation level compared to no supplementation, there was a 4% increase in energy efficiency on an ECM basis and an increase in N efficiency of 6.4%.

Two herds in Southern PA – both between 100 and 150 cows with diets formulated using similar dietary metrics as the previous study – these values represent the whole herd - these are Holstein cattle. Milk fat in both herds was about 4.2% before dietary interventions. Milk protein was approximately 3.1% prior to diet change.

Herd 1		Herd 2	
Milk yield, kg	41	Milk yield, kg	41.5
Milk fat, %	4.64	Milk fat, %	4.76
Milk true protein, %	3.48	Milk true protein, %	3.46
Milk fat yield, kg	1.87	Milk fat yield, kg	1.95
Milk protein yield, kg	1.42	Milk protein yield, kg	1.42

Holstein dairy in Northern NY - 3,700 cow

41+ kg milk/d in April

	Bulk Tank 1	Bulk Tank 2
Butterfat, %	4.68	4.77
True Protein, %	3.44	3.47

**~250 genomic Holstein heifers in the same herd
on a similar diet – 40 kg milk, >5.2% fat, >3.6% protein**

Observations

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

Some Steps to Optimize Energetic Efficiency and Reduce Urinary N

- Determine the most limiting nutrient – energy or protein – do cows and model agree?
- Evaluate the rumen N balance and urinary N excretion – if high, then work to reduce the soluble protein – within CNCPS rumen NH_3 balance between 120-140% and pay attention to BCFVA requirements and supply
- If grams MP is in excess, then decrease MP from feed in small increments
- Once you have ME and MP in balance and are happy with rumen N balance, focus on AA
- Met – use 1.15-1.19 g MP Met per Mcal ME (CNCPS v6.55)
- Lys – maintain a Lys:Met of $\sim 2.7:1$

Some Steps to Optimize Energetic Efficiency and Reduce Urinary N

- Pay attention to aNDFom digestibility and allocate the highest digestibility forages to the fresh and high cows
- With forages you want the lowest uNDF pool as possible to maximize the digestible aNDFom
- Don't overfeed starch or fatty acids and add some sugar – need butyrate
- Formulate sugar at 5% to 8% DM
- Good rumen digestible starch sources in the 25-27% DM range
- Ether extract 4.4-4.7% and work towards a 1.5:1 relationship between palmitic and oleic

Diet Formulation Strategies to Reduce Carbon Intensity and Reduce Urinary Nitrogen

- Make sure you have current and appropriate feed analysis to make the best possible decisions using the forages for a particular farm
- Maximize the amount of digestible aNDFom in the diet and rumen
- Meet the ruminal ammonia and branched-chain volatile fatty acid requirements to optimize aNDFom digestion
- Feed adequate starch from sources that are ruminally available to maximize microbial growth and propionate production
- Feed some sugar to enhance microbial growth and butyrate production
- Meet the requirements for metabolizable amino acids – using metabolizable energy as the reference for requirements
- Don't overfeed fat and feed a blend of fatty acids that optimize milk component yield

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



Maximizing feed efficiency in high producing dairy cows



Dr. Isaac Salfer

4-State Dairy Nutrition & Management Conference



University of Minnesota
Department of Animal Science

1

How do we define feed efficiency?

- **Whole-farm Feed Efficiency**
 - Feed cost/Cwt of milk sold
 - Feed cost/head
 - Income over feed cost (IOFC) = [milk price x (milk/d/100)] – (feed \$/d)
- **Cow-Level Feed Efficiency**
 - **Gross FE - Milk basis:** Lbs. of milk/lbs. of feed
 - **Gross FE - Energy-Correct Milk (ECM) basis:** ECM, lbs./ lbs of feed
 - $ECM = (0.327 \times \text{milk lbs}) + (12.95 \times \text{fat lbs}) + (7.2 \times \text{protein pounds})$
 - **Component Efficiency:** (lbs of fat + lbs of protein)/intake *100%
 - **Residual Feed Intake:** Actual DMI - Predicted DMI



2

What is your limiting resource?

- Money?
- Feed?
- Acres?

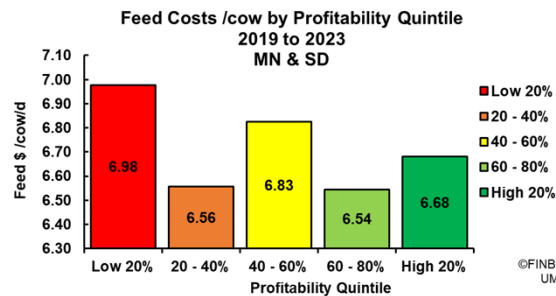
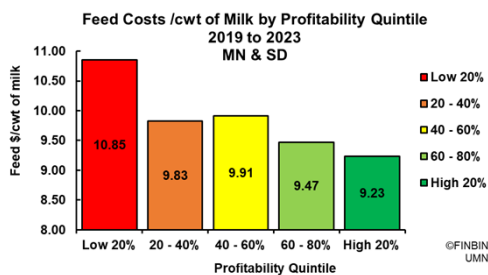
What is your primary output?

- Milk
- Fat + Protein
- Growth
- Cull cows?

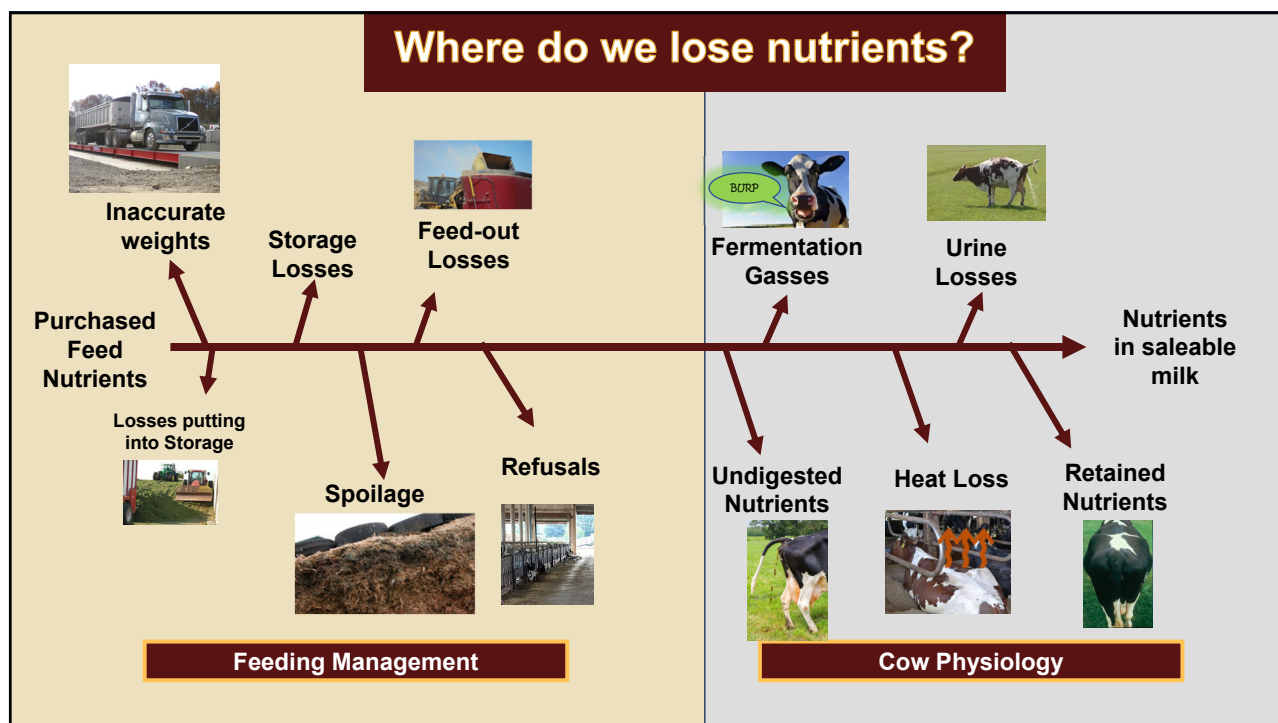


3

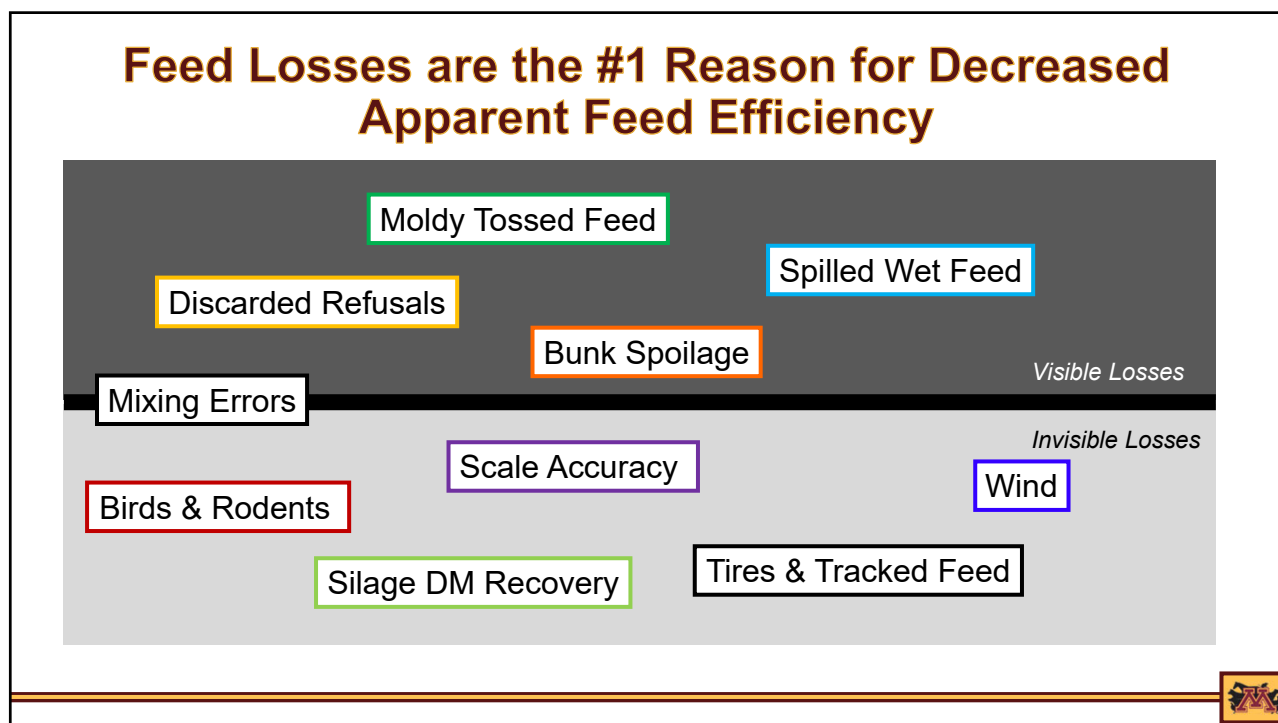
Which Feed Efficiency Benchmarks are Most Associated with Profitability?



4



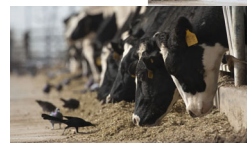
5



6

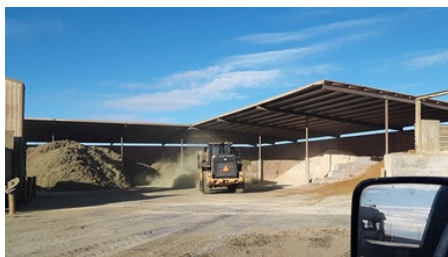
What is the value of shrink losses?

Herd Size	Annual loss @ \$7.50 Feed cost /cow/d			Cost Savings
	8%	10%	12%	
1	219	274	329	\$110
500	\$ 109,500	\$ 136,875	\$ 164,250	\$54,750
1,000	\$ 219,000	\$ 273,750	\$ 328,500	\$109,500
2,000	\$ 438,000	\$ 547,500	\$ 657,000	\$219,000
5,000	\$1,095,000	1,368,750	\$1,642,500	\$547,500



7

How does shrink vary by feedstuff?



Ingredient	Open Piles	Covered 3-sided bays	Closed bins
Dry meals, typical	5 to 10%	3 to 8%	2 to 4%
Dry grains, typical	5 to 8%	4 to 7%	2 to 4%
Alfalfa, chopped	10 to 20%	5 to 10%	
Cottonseed, whole	10 to 20%	5 to 15%	-
Distillers grains, dry	15 to 22%	7 to 10%	3 to 6%
Distillers grains, wet	15 to 40%	15 to 40%	-
Soybean hulls	12 to 20%	3 to 8%	2 to 4%

Kertz (1998) J Dairy Sci 81:3075-3084



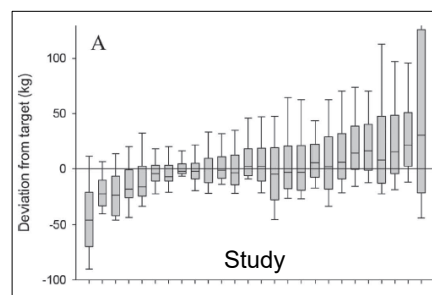
8

There is High Variability in Ingredient Loading Accuracy Across Farms

- 26 Californian dairies
- In 2.5% of the total loads, ingredients were underloaded
- At least 20% of the time ingredients were loaded with a deviation from target >80 lbs. on 7 dairies or <= 80 lbs. on 2 dairies.
- The ration cost increased by at least \$3 per metric ton <5% (15 dairies), 5 to 20% (6 dairies), or >20% (2 dairies) of the times.



(Trillo et al., 2016)

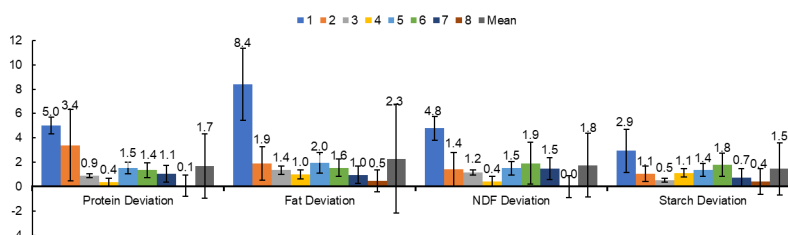


Slide courtesy of Fernando Diaz, Rosecrans Dairy Consulting, LLC

9

Associations between nutrient variation and feed efficiency

Average Daily Deviation in Nutrition Composition on 8 Commercial Farms



N

Evaluated feeding records of 8 commercial dairies over 52 weeks

Response	Average daily nutrient deviation (SEM, P-value)			
	Starch Deviation	Fat Deviation	NDF Deviation	Protein Deviation
DMI (kg/d)	-0.0483 (0.01265, <0.01)			0.0211 (0.009418, 0.03)
Milk yield3 (kg/d)	0.0486 (0.02110, 0.02)		-0.0298 (0.02202, 0.18)	
ECM yield3, 4 (kg/d)	0.145 (0.0328, <0.01)	-0.143 (0.0427, <0.01)	-0.0421 (0.02086, 0.05)	
Pregnancy rate5		0.385 (0.1635, 0.02)		-0.420 (0.1879, 0.03)
Feed conversion ratio	0.0149 (0.00548, <0.01)	-0.00312 (0.00688, 0.65)		

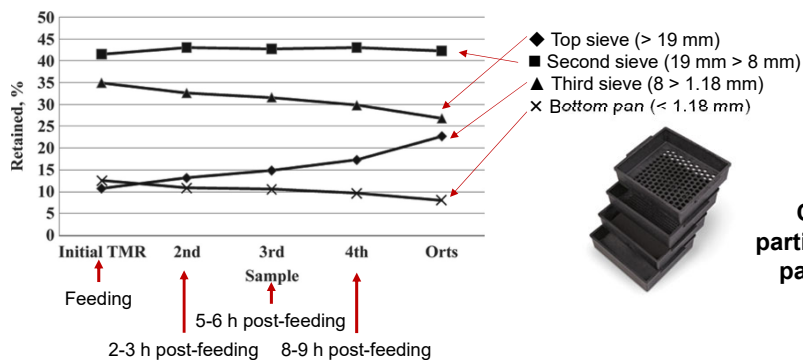
Carroll et al. (2024) *JDS Communications*. 5(6):584-552. <https://doi.org/10.3168/jdsc.2024-0584>

10

Feed Sorting Can Decrease Efficiency

Sova et al. observed a 3% decrease in kg milk/kg of feed for every 1% increase in group sorting for small (< 1.18 mm) particles

Survey of 50 freestall herds in central & SE Minnesota



Cows tend to eat more small particles early in the day, and larger particles remain later in the day

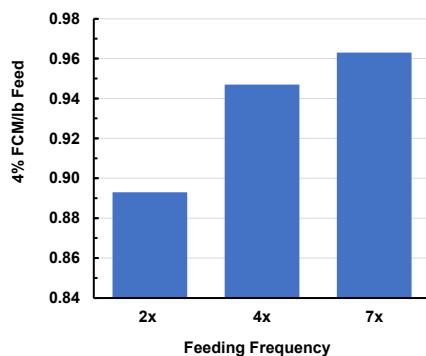
Endres & Espejo (2010) *J. Dairy Sci.* 93(2):822-829



11

Effects of Feeding Frequency on Feed Efficiency

Campbell and Merilan 1961, *J Dairy Sci*



Study Done in Guernseys!



Also apparently before *P*-values or SEMs were reported

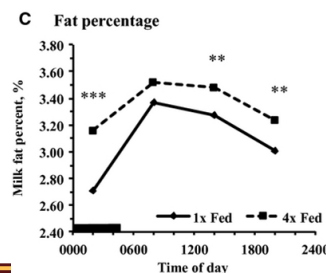


12

Table 2. Daily milk production and feed intakes in cows fed once per day or in four equal meals every 6 h when milked every 6 h.

Parameter	Treatment ¹		P-values ²			
	1 × Fed	4 × Fed	SEM	Trt	Time	Trt × Time
Milk Yield, kg	47.3	47.1	1.5	0.64	<0.001	0.05
Fat, %	3.09	3.35	0.15	<0.001	<0.001	<0.05
Fat Yield, g/day	1465	1592	90	<0.001	<0.01	0.05
Protein, %	2.96	2.90	0.03	<0.001	<0.001	<0.001
Protein Yield, g/day	1389	1360	45	0.06	<0.01	<0.05
DMI, kg	28.2	30.4	1.0	<0.01	-	-

Increasing from 1x/d to 4x/d feeding increases milk fat yield & concentration



13

Do automated feeding systems represent an opportunity to minimize feeding variation?



Maybe?

14

Observational study designed as a randomized block

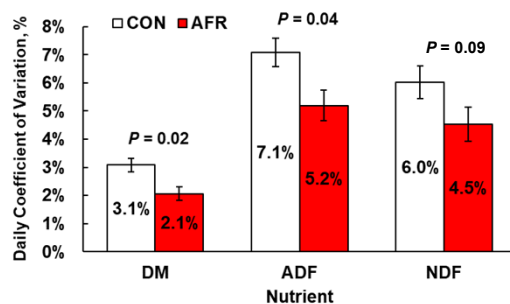
Block	Dates Visited	Location	# of AMS ¹		# of Cows in Tank		Cows/AMS		Average DIM		Average Parity		Bunk Space/Cow		x Fed/d CFS
			CFS	AFR	CFS	AFR	CFS	AFR	CFS	AFR	CFS	AFR	CFS	AFR	
1	8/9/21- 8/12/21	NE IA	2	3	111	188	55.5	62.7	157	190	2.6	2.6	16.8	14.2	2
2	8/28/21- 8/30/21	Central WI	4	2	207	116	51.8	51.8	204	181	1.8	2.1	27.8	23.3	2
3	8/28/21- 8/30/21	Central WI	2	1	113	65	56.5	44	189	131	2.2	2.5	30.1	22.3	2
4	10/02/21-10/04/21	Central MN	2	3	134	181	67	60.3	164	193	2	2.2	17.5	17.9	2
4	10/16/21- 10/19/21	SE MN	2	2	125	125	62.5	62.5	151	194	2.1	2.2	20.8	31.9	1
6	11/24/21- 11/26/21	NW MN	3	3	132	177	44	59	240	208	2.1	2.3	17.7	15.7	2
7	11/27/21- 11/29/21	NW MN	2	3	154	170	77	56.7	196	205	2.5	2.8	22.3	19	2
8	01/31/22 - 2/3/22	Central MN	2	3	200	116	66.7	58	188	195	2.5	2.6	25.2	17.6	1
Ave.			2.5	2.4	147	142	60.1	56.9	186	187	2.2	2.4	22.3	20.2	1.75

Kamau et al. 2025. *Animals*. 15(8):1103. <https://doi.org/10.3390/ani15081103>



15

Feed bunk dry matter and fiber concentration were less variable across the day in herds with AFR

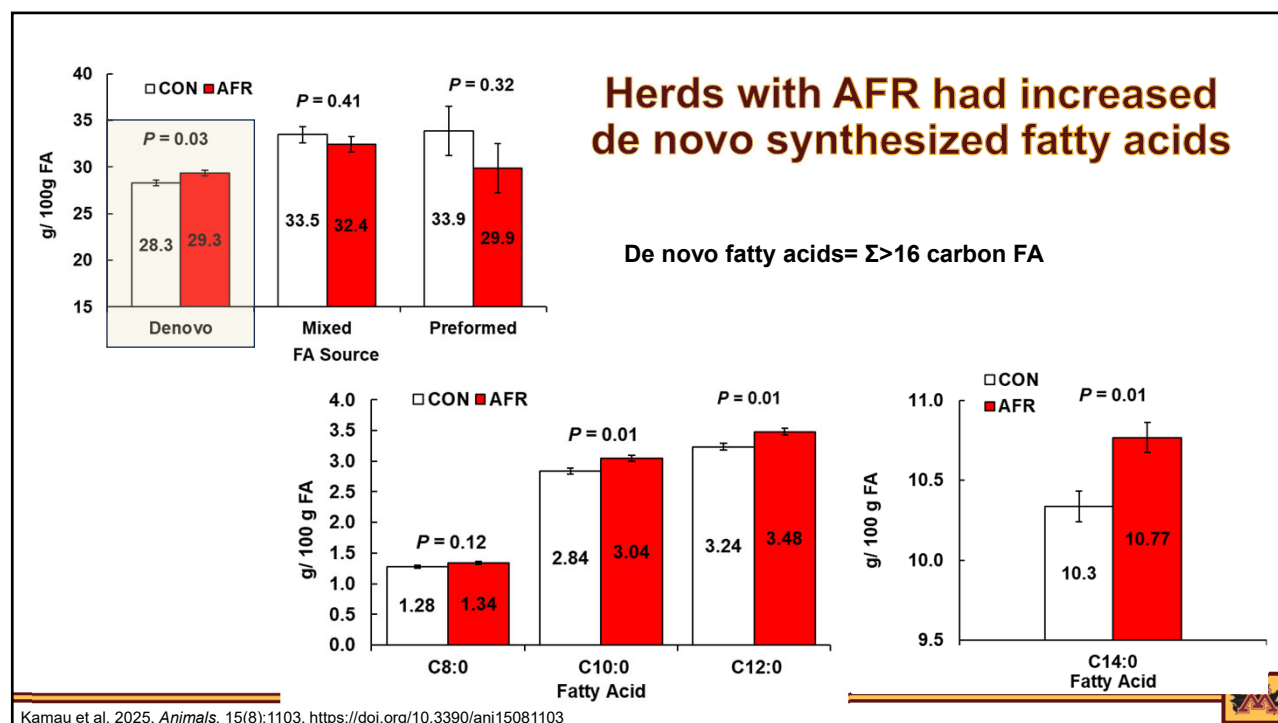


Item ²	Feeding System ¹		SEM	P-Value
Daily Variation in PMR Nutrient Composition ³				
CV of CP, %	2.50	3.23	0.32	0.15
CV of SP, %	5.27	3.40	0.94	0.22
CV of ADIN, %	4.53	3.08	0.72	0.20
CV of NDIN, %	7.33	6.03	0.86	0.26
CV of Lignin, %	7.40	6.26	5.19	0.40
CV of Ethanol-Soluble Carbohydrate, %	13.0	8.42	3.08	0.32
CV of Starch, %	6.44	5.38	0.65	0.32
CV of Total Fatty Acids, %	7.34	8.75	0.74	0.21
CV of Ash, %	2.92	3.30	0.50	0.61
Daily Variation in PMR Particle Size Distribution ⁴				
CV of Upper Sieve (> 19.0mm), %	23.3	26.7	3.02	0.41
CV of Middle Sieve (19.0 to 8.0 mm), %	8.84	10.3	1.78	0.57
CV of Lower Sieve (8.0 to 4.0+4.8 mm), %	6.80	12.1	2.74	0.20
CV of Bottom Pan (< 4.0+4.8 mm), %	10.7	13.4	2.15	0.33

Kamau et al. 2025. *Animals*. 15(8):1103. <https://doi.org/10.3390/ani15081103>



16



17

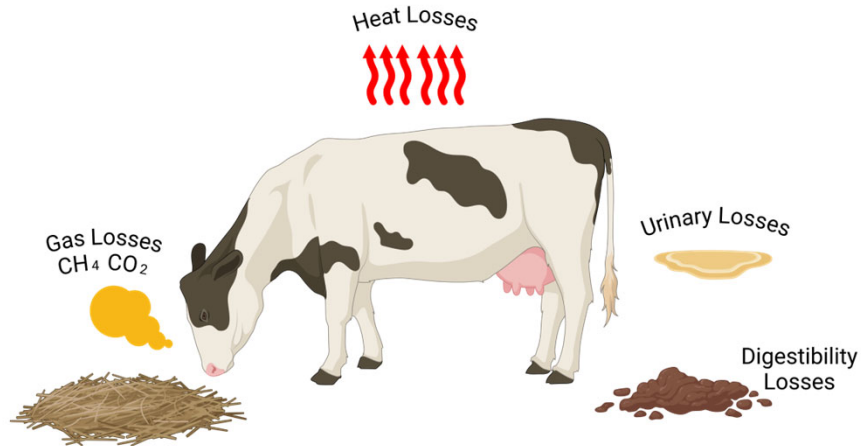
Herds with AFR also had greater frequency of AMS visits

Item	Feeding System		SEM	P-Value
	CFS	AFS		
Feed allocation in AMS, kg/cow/d	5.19	4.56	0.063	<0.0001
Milk yield, kg/d	37.5	37.3	0.25	0.68
Milk fat indication ² , %	4.01	4.03	0.010	0.18
Milk protein indication, %	3.12	3.14	0.020	0.51
Fat yield ³ , g/d	1503	1499	9.76	0.84
Protein yield ⁴ , g/d	1170	1172	7.23	0.90
Fat + protein, g/d	2676	2670	16.72	0.87
Rumination, min/d	492	497	3.86	<0.0001
Refusals, #/d	1.25	1.79	0.05	<0.0001
AMS Visit Interval, h	7.62	7.30	0.27	<0.0001
AMS Milking Interval, h	8.64	8.63	0.060	0.91

Kamau et al. 2025. *Animals*. 15(8):1103. <https://doi.org/10.3390/ani15081103>

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Sources of metabolic losses from cattle

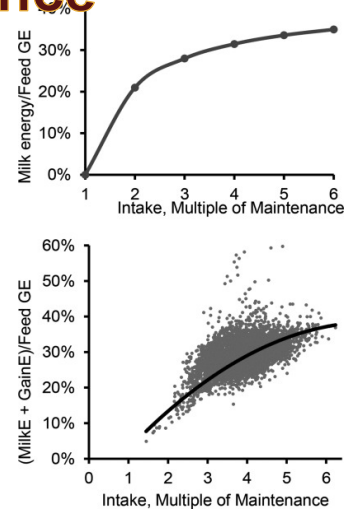
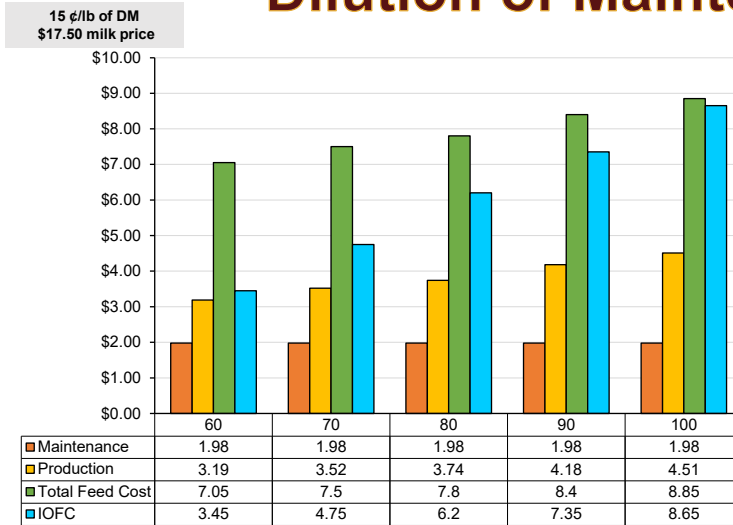


Created in <https://biorender.com>



19

Dilution of Maintenance

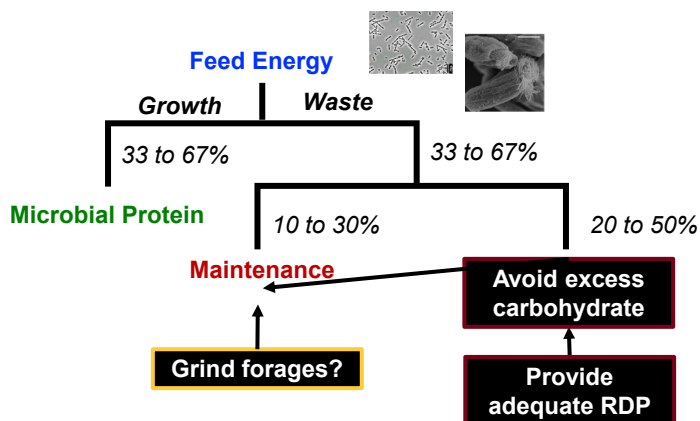


VandeHaar et al. (2016) <https://doi.org/10.3168/jds.2015-10352>



20

Rumen microbes waste a lot of energy



How do we reduce energy wasting in rumen microbes?

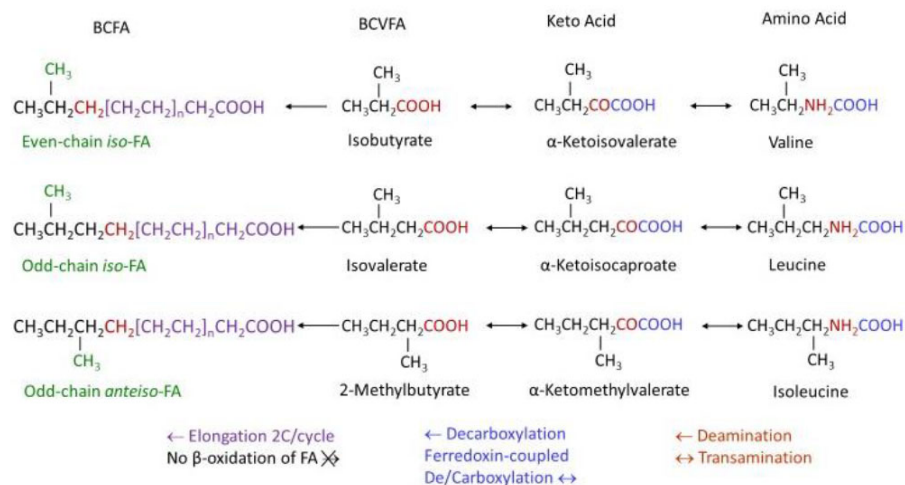
Other Strategies

- Monensin & other microbial modifiers
- Yeast?
- Avoid acidosis (*S. bovis* is very wasteful)
- Slow release CHO & N

Adapted from Hackmann (2014) *Florida Ruminant Nutrition Symposium*

21

Revisiting Iso-Acids to Improve Efficiency of Fermentation



Firkins (2023) *Proceedings of the Cornell Nutrition Conference*

22

Branched Chain Volatile Fatty Acids to Improve Production & Efficiency

Experiment	Treatment	No. Cows	Milk response to isoacids
Rogers & Cook (1986)	120 g AS-BCVFA ¹	567	+ 2.3 kg/d
Rogers et al. (1986)	100 g CS-BCVFA	349	+1.8 kg/d
Newman et al (1986)	82 g CS-BCVFA	462	+1.9 kg/d
Papas et al. (1984)	120 g AS-BCVFA	55	+2.0 ECM kg/d

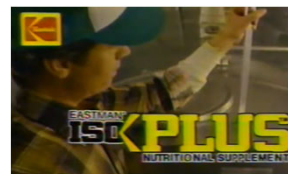
¹Ammonium salts of BCVFA

²Calcium salts of BCVFA

Muller (1987) Penn State Experiment Station

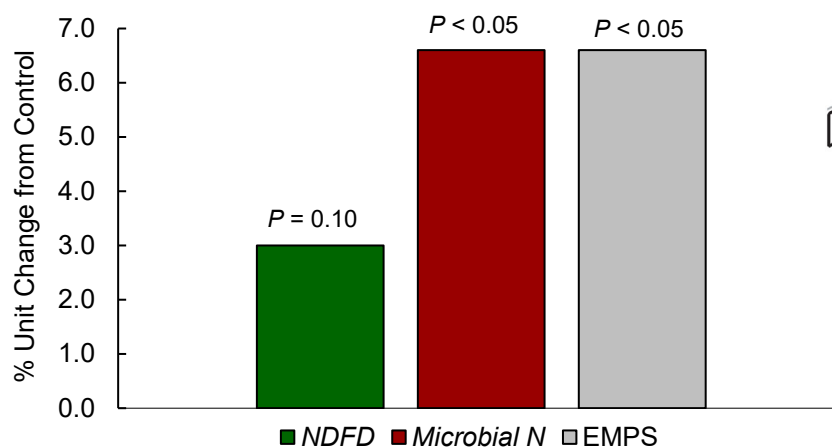
Branched chain VFA – Substrates for microbial protein synthesis

- Improve NDF digestibility
- Reduce methane synthesis



23

MPS and EMPS Change When Dosing BCVFA in Continuous Cultures



Slide Courtesy of Jeff Firkins, OSU

Mitchell et al. (2023) <https://doi.org/10.3168/jds.2022-23193>

24

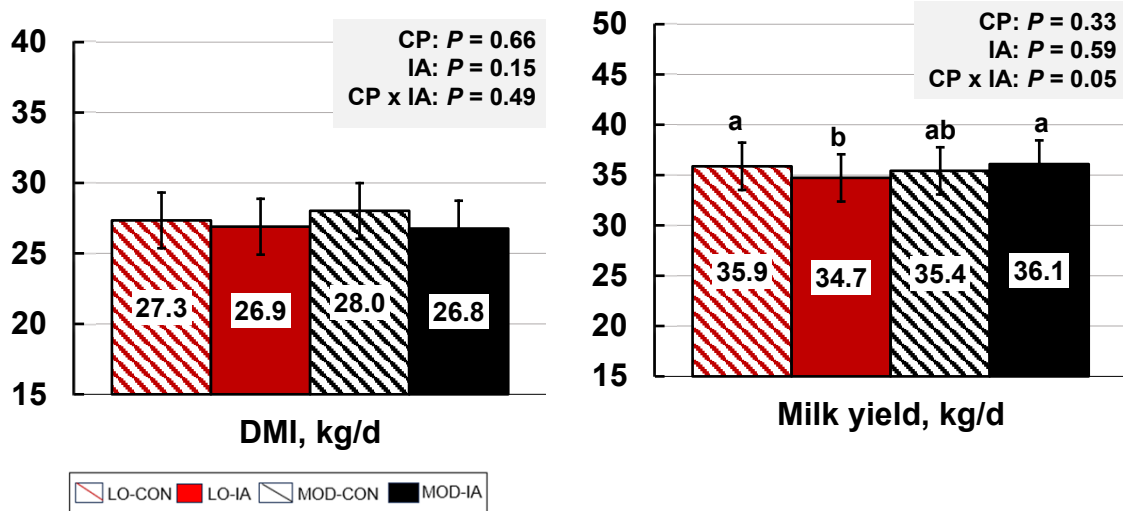
Do Iso-Acids improve efficiency of microbial protein synthesis *in vivo*

- ❖ 16.5% CP + Isoacids (MOD-IA)
- ❖ 16.5% CP no Isoacids (MOD-CON)
- ❖ 15% CP no Isoacids (LO-CON)
- ❖ 15% CP + Isoacids (LO-IA)



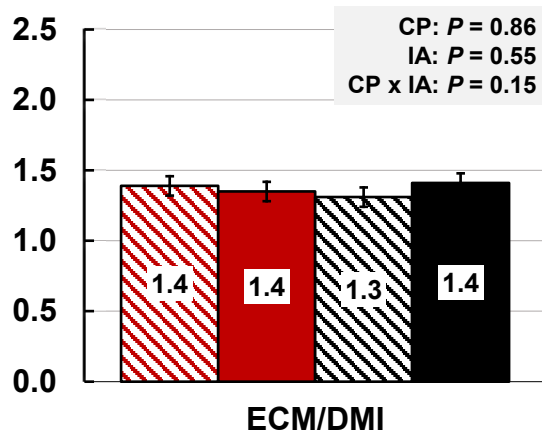
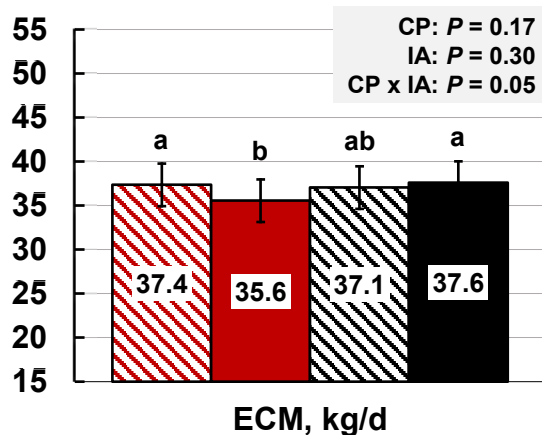
25

