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Animal
Nutrition
Conference

MAY 6-7, 2026

2026 Conference and Technical Symposium

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Technical Symposium
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California Animal Nutrition Conference

Metabolic Disorders Overview

Energy, Protein and Mineral Considerations for Transition Cow Health

Jesse Goff DVM, PhD

Ames, IA 50011 USA

Jesse Goff Conflict of Interest

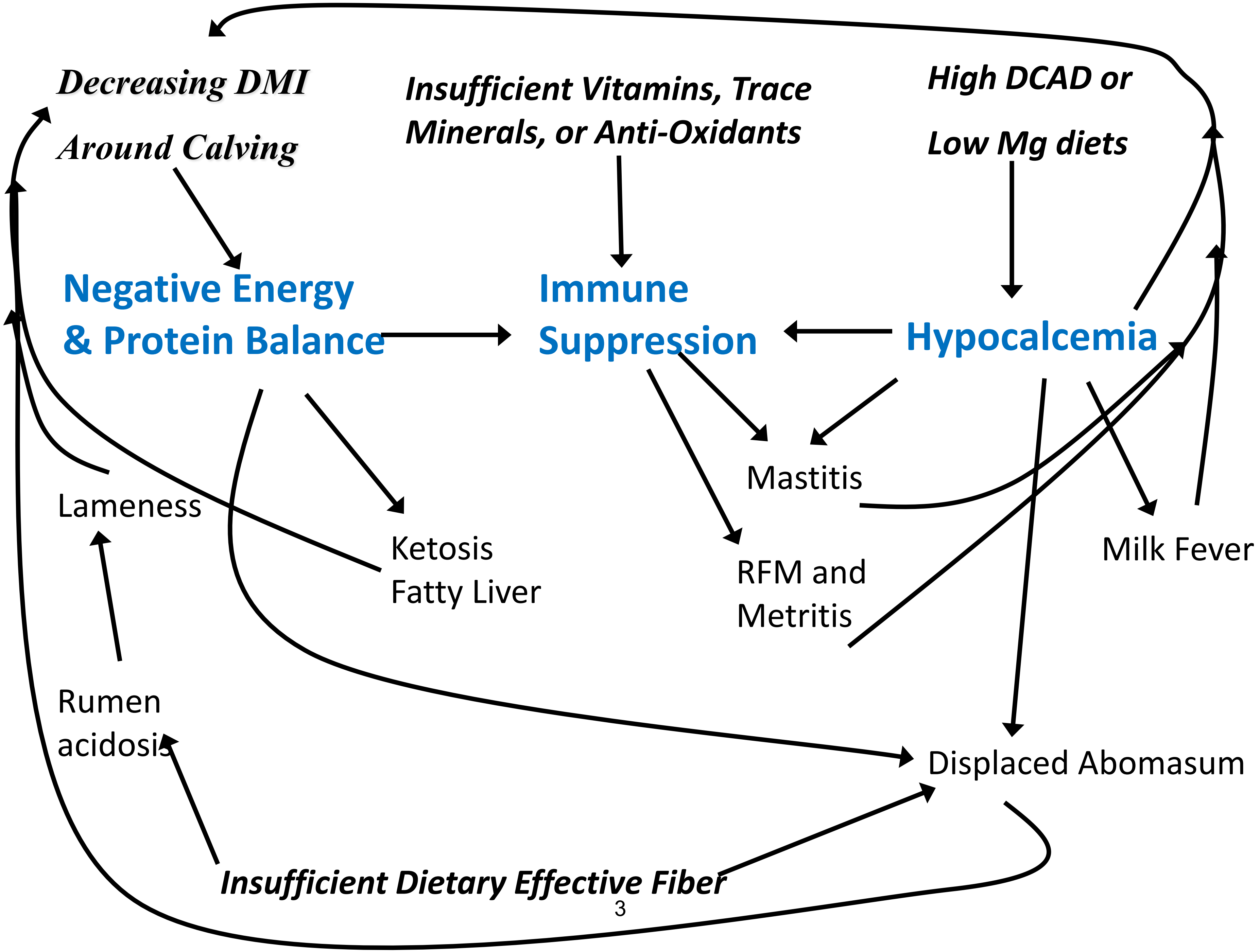
Invented Soychlor anionic supplement – work as advisor for the Landus Farmer's Cooperative on issues related to formulating diets with Soychlor.

Invented calcium propionate drench formulations.

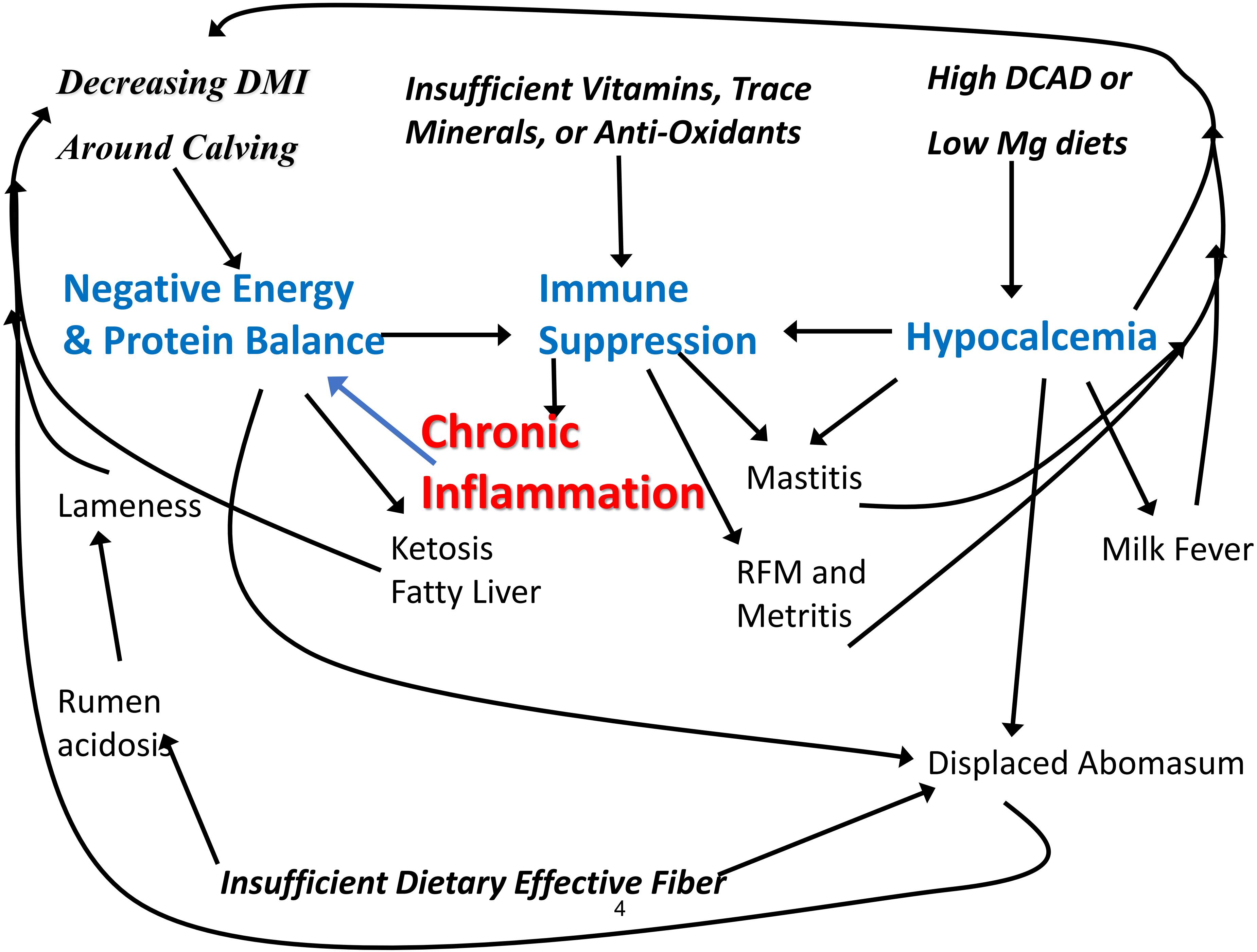
Designed, Tested, and Plan to help market Solanum glaucophyllum bolus with Silberhorn Animal Health called Goff-Bol.

Owner of GlycoMyr- a company that makes vitamin drench for neonatal pigs.
Holds patent on use of glycosides of vitamin D for colon health uses

Have been a paid speaker at conferences put on by Elanco, Pfizer, GLC Minerals, Costa Rica Veterinary Congress, Ca Animal Nutr Conference, Independent Dairy Vet Consultants meeting, Northeast Dairy production Medicine conf, Turkish Veterinary Congress, Balchem pre-conference symposia.