Iso-acids did not impact feed intake or milk yield



26

Iso-acids did not impact energy corrected milk or feed efficiency

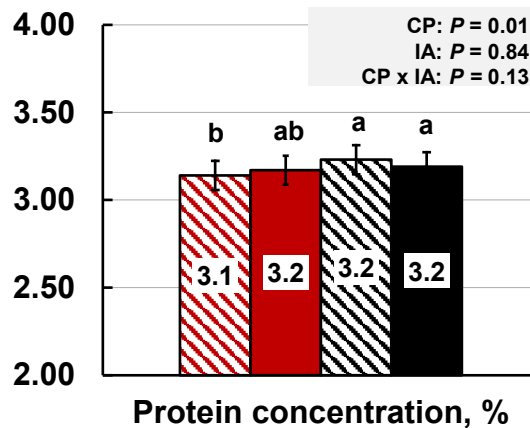
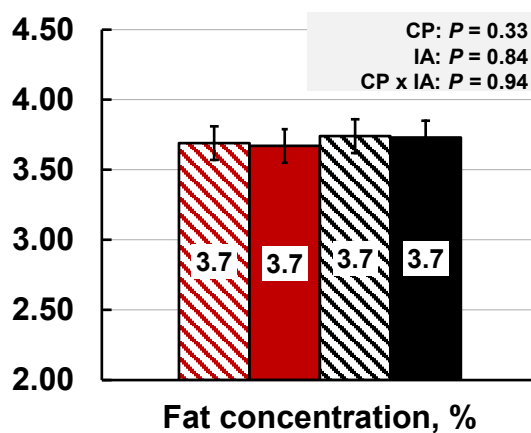


LO-CON LO-IA MOD-CON MOD-IA

(NRC,2001; Copelin et al. 2021, Liu et al. 2018, Mitchell et al., 2023)

27

Iso-acids did not impact milk component concentrations



LO-CON LO-IA MOD-CON MOD-IA

(Copelin et al, 2020, Mitchell et al. 2023)

28

Iso-acids tended to improve apparent CP digestibility, and increased NDF in the Low CP diet

Item	LO-CON	LO-IA	MOD-CON	MOD-IA	SEM	PROT	ISOA	PROT X ISOA
Intake								
DM	26.8	25.9	27.8	27.0	1.73	0.05	0.13	0.97
CP	4.08 ^b	4.02 ^b	4.60 ^a	4.39 ^a	0.30	<0.0001	0.14	0.41
aNDFom	8.29 ^a	8.14 ^a	8.13 ^a	7.76 ^b	0.58	0.13	0.16	0.53
Starch	8.12 ^a	7.98 ^a	7.83 ^a	7.48 ^b	0.24	0.03	0.16	0.55
Apparent TTD								
CP	69.9 ^d	70.3 ^c	73.9 ^b	74.9 ^a	0.40	<0.0001	0.01	0.32
NDF	55.2 ^b	56.9 ^a	54.6 ^{bc}	53.7 ^c	0.81	0.002	0.53	0.02
Starch	80.4 ^c	81.9 ^a	81.4 ^{ab}	80.9 ^{bc}	0.58	0.98	0.25	0.02

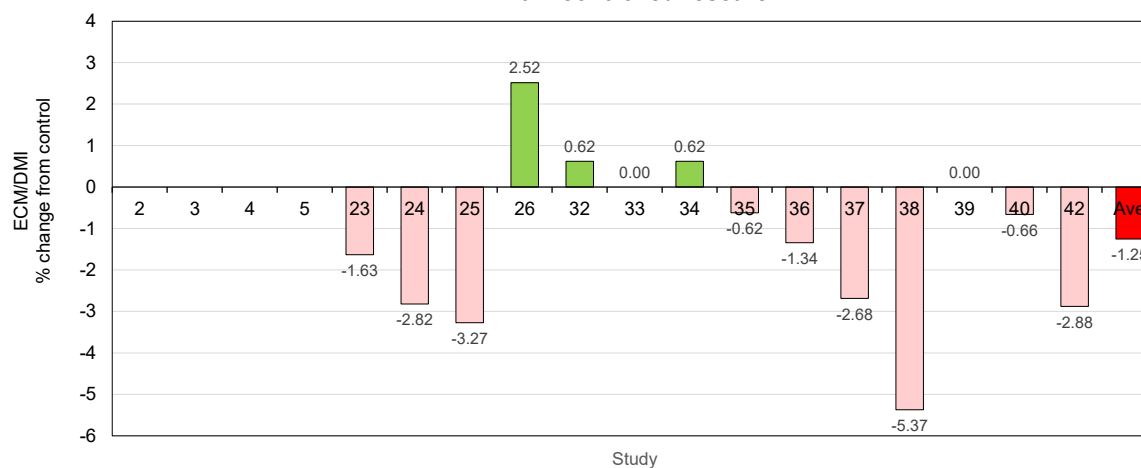


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Feed efficiency response to iso-acids is dependent on ruminal nitrogen availability

Research projects with rumen-available N < 130% of CNCPS requirement from controlled research



© Zinpro Corporation

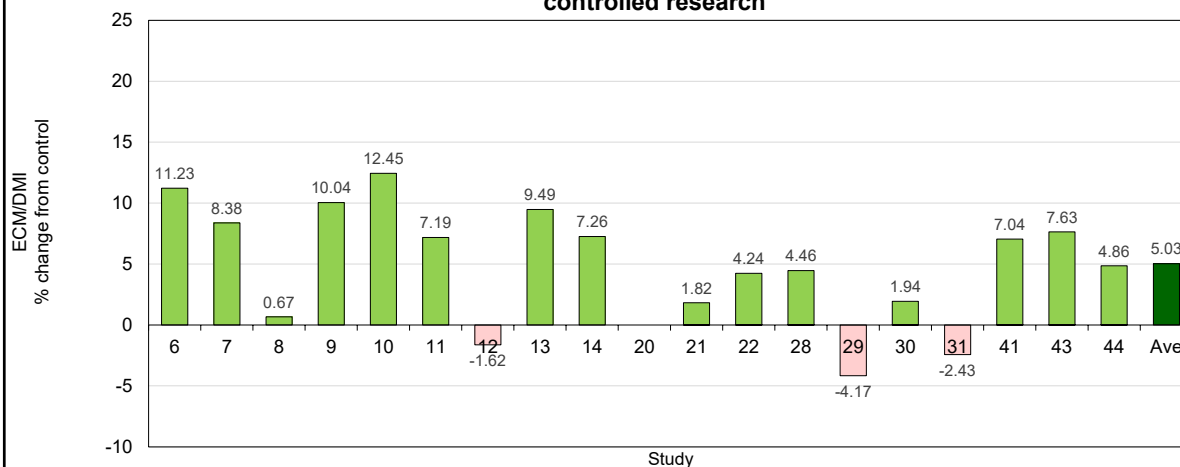
Slide adapted from Daryl Kleinschmidt, Zinpro

30



Feed efficiency response to iso-acids is dependent on ruminal nitrogen availability

Research projects with rumen-available N >130% of CNCPS requirement from controlled research

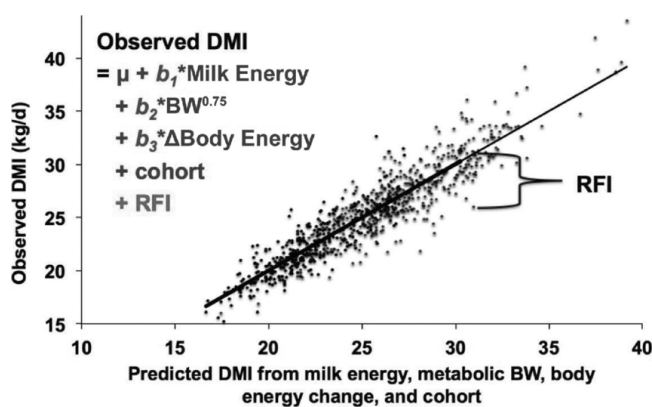


© Zinpro Corporation

Slide adapted from Daryl Kleinschmidt, Zinpro

31

When we genetically select for improved feed efficiency, what are we actually doing?



Residual Feed Intake (RFI)

Residual = Difference between observed & predicted value in a model

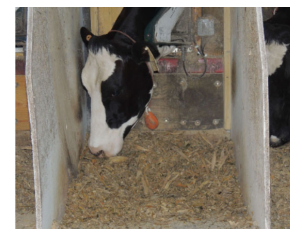
Vandehaar et al. 2016 *J Dairy Sci.* 99(6): 4941-4954 DOI:[10.3168/jds.2015-10352](https://doi.org/10.3168/jds.2015-10352)



32

Is feed efficiency heritable?

Item	Heritability ($\mu \pm \text{SEM}$)
Residual feed intake- primiparous	0.14 ± 0.03
Residual feed intake- multiparous	0.13 ± 0.03
DMI efficiency	0.16 ± 0.06
NE _L efficiency	0.16 ± 0.05
CP efficiency	0.21 ± 0.05
<i>Milk Yield</i>	0.23 ± 0.04



Vandehaar et al. 2016 *J Dairy Sci.* 99(6): 4941-4954 DOI:[10.3168/jds.2015-10352](https://doi.org/10.3168/jds.2015-10352)
 Hardie et al. (2017). <https://doi.org/10.3168/jds.2017-12604>



33

Compared to “traditional” traits, RFI is a genomic-only trait that requires data collection in cows fed individually

Table 1. – US RFI phenotypes by contributing institution as of April 2021

Institution ¹	NIFA	FFAR/CDCB	TOTAL
Miner	58		58
VA Tech	96		96
PANC	184		184
DFRC	624		624
UW	1,054	623	1,677
MSU	315	251	566
ISU	1,006	207	1,213
AGIL	834	370	1,204
UF	582	338	920
Total	4,753	1,789	6,542

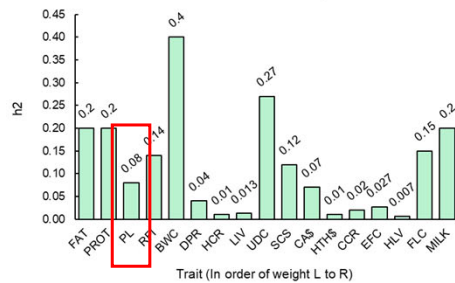
¹ Miner = Dairy Research Facility at the Miner Institute (Chazy, NY); VA Tech = Virginia Polytechnic Institute and State University (Blacksburg, VA); PANC = Purina Animal Nutrition Center (Gray Summit, MO); DFRC = Dairy Forage Research Center (ARS, USDA; Madison, WI); UW = University of Wisconsin (Madison, WI); MSU = Michigan State University (East Lansing, MI); ISU = Iowa State University (Ames, IA); AGIL = Animal Genomics and Improvement Laboratory (ARS, USDA; Beltsville, MD); UF = University of Florida (Gainesville, FL)



34

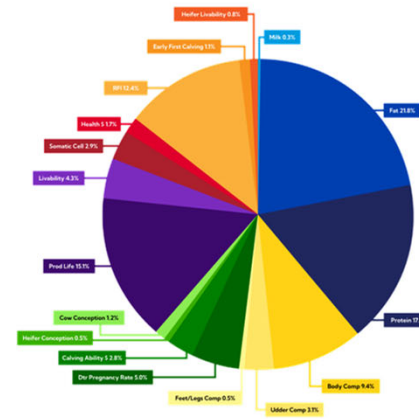
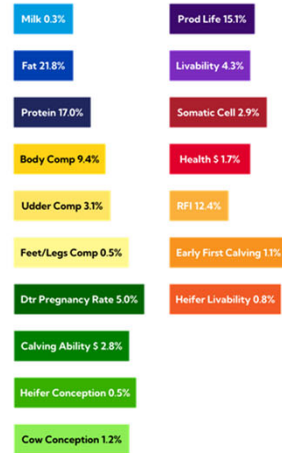
Feed saved is included w/ a 12.5% weight in the NM\$ index – 2021 update

Heritabilities of Traits in NM\$ Index



Weighting of Traits in Net Merit Dollars (\$)

Holstein



35

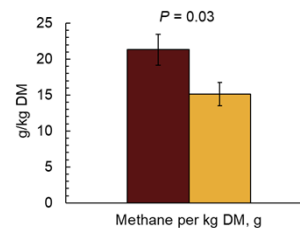
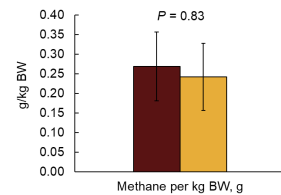
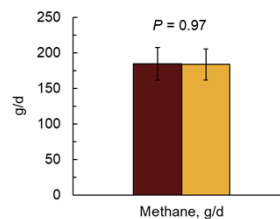
Has genetic selection impacted methane emissions?



"Unselected" Holsteins
- Continually bred with semen from before 1964



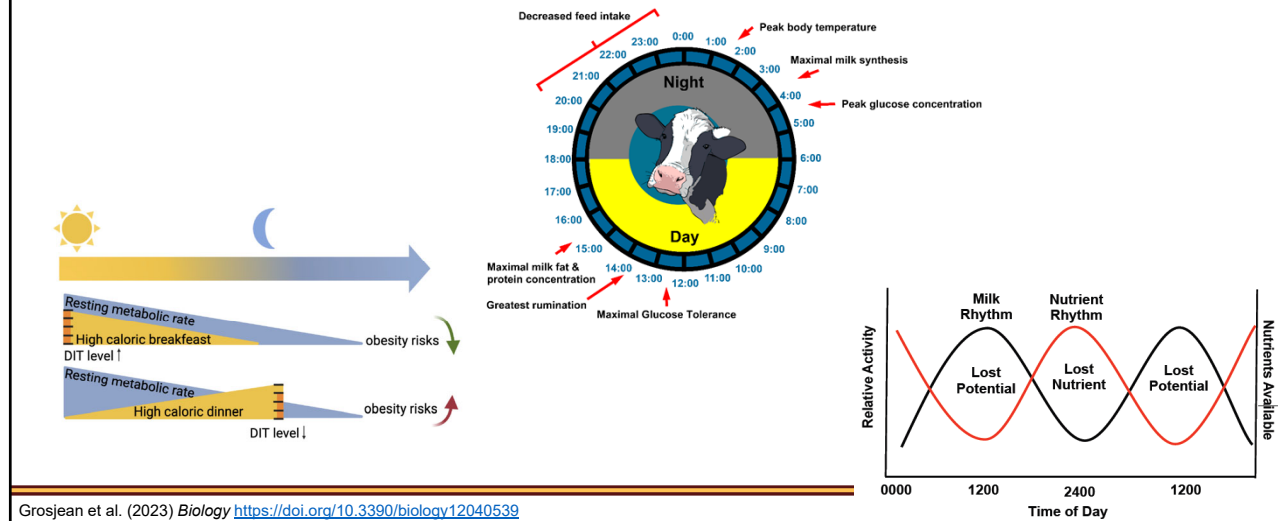
■ Unselected HO ■ Contemporary HO



Felton 2025 Unpublished. Data is preliminary – Do not reproduce

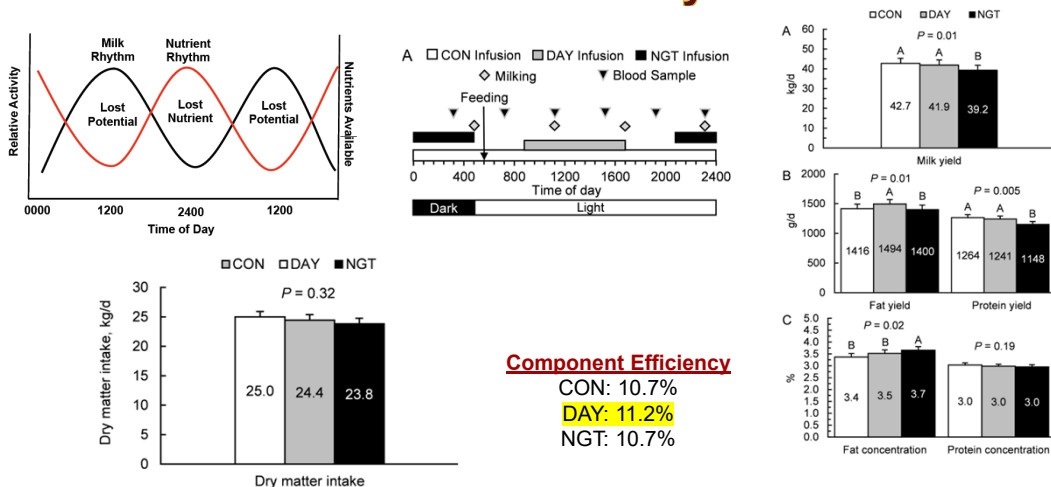
36

Humans metabolize nutrients differently across the day – do cows?



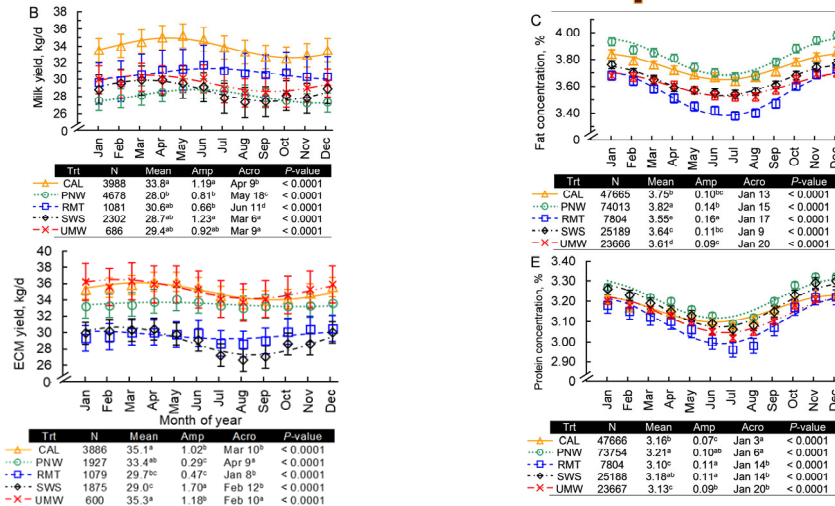
39

Are we missing the opportunity to feed cows based on their circadian rhythms to gain efficiency?



40

Milk yield & components follow a well-established seasonal pattern

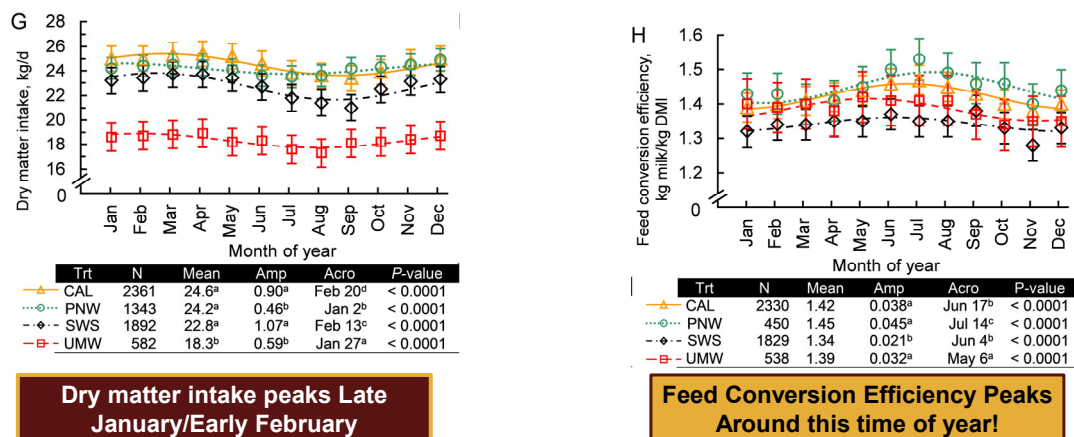


Sanchez 2025 Unpublished. Data is preliminary – Do not reproduce



41

Feed conversion efficiency follows a seasonal rhythm



Dry matter intake peaks Late January/Early February

Feed Conversion Efficiency Peaks Around this time of year!

Sanchez 2025 Unpublished. Data is preliminary – Do not reproduce



42

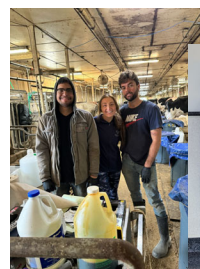
Summary

- **Improve whole herd feed efficiency by improved feed management:**
 - Accurate ingredient weights & daily dry matter measurement
 - Better silage management
- **Improve digestive & metabolic efficiency:**
 - Greater production = greater efficiency
 - Higher forage digestibility
 - Match RDP & fermentable carbohydrate intake
- **Future Opportunities:**
 - Genetic selection for feed efficiency & efficient microbial growth?
 - “Post-TMR” feeding strategies to better match nutrient needs with nutrient demand



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Acknowledgements



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 Jennifer Felton

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Salfer Lab



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 Dr. Brian Crooker, UMN
 Dr. Andres Gomez, UMN

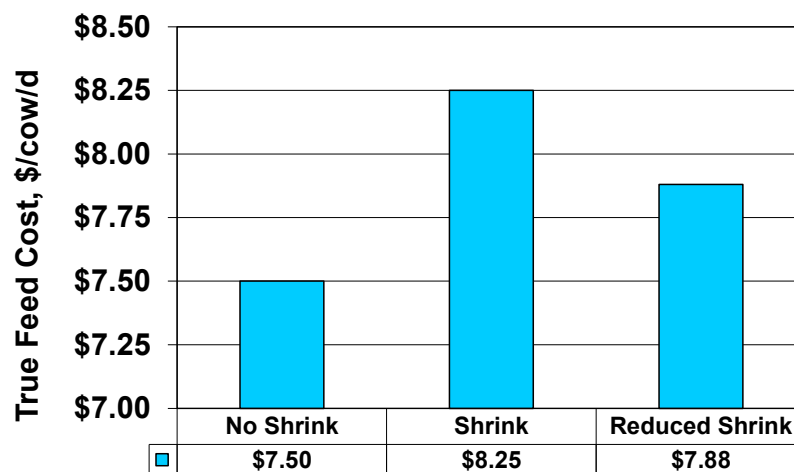
Dr. MaryGrace Erickson, UMN
 Dr. Pedro Urriola, UMN
 Dr. D. Jo Heuschele, UMN
 Dr. Kevin Harvatine, Penn State
 Dr. Ghazanfar Ali Chisti, UVAS Pakistan

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Shrink increases true feed cost



Slide courtesy of Mike Brouk, KSU



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Where do we lose nutrients?

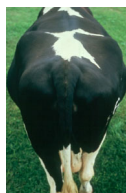
Feeding/ Feed Management

- Shrink
- Refusals



Metabolic Efficiency

- Urine (excess N)
- Heat production
- Nutrient partitioning



Digestive Efficiency

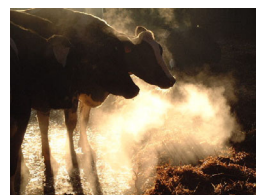
- Manure (undigested feed)
- Fermentation gasses
- Heat



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Feed Efficiency

- Time scale – are you improving efficiency now at the sacrifice of future gains?
- Are we capturing all our outputs?



Where are resources escaping from the system?

- Are they truly escaping, or are they just hidden?



48

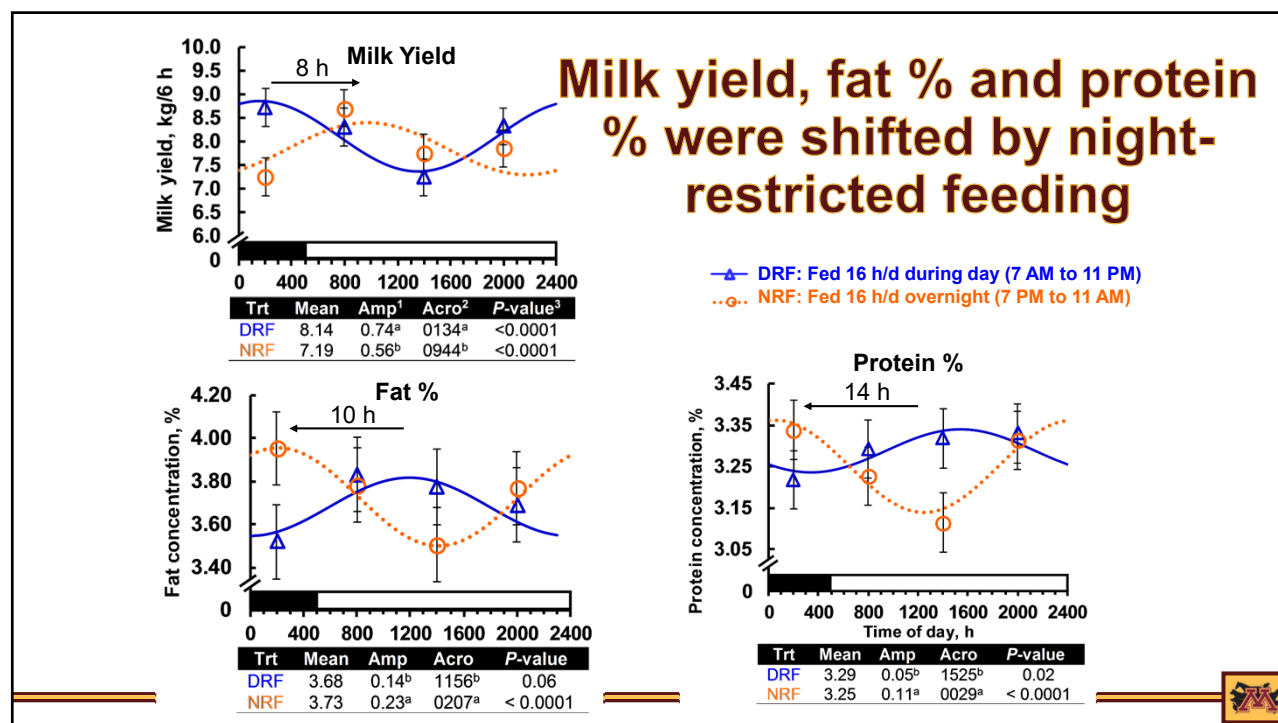
Improving Feed Efficiency by Reducing Methane Production

Item	Treatment		SEM	P - value
	CON	3-NOP		
Methane production, g/d	362	269	8.65	<0.001
DMI, lb/d	54.8	52.1	0.088	0.57
DMI, % of BW	3.92	4.00	0.088	0.57
Milk yield, lbs/d	96.6	97.0	1.55	0.91
ECM, kg/d	90.64	92.4	1.49	0.62
Feed efficiency, milk basis	1.77	1.88	0.042	0.01
Feed efficiency, ECM basis	1.75	1.87	0.047	0.02

Melgar et al (2020). <https://doi.org/10.3168/jds.2019-17085>

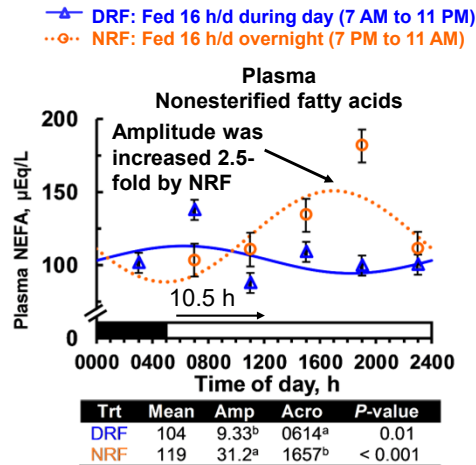


49



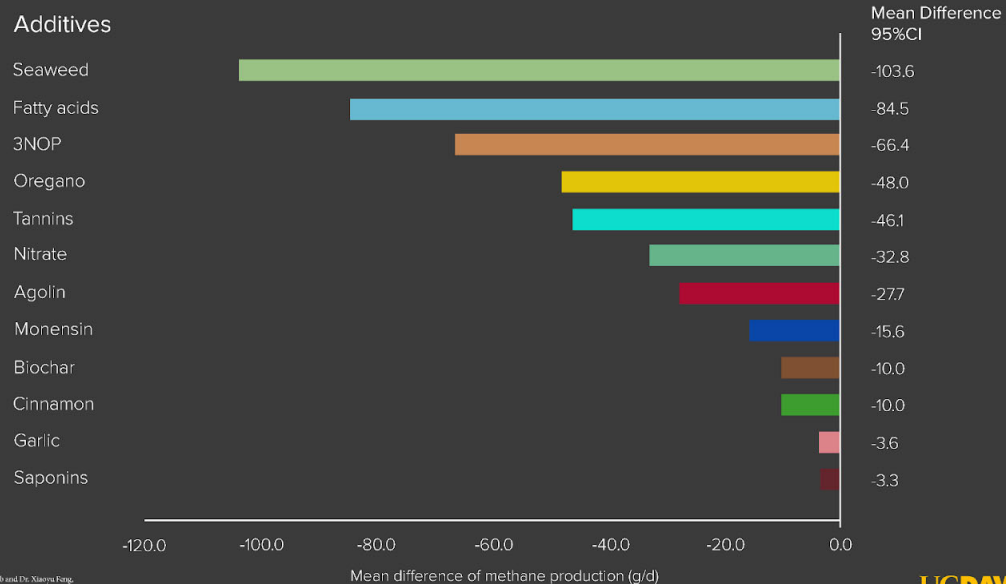
50

Nonesterified fatty acids were shifted 10 h and amplitude was increased by night-restricted feeding



51

Methane Reductions from Feed Additives



Created based on the work of Dr. Emma Kohn and Dr. Xiaoyu Fang,
 University of California, Davis.
https://www2.ucdavis.edu/news/details/files/2020_12/179D418.pdf

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 UNIVERSITY OF CALIFORNIA

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What genetic progress have we made in improving the efficiency of dairy cows?



"Unselected Cows"
- Continually bred with
semen from before 1964



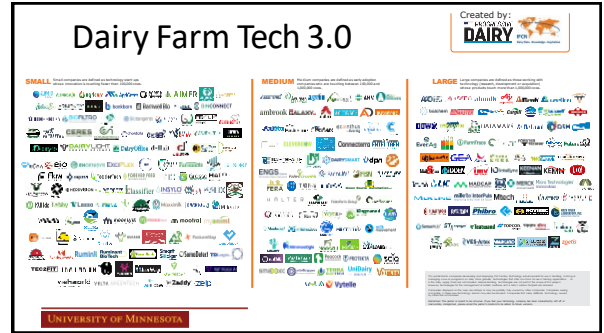
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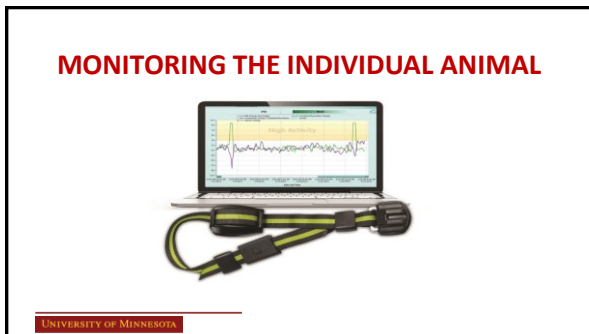
54



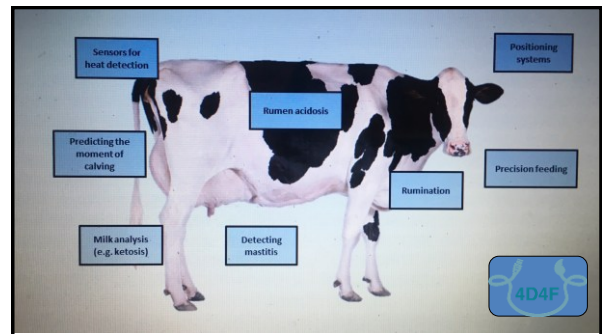
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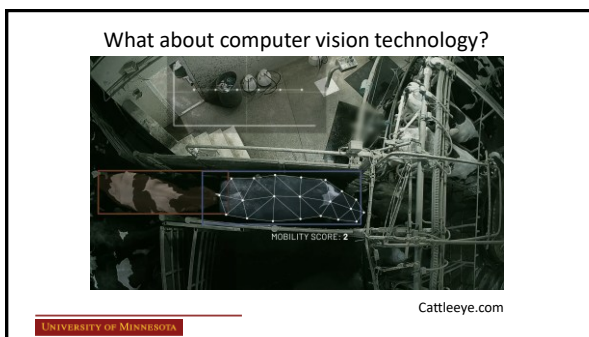
2



3



4



5



6

Cow location



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7

Startup Companies



BROLIS

dpn
CONNECT

ICHASE

ISOmark
HEALTH

Livestock 3D



LVS

Livestock
Visibility Solutions
Orbital returns through artificial intelligence

metha.ai

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AUTOMATED MILK FEEDERS FOR CALVES

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9



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ROBOTIC MILKING



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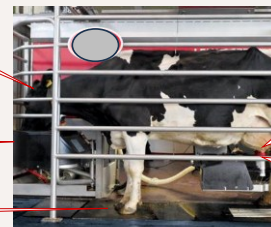
Weekly long term analysis: > 120 Values/cow/day

Activity*
Rumination*

Feed intake

Weight*

* = option



Milk Yield
Milk Fat*
Milk Protein*
Milk Lactose*
Milking Speed
Milk Temperature*
SCC*
Robot visits
Box times
Per Quarter:
- Yield contribution
- Teat position
- Pre Milk Time
- Milk Time
- Conductivity
- Color

+ combinations of all of the above ...
+ combinations with calendar + health events

From: Ben Smink, Lely

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Health report

Edit
Copy
Delete
Print
Export
Schedule
Settings
Routing
Execute
Close
Home

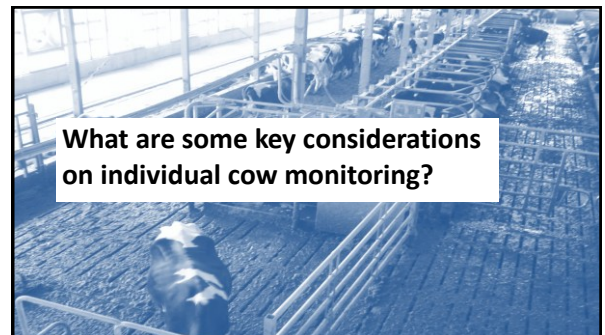
Count:10

Animal Number	Animal Name	Group	Lactation days	Day Physician (24h)	Sensor	Value	Severity	Sick Chance
1498	Heifers 60-150 DDM		140	26.7 Milk Drop	Blood RR	-35.7	96	
					Activity(humination)	81		
					Conductivity RR	102		
					Abnormal LR, RR	-80		
					Weight loss	-36.5		
295	152 REG 1	Cows 150+ DDM	235	36.2 Milk Drop	Activity(humination)	-36.5	37	
1426	Milking Cows-Control		45	113.1 Milk Drop	77	31		
				Fat Protein Ratio	0.89			
377	Milking Cows-Control		14	67.7 Activity(humination)	82	23		
				Fresh cow performance	67			
				Weight loss	-70			

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From: Chad Kieffer

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Is the technology accurately measuring the behavior or physiological parameter it is supposed to measure?

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So what?

What do we do with it?

Reproductive management?

Health management?

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What do we do if a cow is flagged by the technology?



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THANK YOU!



www.precisiondairy.org

miendres@umn.edu

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Cocktail Forage Mix Research: Agronomic and Dairy Cow Production

Matt Akins - Environmentally Integrated Dairy Management Research Unit; Marshfield, WI

Luiz Ferraretto – University of Wisconsin Madison

Hidir Gumus - Burdur Mehmet Akif Ersoy University, Turkey

***Research partially supported by WI Dairy Innovation Hub**

Use of 'Cocktail' Forage Mixes

- Use of cocktail forage mixes is of interest to dairy farms as part of an annual forage cropping system
 - Double-cropping after a cereal forage harvest
 - Increased use of manure during growing season
- 'Cocktail' forage mixes of BMR sorghum-sudan, Italian ryegrass, and legumes (red clover, berseem clover, and hairy vetch) becoming more common
- Previous data is limited on potential yield and quality
- Data from Waupaca County cocktail forage field study:

Forage Crop	TDM / Acre	CP	NDF	NDFD
Winter Rye (WR)	0.7	12	48	71
Corn Silage (CS)	7.3	7	43	61
"Cocktail" (MIX)	3.9	16	45	69
Annual Ryegrass (ARG)	4.1	16	50	62
Alfalfa (ALF)**	4.4	22	39	48

* Values rounded to the nearest "100" using MILK 2006 (CS) and MILK 2006 (WR) data.