Decreasing DMI
Around Calving
Insufficient Vitamins, Trace Minerals, or Anti-Oxidants
High DCAD or
Low Mg diets
Negative Energy & Protein Balance
Immune Suppression
Hypocalcemia
Mastitis
Lameness
Ketosis
Fatty Liver
RFM and Metritis
Milk Fever
Rumen acidosis
Displaced Abomasum
Insufficient Dietary Effective Fiber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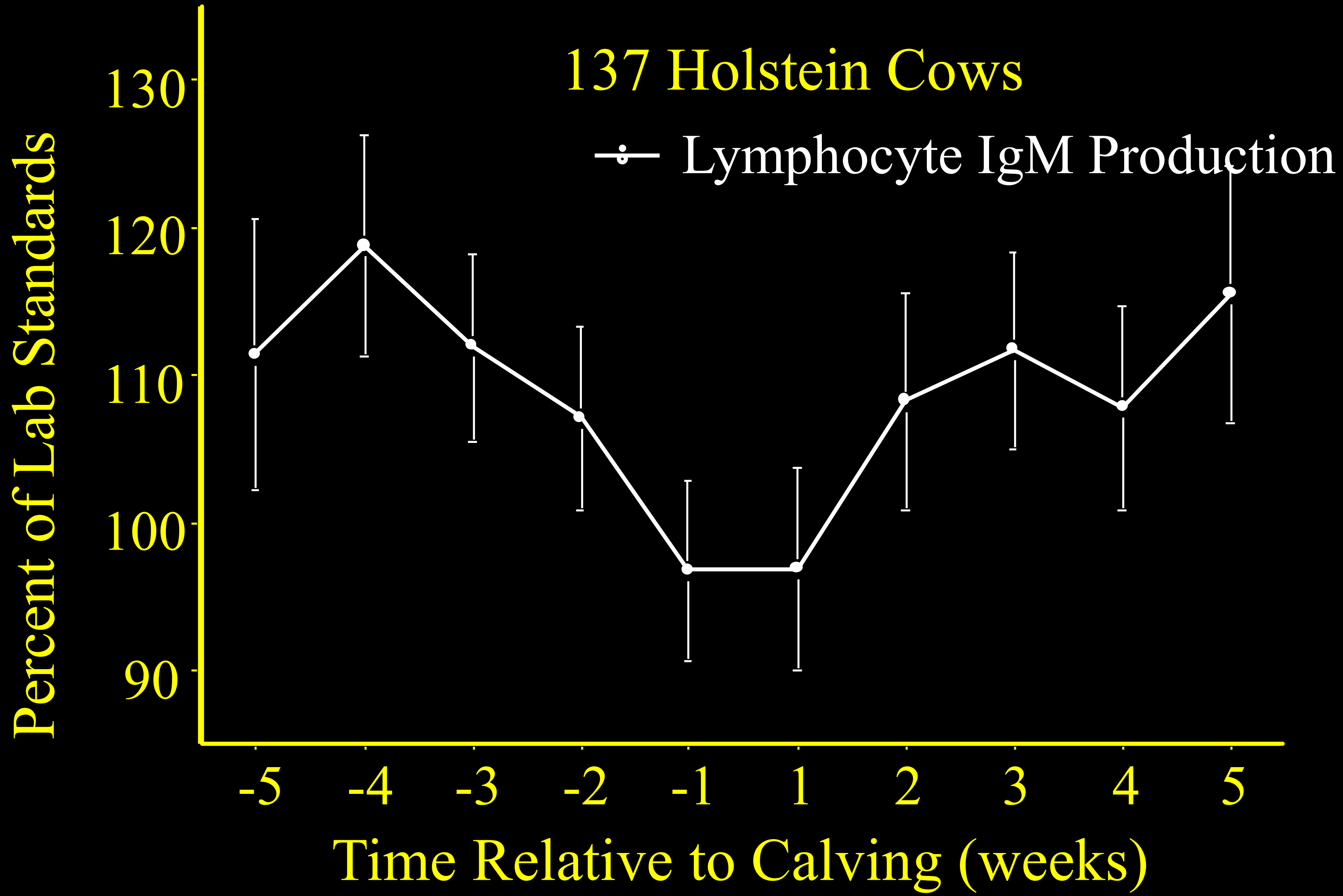
acidosis
Displaced Abomasum
Insufficient Dietary Effective Fiber

Periparturient immunosuppression

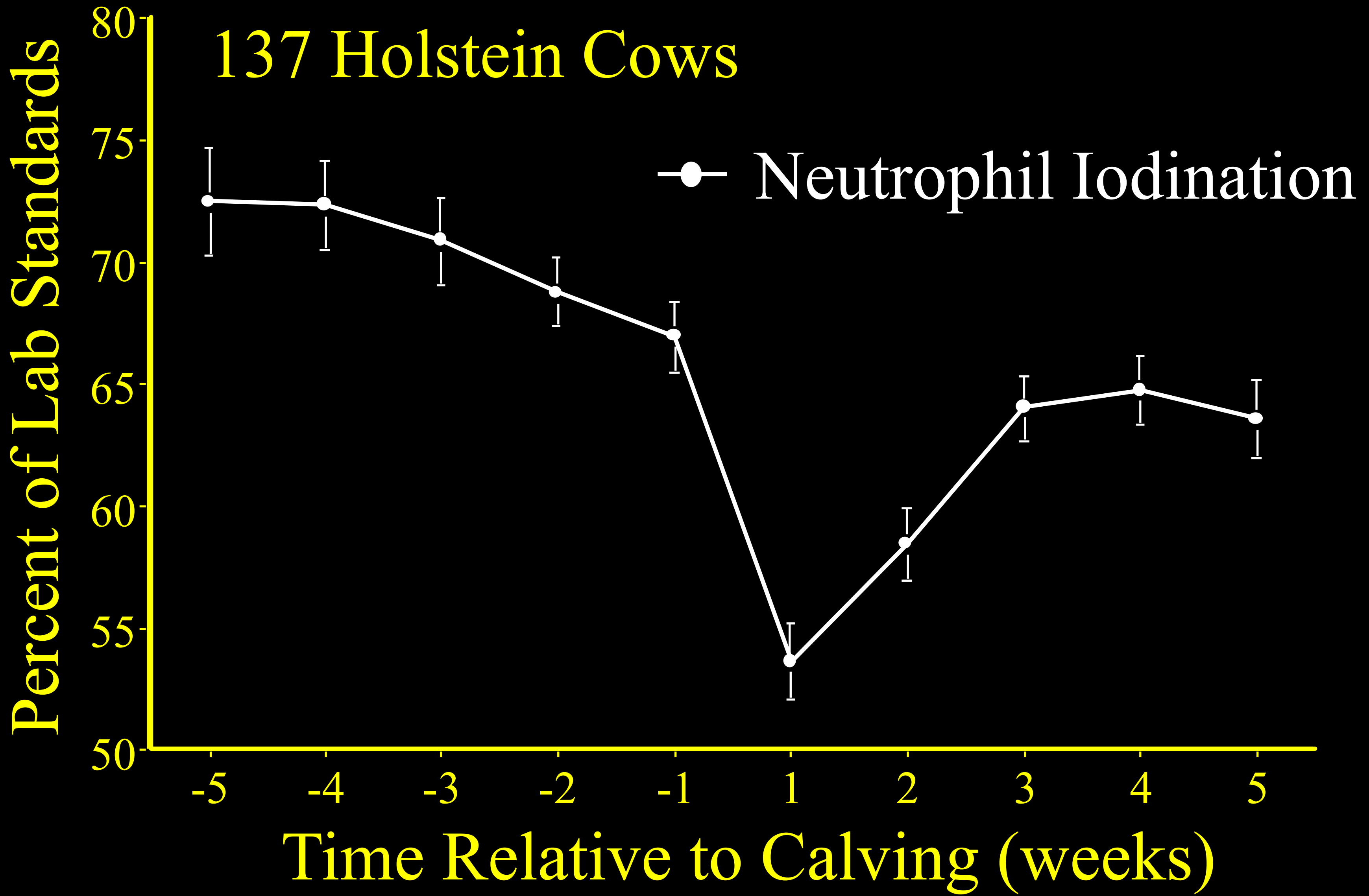
1. High incidence of mastitis. 25% of coliform mastitis cases occur in first 2 wks of lactation.
2. Clinical manifestation of chronically carried disease;

   Johne's, Salmonellosis breaks after calving.
3. RETAINED PLACENTA, METRITIS, ENDOMETRITIS DUE TO POOR IMMUNE FUNCTION!!

Guidry, et al. 1976. *Am J Vet Res*. 37:1195; Newbould. 1976. *Can J Comp Med*. 40:111; Wells, et al. 1977. *Clin Exp Immunol*. 29:159: Hill. 1981. *Res Vet Sci*. 31:107; Manak. 1982. *J Reprod Immunol*. 4:263; Kashiwazaki, et al. 1985. *Jpn J Vet Sci*. 47:337; Ishikawa. 1987. *Jpn J Vet Sci*. 49:469.