** Estimates using WI Alfalfa Yield & Persistency Project 2007-2018 data.

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Project Overview

- 1) Plot studies on yield and quality of a cocktail forage mix (lab/data analysis in progress)
 - Row width of sorghum-sudan and planting depth of ryegrass/legumes
 - Clover varieties
- 2) Production farm yield data from 4 WI dairy farms
- 3) Lactating cow feeding study with cocktail forage mix at Marshfield ARS



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Production Farm Field Management

- Planted after cereal grain forage harvest at 3 locations
- Mix composition (early June planting)
 - 3 farms: 35 lb/acre with 60% sorghum-sudan, 25% Italian rye, 5% each of red clover, berseem clover and hairy vetch
 - 1 farm: 50 lb/acre with 59% cowpeas, 17% Italian rye, 6% each from millet, alfalfa and red clover, 4% timothy, and 2% radish
- Fertility
 - 2 farms used only inorganic N at planting (20 lb N/ac) or between cuttings (45 lb N/ac)
 - 1 farm used injected liquid manure pre-plant (9000 gal/ac; 94 lb available N/ac) and commercial N for 1st cutting (35 lb N/ac) and between cuttings (60 lb/ac)
 - 1 farm used commercial N at planting (66 lb N/ac), then manure between cuttings (6000 gal/ac; 21 lb available N/ac)



Cereal Forage Harvest and 1st Cocktail Harvest -Outagamie County



Credit: Kevin Jarek



1st Cocktail Harvest – Oconto County



USDFRC

Credit: Dan Olson



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3rd Cocktail Harvest – Oconto County

No Manure Applied



Manure Applied



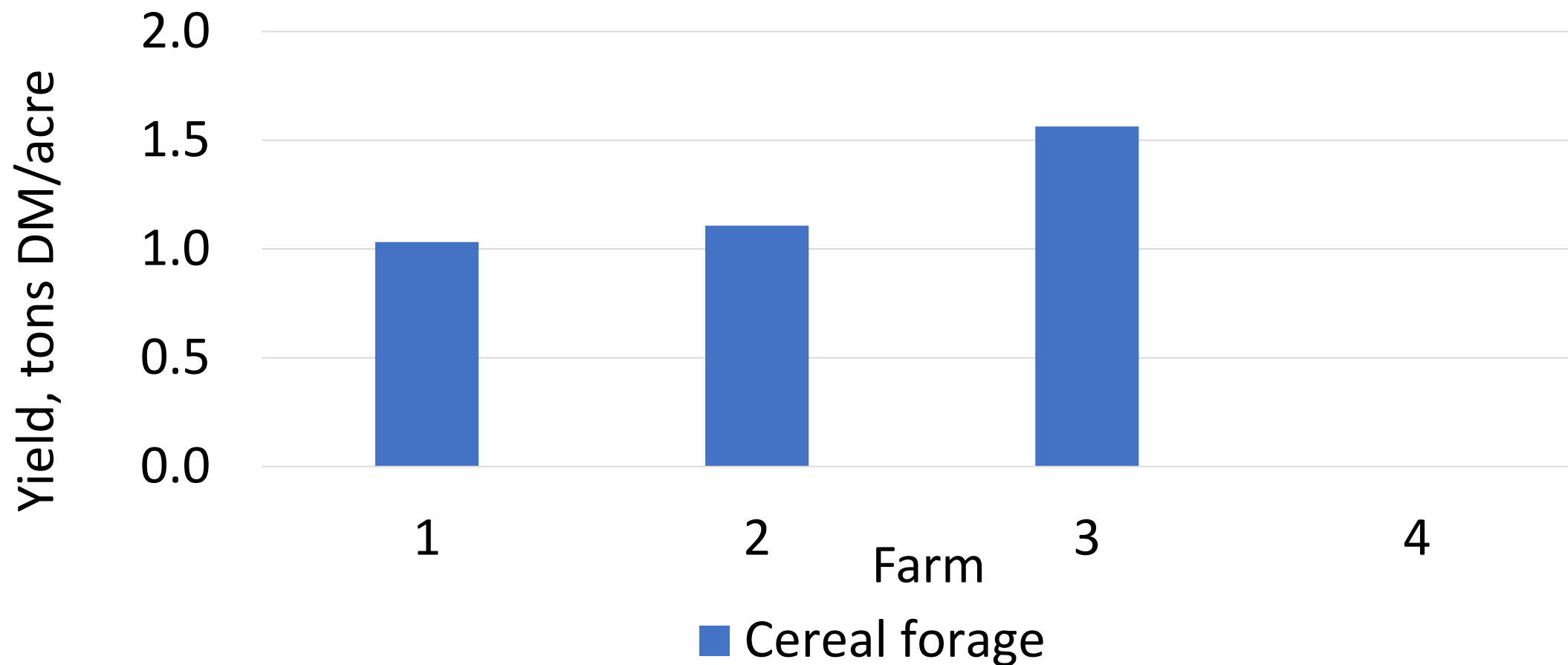
Credit: Kevin Jarek



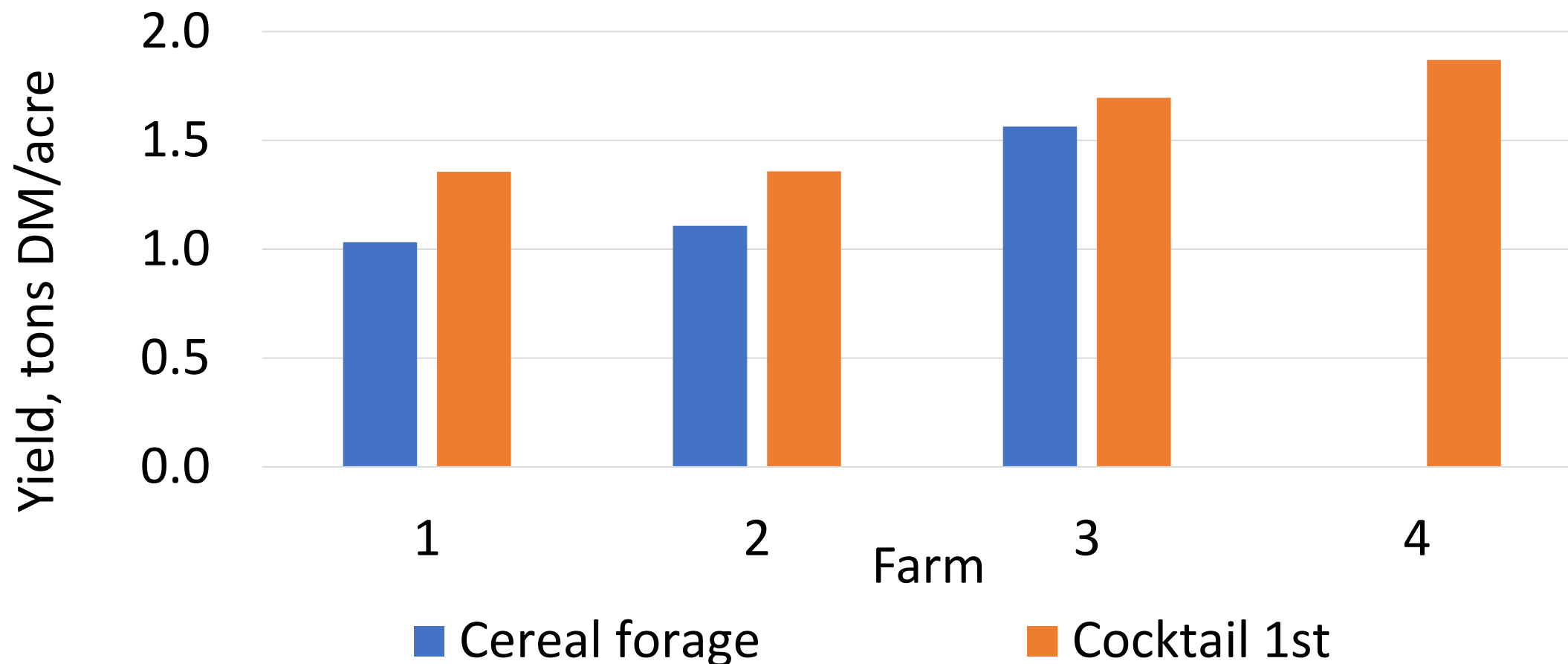
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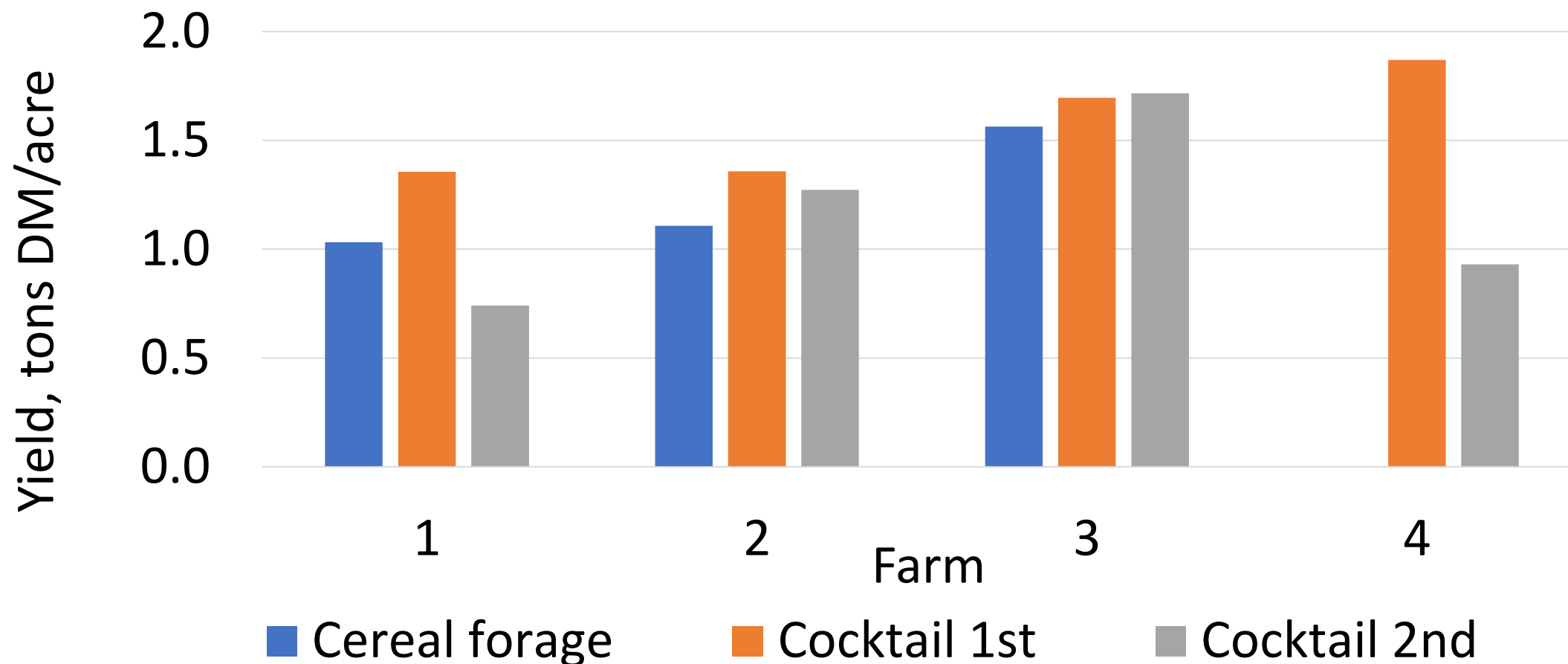
On-Farm Forage Yields



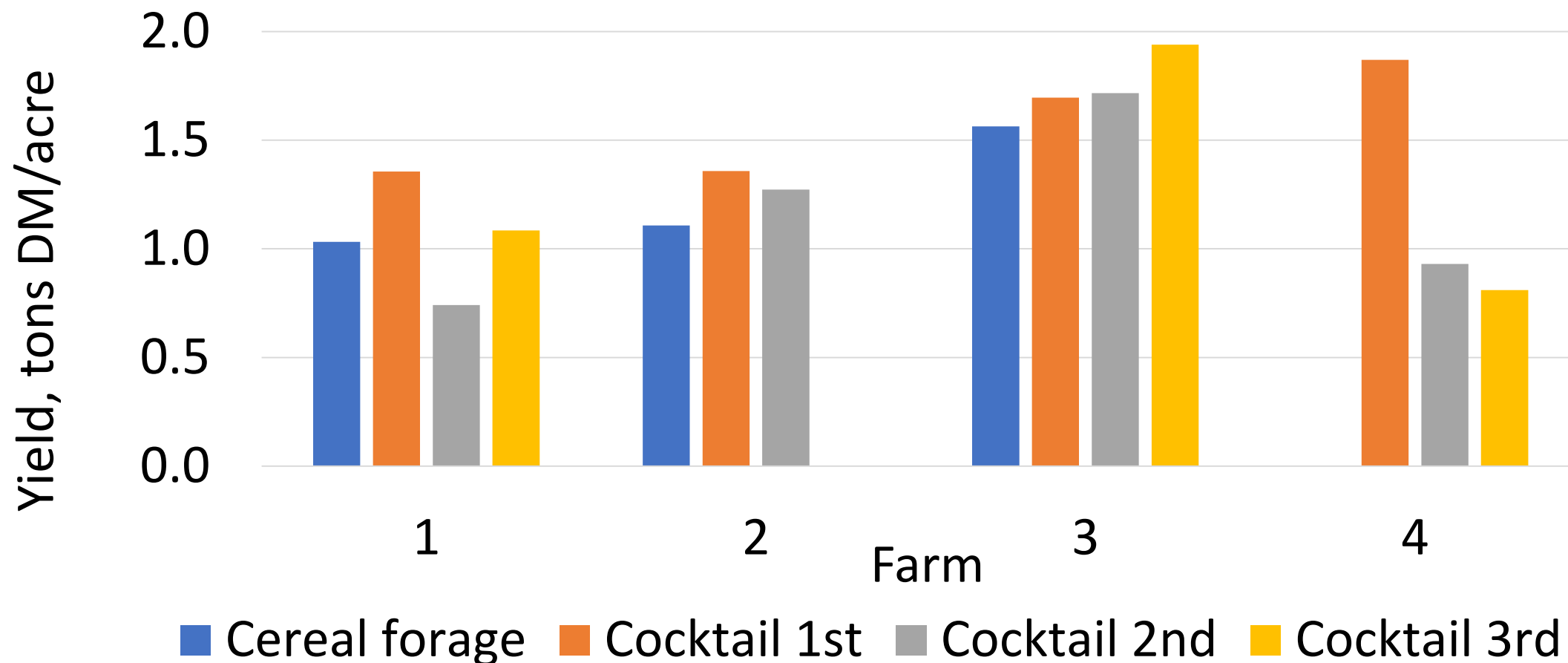
On-Farm Forage Yields



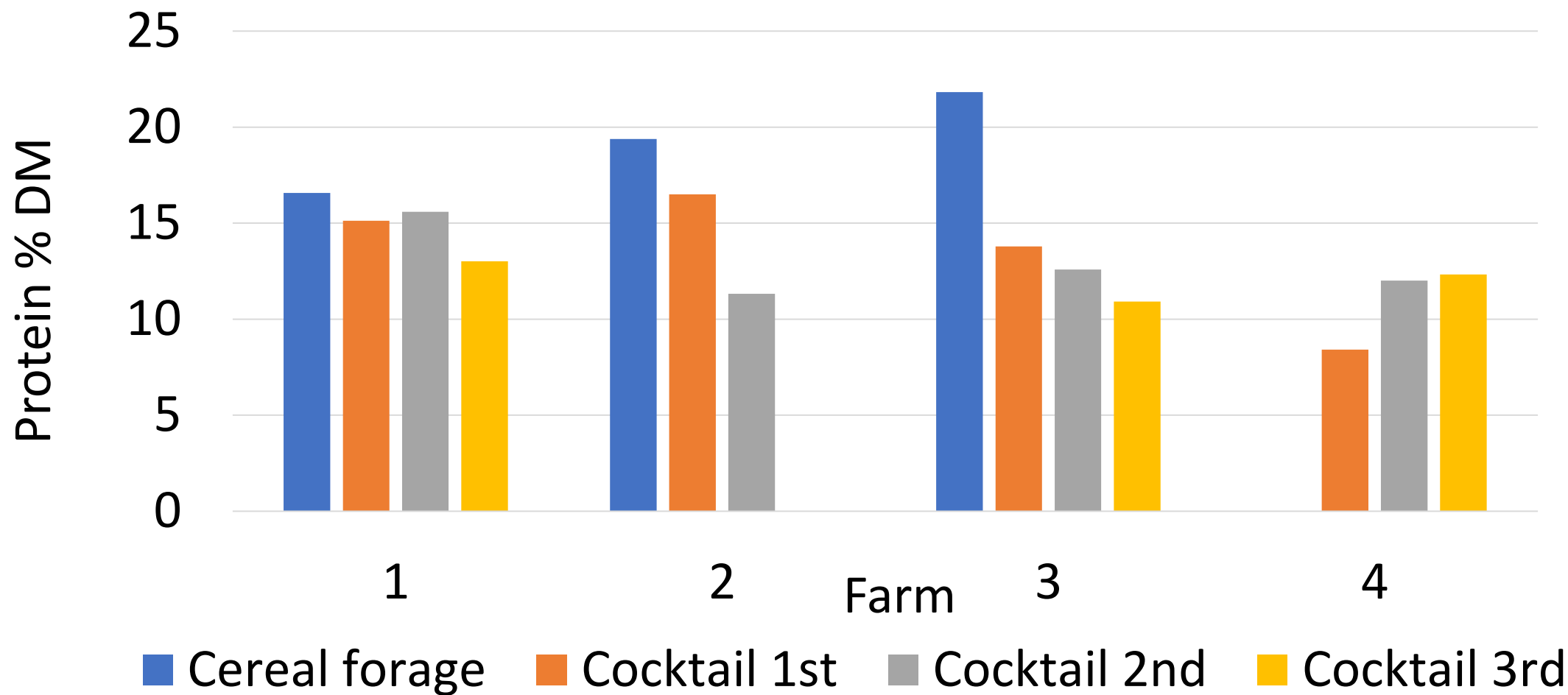
On-Farm Forage Yields



On-Farm Forage Yields



Forage Quality - Protein

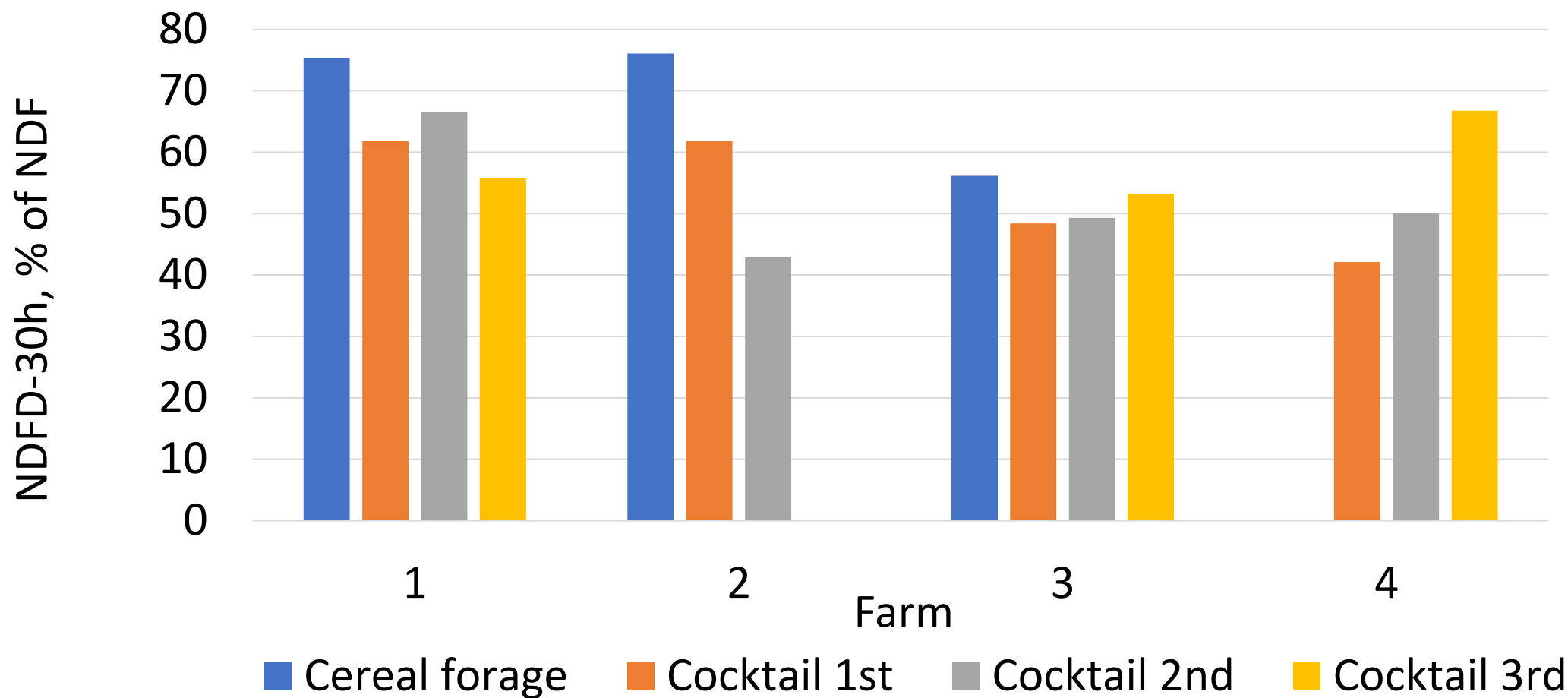


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Forage Quality – NDFD-30h



Lactating Cow Feeding Project

- Conducted at Marshfield ARS
- 32 first-lactation Holstein cows
- 2 diets fed for 8 weeks
 - Control – Corn silage and alfalfa silage
 - Treatment – Corn silage and cocktail mix (2nd harvest)



Forage Quality

	Alfalfa/grass silage	Cocktail mix silage
Crude protein, % of DM	18.5	12.9
NDFom, % of DM	40.4	51.6
NDFD 30h, % of NDF	52.2	68.7
TDN, % of DM	58.6	57.8

Diet Composition

% of diet DM	Control	Cocktail
Corn silage	29.2	29.2
Alfalfa silage	18.3	-
Cocktail mix	-	18.3
Dry ground corn	19.3	17.5
Soybean meal	-	1.8
Protein mix	23.5	23.5
Liquid whey permeate	9.2	9.2
Mineral/urea	0.5	0.5
Crude protein	16.8	17.0
NDFom	22.3	26.0
NDFD 30 h, % of NDF	61.9	68.0
Starch	28.4	26.8
TDN	73.7	70.8



Nutrient digestibility and Fermentation losses

	Control	Cocktail
<u>Total tract digestibility, %</u>		
DM	81.5 ^a	78.7 ^b
NDF	63.8 ^a	66.2 ^a
<u>Rumen CH₄ losses</u>		
CH ₄ , g emitted	450 ^a	411 ^b
CH ₄ , g/lb DMI	7.62 ^a	6.89 ^b
CH ₄ , g/lb ECM	4.49	4.28

Intakes and Milk Production

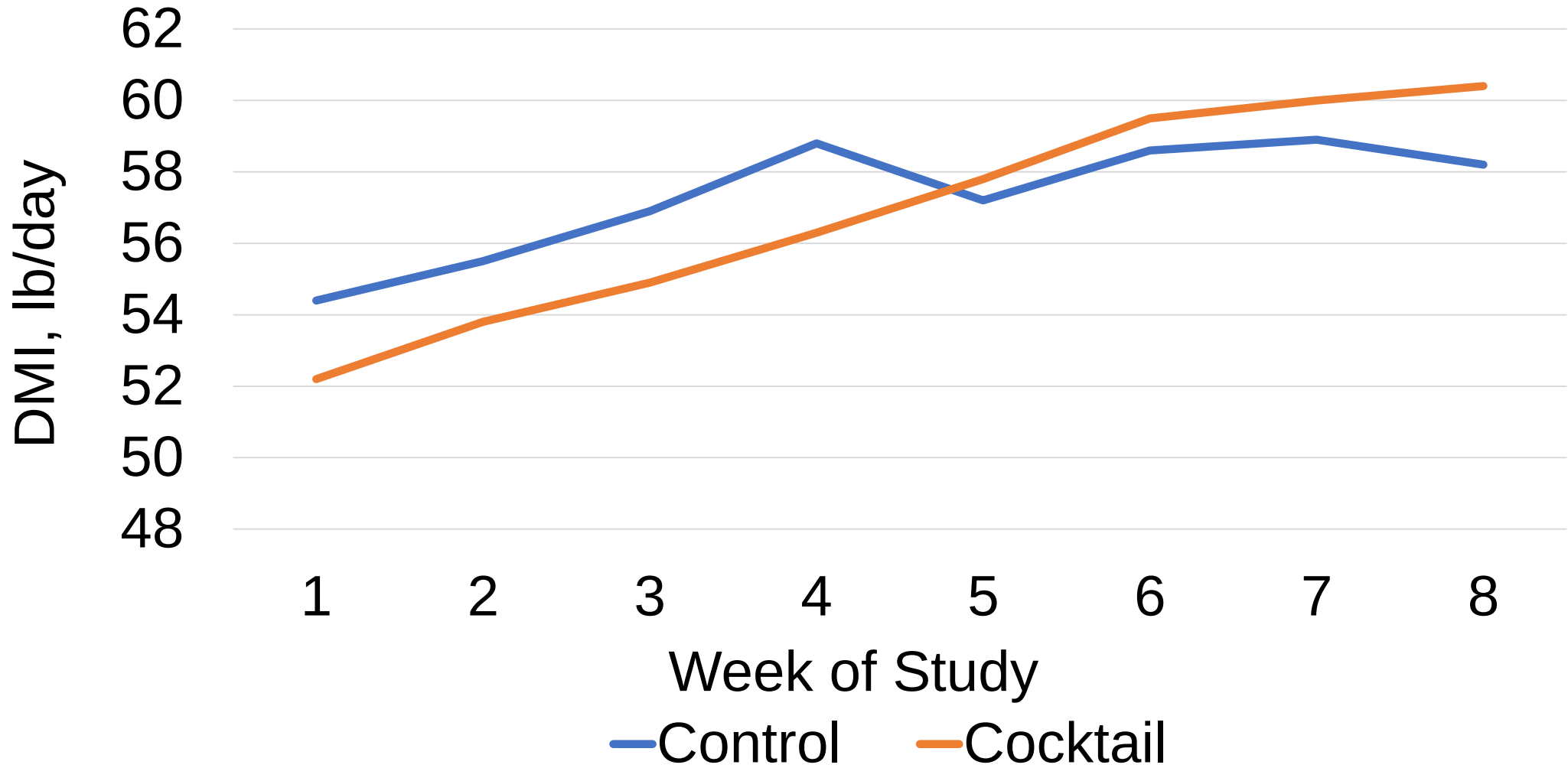
	Control	Cocktail
DMI, lb/day	57.3	56.9
Milk, lb/day	83.7*	81.4*
Efficiency, lb milk/lb DMI	1.47*	1.43*
Energy corrected milk, lb/day	89.9	88.7
Fat, %	4.74	4.83
Fat, lb/day	3.96	3.92
Protein, %	3.38*	3.45*
Protein, lb/day	2.82	2.80
Lactose, lb/day	4.02*	3.88*
MUN, mg/dL	11.7	11.6

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Feed Intake



Summary

- Season total yield for Cereal forage and Cocktail mix of 4-5 tons
 - Possibly higher with good conditions and adequate nutrients
- Quality high for cereal forages, but variable for cocktail mix
 - Variation in species at each cocktail harvest
 - Sorghum-sudan and ryegrass dominant all harvests
 - Harvest timing, yield and ryegrass/legume content main factors
- Lactating cow performance similar when fed cocktail mix
 - Similar intakes, fat and protein yields, but lower lactose yields
 - Harvest at optimal critical to inclusion in cow diets





Questions?

Matt Akins

Environmentally Integrated Dairy Management Research Unit

Email: matthew.akins@usda.gov

How can corn silage production affect feed efficiency by dairy herds?

Luiz F. Ferraretto, Ph.D., PAS

Assistant Professor and Ruminant Nutrition Extension Specialist



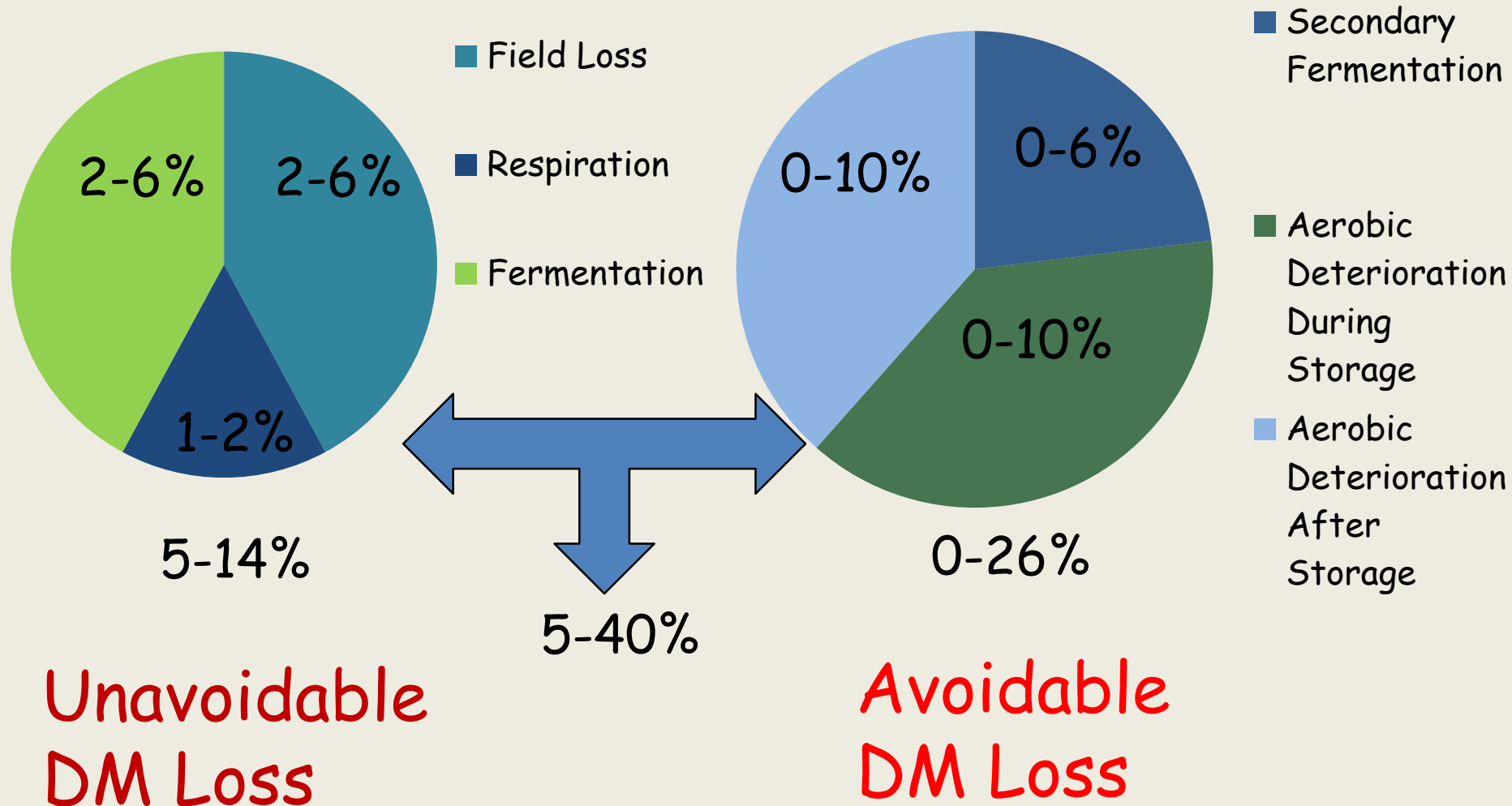
Department of
Animal & Dairy Sciences
UNIVERSITY OF WISCONSIN-MADISON



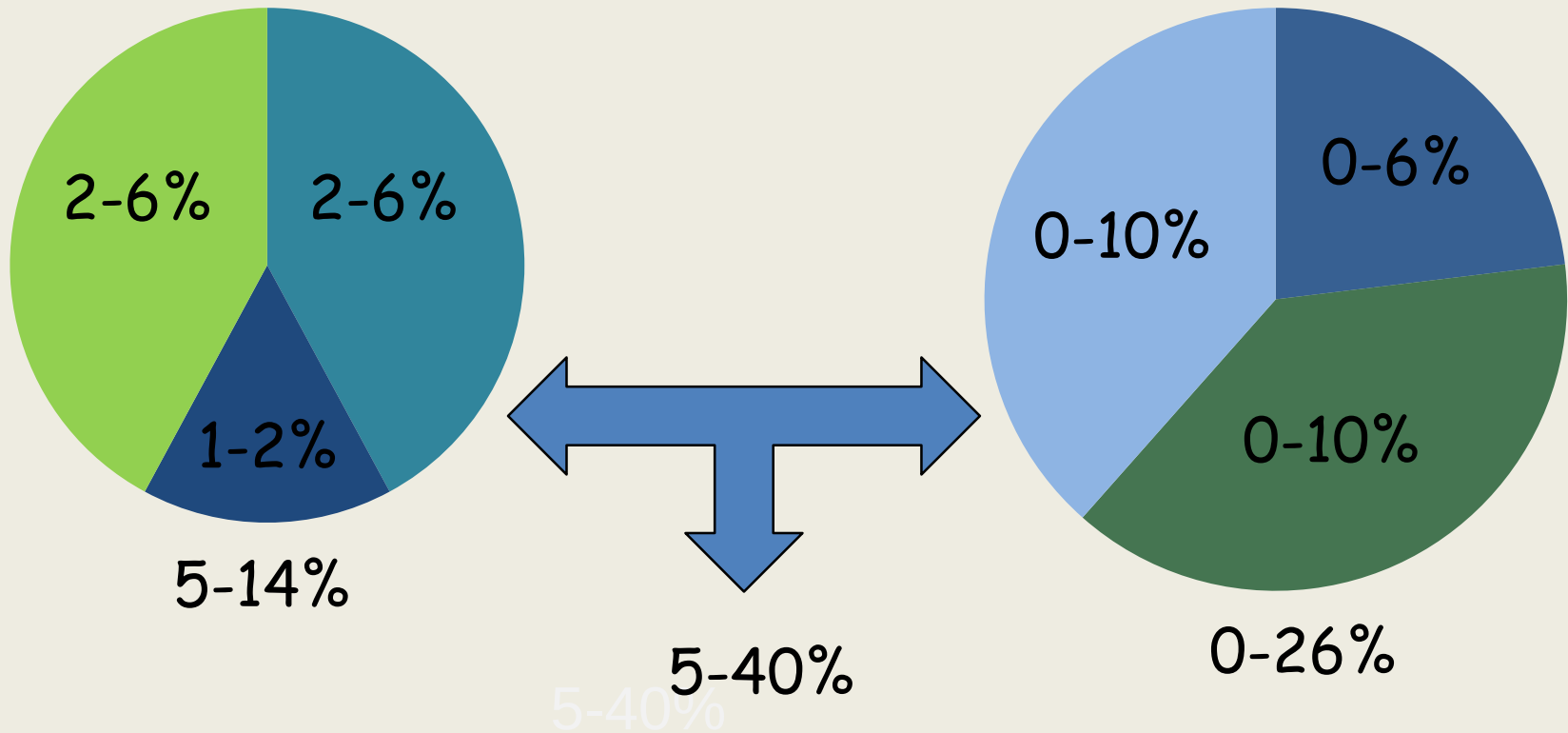
Silage Shrink

- The quantity of silage produced that is not fed to the cow or the cow doesn't eat
- Varies from 5 to > 40% depending on management

Forage Losses



Forage Losses



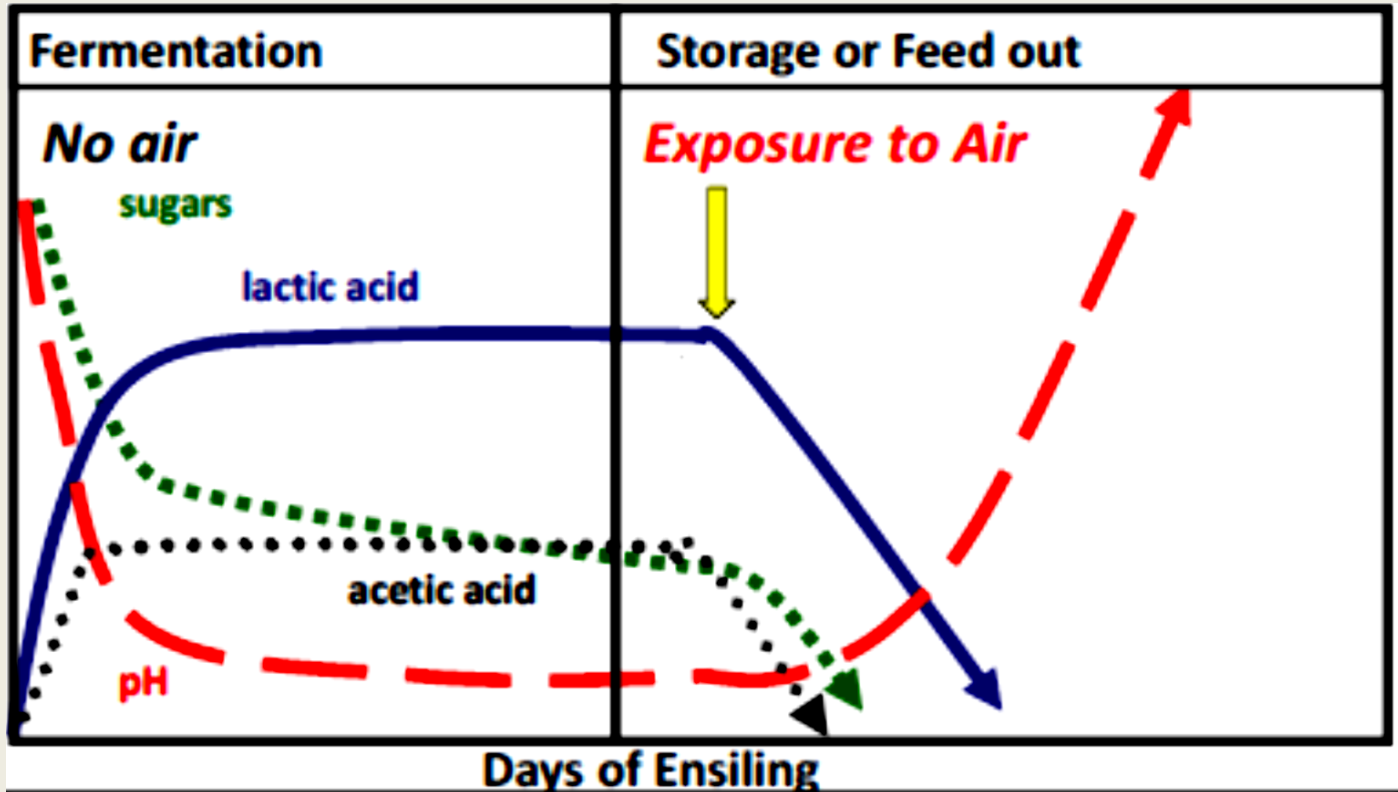
How much is this?

Goes to the silo = 1,000 t.

Feed out = 600-950 t,

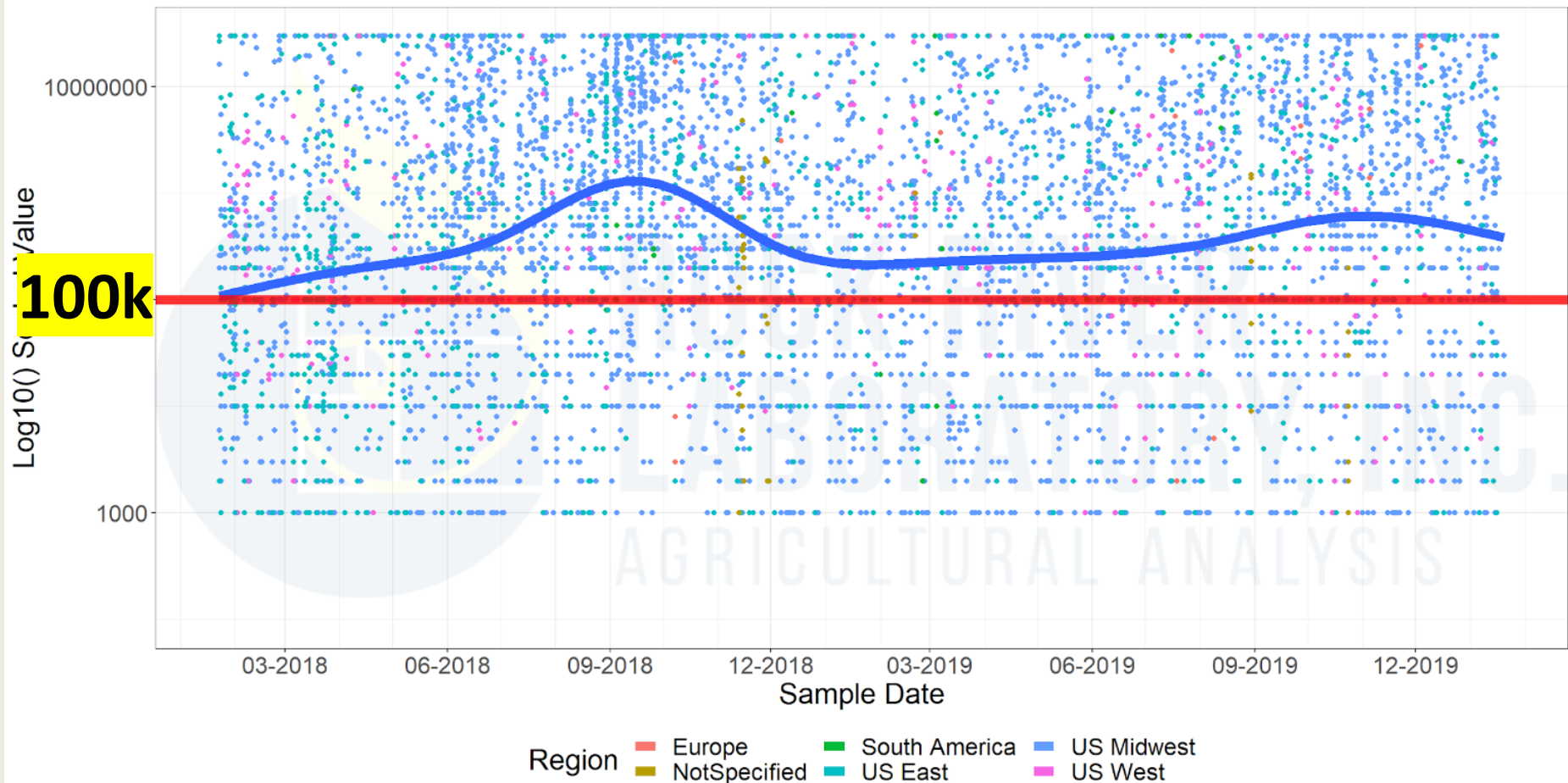
Silage \$\$/t = ?

After silo opening



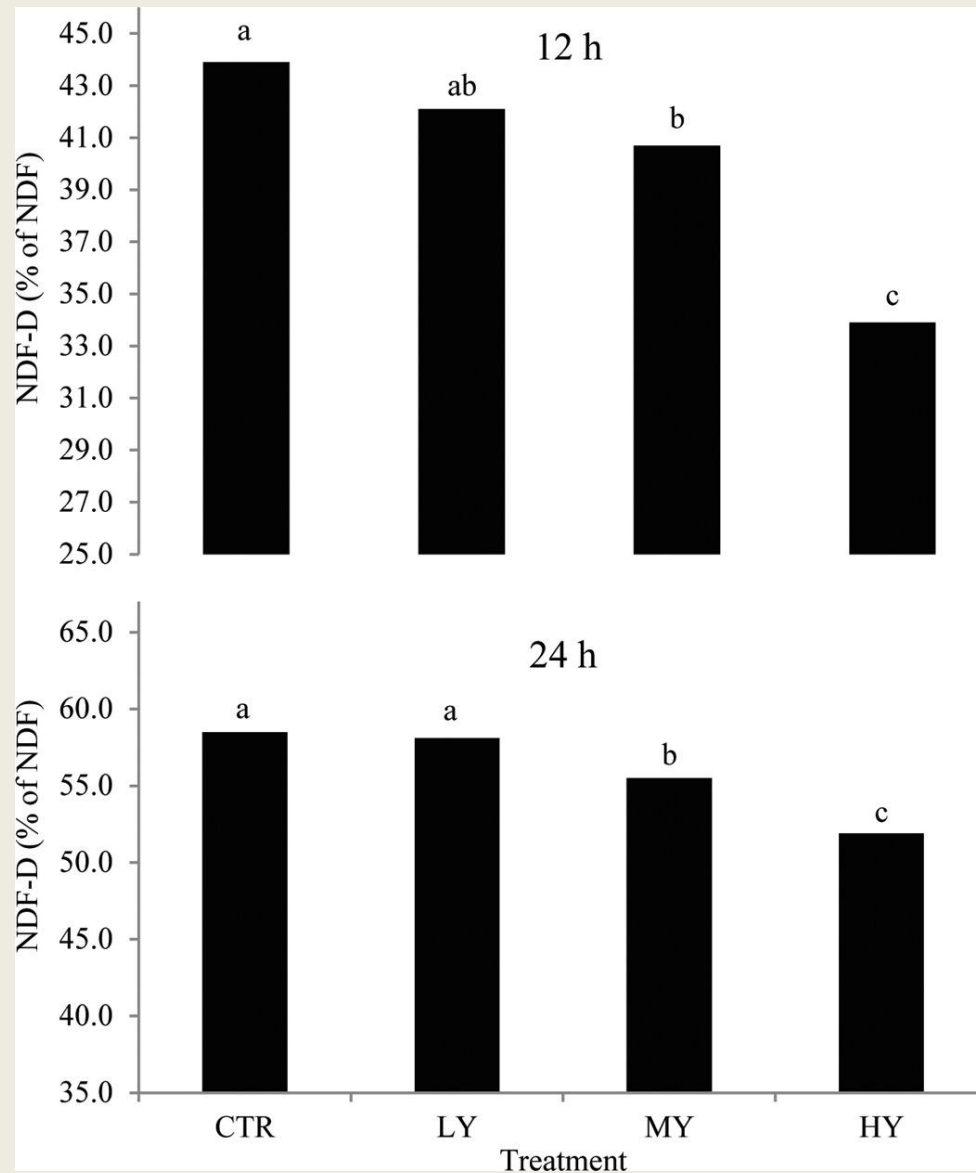
Yeast load, cfu/g

Yeast



Fungal contamination is a substantial opportunity

Spoilage reduces NDFD



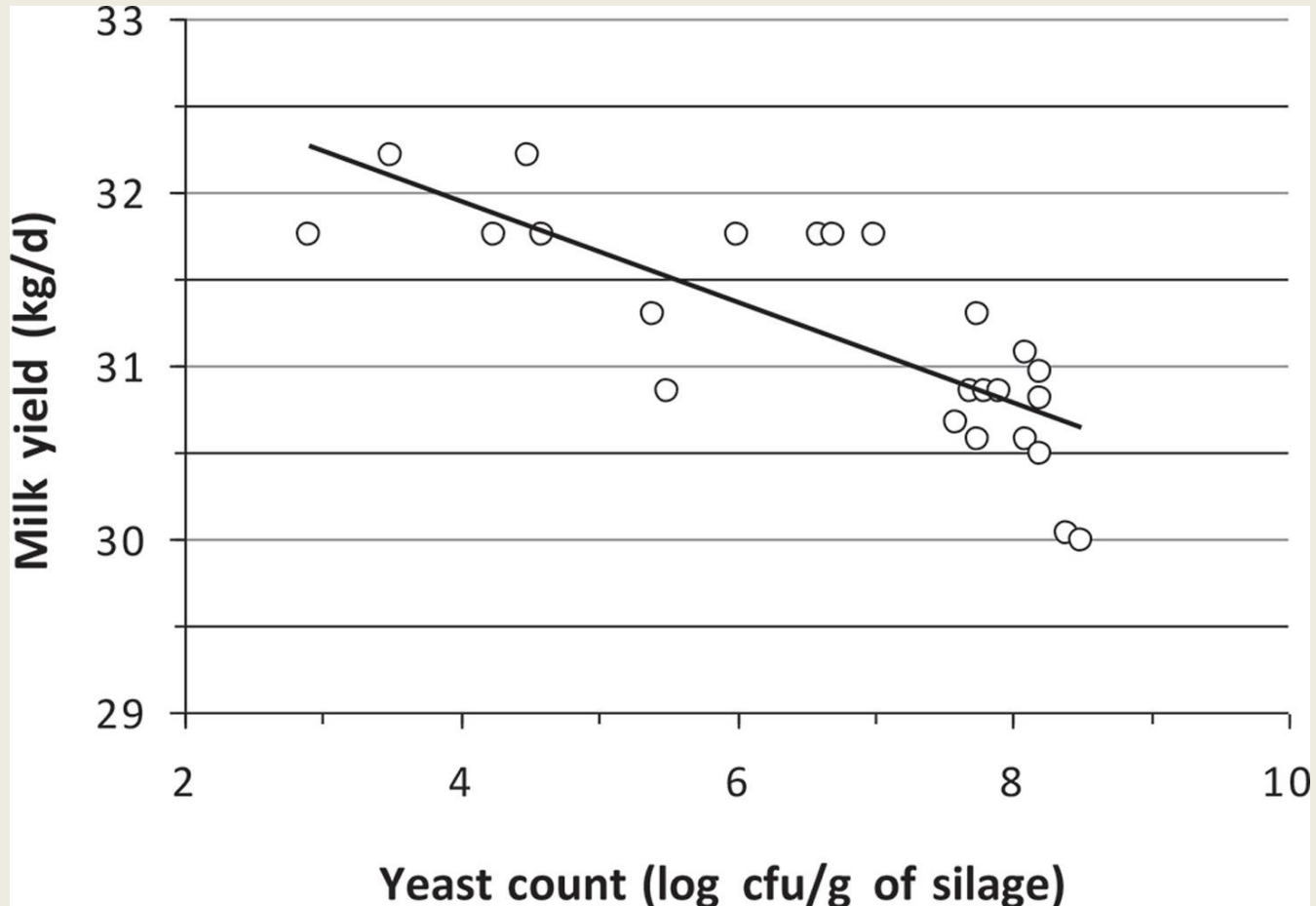
Spoilage reduces NDFD

12 h	Yeast, log cfu	NDFD, %NDF	Milk/ton
CTR	-	43.9%	3010
LY	4.02	40.7%	2976
HY	8.18	33.9%	2896

UW - yeast contamination study

Item ²	CON ¹	Low	Med	High	SEM ³	P-value
pH	4.55	4.85	4.81	4.75	0.10	0.06
Total acids, %DM	0.99	1.00	1.20	1.23	0.20	0.53
Lactic acid, %DM	0.83	0.76	0.91	0.93	0.17	0.75
Acetic acid, %DM	0.12 ^b	0.21 ^a	0.24 ^a	0.27 ^a	0.03	0.01
Ethanol, %DM	0.57 ^c	1.33 ^b	1.69 ^a	1.90 ^a	0.12	0.001
Ammonia-N, %CP	2.53	2.58	2.81	2.63	0.28	0.76
Yeast, log cfu/g	3.36 ^b	5.47 ^a	5.73 ^a	5.68 ^a	0.18	0.001
Aerobic stability, h	12.1	17.5	15.6	13.4	3.26	0.40
7h DMD, %DM	63.4 ^a	57.4 ^{a,b}	56.2 ^b	53.3 ^b	2.40	0.004

Yeasts reduce production



Borreani et al., 2018 (adapted from Hoffman and Ocker, 1997)

L. buchneri microbial inoculants meta-analysis

Item	Control	Difference	P-value
pH	4.13	0.06	0.01
DM recovery, %	93.8	-0.4	0.23
Lactate, % of DM	4.30	-0.31	0.01
Acetate, % of DM	1.70	1.05	0.01
Butyrate, % of DM	0.28	-0.03	0.03
1,2-Propanediol, % of DM	0.22	0.80	0.001
Yeast, log cfu/g	4.19	-0.84	0.01
Mold, log cfu/g	2.89	-0.40	0.01
Aerobic stability, h	111	82	0.01

Difference calculated as TRT - CON

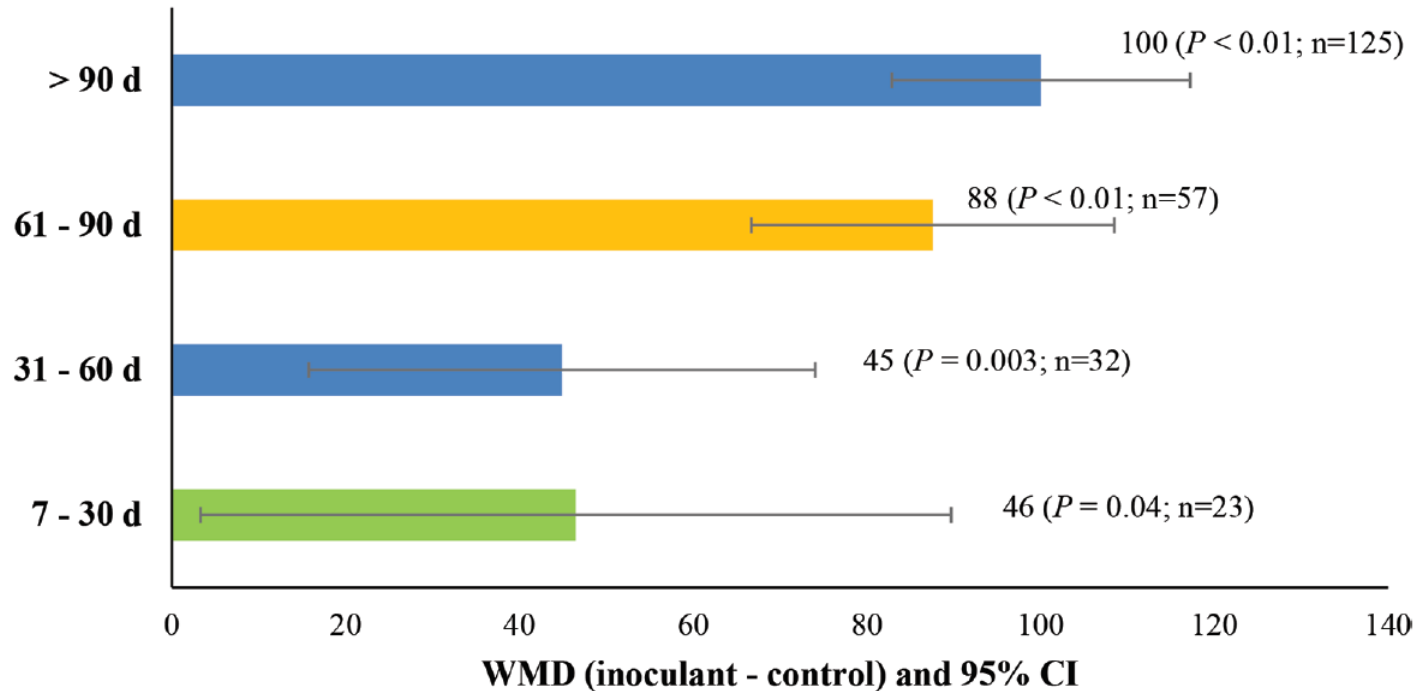
Arriola et al., 2021

Aerobic Stability

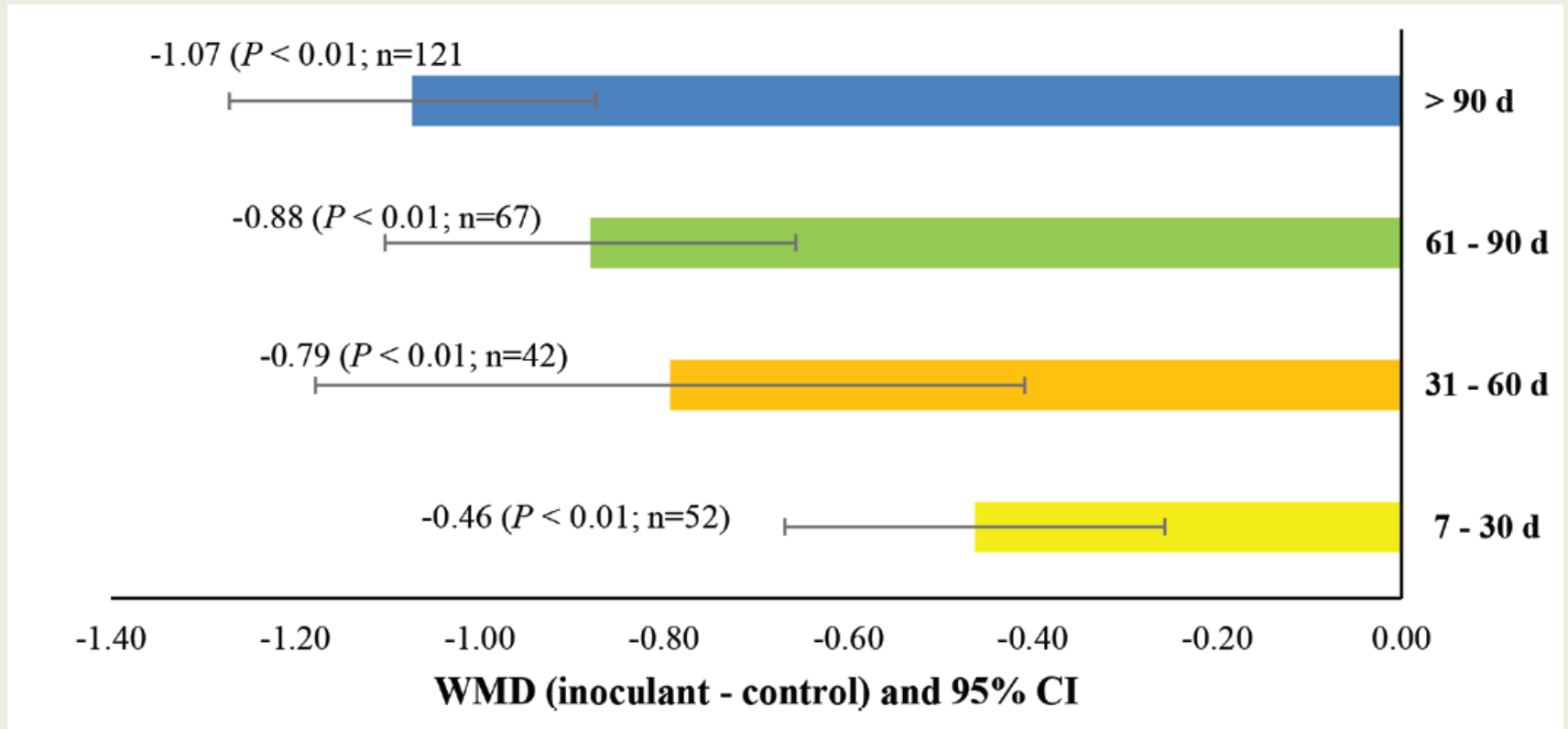
Arriola et al.: META-ANALYSIS OF *LACTOBACILLUS BUCHNERI* EFFECTS

A

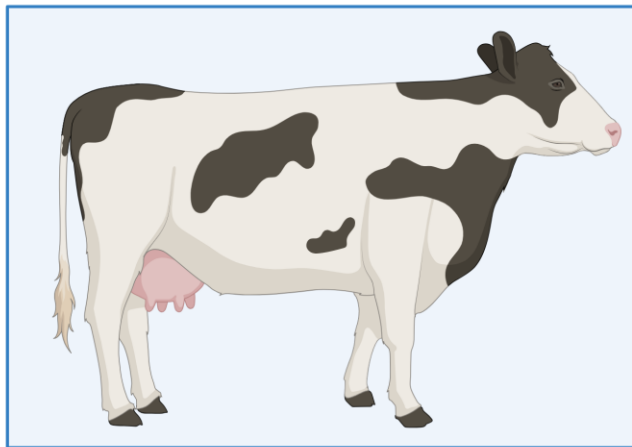
Aerobic stability, h



Yeast counts, log cfu/g



UW - inoc feeding trial



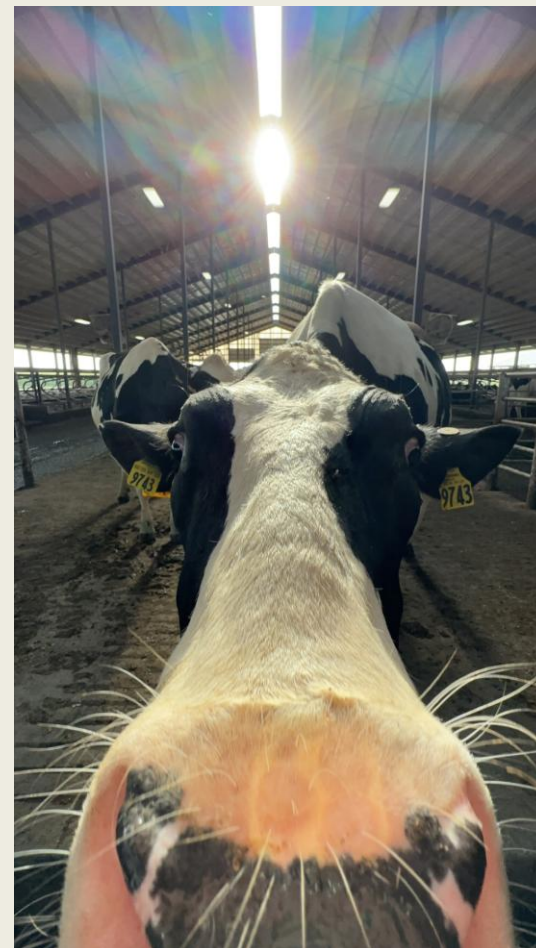
64 cows



86 ± 25 DIM



738 ± 78 kg BW



UW - starch oscillation study

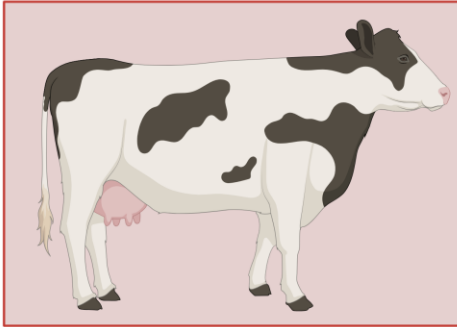
What are the effects of prolonged nutrient oscillation?

Any effects on feeding behavior?

Would the rumen microbiome change?



UW - starch oscillation study



64 cows



47 ± 21 DIM



720 ± 71 kg BW



UW – starch oscillation study

- All cows fed the same diet during the acclimation period (1 week) and covariate period (2 weeks). Cows were fed treatment diets for 8 weeks:
 - NS-CON: static dietary starch concentration and no supplementation of cashew nut shell extract
 - NS-NSE: static dietary starch concentration and the supplementation of cashew nut shell extract
 - OS-CON: oscillating dietary starch concentration with diet changes at 48 h intervals and no supplementation of cashew nut shell extract
 - OS-NSE: oscillating dietary starch concentration with diet changes at 48 h intervals and the supplementation of cashew nut shell extract

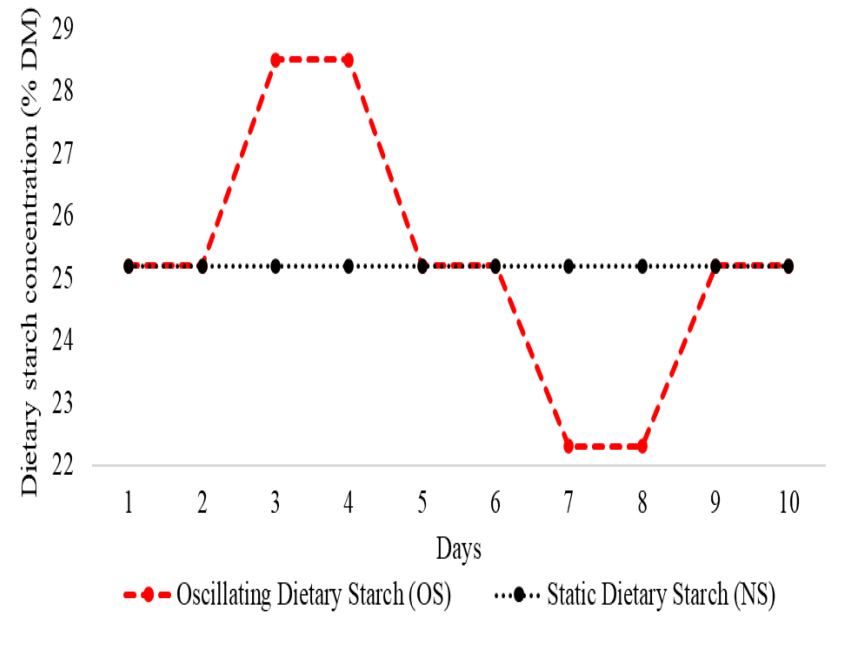


Figure 3. Feeding sequences with static dietary starch concentration containing 25% DM (NS) or oscillating dietary starch concentration (OS) with diet changes at 48 h intervals: normal (25% DM), high (29% DM), and reduced (22% DM).

UW - starch oscillation study

Item	Covariate Diet	NS	RS	HS
	% DM			
Corn Silage	28.4	35.7	44.9	26.7
Alfalfa Silage	23.1	23.2	23.2	23.2
High-Moisture Corn	12.7	9.2	0.0	18.2
Whole Cottonseed	4.5	4.5	4.5	4.5
Concentrate Mix	31.3	27.4	27.4	27.4

¹Covariate diet offered during the acclimation and covariate periods; Normal Starch diet (NS; starch at 25% DM); Reduced Starch diet (RS; starch at 22% DM); High Starch diet (HS; starch at 29% DM) offered during treatment period.

UW - starch oscillation study

Item ¹	NS	OS	SEM	<i>P</i> - Values
Total DMI, kg of DM	32.6	32.6	0.44	0.82
Milk, kg/d	53.1	52.9	0.82	0.79
4% FCM, kg/d	53.7	52.9	0.82	0.22
ECM, kg/d	56.8	56.2	0.82	0.27
SCM, kg/d	52.5	51.9	0.79	0.31

UW - starch oscillation study

Item ¹	NS	OS	SEM	<i>P</i> - Values
Fat, %	4.13	4.03	0.10	0.17
Fat Yield, kg/d	2.16	2.12	0.05	0.21
Protein, %	3.20	3.19	0.03	0.97
Protein Yield, kg/d	1.68	1.68	0.03	0.89
Lactose, %	4.73	4.73	0.02	0.74
Lactose Yield, kg/d	2.51	2.50	0.04	0.89
Solids non-Fat, %	9.02	9.02	0.04	0.76
MUN, mg/dL	14.3	14.2	0.30	0.69

UW - starch oscillation study

Item	NS	OS	SEM	<i>P</i> - Values
Bunk visits, no./d	39.4	41.0	2.93	0.50
Eating time, min/d	202.1	211.6	5.25	0.02
Eating rate, kg of DM/min	0.182	0.172	0.01	0.16
Meal frequency, no./d	5.81	6.05	0.16	0.02
Meal length, min/meal	36.9	36.9	1.56	0.99
Largest meal size, kg of DM	11.0	10.8	0.39	0.49
Interval between meals, min	194.2	187.5	4.98	0.04
Largest interval between meals, min	335.0	325.6	8.13	0.04

UW - starch oscillation study

Item	NS	OS	SEM	<i>P</i> - Values
Log-Var-DMI	1.30	1.30	0.07	0.99
Log-Var-Milk	1.58	1.66	0.08	0.08
Log-Var-Eating time	851	1177	240.4	0.01
Log-Var-Meal frequency	1.52	1.45	0.24	0.50
Log-Var-Interval between meal	1395	1560	285.4	0.31

Implications

- Multiple factors affect silage fermentation, but modulating fermentation with bacterial inoculants can help minimize losses
- Yeast contamination is an under looked factor but create challenges for fermentation and nutritive value
- Cows can adjust to nutrient variation (oscillation), but at the expense of feeding behavior changes

Questions



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Department of
Animal & Dairy Sciences
UNIVERSITY OF WISCONSIN-MADISON



Why Calcium and Negative DCAD Matter for Reproductive Success and Troubleshooting Management Issues



Phil Cardoso DVM, MS, PhD

Professor



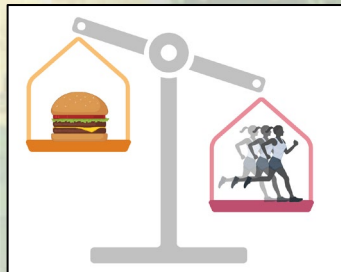
UNIVERSITY OF
ILLINOIS
URBANA - CHAMPAIGN



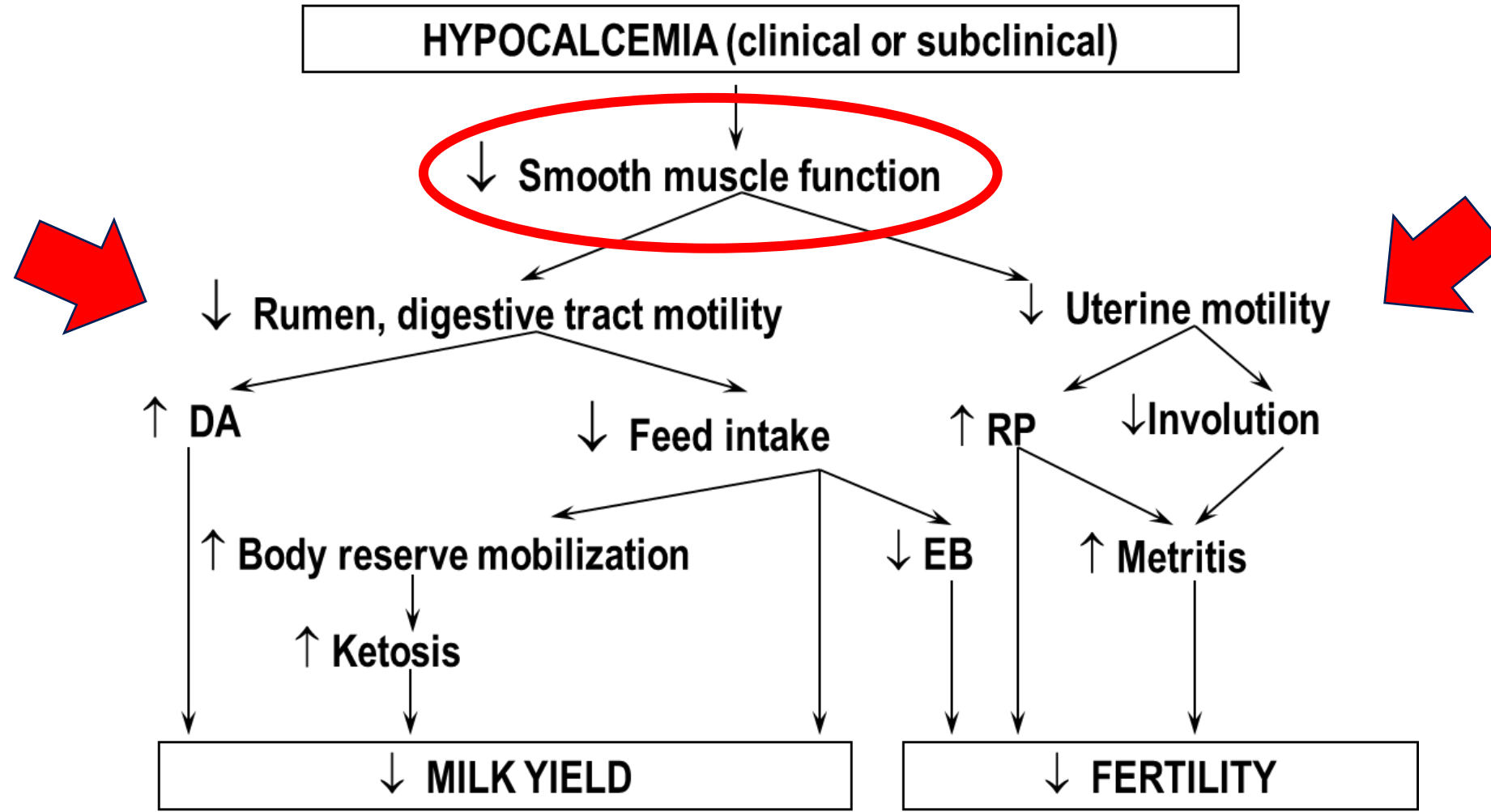
Displaced Abomasum – a Transition problem



NEB



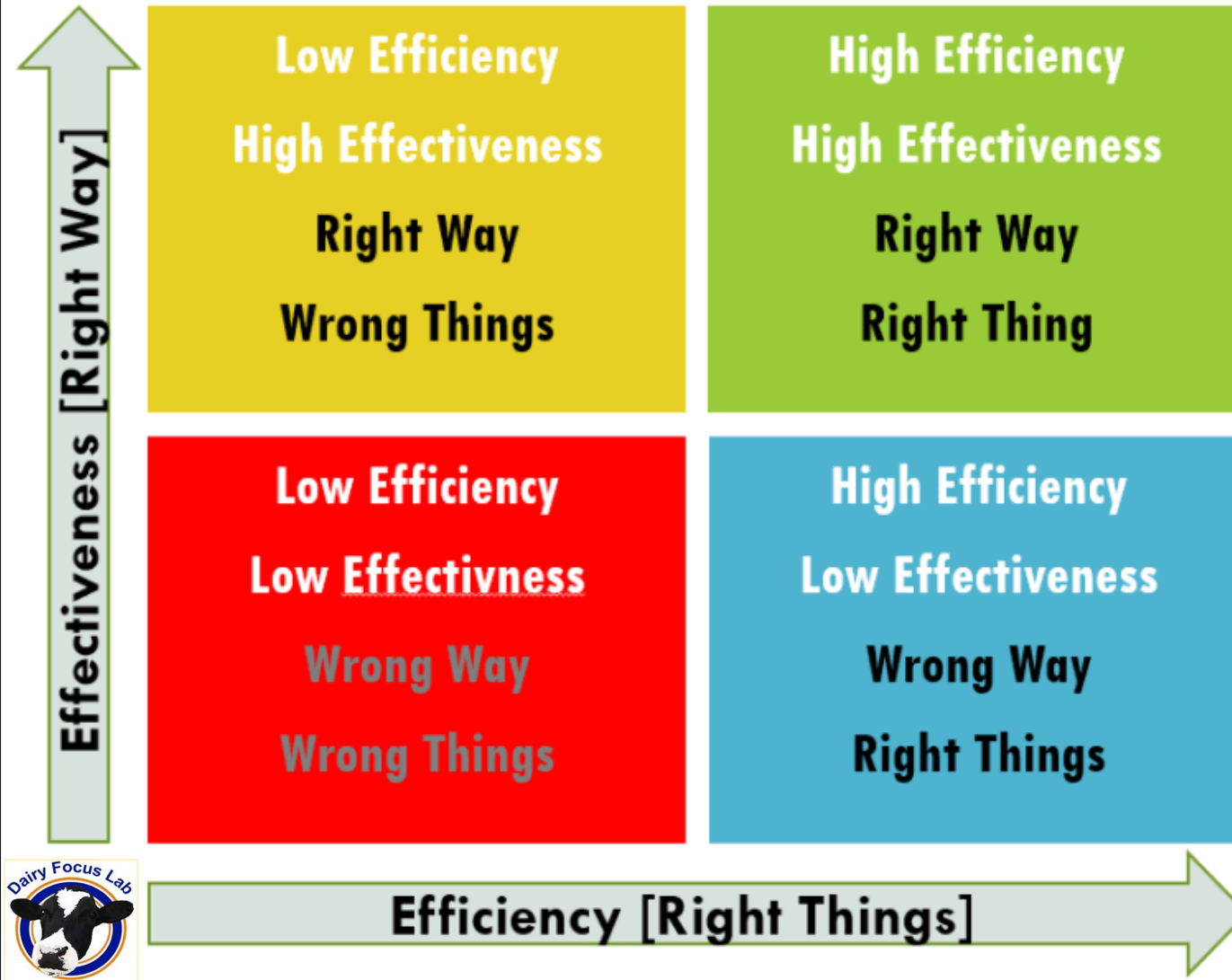
Early Postpartum Hypocalcemic Cascade



Should we adapt the cow to the environment or the environment to the cow?