Detilleux et al., 1995

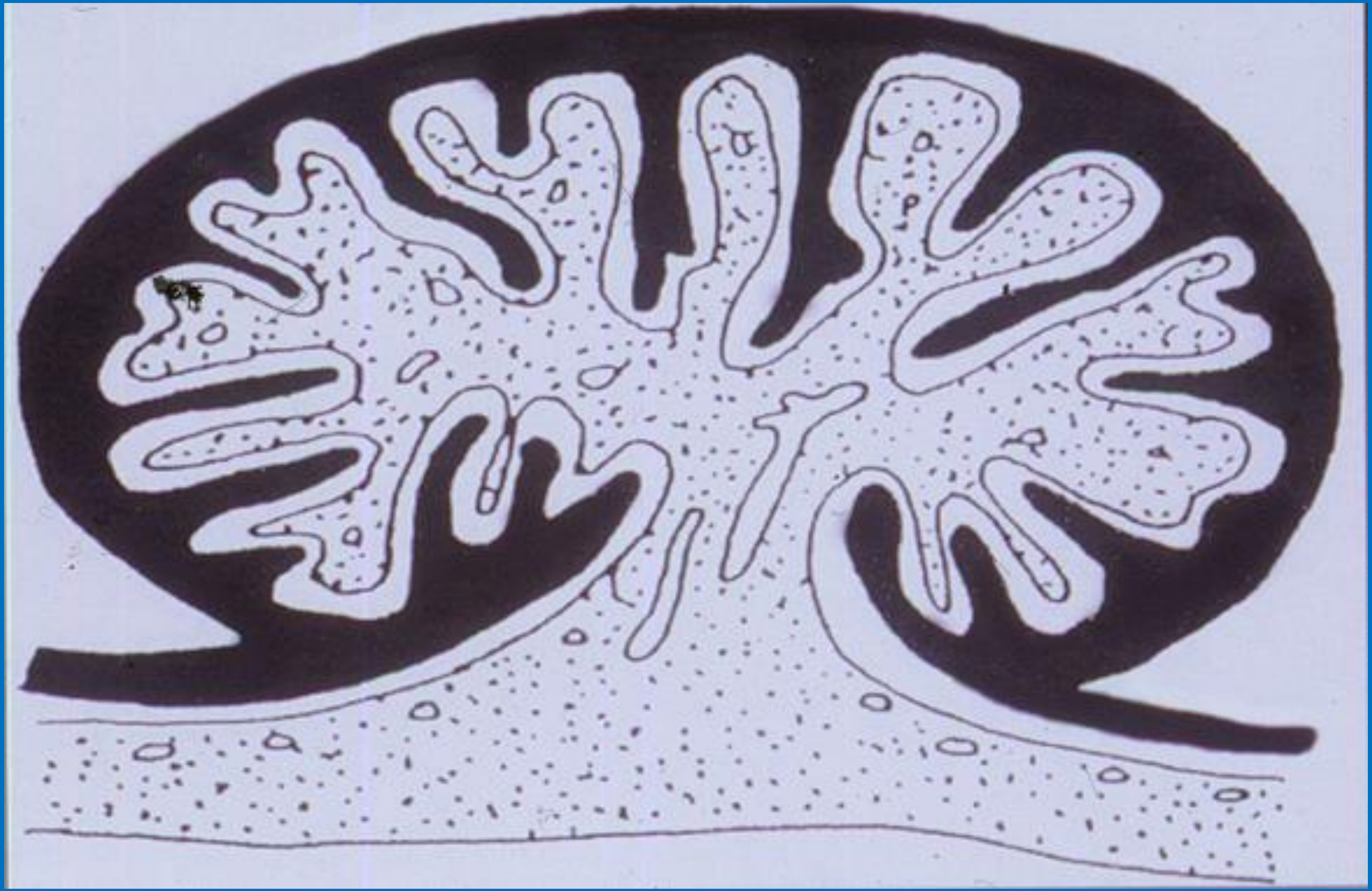


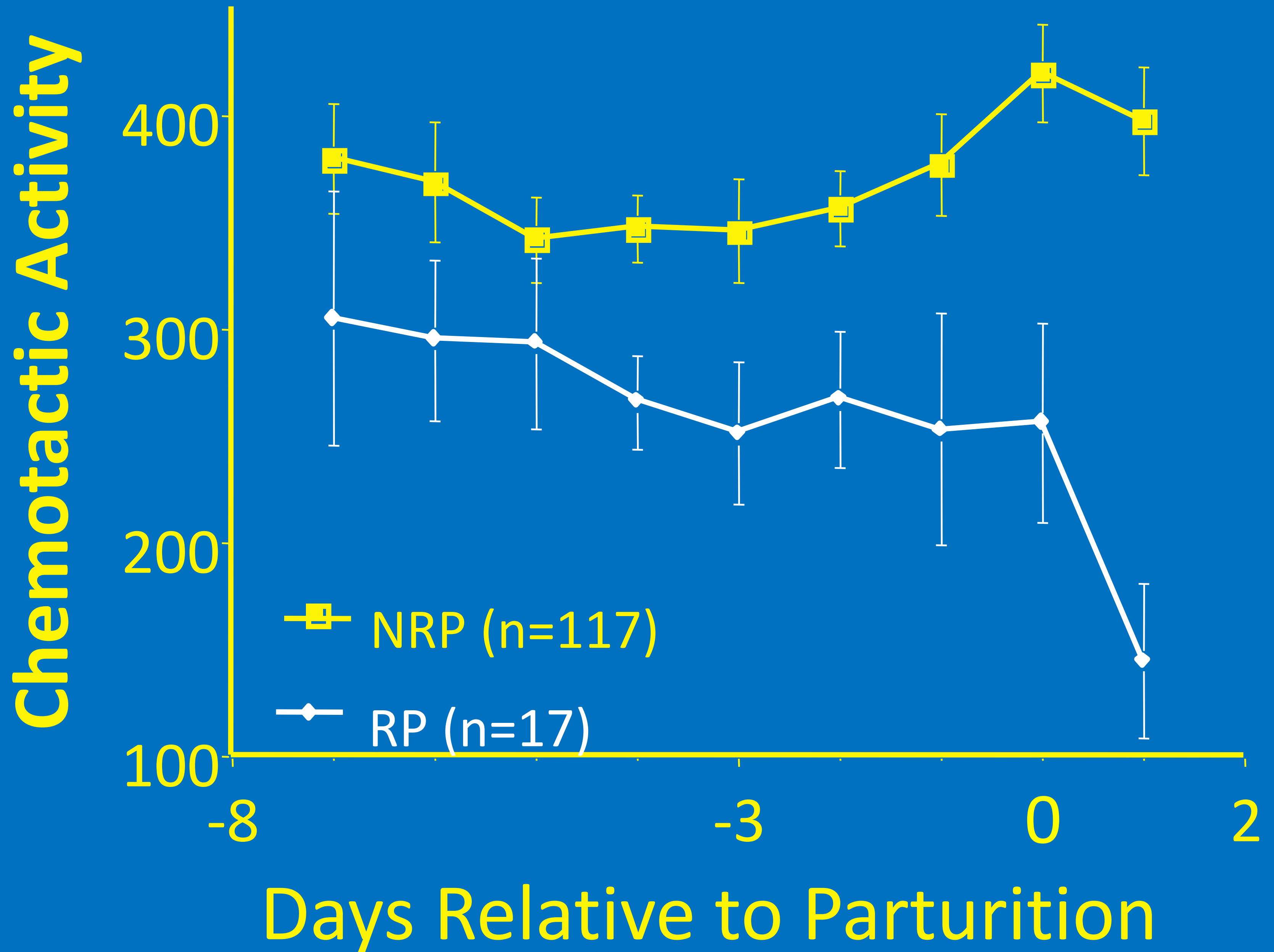
Detilleux et al., 1995

Immune Suppression and Retained Placenta

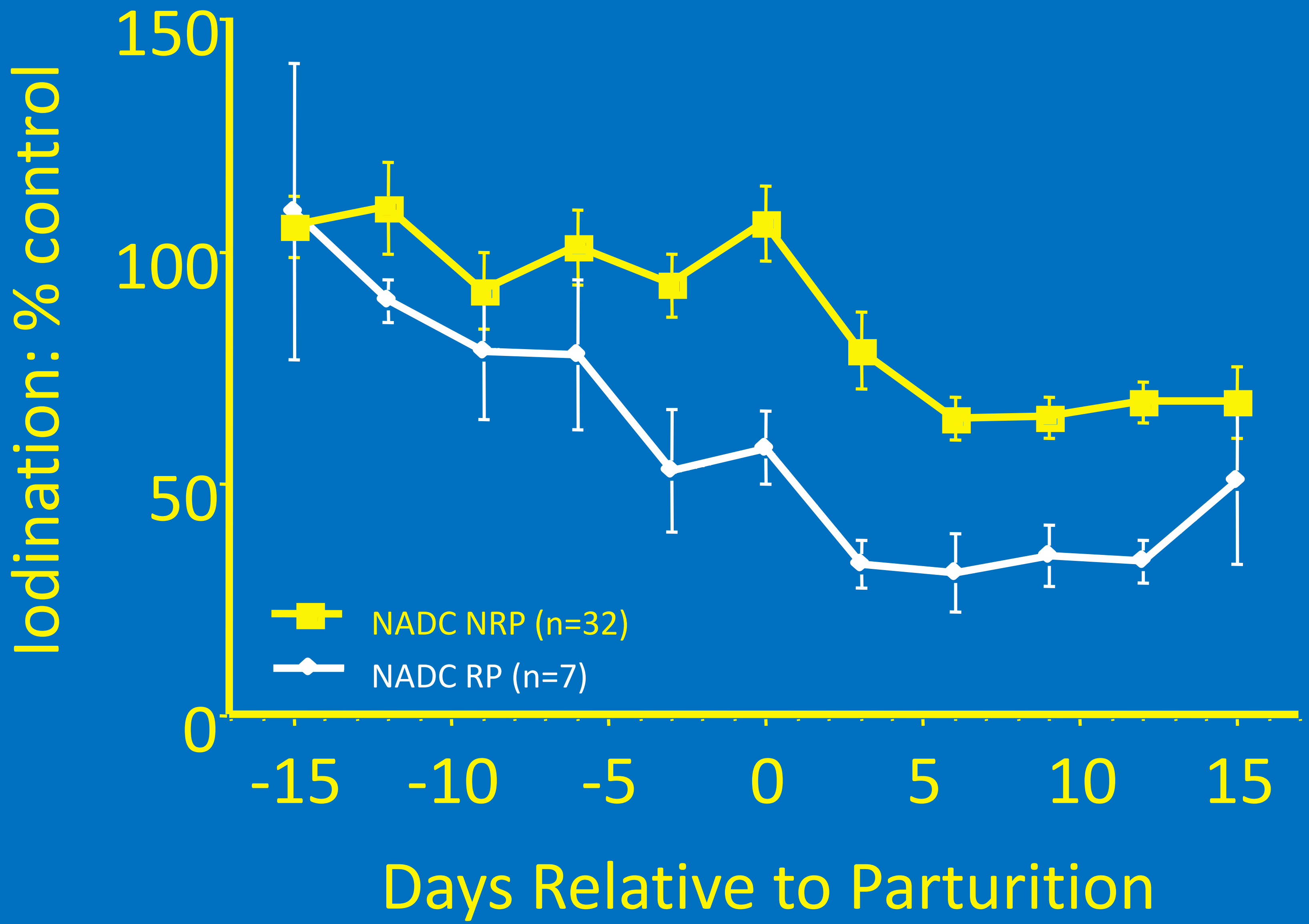
Gunnink, 1983, Vet Q J

Kimura et al., 2002 JDS





Kimura et al., 2002

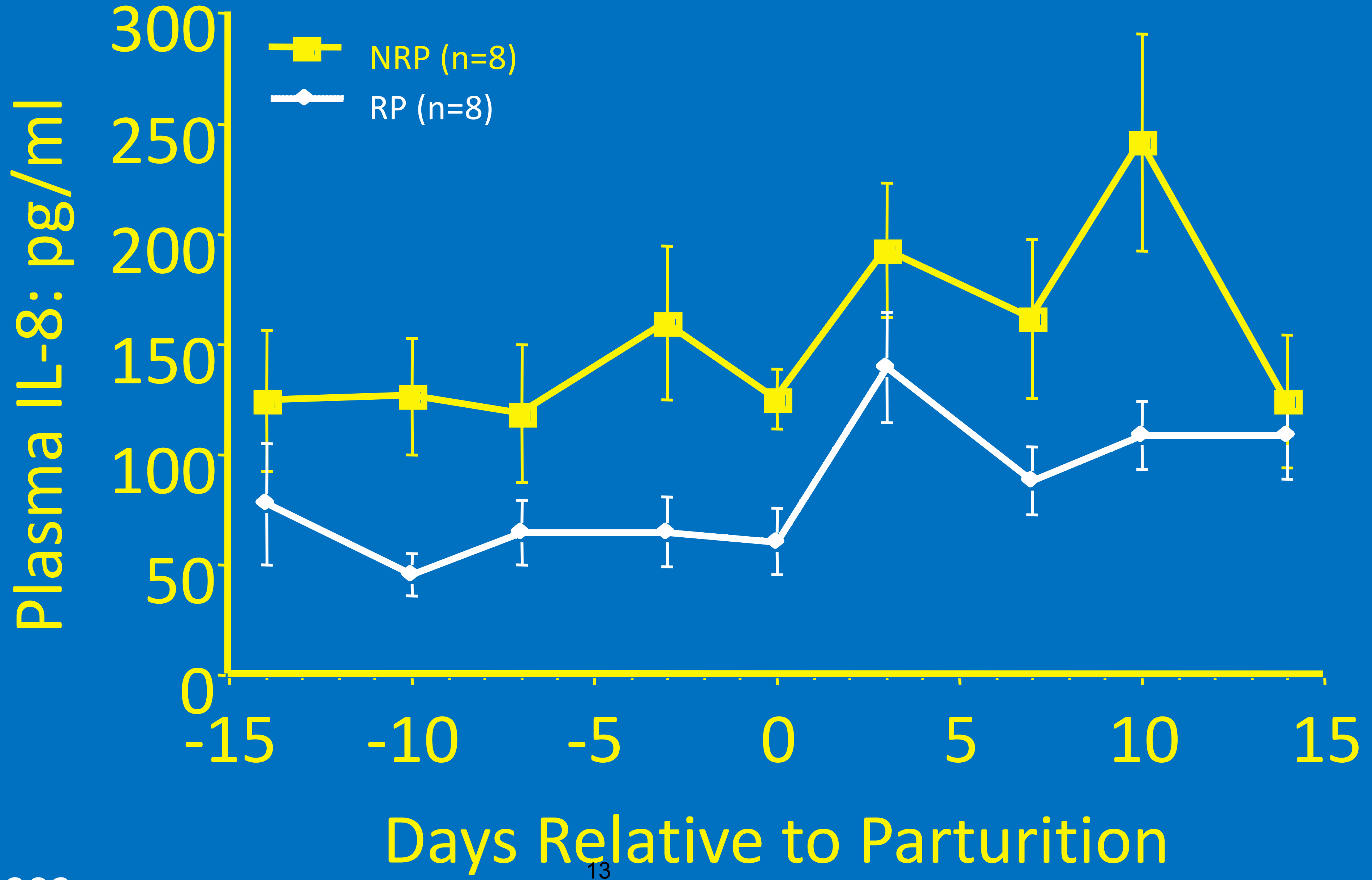


Iodination: % control
150
100
50
0
-15
-10
-5
0
5
10
15
Days Relative to Parturition
NADC NRP (n=32)
NADC RP (n=7)

Key Functions of IL-8

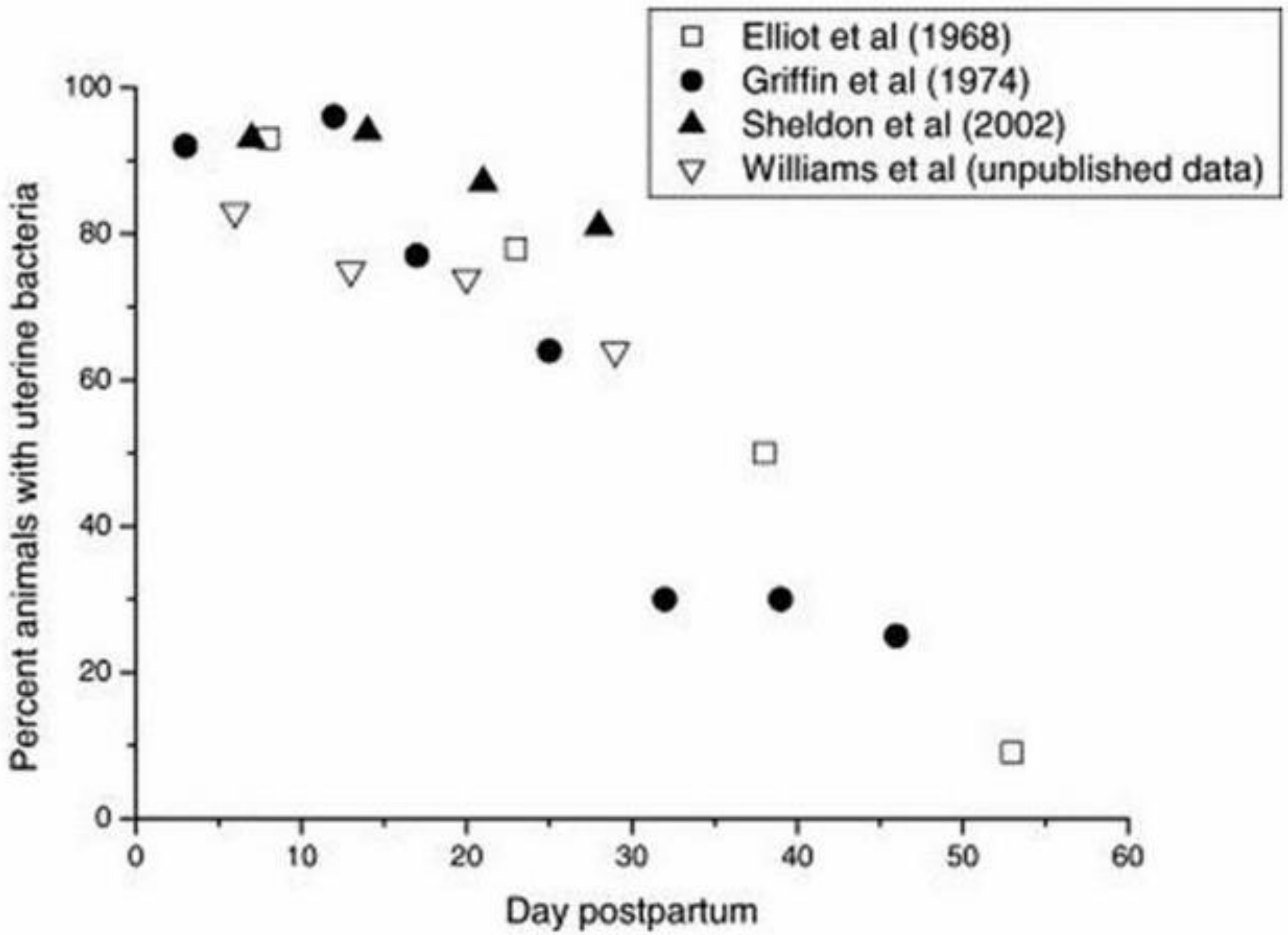
- **Neutrophil Chemotaxis & Recruitment:** IL-8 recruits neutrophils from the bloodstream to site of tissue damage or infection.
- **Neutrophil Activation:**
 IL-8 activates neutrophils to release enzymes, increase intracellular calcium, and produce reactive oxygen species (ROS) to kill microbes.
- **Angiogenesis:** It stimulates the growth of new blood vessels, aiding in tissue repair.
- **Immune Modulation:** Beyond neutrophils, IL-8 attracts lymphocytes and basophils to inflammation sites

Plasma IL-8 level is lower in RP cows.