EFFECTIVENESS VERSUS EFFICIENCY CHART



Top DHI Dairy Farm in North Illinois



431 lactating cows.
Annual rolling herd
milk average: **37,424 lb**
(16,975 kg)

122.7 lb/cow/day
(55.65 kg/cow/day)

Milk fat: 4.2%

Milk protein: 3.1%

Fat + protein yield:

8.95 lb/cow/day
(4.06 kg/cow/day)





Haybuster with a 2" to 3" screen

Transition period “best practices”



- Improve cow comfort
- Calve cows at ~3.0 BCS
- Do not overfeed energy in the far-off dry period; close-up diet should be intermediate to far-off and fresh
- Meet metabolizable protein (AA) requirements
- Prevent hypocalcemia – use anionic salts or other
- Boost immune system, control inflammation and oxidative stress



The right diet



Dietary Recommendations for Dry Cows

- **NEL:** Control energy intake at 19 to 20 Mcal daily [diet ~ 1.43 Mcal/kg (0.65 Mcal/lb) DM] for mature cows
- **Crude protein:** 12 – 14% of DM
- **Metabolizable protein (MP):** > 1,200 g/d
- **Starch content:** 12 to 15% of DM (NFC < 26%)
- **NDF from forage:** 40 to 50% of total DM or 4.5 to 6 kg per head daily (~0.7 – 0.8% of BW). Target the high end of the range if more higher-energy fiber sources (like grass hay or low-quality alfalfa) are used, and the low end of the range if straw is used (2-5 kg)
- **Total ration DM content:** <50% (add water if necessary)
- **Minerals and vitamins:** follow guidelines (For close-ups, target values are 0.40% magnesium (minimum), 0.35 – 0.40% sulfur, potassium as low as possible (Mg:K = 1:4), a DCAD of near zero or negative, calcium without anionic supplementation: 0.9 to 1.2% (~125g) calcium with full anion supplementation: 1.5 to 2.0% (~200g), 0.35 – 0.42% phosphorus, at least 1,500 IU of vitamin E, and 25,000 – 30,000 IU of Vitamin D (cholecalciferol))



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DCAD – Dietary cation-anion difference

DCAD mEq (milliequivalents)/100g (grams) dietary DM

$(\text{Na} + \text{K}) - (\text{Cl} + \text{S})$; Ender (1971) (DCAD1 in AMTS)

$\text{Na} + \text{K} - \text{Cl}$; Mongin (1981); NASEM 2021

$(\text{Na} + \text{K} + 0.15 \text{ Ca} + 0.15 \text{ Mg}) - (\text{Cl} + 0.6 \text{ S} + 0.5 \text{ P})$; Goff et al. (1997); NRC 2001 (DCAD2 in AMTS)

$\text{Na} + \text{K} - \text{Cl} - 0.6\text{S}$; Goff et al. (2004)

Negative DCAD: prevent metabolic disorders (dry cows)

Positive DCAD: increase milk yield and composition (lactating cows)



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$(\text{Na} + \text{K} + 0.15 \text{ Ca} + 0.15 \text{ Mg}) - (\text{Cl} + 0.6 \text{ S} + 0.5 \text{ P})$; Goff et al. (1997); NRC 2001 (DCAD2 in AMTS)

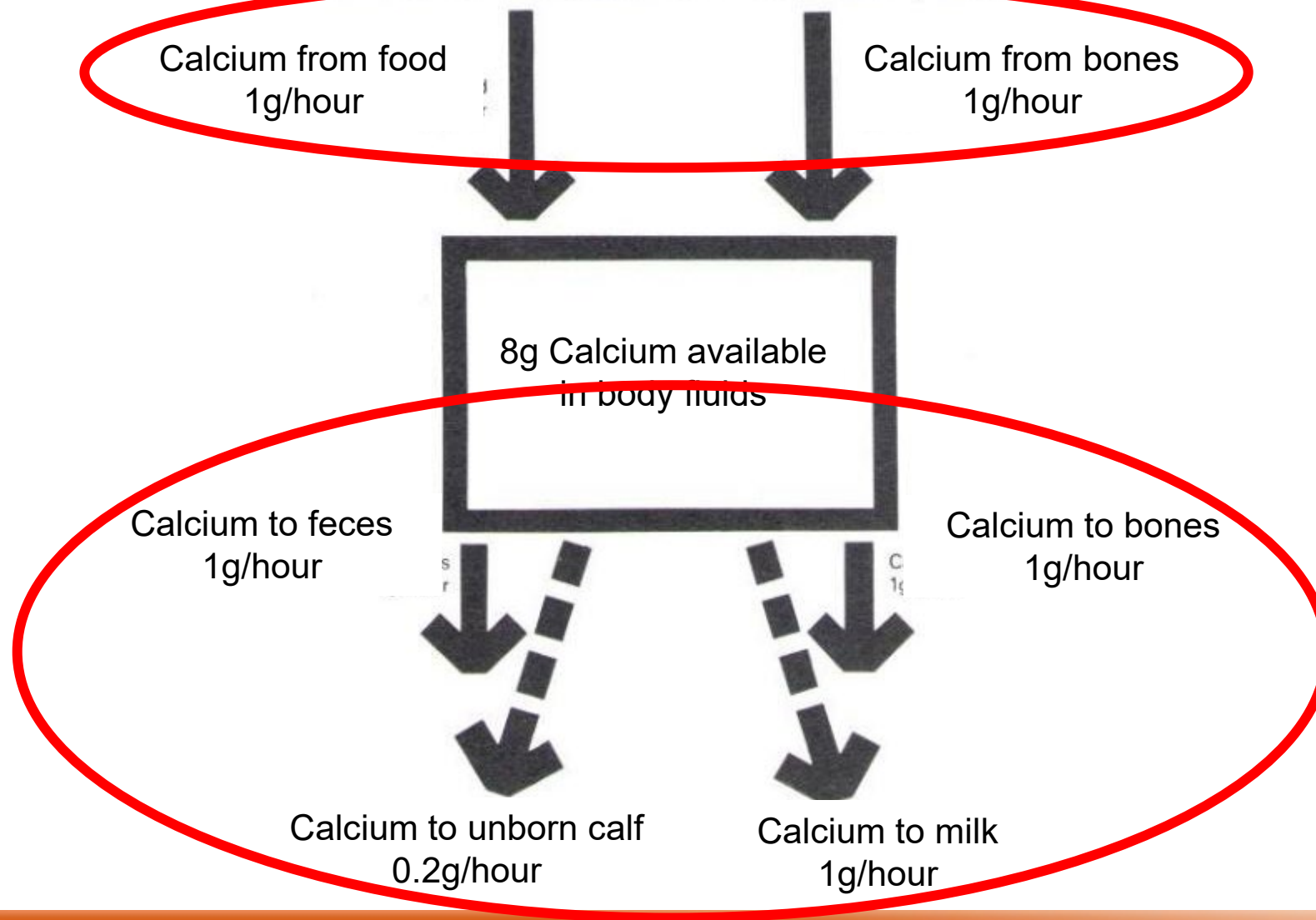
$\text{Na} + \text{K} - \text{Cl} - 0.6\text{S}$; Goff et al. (2004)

Negative DCAD: prevent metabolic disorders (dry cows)

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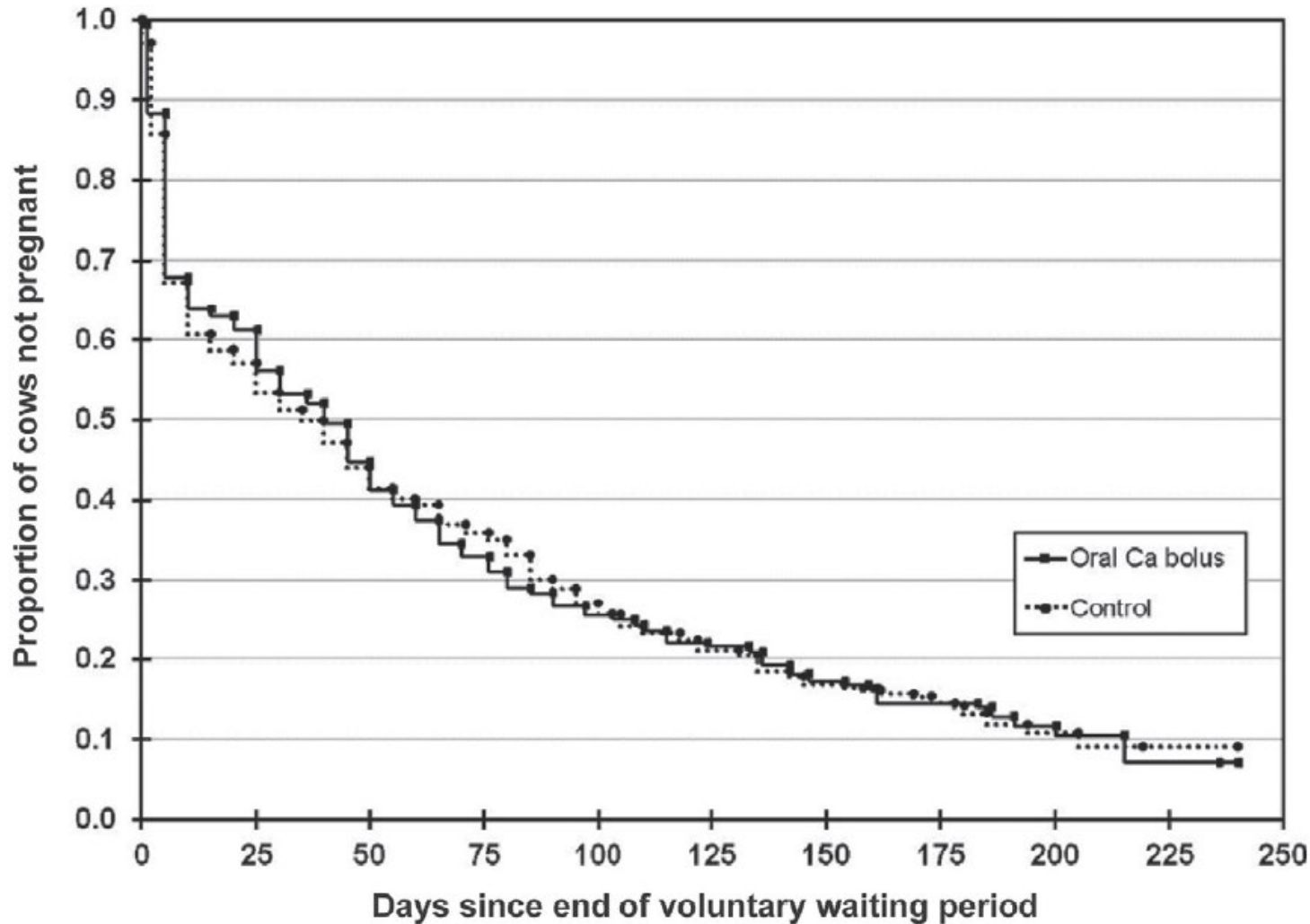
Calcium Metabolism in the Dairy Cow



Effects of oral calcium bolus supplementation

- 927 cows
- 2 oral Ca boluses
- 1st – 0.5% of body weight
- 2nd – 0.5% of body weight

Supplementation
greater voluntary intake
program benefited

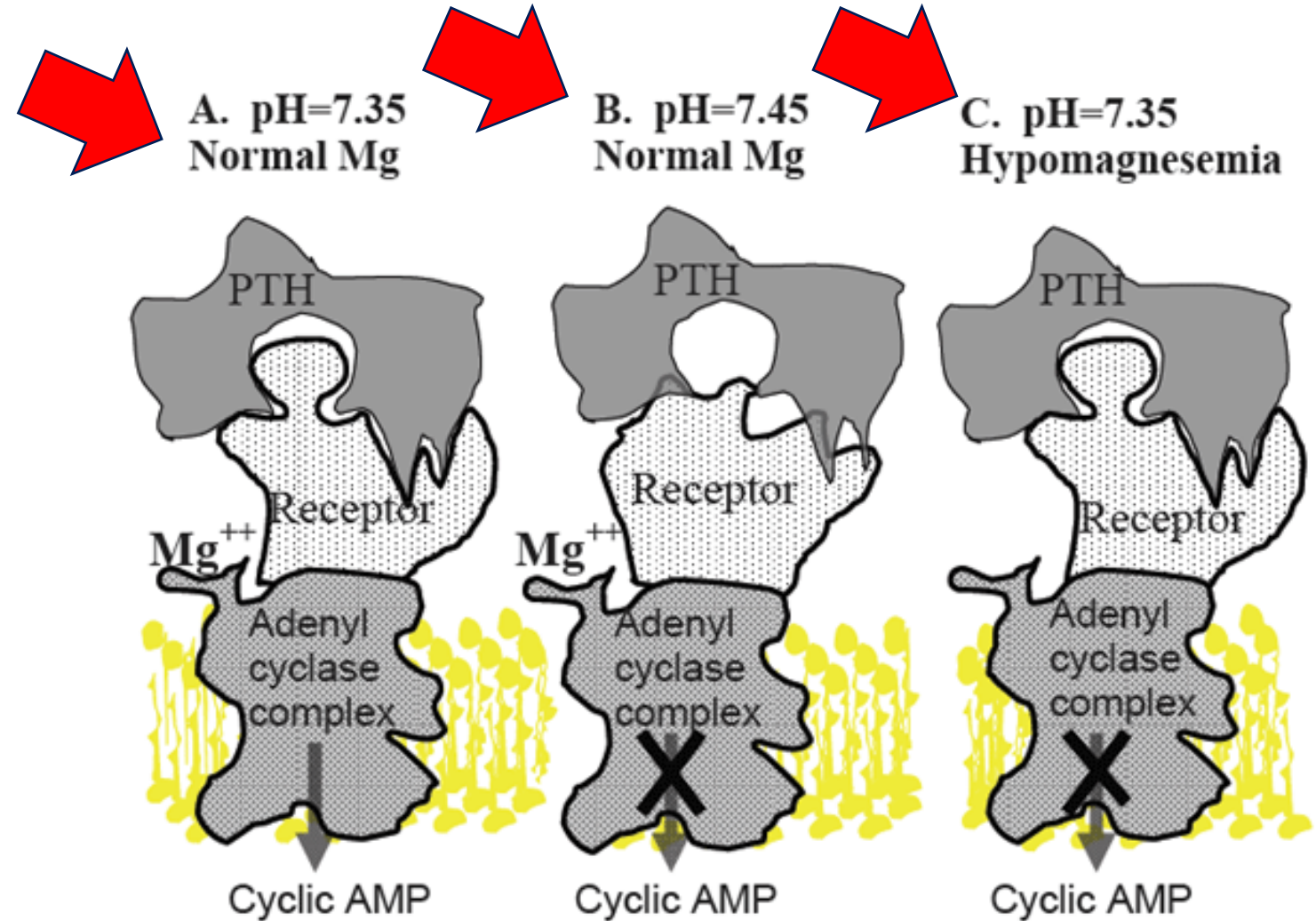


PTH is responsible for Ca release in blood

A. Parathyroid hormone (PTH) receptor located on the surface of bone and kidney cells.

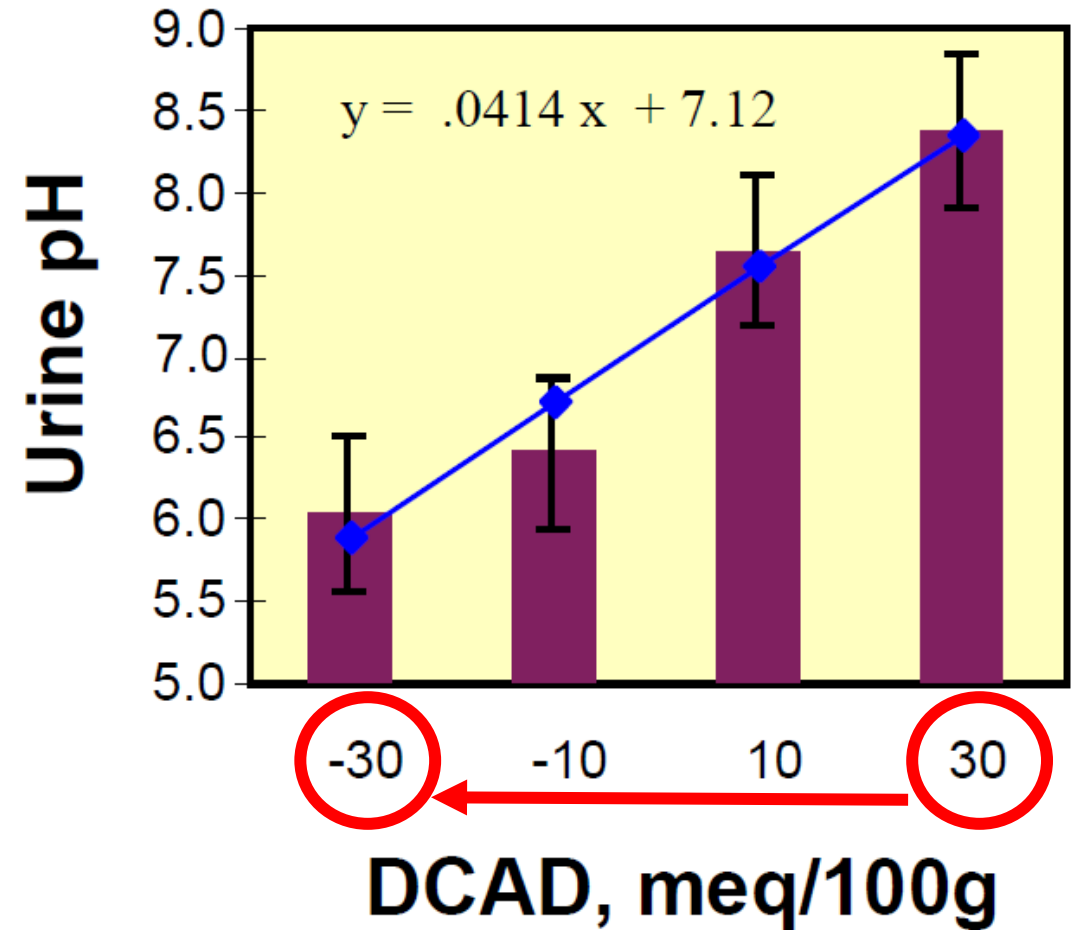
B. Example: high potassium (K) diets.

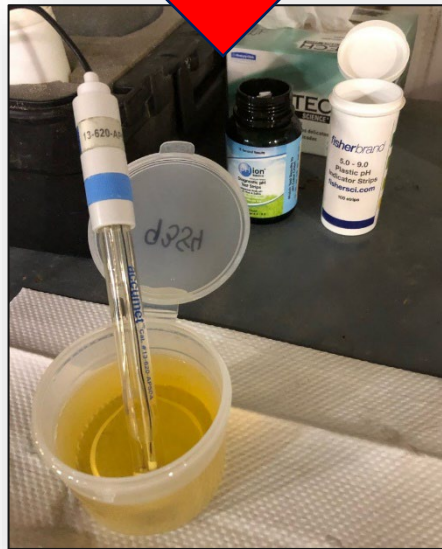
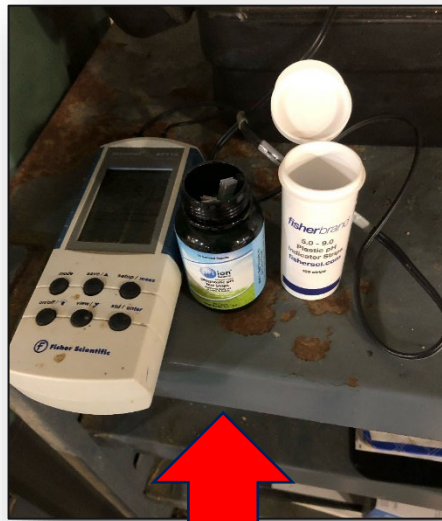
C. Example: diets with low magnesium (Mg).



DCAD – Dry Cows

To measure whether your negative DCAD diet is effective, determine urine pH on a regular basis.





JDS
Communications®
TBC; TBC:1-6

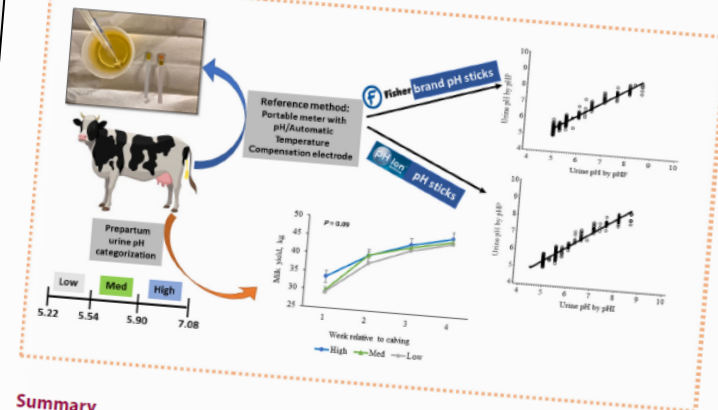
<https://doi.org/10.3168/jdsc.2021-0130>
Short Communication
Animal Nutrition and Farm Systems

JDS0130

Validation of 2 urine pH measuring techniques in a prepartum negative dietary cation-anion difference diet and the relationship with production performance

L. K. Fehlberg,¹ A. Pineda,² and F. C. Cardoso^{1*}

Graphical Abstract



Summary

Acidified diets prepartum are utilized in dairy cows to decrease the likelihood of hypocalcemia; however, the effect of the extent of acidification on cow performance is still debated. Our objective was to validate the accuracy of 2 pH strips to measure urine pH (categorized as low, medium, or high) in dairy cows consuming an acidified diet prepartum and the association of urine pH with production performance. We determined that both pH strips are an accurate and affordable method to determine urine pH. Additionally, varying urine pH was not associated with dry matter intake when cows consumed an acidified diet; however, milk yield was moderately affected during week 1 postpartum when average urine pH prepartum was <5.67.

Highlights

- Accurate and cheap measurement of urine pH is desirable for the dairy industry.
- The two urine pH strips tested were accurate in measuring urine pH in prepartum cows.
- Varying urine pH was not associated with altered dry matter intake prepartum.

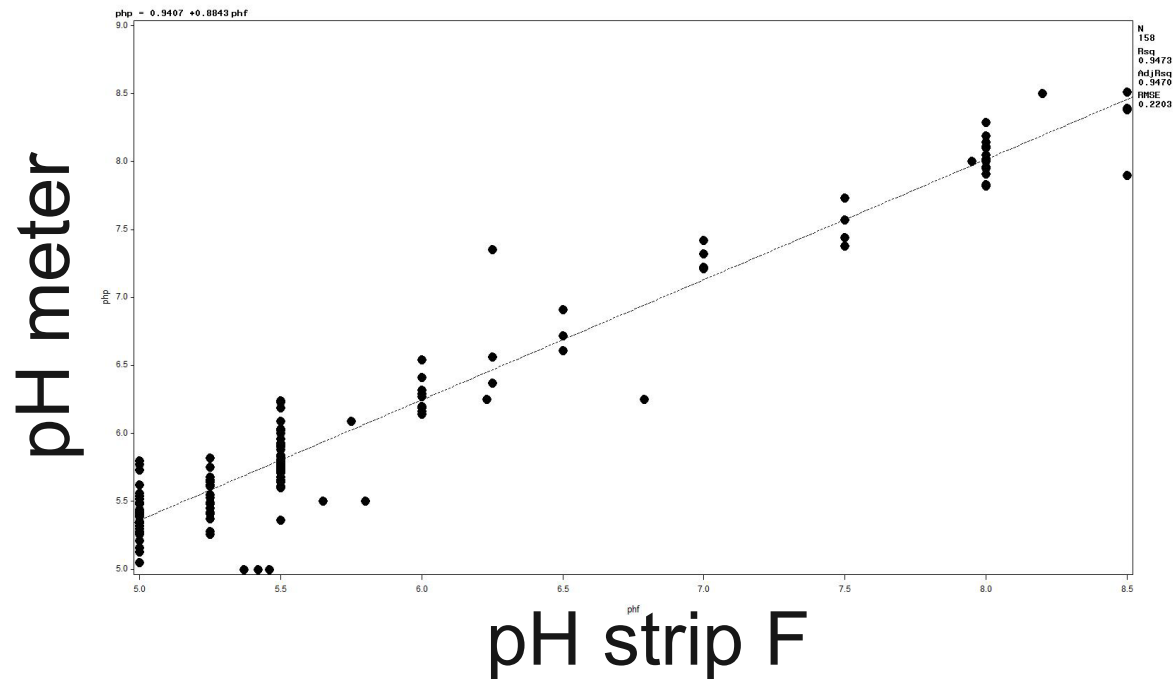
¹Department of Animal Sciences, University of Illinois, Urbana 61801, ²Department of Animal Biosciences, University of Guelph, Guelph, ON, Canada, N1G 2W1. *Corresponding author: cardoso2@illinois.edu. © 2022, The Authors. Published by Elsevier Inc. and Fass Inc. on behalf of the American Dairy Science Association. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>). Received May 14, 2021. Accepted September 14, 2021.



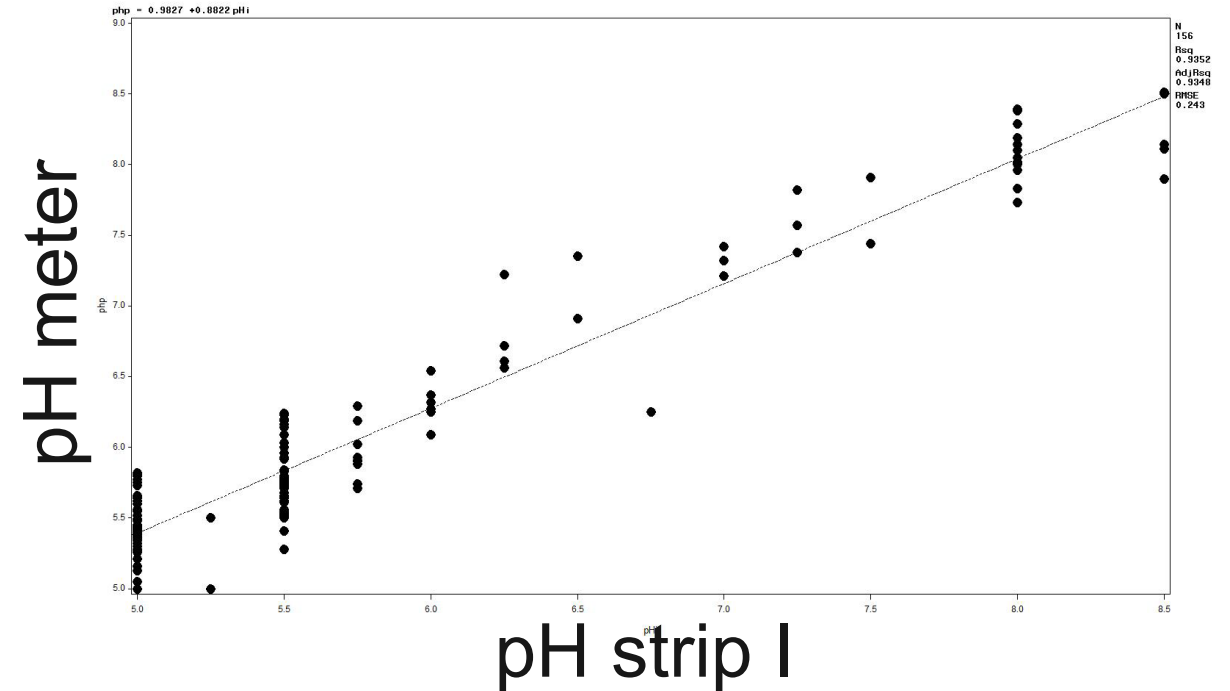
University of Illinois at Urbana-Champaign

Fehlberg et al., 2021

Measuring urine pH



$$\text{pH} = 0.9407 + 0.8843 \text{ pH strip F}$$
$$R^2 = 0.9473$$

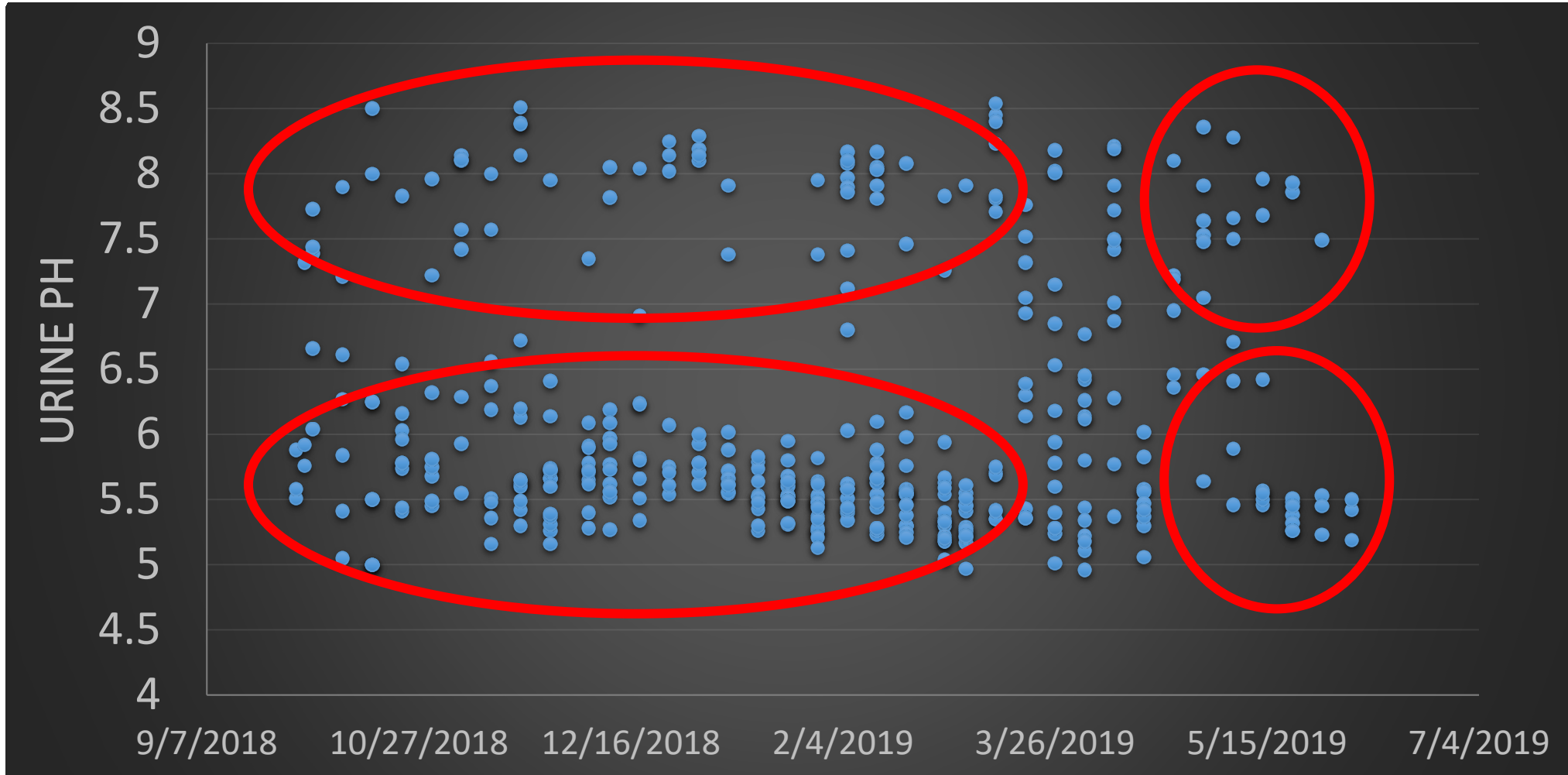


$$\text{pH} = 0.9827 + 0.8822 \text{ pH strip I}$$
$$R^2 = 0.9352$$



Urine pH prepartum

396 samples
88 Holstein cows



Mixer management



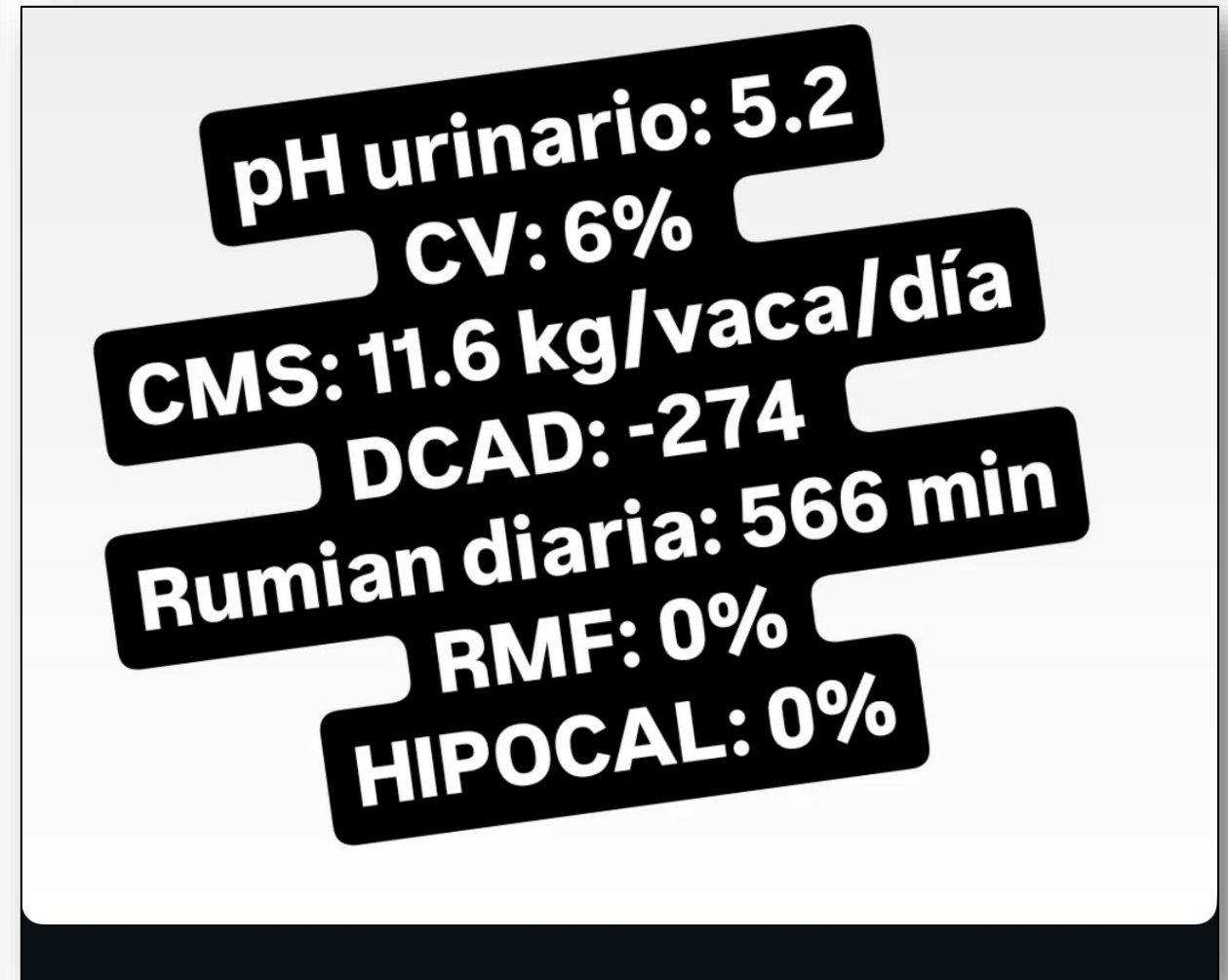
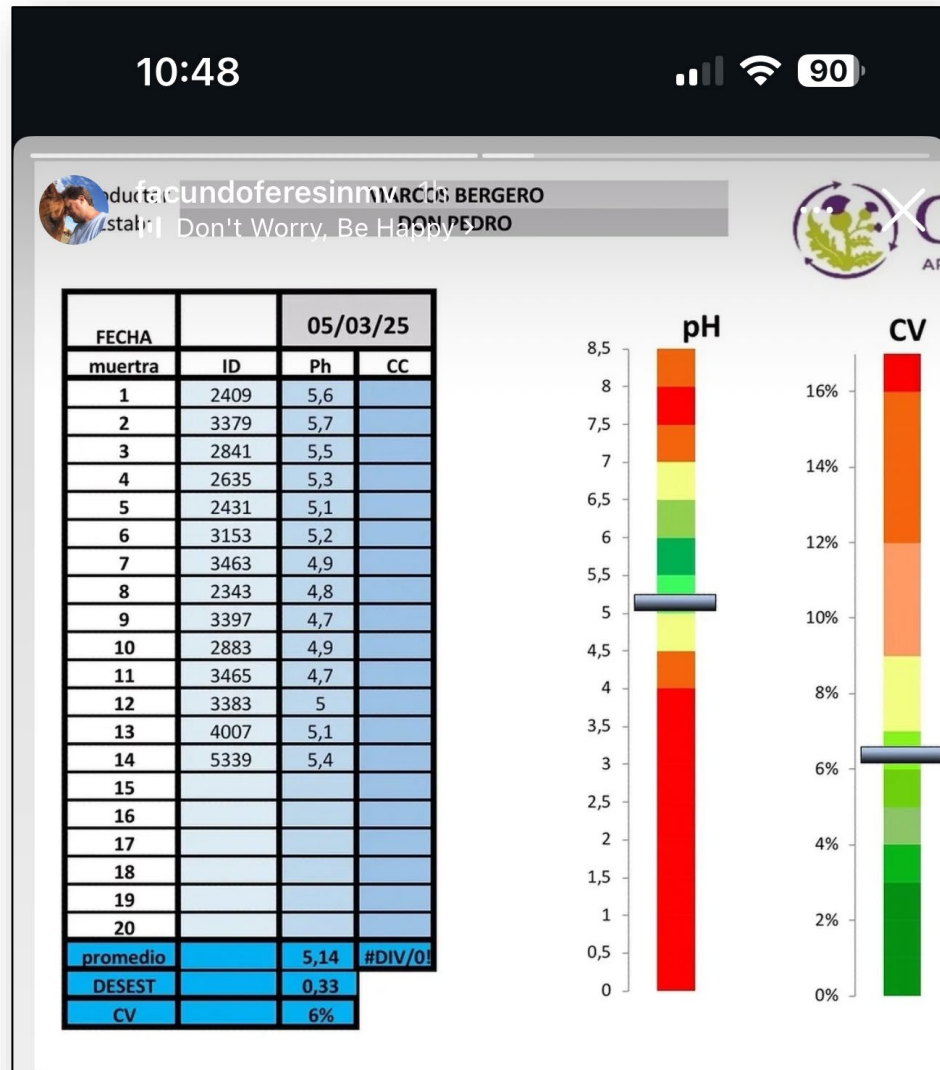
“We feed for 5% refusals” ... maybe not 😊