Kimura et al., 2002

Figure 1. Percent of cows with positive bacterial culture by days postpartum.



Credit: Sheldon and Dobson (2004).

Sheldon, 2020. Theriogenology Review of Post partum Uterine Disease

Prior to the development of disease there is evidence that many of the *bacteria types are similar* in cows that will or will not develop metritis.

First 2 weeks

Endometrial pathogenic E.coli come to predominate in cows that will have uterine disease. Often co-infected with Fusobacterium necrophorum (stink!!) → metritis

Beyond 3 weeks

Trueperella pyogenes, often co-infected with Prevotella sp., comes to predominate → endometritis DX after 26 days

Immune Competent Cows

Large influx of neutrophils in response to first invading bacteria.

- intrauterine infusion of IL-8 reduced metritis from 34% to 10% (Zinicola et al., 2019 JDS)

Immune system overwhelms these invaders before they can become established.

Immune cells not depleted – so can attack each new invader that comes in before cervix closes

- Granulocyte colony stimulating factor increases size of neutrophil army to reduce mastitis (Ruiz et al 2017, Powell et al., 2018)

Energy and protein is needed to repair the endometrium after parturition and resist pathogens.
But this is at odds with metabolic demands of lactation [LeBlanc, 2012].

Cows in severe NEB at 2 wks post-partum develop endometritis; cows with mild NEB repair endometrium by 2 wks after parturition [Wathes, et al., 2009].

Reduced DMI before parturition predicts the development of metritis [Hammon et al., 2006; Huzzey et al., 2007].

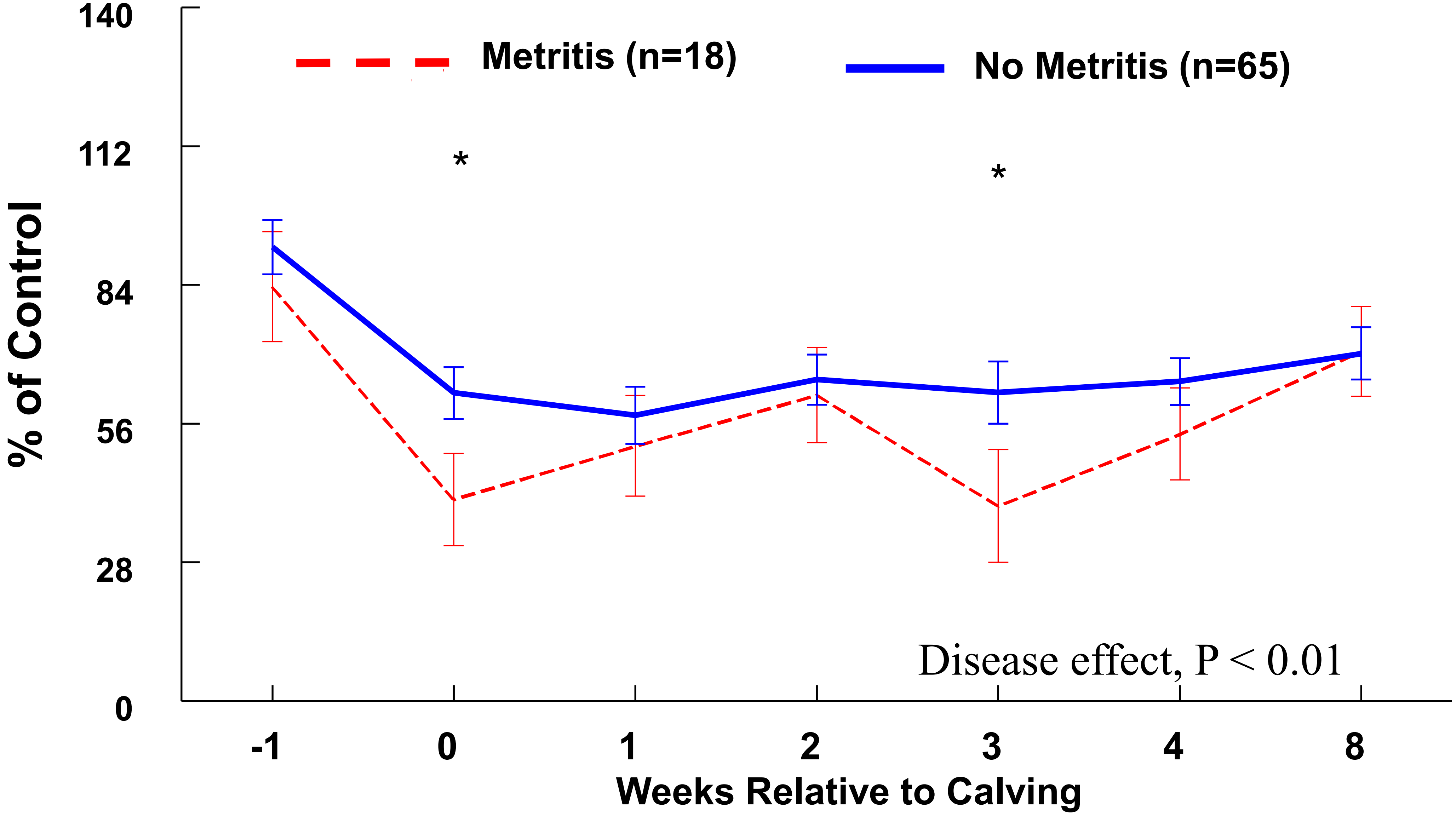
Deficiencies in glucose or glutamine blunt the inflammatory response in the endometrium [Turner et al., 2016; Noleto et al., 2017].

Activated Immune cells rely on glucose for energy and it is often in short supply (Kvidera et al., 2017).

Hammon et al., 2006

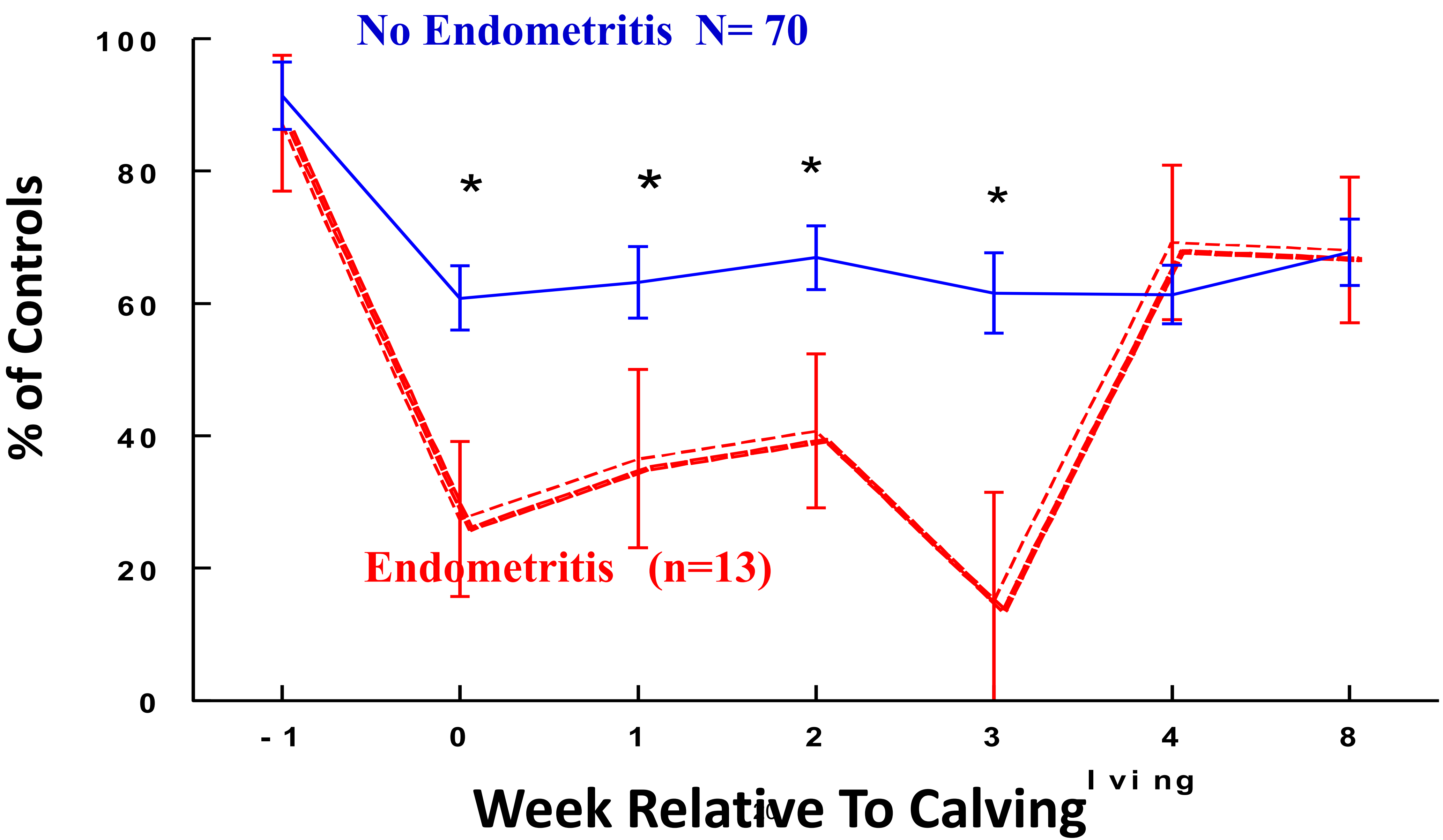
- **Studied 83 cows going thru calving period**
- **Blood samples weekly to assess neutrophil function**
- **Cows examined for metritis first ten days of lactation - foul smelling, watery, brown discharge with or without a fever**
- **Endometritis diagnosed at 28 days post calving based on uterine wash cytology**