# of cows US	# of cows FW	Actual TMR amount fed daily	Orts	TMR Eaten
125	125	11080	0	11080
139	139	13400	3563	9836
152	152	13300	1600	11700
122	126	11030	287	10743
138	134	12130	375	11754
120	144	13620	2981	10639
124	133	11070	952	10117
129	128	11370	0	11370
129	130	11070	89	10981

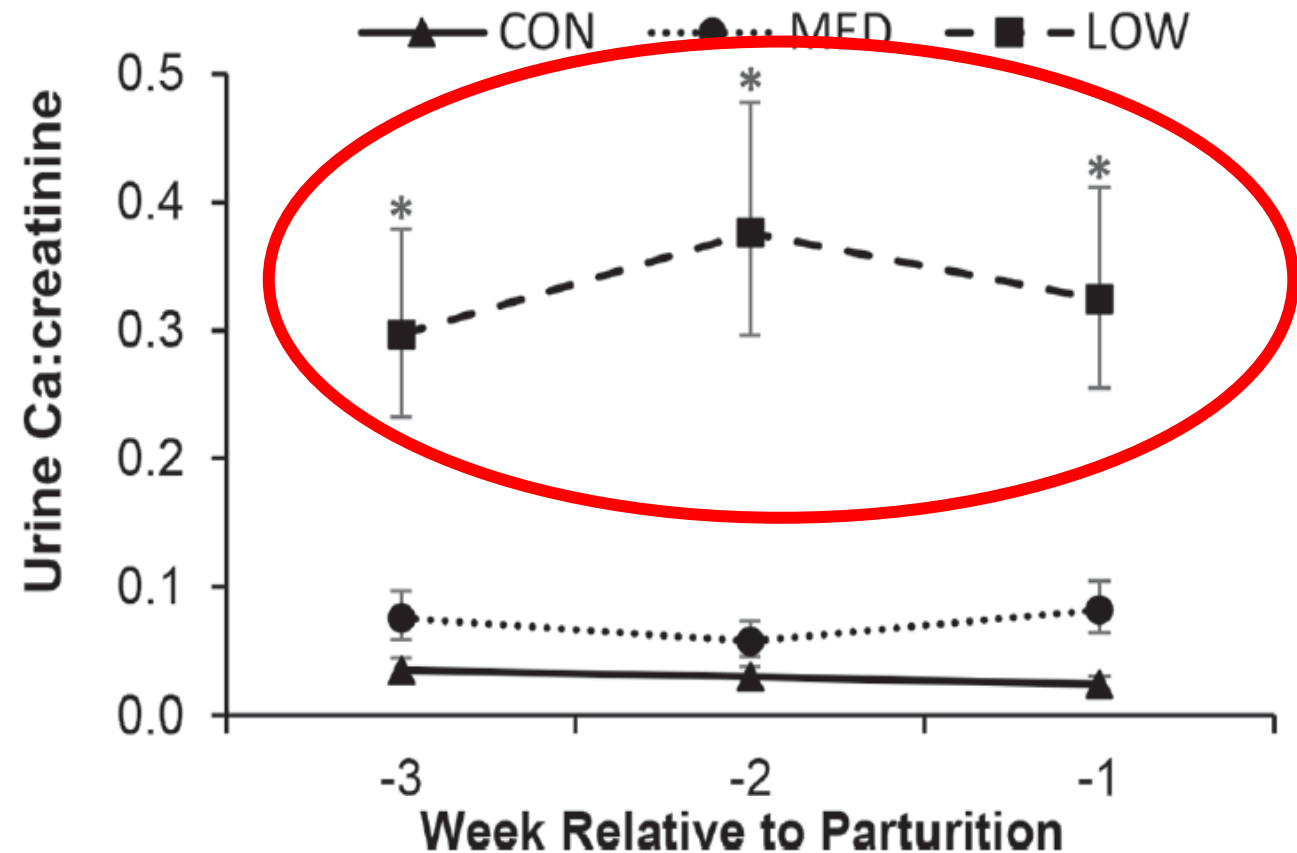
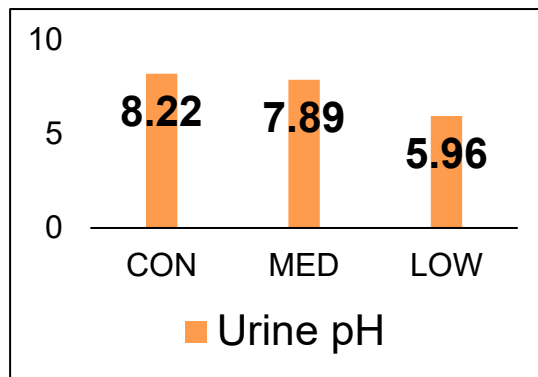


Right way Right thing – Example from ARG



Metabolic acidosis caused by negative DCAD increases Ca excretion in urine

Dietary DCAD (mEq/100 g of DM)
CON = **18.3**
MED = **5.9** (partial)
LOW = **-7.4** (full)



Cows in a fully acidified DCAD diet prepartum yielded more milk after calving

Variable	Diet (DCAD)			SEM	<i>P</i>
	CON	MED	LOW		
DCAD, mEq/100 g DM	18.3	5.9	-7.4		
DMI, kg/d					
wk -3 to -1	13.6	14.0	13.2	0.2	Q, 0.01
wk 1 to 3	20.2	20.9	21.3	0.5	L, 0.09
% of BW	2.88	2.98	3.07	0.06	L, 0.04
Milk, kg/d	40.8	42.4	43.9	1.0	L, 0.03

Q = quadratic effect, L = linear effect





J. Dairy Sci. 103:7039–7054
<https://doi.org/10.3168/jds.2019-18068>

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Negative dietary cation-anion difference and amount of calcium in prepartum diets: Effects on milk production, blood calcium, and health

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²Phibro Animal Health Corp., 229 Radio Rd, Quincy, IL 62305

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⁴Phibro Animal Health Corp., Teaneck, NJ 07666-6712

... (3) negative DCAD diet, −24 mEq/100 g of DM, target urine pH 5.5 to 6.0, high dietary Ca (2.0% DM; NDCA). Preplanned treatment contrasts were: (1) CON versus (ND and NDCA), and (2) ND versus NDCA. Individual DMI were recorded daily. Cows were milked 3 times daily, with individual DMI and milk yield summarized by week. Whole blood sampled at calving and 24 h, 48 h, and 4 d after calving was analyzed for ionized Ca concentration, and serum was analyzed for total Ca. Prepartum urine pH for cows fed ND or NDCA averaged 5.7, whereas cows fed CON remained >7.5. During the 3 wk before calving, cows

Key words: calcium, production, transition, negative dietary cation-anion difference

INTRODUCTION

The transition period is arguably the most challenging time of cows' production cycle, with clinical and subclinical hypocalcemia (SCH) contributing a major portion of the challenges. Circulating Ca (calcium) concentration normally is kept within a narrow range, tightly regulated by parathyroid hormone (PTH), calcitriol, and calcitonin to maintain a plasma Ca concentration of 2.25 to 2.5 mM (Goff and Horst, 1997). At the end of gestation, dairy cows require only enough Ca for maintenance, late-stage fetal growth, expected endogenous loss, and colostrogenesis, totaling approximately 20 to 32 g/d. However, at the onset of lactation, 30 to 50 g/d of Ca is needed for milk production in high-producing dairy cows (Horst et al., 2005). Any delay in endocrine signaling or response to replenish the available circulating Ca pool can have detrimental

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*These authors contributed equally to this work.
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Dietary treatments

- Treatments began at 28 days before expected calving and ended at parturition. Lactation diet was the same until ~ 30DIM. Treatments:
 - **CON**, (n = 26); controlled energy diet, 46.2 ± 15.2 g/d of calcium in TMR and no anion supplement [DCAD = + 6 mEq/ 100 g dry matter]
 - **ND**, (negative DCAD, n = 24); controlled energy diet, 44.1 ± 16.1 g/d of calcium in TMR with anion supplement [DCAD = -24 mEq/ 100 g DM]
 - **NDCA**, (negative DCAD with Ca, n = 26) controlled energy diet, 226.6 ± 96 g/d of calcium in TMR with anion supplement [DCAD = -24 mEq/ 100 g DM].

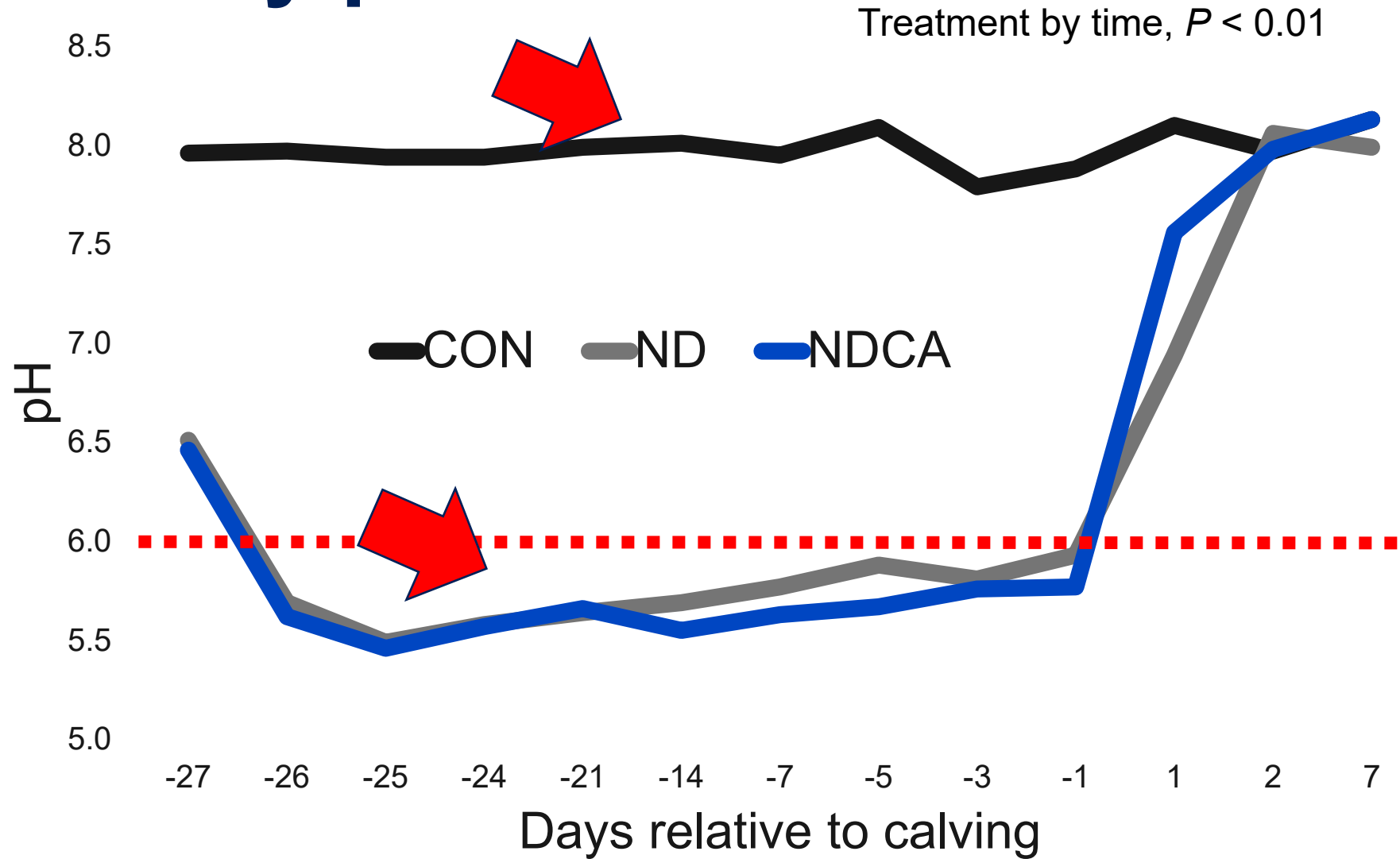


TMR chemical analysis

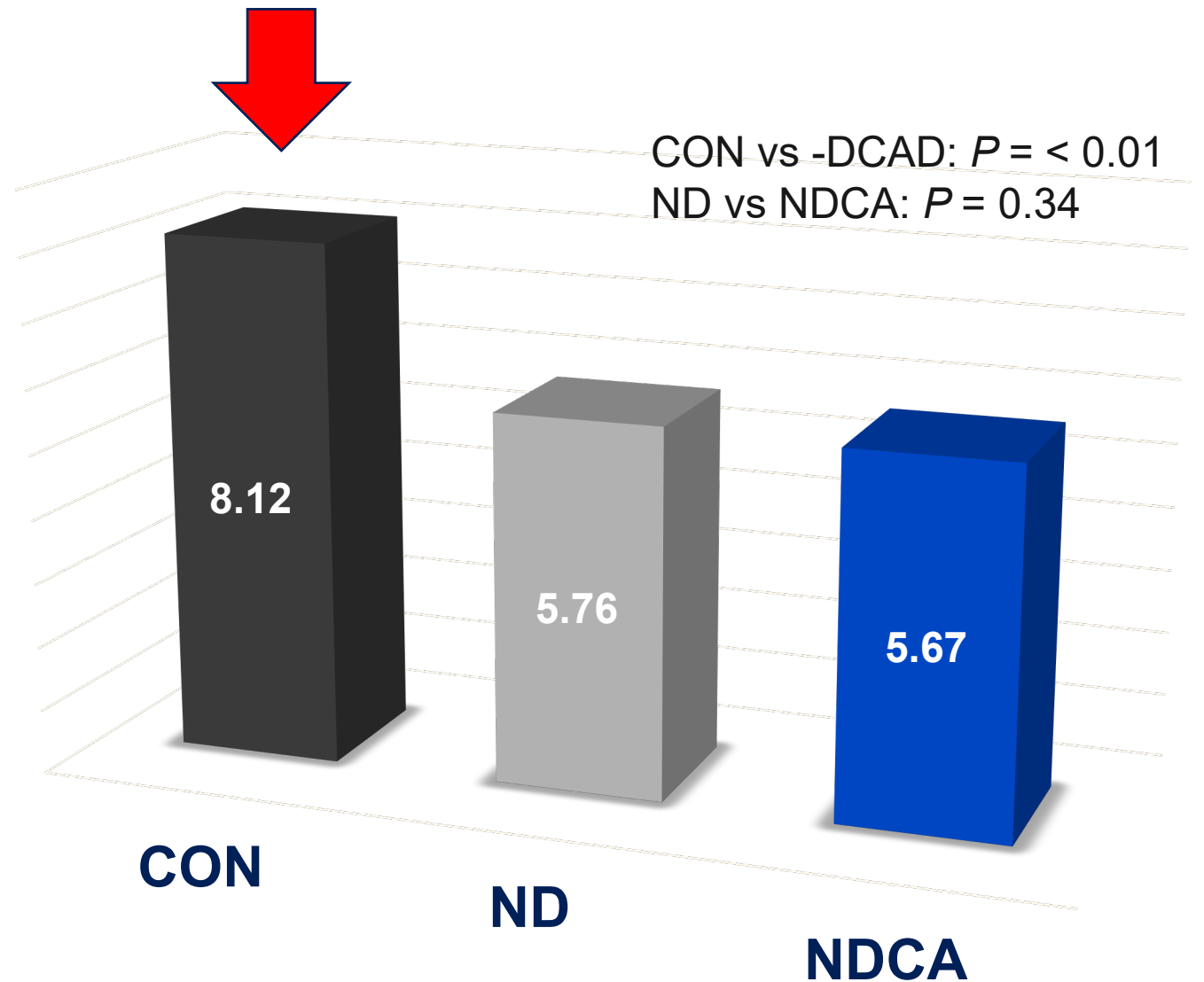
Components	Dry Cow Diets			
	CON	ND	NDCA	Lactation
DM, % as fed	45.9 ± 2.5	46.8 ± 2.6	46.3 ± 2.7	48.3 ± 1.7
CP, % of DM	15.1 ± 1.3	16.6 ± 1.5	16.4 ± 1.0	17.8 ± 0.6
aNDFom, % of DM	49.3 ± 2.6	47.7 ± 4.1	47.0 ± 4.8	30.4 ± 1.4
Starch, % of DM	14.1 ± 2.2	12.7 ± 2.2	12.8 ± 1.2	30.8 ± 1.5
NE _L , Mcal/kg of DM	1.4 ± 0.04	1.4 ± 0.07	1.4 ± 0.04	1.6 ± 0.02
Ca, % DM	0.4 ± 0.06	0.4 ± 0.05	2.0 ± 0.6	1.2 ± 0.3
P, % DM	0.4 ± 0.03	0.4 ± 0.04	0.4 ± 0.05	0.5 ± 0.04
DCAD, mEq/100 g DM	6.0 ± 9.5	-24.0 ± 6.0	-24.1 ± 5.3	25.4 ± 2.3



Mean urinary pH

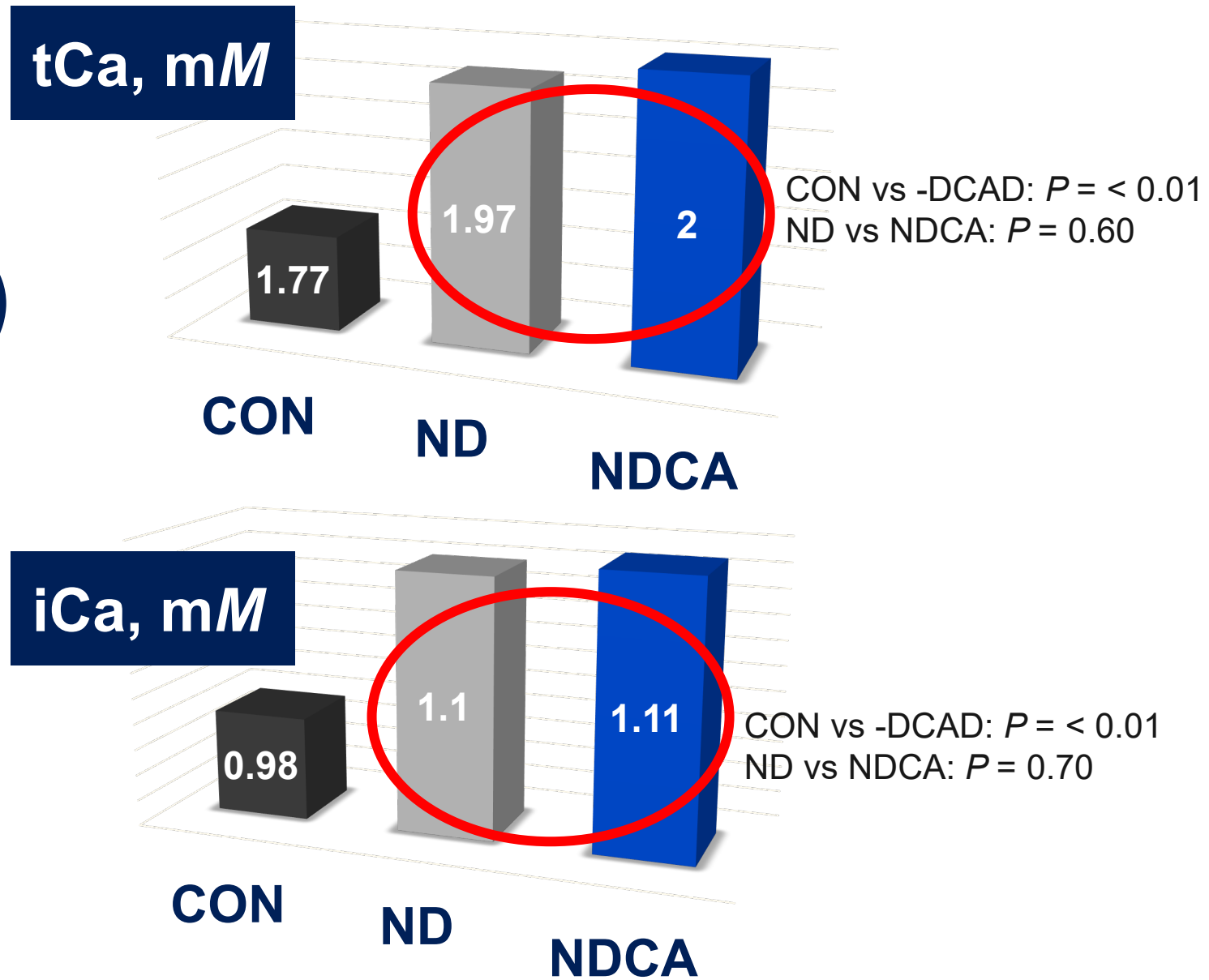


Lower urinary pH for cows fed negative DCAD prepartum



Higher plasma tCa and iCa (mM) 1 h after calving for cows fed negative DCAD prepartum

Same statistical inference at 24 h.
No difference at 48 h and 4 d after calving



Variables measured during the close-up prepartum period

Variable	Treatments			SE	Contrasts	
	CON	ND	NDCA		C vs -DCAD	ND vs NDCA
DMI, kg/d	12.0	10.0	11.0	0.4	< 0.01	0.10
DMI, % of BW	1.51	1.29	1.47	0.06	0.06	0.04
Ca intake, g/d	45.2	43.4	226.6	9.6	< 0.01	< 0.01
BW, kg	814	780	798	6	< 0.01	0.03
BCS	3.93	3.77	3.80	0.04	< 0.01	0.54



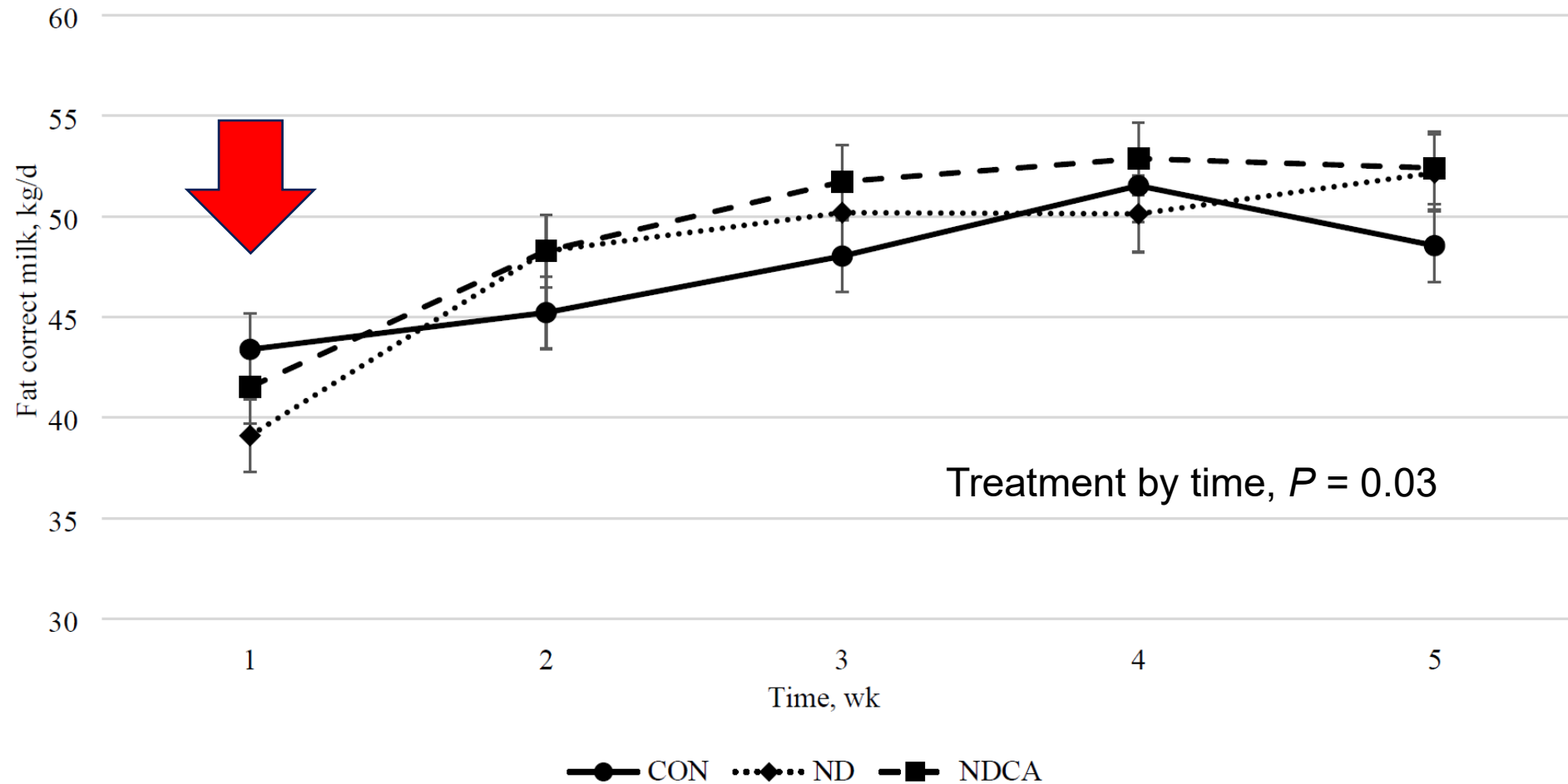
Measurements after calving

Variable	Treatments				Contrasts	
	CON	ND	NDCA	SE	C vs -DCAD	ND vs NDCA
DMI, kg/d	17.6	18.4	18.6	0.69	0.22	0.65
DMI, % BW	2.57	2.78	2.75	0.11	0.08	0.84
BW, kg	726	681	695	14.5	<0.01	0.11
Milk, kg/d	42.1	42.6	44.9	1.7	0.22	0.94
FCM*, kg/d	47.3	48.0	49.4	1.9	0.56	0.61

*Treatment by time, $P = 0.03$

Measurements after calving

*Fat-corrected milk



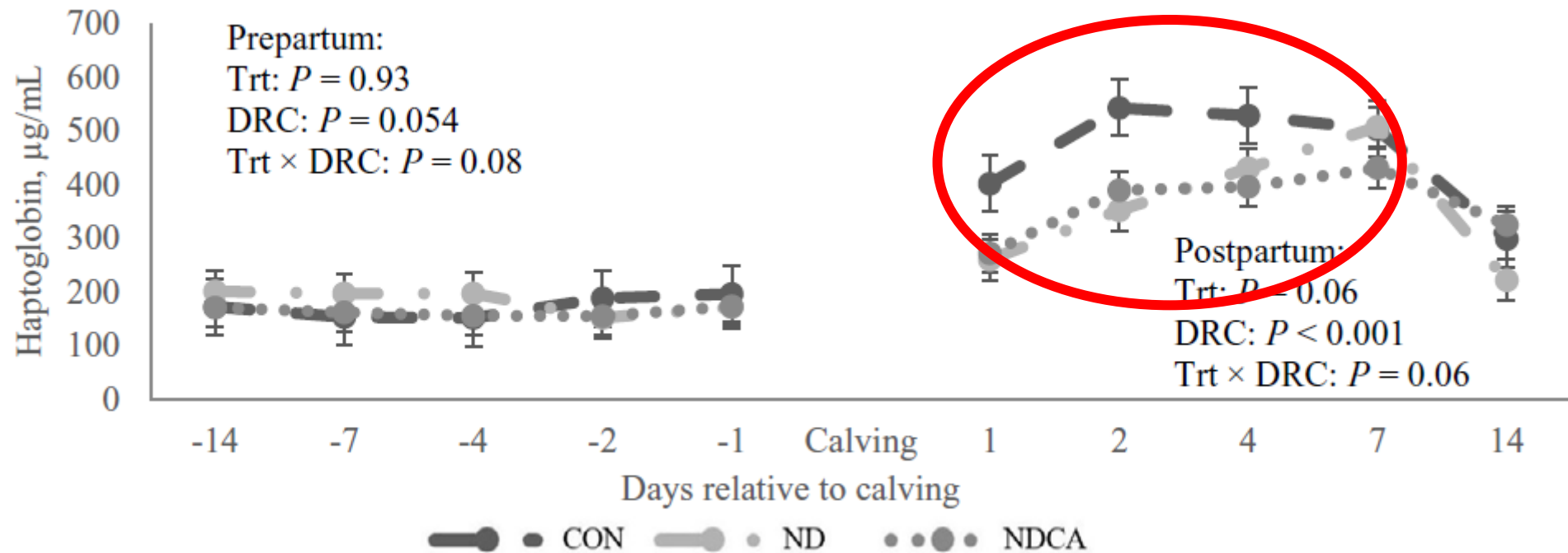
Frequency of health events

Variable	CON	ND	NDCA
Ketosis	5/28	4/27	3/26
Milk fever	2/28	3/27	0/26
Mastitis	3/28	3/27	1/26
Metritis	1/28	0/27	1/26
Retained placenta	3/28	2/27	2/26
Displaced abomasum	2/28	1/27	1/26
Adverse Health Score*	2.10	1.22	0.64

*Accounting for **severity and multitude of health events**, a weighted value is assigned to calculate the overall cost of the disorder. Ranging from 1 (udder edema) to 5 (death)
(Nace et al., 2014)



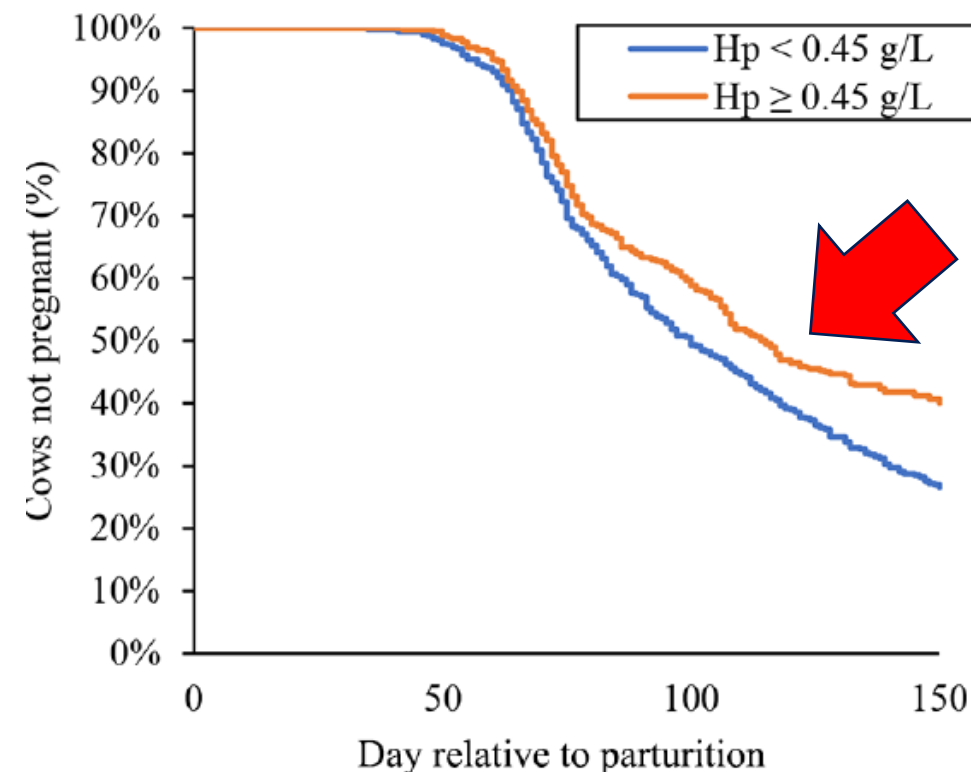
Cows in CON had higher plasma Haptoglobin concentrations than cows in NDCA around calving



Haptoglobin (hp) negatively impacts cow's health and reproductive performance

Health event	Estimate	SE	P-Value	Risk Ratio	95% CI
Metritis (hp ≥ 0.96 vs. < 0.96 g/L)	1.55	0.52	0.003	4.7	1.7-13
Culled by 30 DIM (hp ≥ 0.45 vs. < 0.45 g/L)	1.43	0.44	0.001	4.2	1.8-10
Locomotion score (≥ 3 vs. < 3)	1.26	0.36	<0.001	3.5	1.7-7.1
Herd-alarm					
Difference in ME305, kg (hp ≥ 0.45 vs. < 0.45 g/L; n = 868)	-492	165	<0.001		
Displaced abomasum, change in cases, % ($>20\%$ of cows had hp ≥ 0.45 g/L; n = 71)	5.3	2.6	0.05		

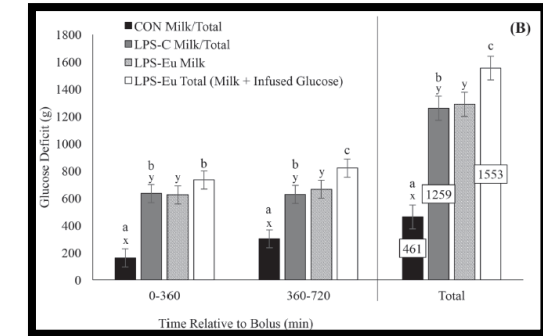
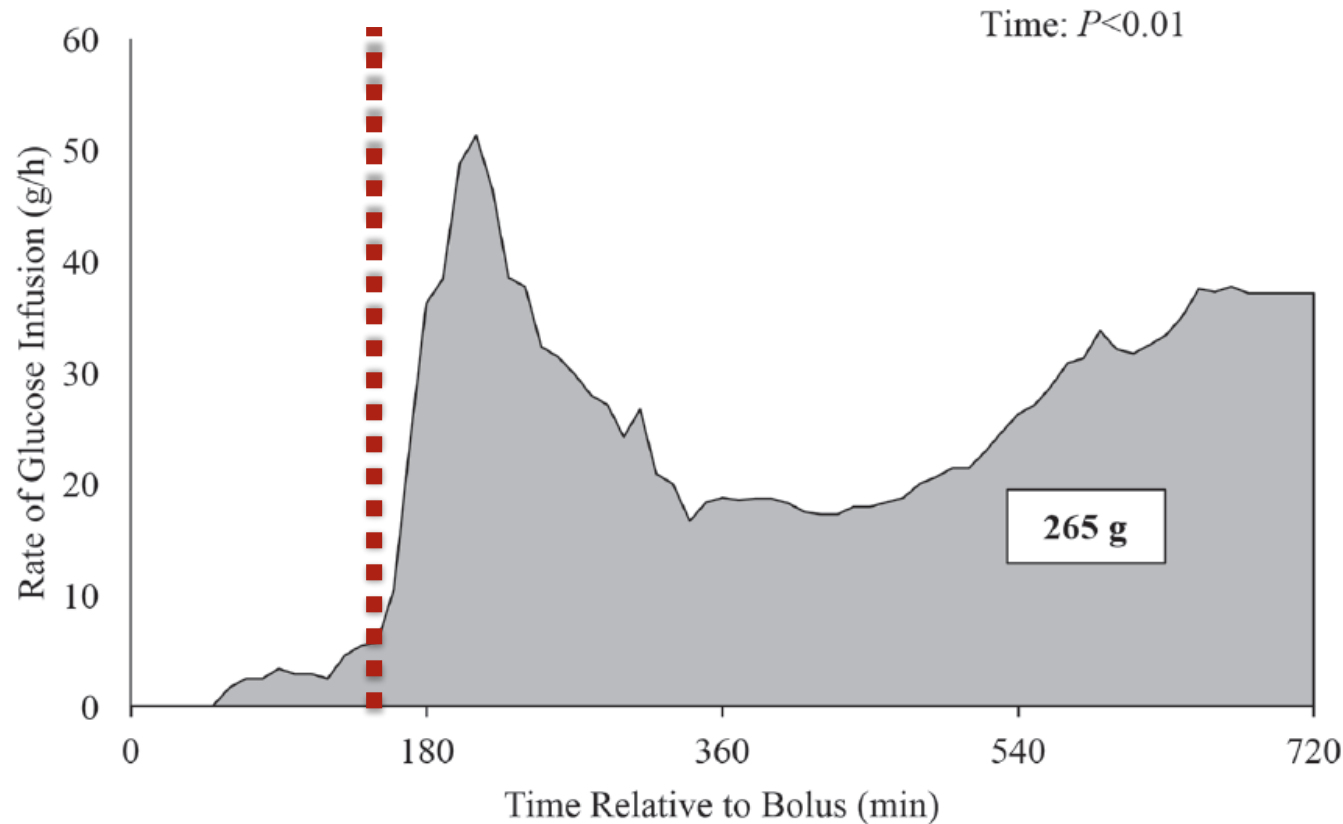
Prospective cohort study, 1,473 cows from 72 farms were enrolled from the northeastern United States.