Neutrophil Function (Iodination test) and Metritis

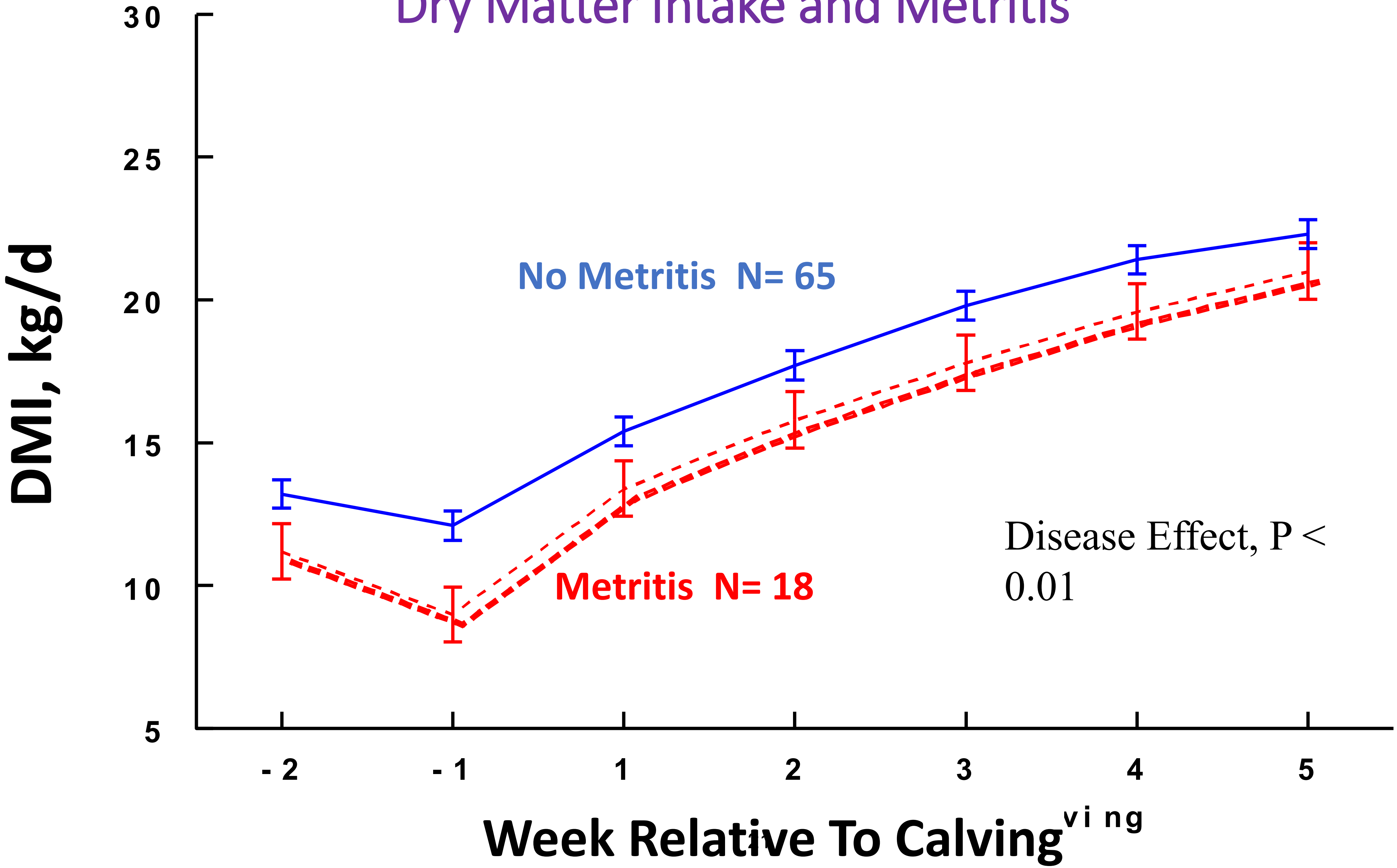


Metritis = fetid discharge or purulent discharge at 3 to 7 DIM with or without fever

Neutrophil Function (Iodination Test) and Endometritis



Dry Matter Intake and Metritis



Uterus exam findings in 19 milk fever cows vs 19 normal matched cows in same herds. Pairs examined at 15-45 days in milk. (Whiteford and Sheldon, 2005)

	Normal	Milk fever
# clinical endometritis	8	15
Diameter of gravid horn	31	49
Diameter of non-gravid	25	39
# animals with a CL	13	4

Hypocalcemia & Metritis Risk
Martinez et al., 2012

74 Cows and 36 heifers placed into high risk or low risk for metritis. "High risk" cows had experienced dystocia, retained placenta, twins or stillbirth.

Sub-clnical hypocalcemia (SCH) defined as Ca < 8.59 mg/dl during day 0, 1, 2

Low Risk Cows

Cows with SCH had more metritis (40.7%) than normocalcemic cows (14.3%).

High Risk Cows

Cows with SCH had more metritis (77.8%) than normocalcemic cows (20.0%).

Martinez et al., 2012

The relative risk of developing metritis decreased by 22% for every 1 mg/dL increase in serum Ca.

Martinez et al., 2012

Fresh Cow Mastitis

Smith et al., 1985
40% of coliform mastitis cases at freshening represent cases where the coliform was present in dry period secretions but held in check until shortly after calving when the infection becomes clinical disease

Burvenich et al., 1994
Incidence of all mastitis infections is highest in early lactation.
Coliform infections are the most common cause during this period.
Severe coliform infections are difficult to treat satisfactorily, especially in early lactation.

Shuster, Lee, and Kehrli, 1996

Six healthy Holstein cows 6-10 DIM were paired with 6 healthy Mid-Lactation cows

Each Pair was challenged with ~ 15 CFU E.coli Macdonald strain 487

One Periparturient cow became recumbent at 36 hrs after challenge and was euthanized when she failed to respond to treatment.

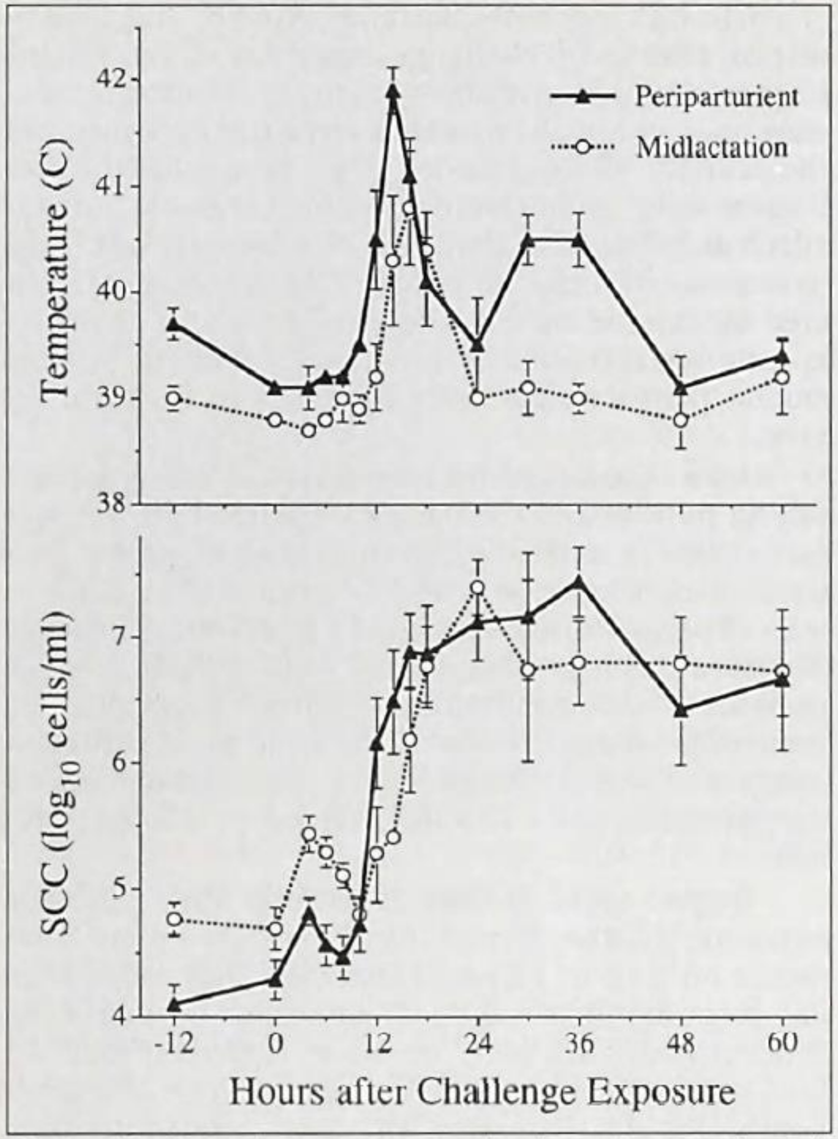


Figure 2—Rectal temperature (top) and somatic cell count (SCC; bottom) in foremilk of infected glands of periparturient and midlactation cows during *E coli* mastitis. One gland of each cow was inoculated with *E coli* at time = 0. *See* Figure 1 for key.