Time to pregnancy for cows in a prospective cohort study involving 72 farms across the northeastern United States (log-rank $P < 0.001$).



Cows challenged with lipopolysaccharide (LPS) had greater glucose utilization



The activated immune system uses **>1 kg** of glucose within 720 min

~8 kg of milk in 24h*

*To produce 1 kg of milk, a dairy cow requires approximately 72-85 grams of glucose per 100 grams of lactose synthesized. Milk is 4.8-5% lactose. The total glucose requirement per kilogram of milk is: 250-280 grams (0.25-0.28 kg) of glucose per kg of milk (NRC 2001).



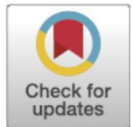




Contents lists available at [ScienceDirect](#)

Theriogenology

journal homepage: www.theriojournal.com



Increased dietary calcium inclusion in fully acidified prepartum diets improved postpartum uterine health and fertility when fed to Holstein COWS

K.T. Ryan ^a, A.R. Guadagnin ^a, K.M. Glosson ^{a, b}, S.S. Bascom ^b, A.D. Rowson ^b,
A.J. Steelman ^a, F.C. Cardoso ^{a, *}

^a Department of Animal Sciences, University of Illinois, Urbana, IL, USA

^b Phibro Animal Health Corporation, Teaneck, NJ, USA

During the transition period (3 weeks before calving through 3 weeks after calving) the cow is subjected to various stressors that include metabolic disorders, prolonged inflammation, and most prevalently, subclinical hypocalcemia (SCH) [1–4]. As the

* Corresponding author. 1207 W. Gregory Drive, Urbana, IL, 61801, USA.
E-mail address: cardoso2@illinois.edu (F.C. Cardoso).
<https://doi.org/10.1016/j.theriogenology.2019.10.014>
0093-691X/© 2019 Elsevier Inc. All rights reserved.

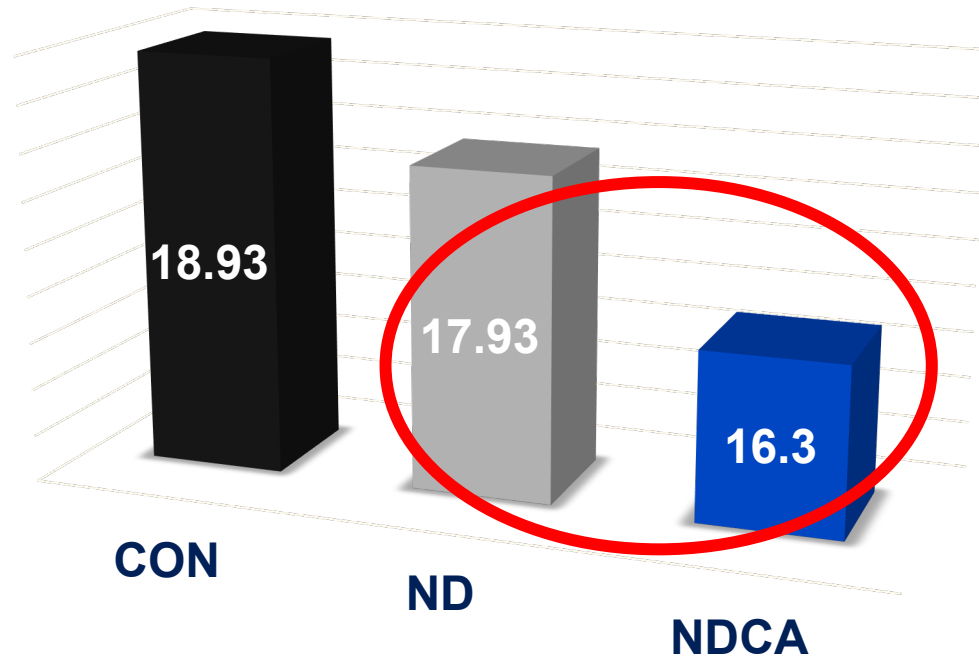
periparturient cow transitions from a pregnant and non-lactating status, to lactation, her energy and nutrient demands increase dramatically [5,6]. In the first 3 days following parturition, the cow is often in a negative energy balance as well as negative Ca status [4,7,8]. If this status is chronic or prolonged, the cow becomes predisposed to numerous disorders observed around calving such as retained placenta, displaced abomasum, ketosis, metritis and mastitis [6,9,10]. If left untreated, hypocalcemia and SCH [11], can reduce the ability of immune cells to respond to stimuli [10], thus increasing susceptibility to infections such as metritis [11]. Many



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Improved reproductive performance for cows fed negative DCAD prepartum

Days to first ovulation, d



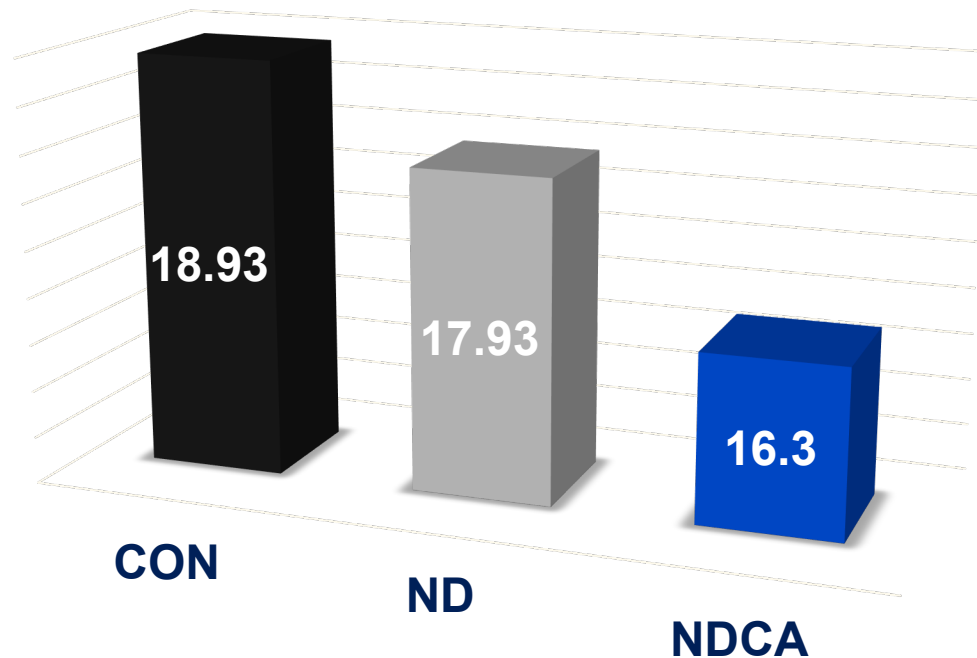
CON vs -DCAD: $P = 0.05$

ND vs NDCA: $P = 0.12$



Improved reproductive performance for cows fed negative DCAD prepartum

Days to first ovulation, d



CON vs -DCAD: $P = 0.05$
ND vs NDCA: $P = 0.12$

Pregnant at first TAI

Treatments	Level	OR	95% CI	P-value
CON	CON-NDCA	0.29	0.06 – 1.22	0.09
–	CON-ND	0.43	0.10 – 1.89	0.26
ND	ND-NDCA	0.67	0.19 – 2.38	0.53

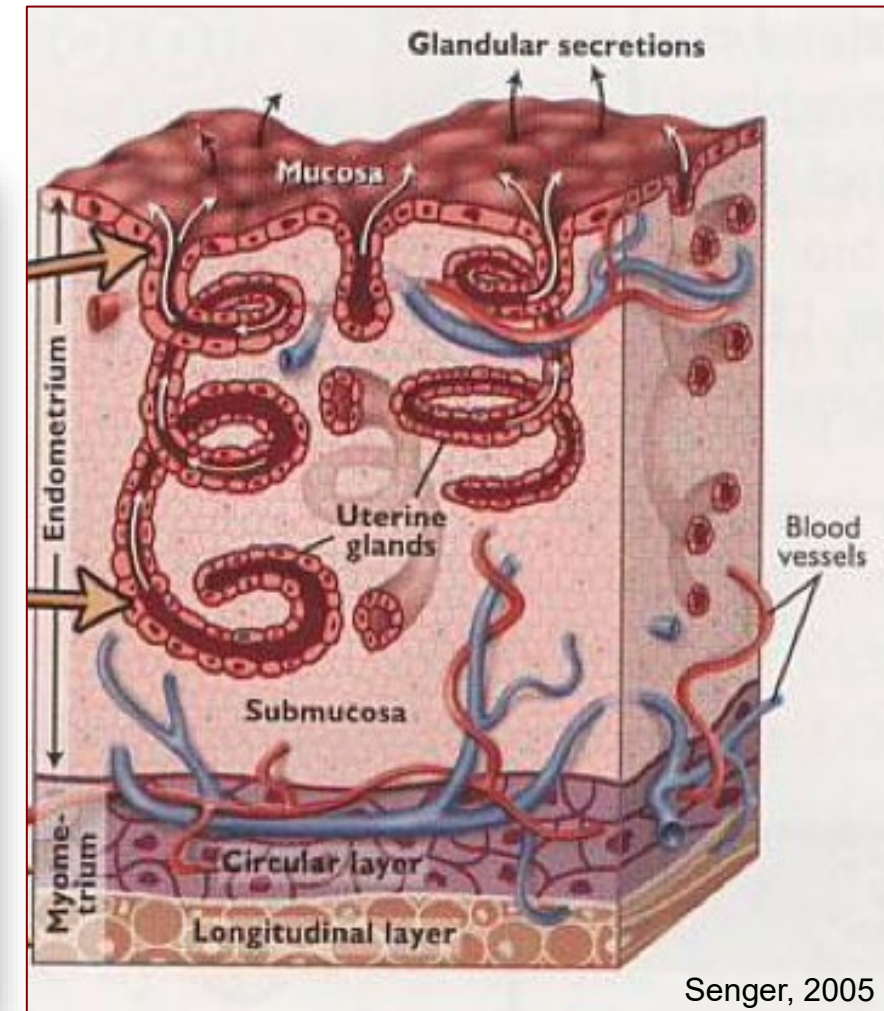
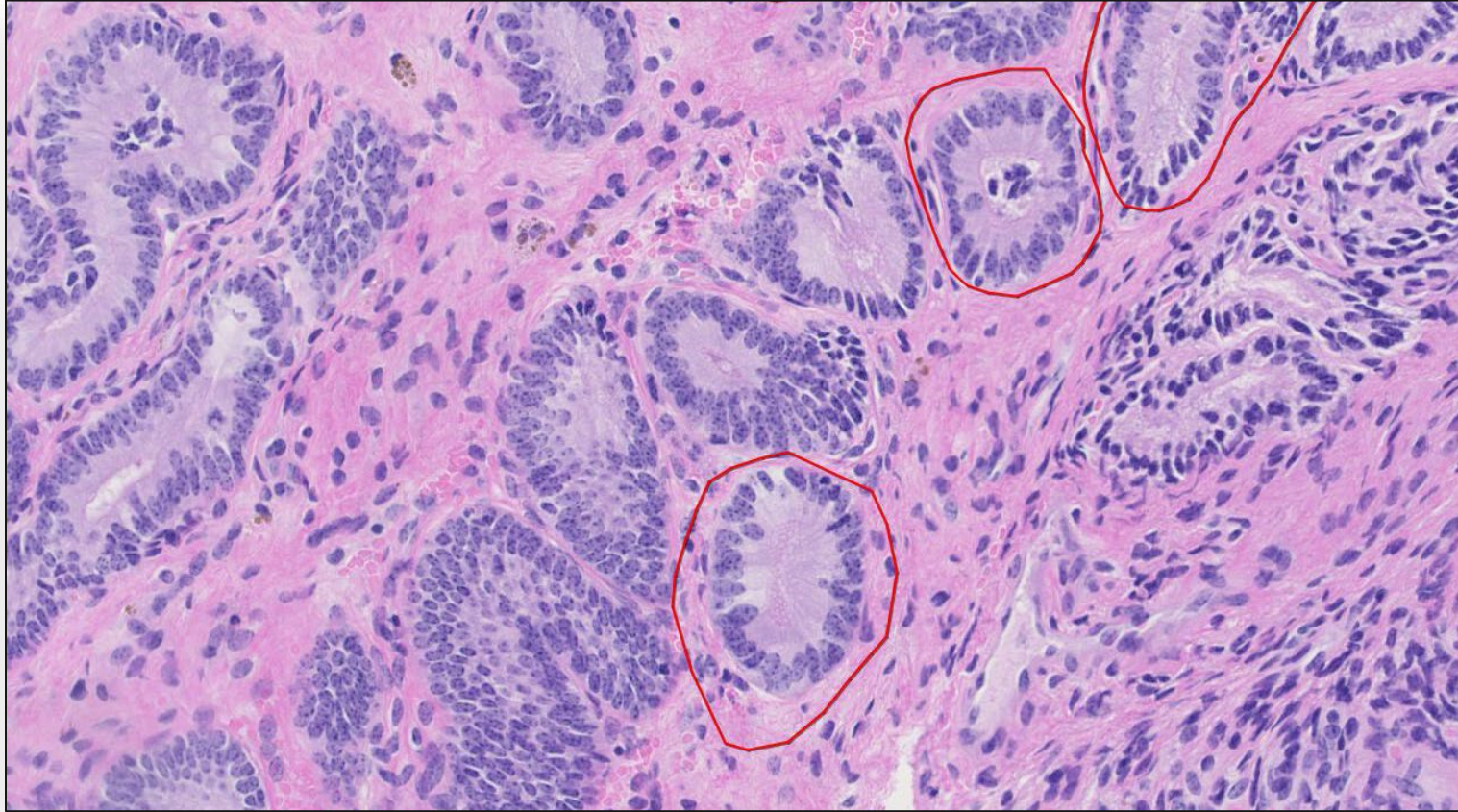


UTERINE BIOPSY

- Samples were taken at 30 ± 2 DIM



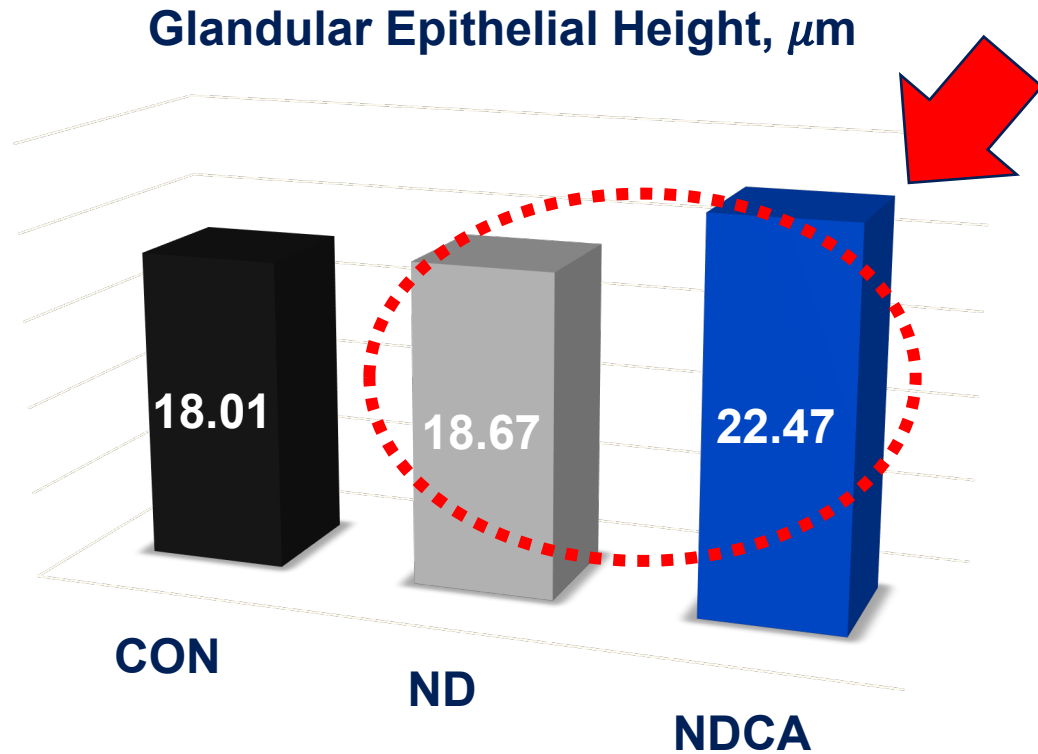
Uterine tissue hematoxylin and eosin (H&E) staining



Senger, 2005



Uterine gland morphology



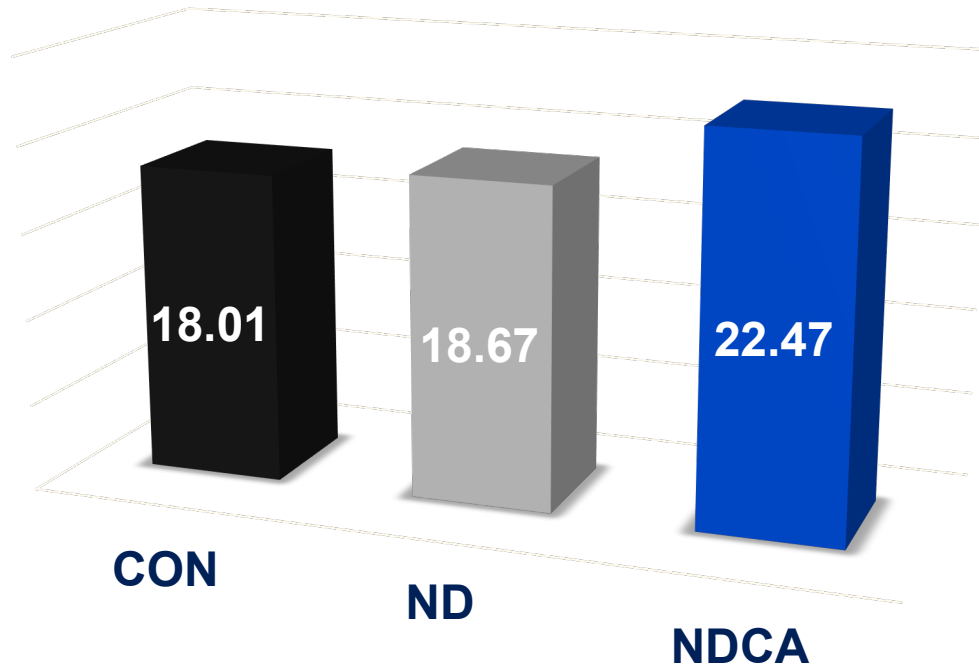
CON vs -DCAD: $P = 0.06$

ND vs NDCA: $P = 0.02$



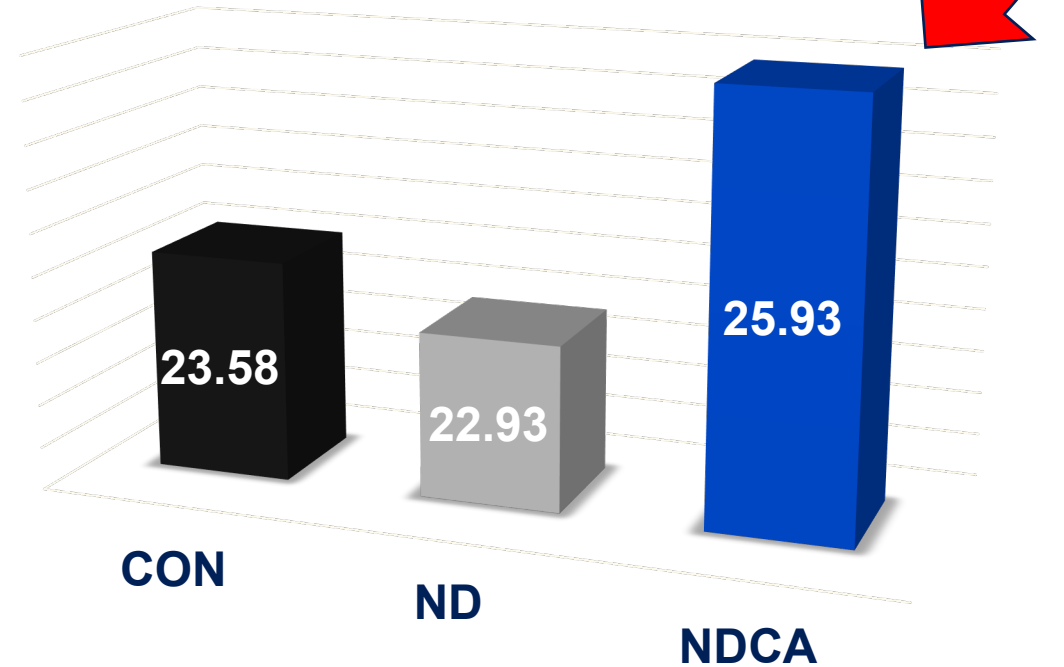
Uterine gland morphology

Glandular Epithelial Height, μm



CON vs -DCAD: $P = 0.06$
ND vs NDCA: $P = 0.02$

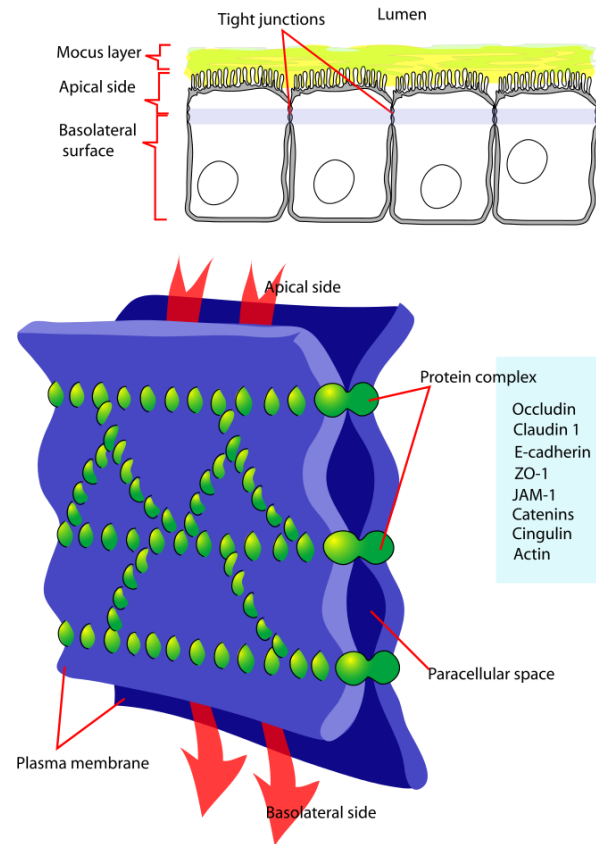
Number of Cells per Gland



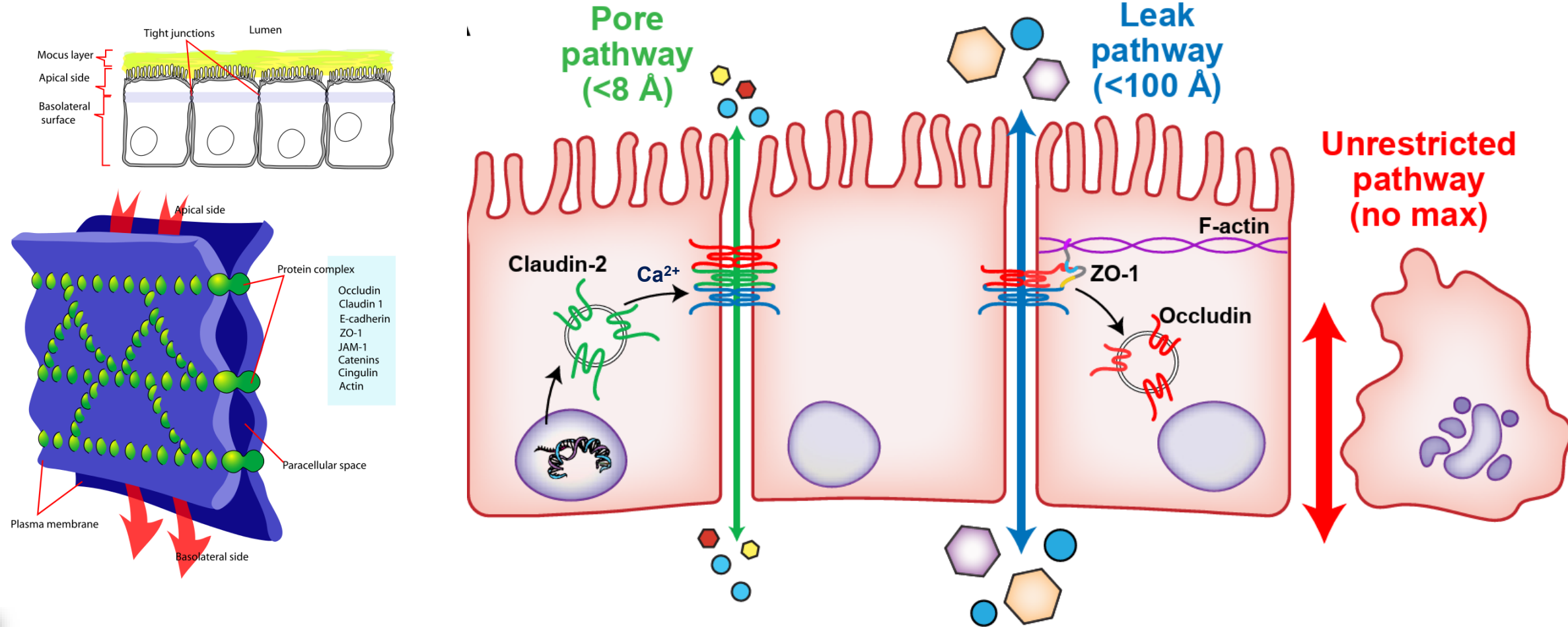
CON vs -DCAD: $P = 0.51$
ND vs NDCA: $P = 0.05$



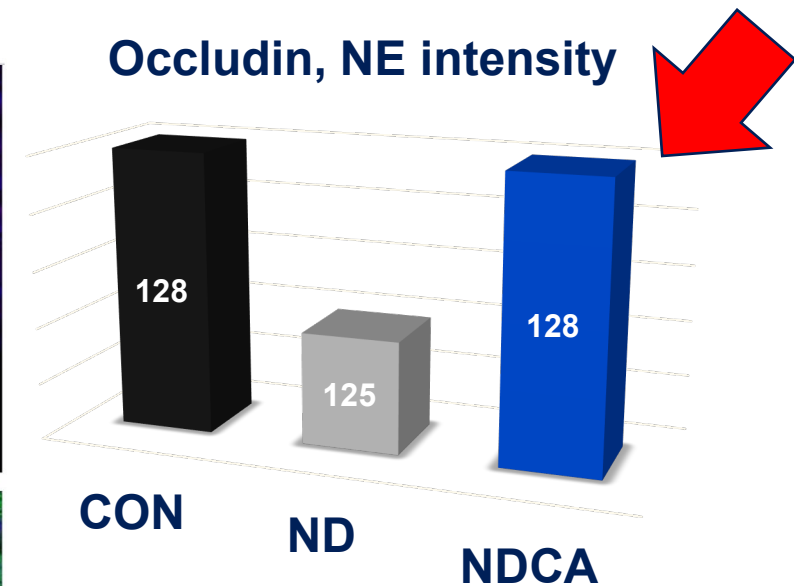
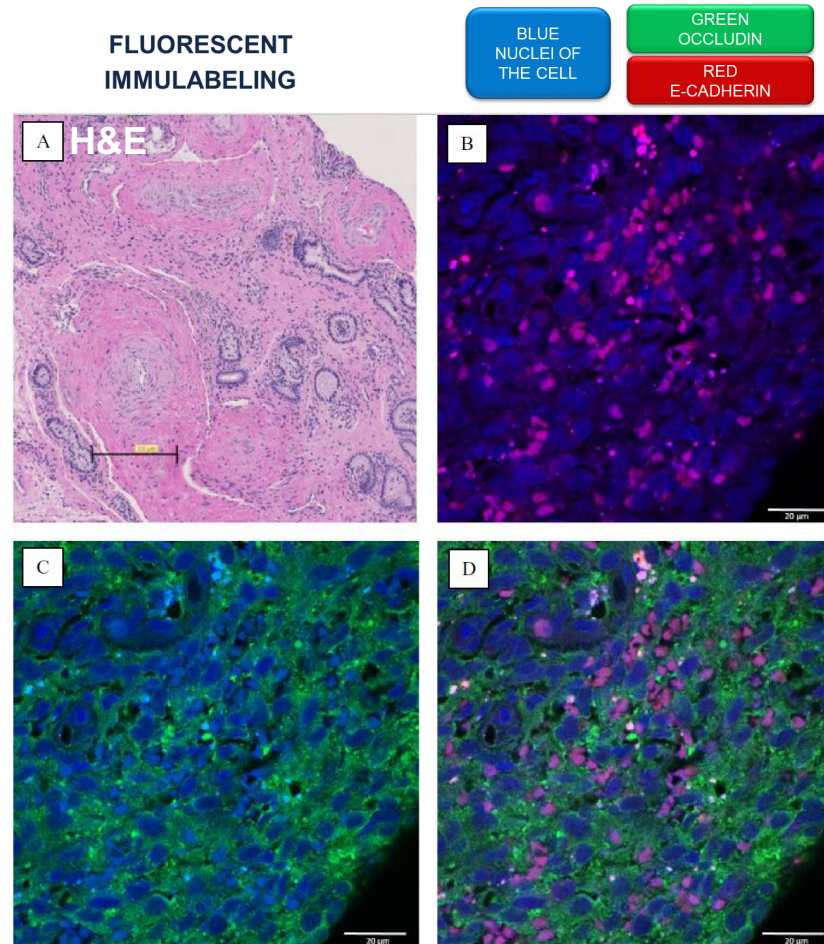
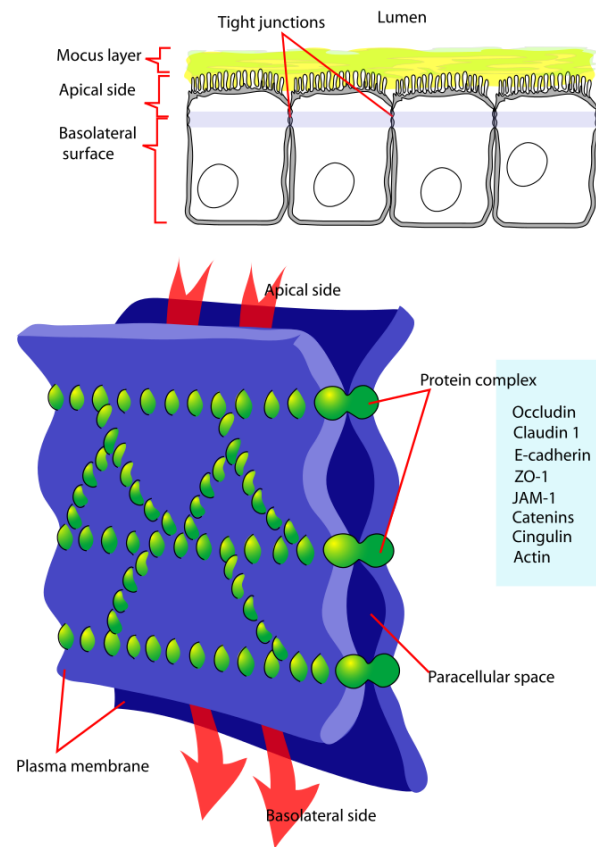
Tendency for increased number of tight junctions for cows fed calcium with negative DCAD prepartum



Tendency for increased number of tight junctions for cows fed calcium with negative DCAD prepartum



Tendency for increased number of tight junctions for cows fed calcium with negative DCAD prepartum



CON vs -DCAD: $P = 0.46$
ND vs NDCA: $P = 0.15$



Take Home Message!

Summary

- Negative DCAD prepartum increased ionized and total Ca after calving
- Ca prepartum lessened effects of negative DCAD on DMI
- Negative DCAD (urine pH ~ 6) plus Ca prepartum
 - prevented milk fever and maximized milk yield
 - improved reproductive performance and uterine environment
 - reduced haptoglobin plasma concentrations around calving
- Low Ca approach was less effective than negative DCAD





I
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Moving Beyond Basics: Dairy Nutrition and Diet Formulation



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Animal Sciences

COLLEGE OF AGRICULTURAL, CONSUMER
& ENVIRONMENTAL SCIENCES



THANKS!