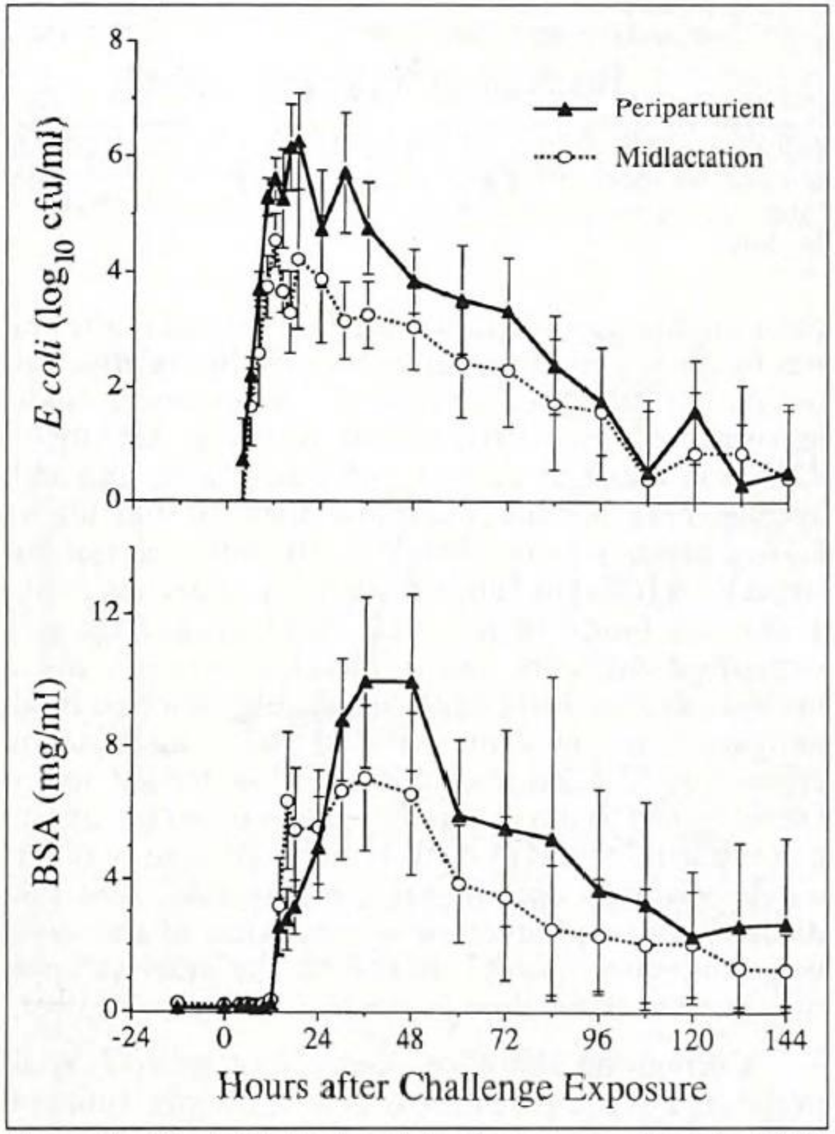
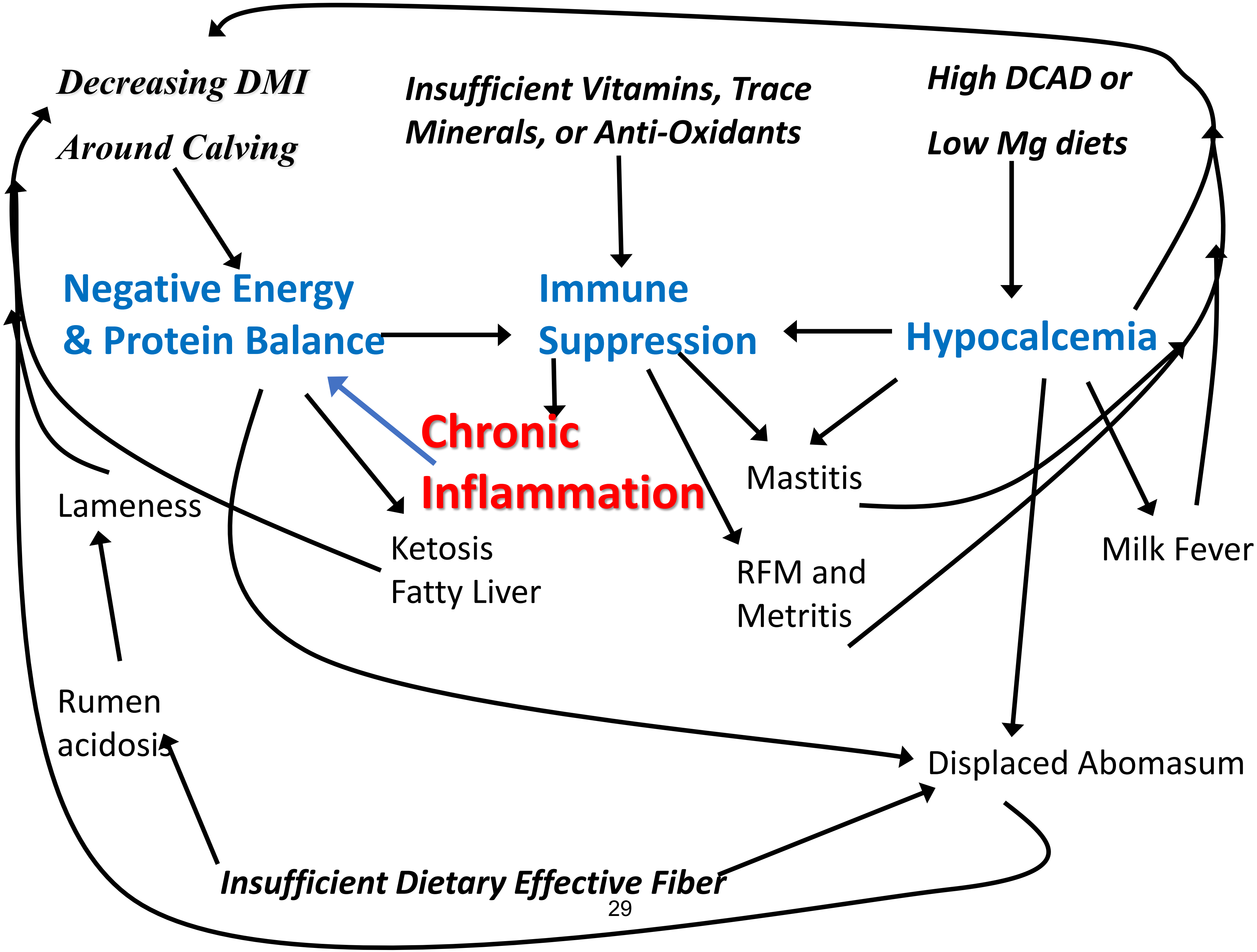


Figure 1—Bacterial (top) and bovine serum albumin (BSA; bottom) concentrations in foremilk samples of periparturient and midlactation cows after *Escherichia coli* challenge exposure of 1 mammary gland in each cow at time = 0. Data are the mean ± SEM of 6 cows/stage of lactation group.

Shuster, Lee, and Kehrli, 1996



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Fatty Liver
RFM and
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acidosis
Displaced Abomasum
Insufficient Dietary Effective Fiber

Effect of vitamin E on Mastitis Cases

Vitamin E dose

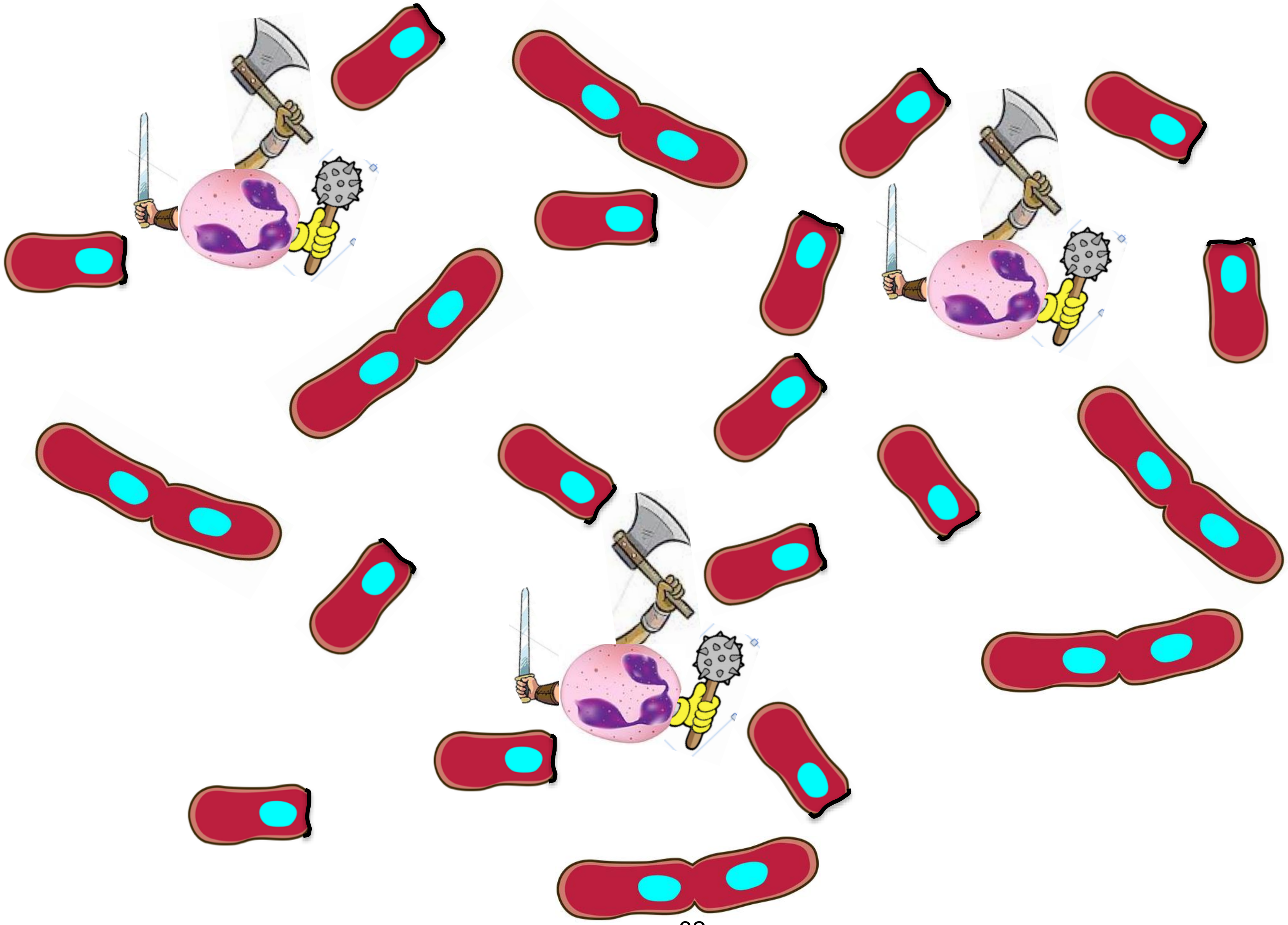
Dry period	lactation	mastitis (%)
100 IU	100 IU	26
1000 IU	500 IU	17
4000 IU	2000 IU	3 *