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Effect of Timing of AI Relative to a Synchronized Ovulation or Increased Activity on Fertility in Lactating Dairy Cows

Paul M. Fricke, PhD

Professor of Dairy Science

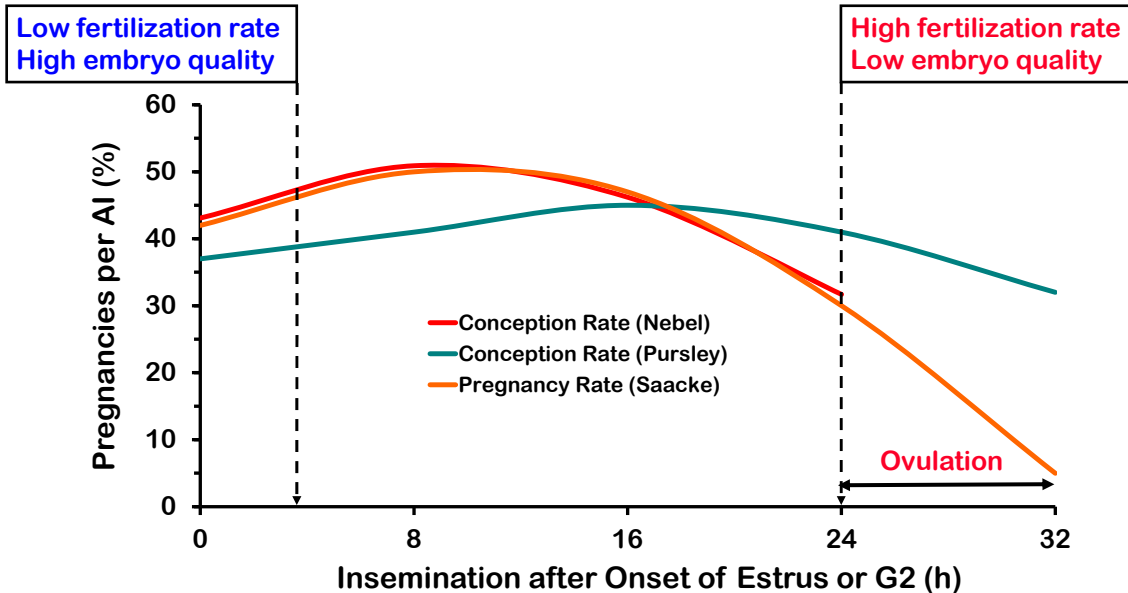


1



2

Timing of AI Relative to Ovulation affects Fertility



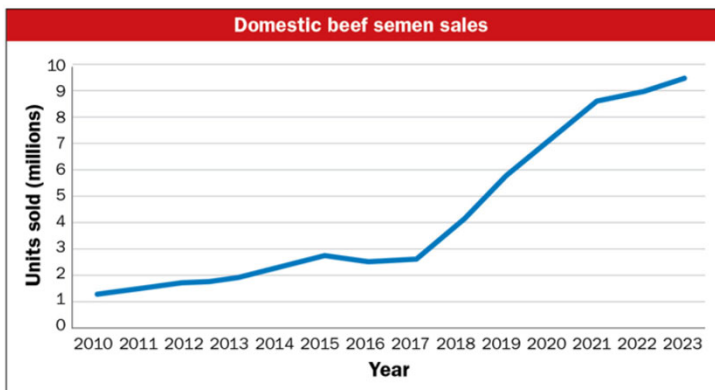
3

HOARD'S DAIRYMAN

Domestic beef semen sales hit a new high

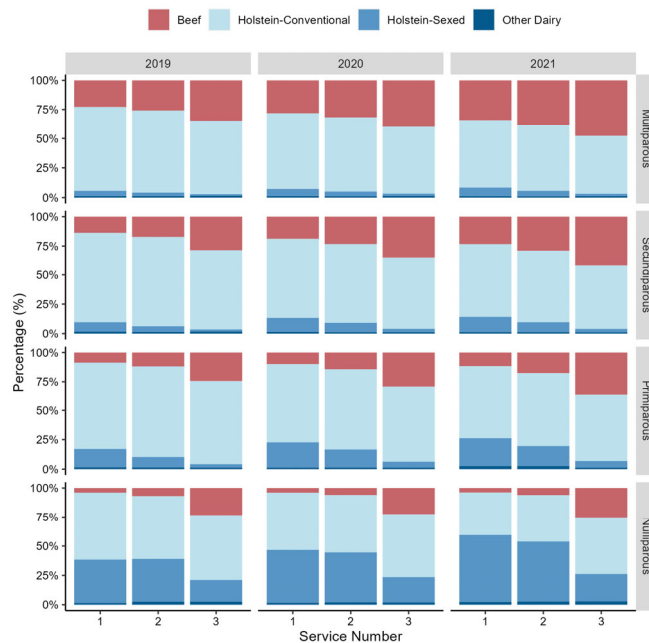
April 15 2024

By Abby Bauer, Managing Editor



- Of the **9.4** million units of beef semen sold domestically in 2023, **7.9** million units were used in dairy herds (NAAB). That was up nearly 1 million units from the year before.
- By contrast, beef semen sold for use in beef cattle, both domestically and in the export market, was down **1.4** million units.

4



Lauber et al., 2023.
Characterization of semen type prevalence and allocation in Holstein and Jersey females in the United States. J. Dairy Sci. 106:3748–3760

8,284,770 insemination records from 3,115,224 Holstein females from 9,196 herds



5



Time of insemination relative to reaching activity threshold is associated with pregnancy risk when using sex-sorted semen for lactating Jersey cows

Gabriel D. Bombardelli^{a,b}, Henrique F. Soares^{a,b}, Ricardo C. Chebel^{a,b,*}

^a Department of Large Animal Clinical Sciences, University of Florida, Gainesville, Florida, USA
^b Department of Animal Sciences, University of Florida, Gainesville, Florida, USA



Research Article
Volume 5 Issue 1 - January 2018
DOI: 10.1002/dvsc.2018.05.00001

Time of Insemination Relative to onset of Activity Threshold of Cow Manager[®] is Associated with Pregnancy Risk When Using Gender Selected[™] Semen for Jersey Cattle

Ray Nebel^{*}

Department of animal reproduction, Select Sires Inc, USA
Submission: October 27, 2017; Published: January 25, 2018



Dairy and Vet Sci |
Copyright © All rights are reserved by Ray Nebel

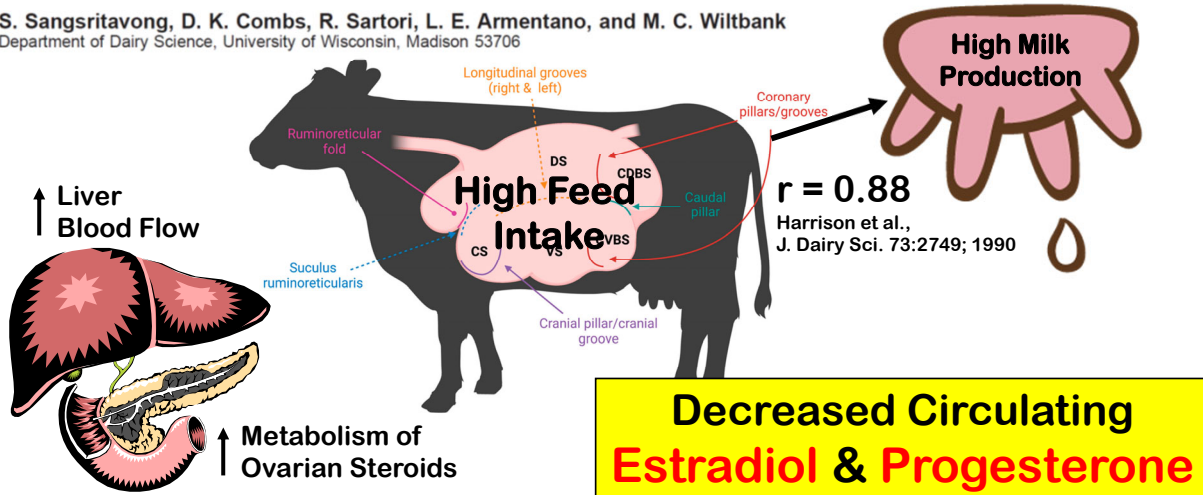
Should we inseminate later with sexed semen?

In both observational studies, inseminating later relative to the onset of activity yielded increased fertility with sexed semen

6

High Feed Intake Increases Liver Blood Flow and Metabolism of Progesterone and Estradiol-17 β in Dairy Cattle

S. Sangsritavong, D. K. Combs, R. Sartori, L. E. Armentano, and M. C. Wiltbank
Department of Dairy Science, University of Wisconsin, Madison 53706

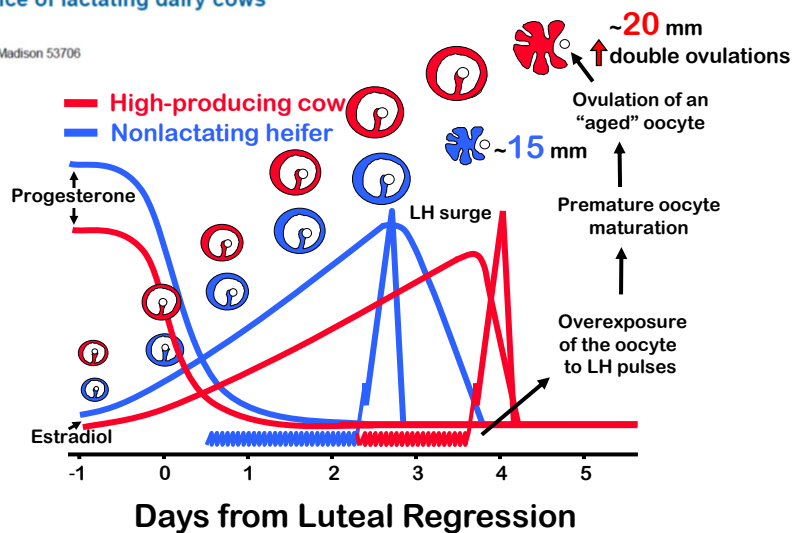


7

Symposium review: The implications of spontaneous versus synchronized ovulations on the reproductive performance of lactating dairy cows*

P. M. Fricke† and M. C. Wiltbank
Department of Animal and Dairy Sciences, University of Wisconsin-Madison, Madison 53706

- Comparison of hormonal events during the periovulatory period in nonlactating heifers and high-producing cows.
- Hepatic metabolism of estradiol and progesterone cause endocrine changes that affect physiology and fertility.



8

**Effect of Time of Artificial Insemination on Pregnancy Rates,
Calving Rates, Pregnancy Loss, and Gender Ratio
After Synchronization of Ovulation in Lactating Dairy Cows**

J. RICHARD PURSLEY,^{*,†} ROY W. SILCOX,[†] and MILO C. WILTBANK^{*,2}

^{*}Department of Dairy Science, University of Wisconsin, Madison 53706

[†]Department of Animal Science, Brigham Young University, Provo, UT 84602

1998 J Dairy Sci 81:2139–2144



**From where did the longstanding
recommendation for TAI at 16 h
after G2 originate?**

9

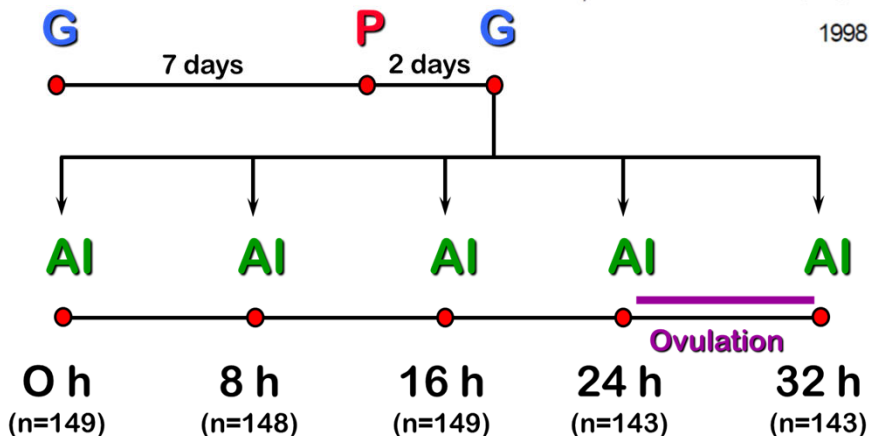
**Effect of Time of Artificial Insemination on Pregnancy Rates,
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After Synchronization of Ovulation in Lactating Dairy Cows**

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^{*}Department of Dairy Science, University of Wisconsin, Madison 53706

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1998 J Dairy Sci 81:2139–2144



10

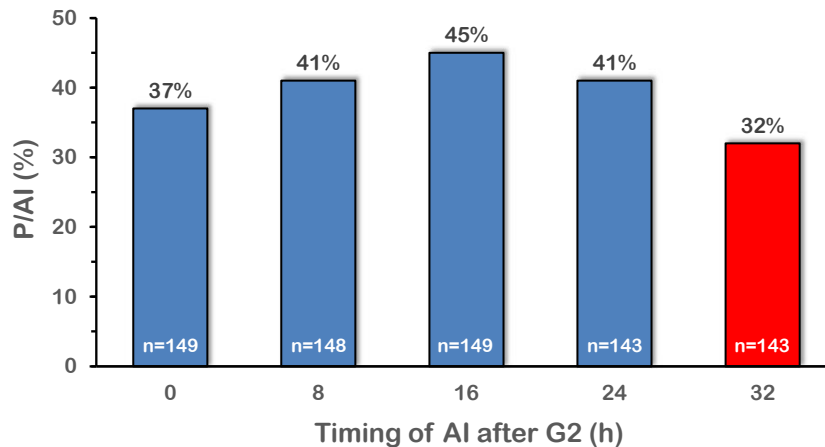
Effect of Time of Artificial Insemination on Pregnancy Rates, Calving Rates, Pregnancy Loss, and Gender Ratio After Synchronization of Ovulation in Lactating Dairy Cows

J. RICHARD PURSLEY,^{*,†} ROY W. SILCOX,[†] and MILO C. WILT BANK^{*,2}

^{*}Department of Dairy Science, University of Wisconsin, Madison 53706

[†]Department of Animal Science, Brigham Young University, Provo, UT 84602

1998 J Dairy Sci 81:2139–2144



- No statistical difference in P/AI when TAI occurred at 0, 8, 16, or 24 h after G2 of Ovsynch.
- TAI at 32 h after G2 of Ovsynch yielded P/AI that was worse than all other time points combined.

11

J. Dairy Sci. 91:1044–1052

doi:10.3168/jds.2007-0409

© American Dairy Science Association, 2008.

Timing of AI Case Study

Altering the Time of the Second Gonadotropin-Releasing Hormone Injection and Artificial Insemination (AI) During Ovsynch Affects Pregnancies per AI in Lactating Dairy Cows

D. J. Brusveen, A. P. Cunha, C. D. Silva, P. M. Cunha, R. A. Sterry, E. P. B. Silva, J. N. Guenther, and M. C. Wiltbank¹

¹Department of Dairy Science, University of Wisconsin, Madison 53706

Conventional Semen

“CoSynch” protocol



“Ovsynch56” protocol

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2023 Timing of AI Case Study

1,850-cow Holstein herd in Wisconsin

Cow – 1st Service CoSync vs OvSync56

Below you'll find cow conception rates for 1st service ONLY by semen type for the different protocols.

The chart below is ONLY 1st service CoSync – up to Nov 24th

Semen Type	95% CI	%Conc	#Preg	#Open	Other	Abort	Total	%Tot	SPC
Sexed	22-32	26	79	221	6	2	306	70	3.8
Beef	45-62	54	69	59	6	3	134	30	1.9
TOTALS	30-39	35	148	280	12	5	440	100	2.9

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J. Dairy Sci. 103:10856–10861
<https://doi.org/10.3168/jds.2020-18836>

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Short communication: Effect of timing of induction of ovulation relative to timed artificial insemination using sexed semen on pregnancy outcomes in primiparous Holstein cows

M. R. Lauber,¹ B. McMullen,² J. J. Parrish,³ and P. M. Fricke^{1*}

¹Department of Dairy Science, University of Wisconsin-Madison, Madison 53706

²Bridgewater Dairy Group, Montpelier, OH 43543

³Department of Animal Sciences, University of Wisconsin-Madison, Madison 53706



Hypothesis:

Induction of ovulation (G2) earlier relative to TAI in a Double-Ovsynch protocol will result in more P/AI

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Standard Double-Ovsynch Protocol

G2 to TAI = 16 h

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					GnRH a.m.	
					PGF _{2α} a.m.	
	GnRH a.m.					
	GnRH a.m.		G2-16			
	PGF _{2α} a.m.	PGF _{2α} a.m.	G2 p.m.	TAI a.m.		

15

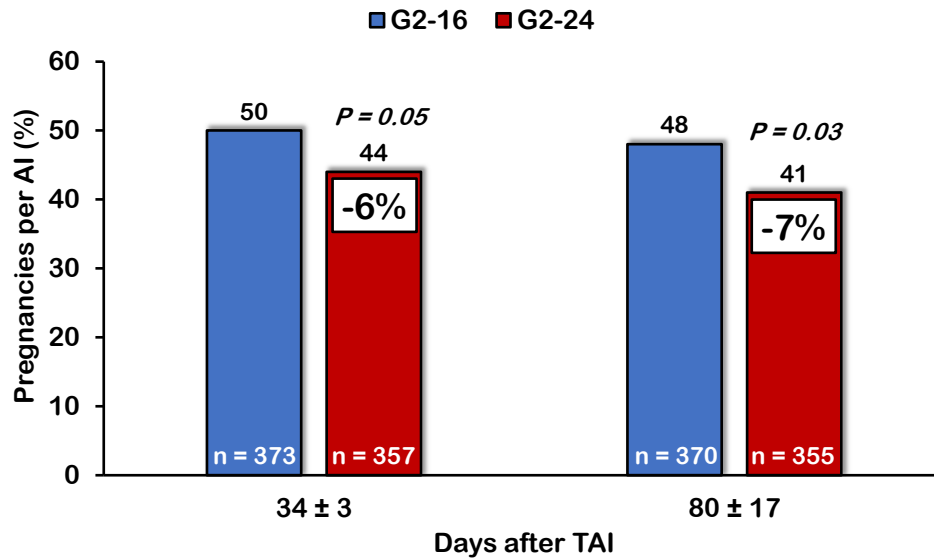
Modified Double-Ovsynch Protocol

G2 to TAI = 24 h

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					GnRH a.m.	
					PGF _{2α} a.m.	
	GnRH a.m.					
	GnRH a.m.		G2-24			
	PGF _{2α} a.m.	PGF _{2α} a.m.	G2 a.m.	TAI a.m.		

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Effect of Treatment on Pregnancy Outcomes



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J. Dairy Sci. 103:12059–12068
<https://doi.org/10.3168/jds.2020-18847>

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Evaluation of delayed timing of artificial insemination with sex-sorted sperm on pregnancy per artificial insemination in seasonal-calving, pasture-based lactating dairy cows

E. Drake,^{1,2} S. A. Holden,¹ V. Aublet,¹ R. C. Doyle,¹ C. Millar,¹ S. G. Moore,¹ C. Maicas,^{1,2} F. Randi,³

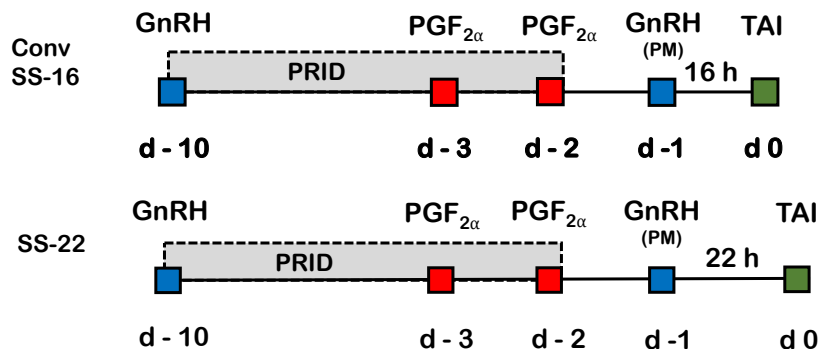
A. R. Cromie,⁴ P. Lonergan,² and S. T. Butler^{1*}

¹Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland P61 C996

²School of Agriculture and Food Science, University College Dublin, Ireland D04 N2E5

³Ceva Santé Animale, Libourne, Bordeaux, France 33500

⁴Irish Cattle Breeding Federation, Highfield House, Shinagh, Bandon, Co. Cork, Ireland P72 X050



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Evaluation of delayed timing of artificial insemination with sex-sorted sperm on pregnancy per artificial insemination in seasonal-calving, pasture-based lactating dairy cows

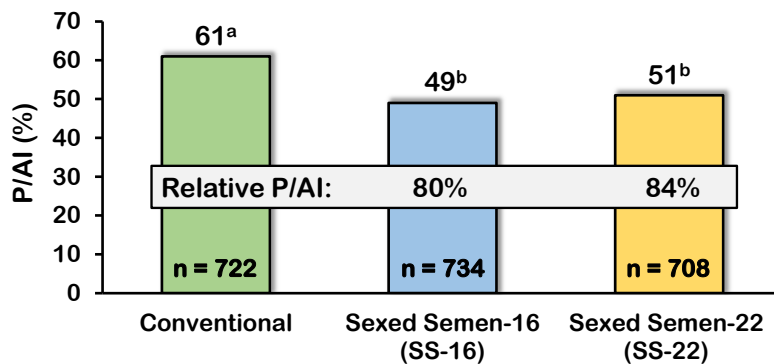
E. Drake,^{1,2} S. A. Holden,¹ V. Aublet,¹ R. C. Doyle,¹ C. Millar,¹ S. G. Moore,¹ C. Maicas,^{1,2} F. Randi,³ A. R. Cromie,⁴ P. Lonergan,² and S. T. Butler^{1*}

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³Ceva Santé Animale, Libourne, Bordeaux, France 33500

⁴Irish Cattle Breeding Federation, Highfield House, Shinagh, Bandon, Co. Cork, Ireland P72 X050



No statistical increase in P/AI when TAI with sexed semen was delayed by 6 h after G2

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Double-Ovsynch Protocol

Keep the standard timing of G2 and TAI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					GnRH a.m.	
					PGF _{2α} a.m.	
	GnRH a.m.					
	GnRH a.m.					
	PGF _{2α} a.m.	PGF _{2α} a.m.	G2 p.m.	TAI a.m.		

20



J. Dairy Sci. TBC
<https://doi.org/10.3168/jds.2025-26428>

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Effect of timing of artificial insemination with conventional or sex-sorted semen on fertility of lactating dairy cows

V. G. Santos,^{1,2*} P. D. Carvalho,^{3,4} A. H. Souza,³ S. Priskas,⁵ J. A. L. Castro,¹ A. M. F. Pereira,^{1,2} P. J. Ross,⁴ J. Moreno,⁴ M. C. Wiltbank,³ and P. M. Fricke³

¹Departamento de Zootecnia, Escola de Ciências e Tecnologia, Universidade de Évora, Évora, 7002-554, Portugal

²Instituto Mediterrâneo para a Agricultura, Ambiente e Desenvolvimento (MED), Universidade de Évora, Évora, Portugal

³Department of Animal and Dairy Sciences, University of Wisconsin–Madison, Madison, WI

⁴ST Genetics, Navasota, TX

⁵Bovis PC, Serres, Greece

Three data sets were analyzed:

- One randomized, controlled experiment
- Two large observational studies



Department of
Animal & Dairy Sciences
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Extension
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Experiment 1 – conventional semen

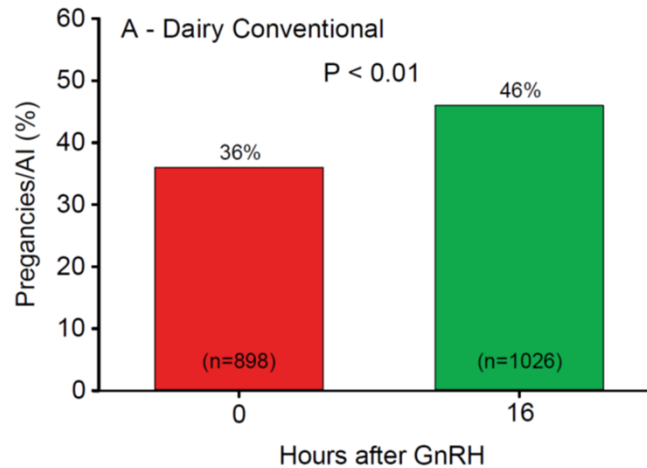
Randomized, controlled trial comparing TAI at 0 vs. 16 h after a Double-Ovsynch protocol for first TAI

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					GnRH	
					PGF	
	GnRH					
	GnRH					
	PGF		GnRH	TAI (0 vs. 16 h)		

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Effect of timing of AI relative to G2 on P/AI

Multiparous lactating Holstein cows (n = 2,225) from 6 dairy herds in Wisconsin were submitted for TAI with conventional semen after a Double-Ovsynch protocol and were randomized to receive TAI at G2 (0 h) or 16 h after G2.



23

Experiment 2 – conventional and sexed semen

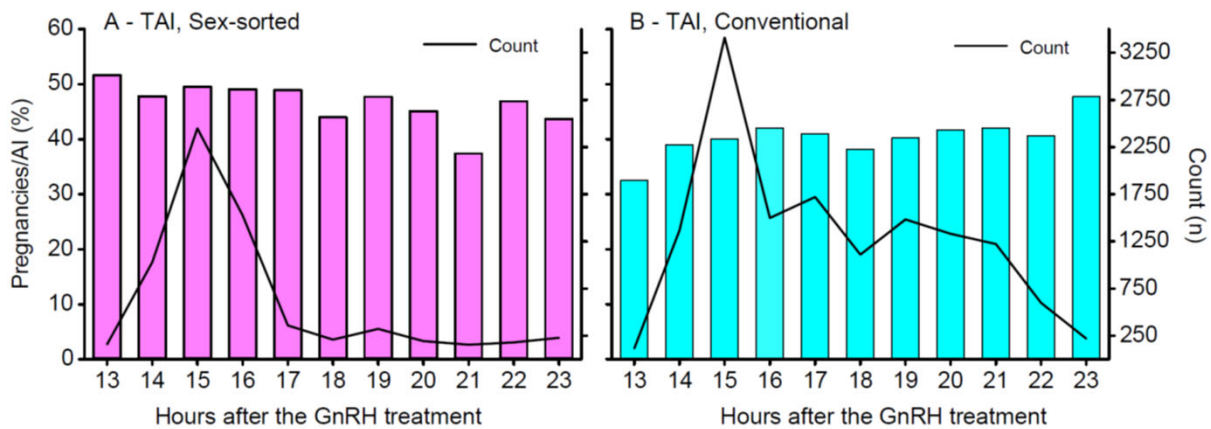
Observational study assessing variability of TAI after G2 of Double-Ovsynch

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					GnRH	
					PGF	
	GnRH					
	GnRH					
	PGF		GnRH	TAI (13 to 23 h)		

24

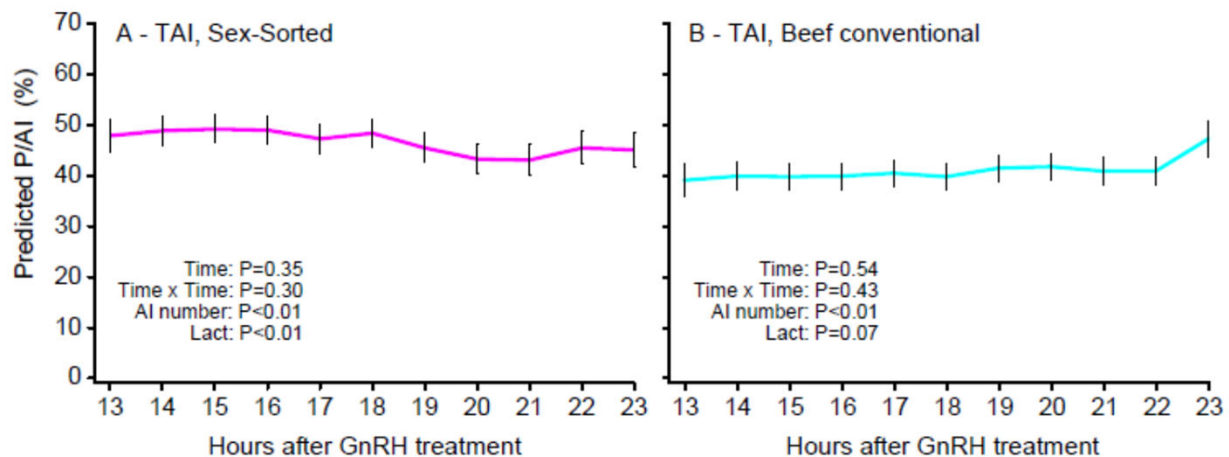
Timing of AI 13 to 23 h after G2 of Double-Ovsynch

Lactating Holstein cows (n = 13,318) from 2 herds in Texas were submitted to a Double-Ovsynch protocol to receive their first TAI (14,089 inseminations) or to a GGPPG protocol for second and greater TAI (6,806 inseminations).



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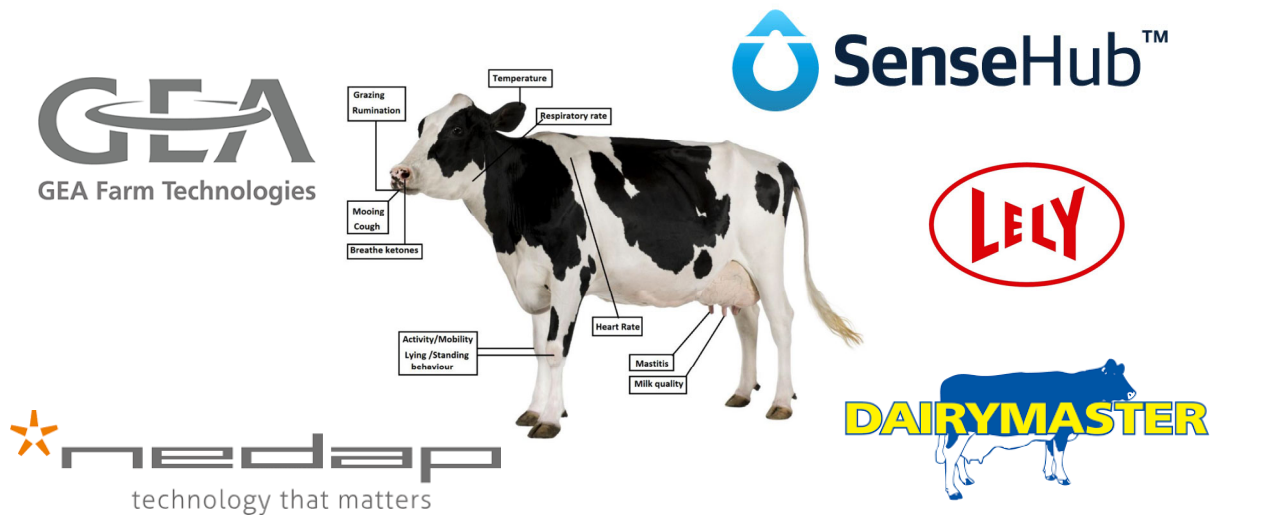
Timing of AI 13 to 23 h after G2 of Double-Ovsynch



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Experiment 3

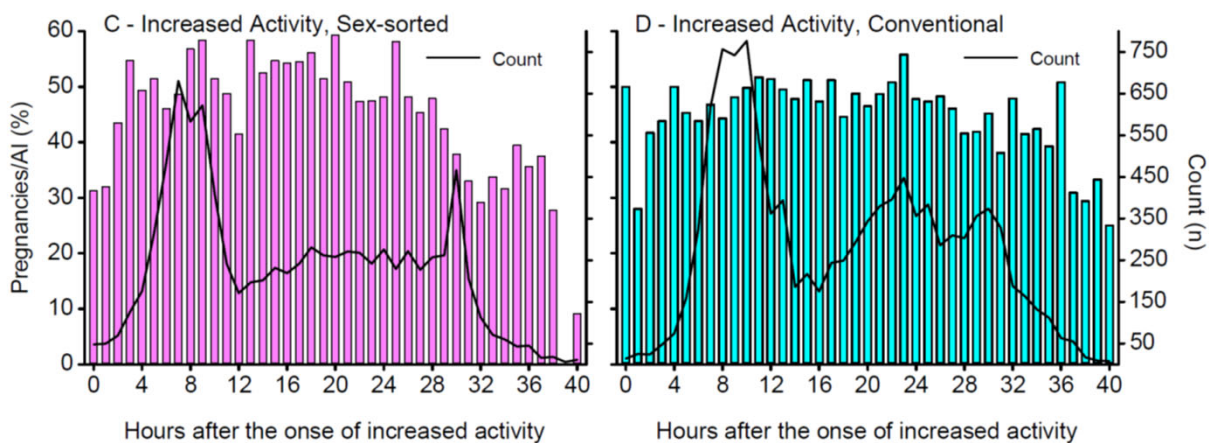
Observational study assessing variation of timing of AI with an Automated Activity Monitoring System using sex-sorted or conventional semen



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Timing of AI Relative to Onset of Activity

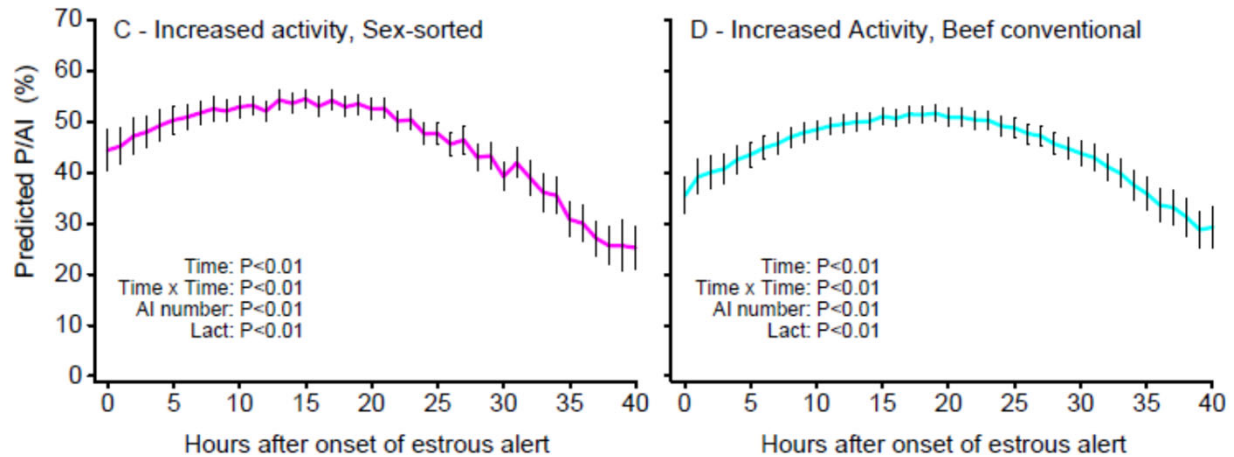
Lactating dairy Holstein ($n = 927$), Jersey ($n = 3,238$), and crossbred ($n = 6,762$) cows from farms in Texas and Arizona (5,549 from farm 1 and 5,468 from farm 2) were fitted with activity-monitoring tags mounted to a neck collar, and the timing of AI relative to the onset of increased estrous alert was recorded (**20,461 inseminations**).



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Timing of AI Relative to Onset of Activity

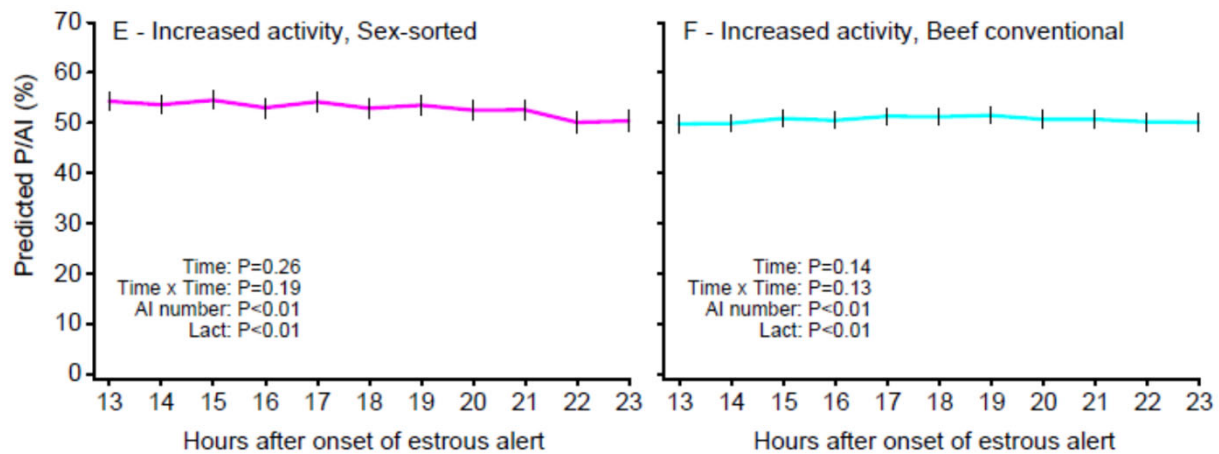
Variation in timing of AI from 0 to 40 h after onset of estrous alert



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Timing of AI Relative to Onset of Activity

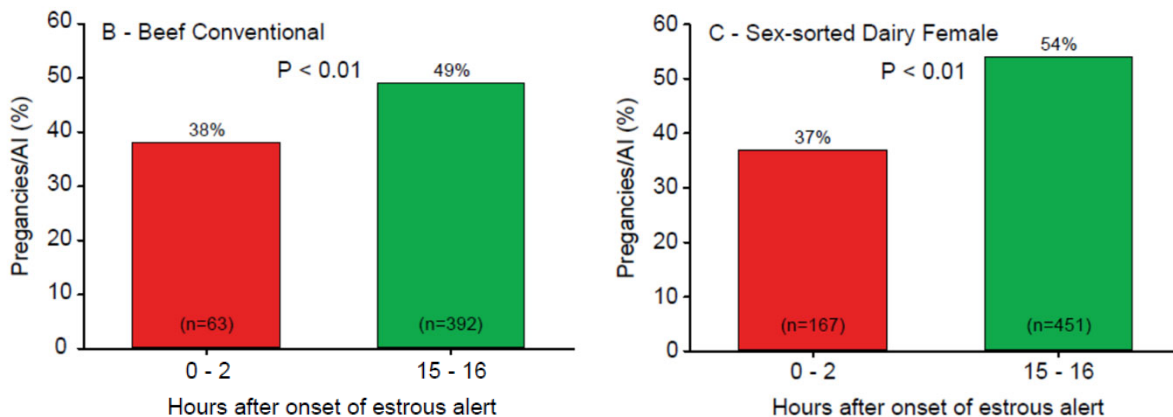
Data restricted to AI from 13 to 23 h after onset of estrous alert



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Effect of timing of AI relative to activity on P/AI

Pregnancies/AI for cows inseminated from 0 to 2 h or from 15 to 16 h after an activity alert using an automated activity monitoring system.



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Take-Home Messages

- Correct timing of insemination is critical for good fertility.
- Cosynch protocols result in poor fertility because insemination occurs too early relative to ovulation.
 - **STOP doing Cosynch!**
- The insemination window for optimal fertility is:
 - Approximately 13 to 23 hours after G2 of a Double-Ovsynch protocol.
 - Approximately 13 to 23 hours after an estrus alert based on an activity monitoring system.
- There was no difference in optimal timing of AI between conventional and sex-sorted semen.

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Thank you!