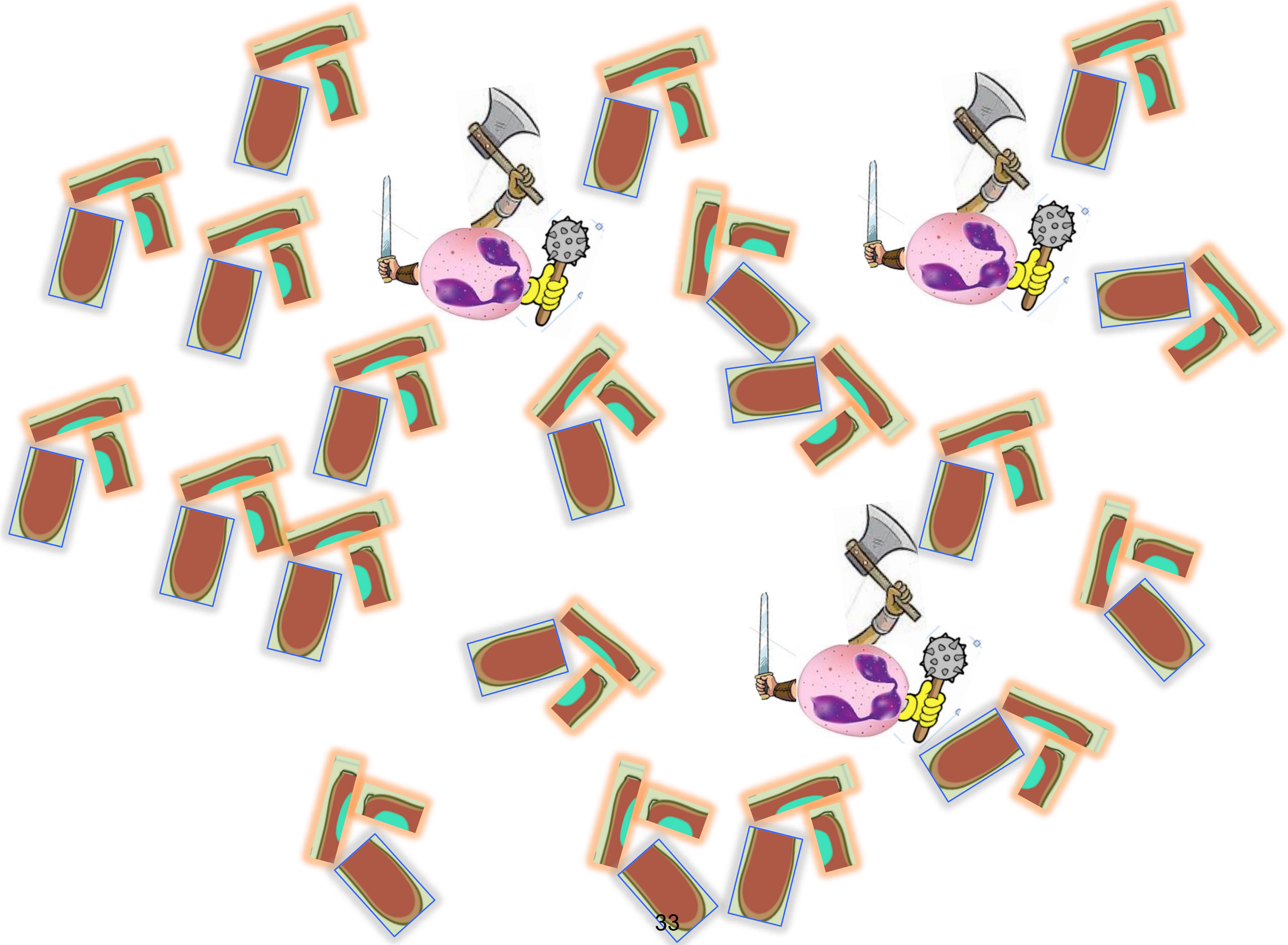
Diet selenium was 0.1 ppm

Weiss et al., 1997

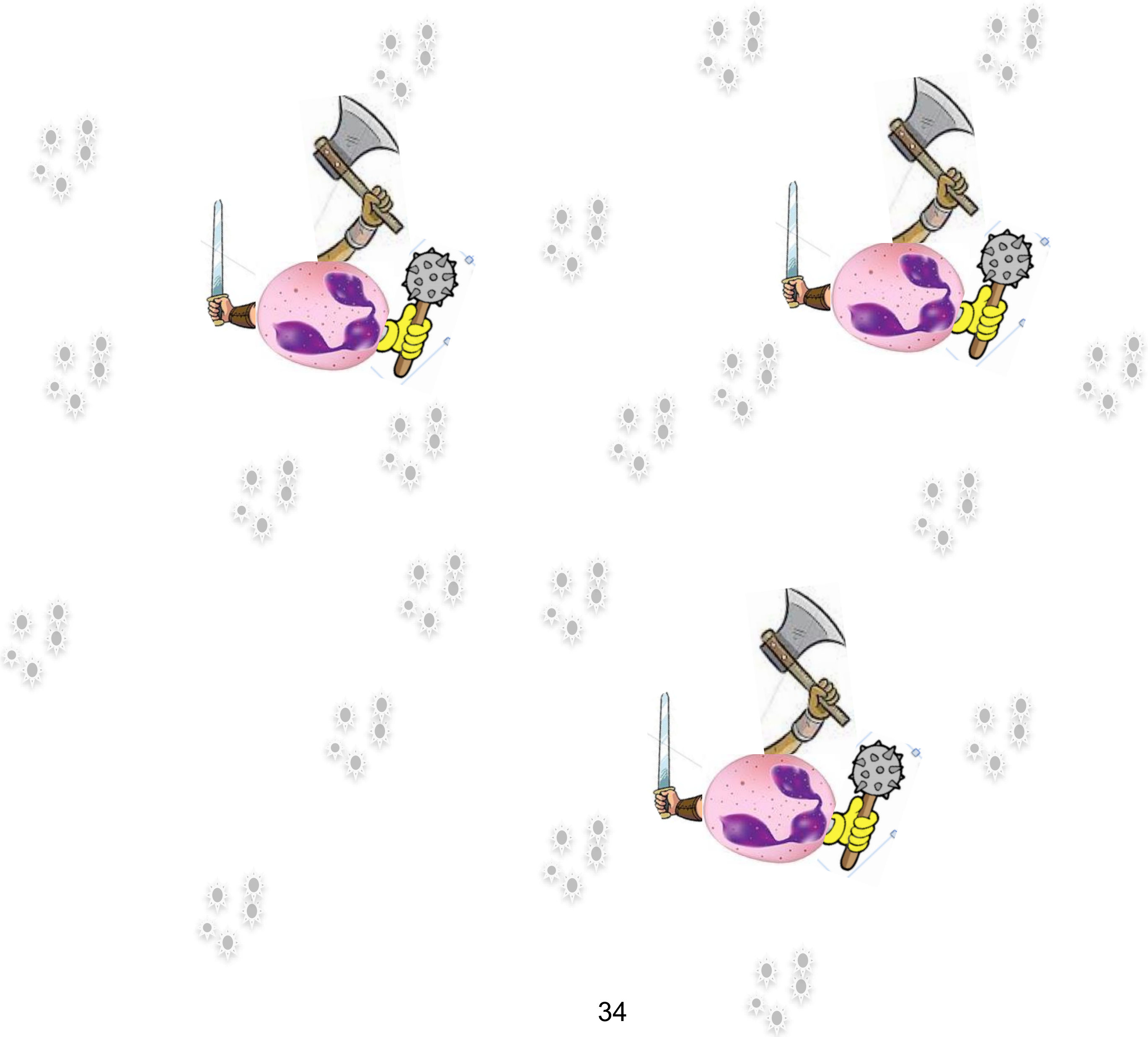
Bacterial Infection

STRONG IMMUNE SYSTEM



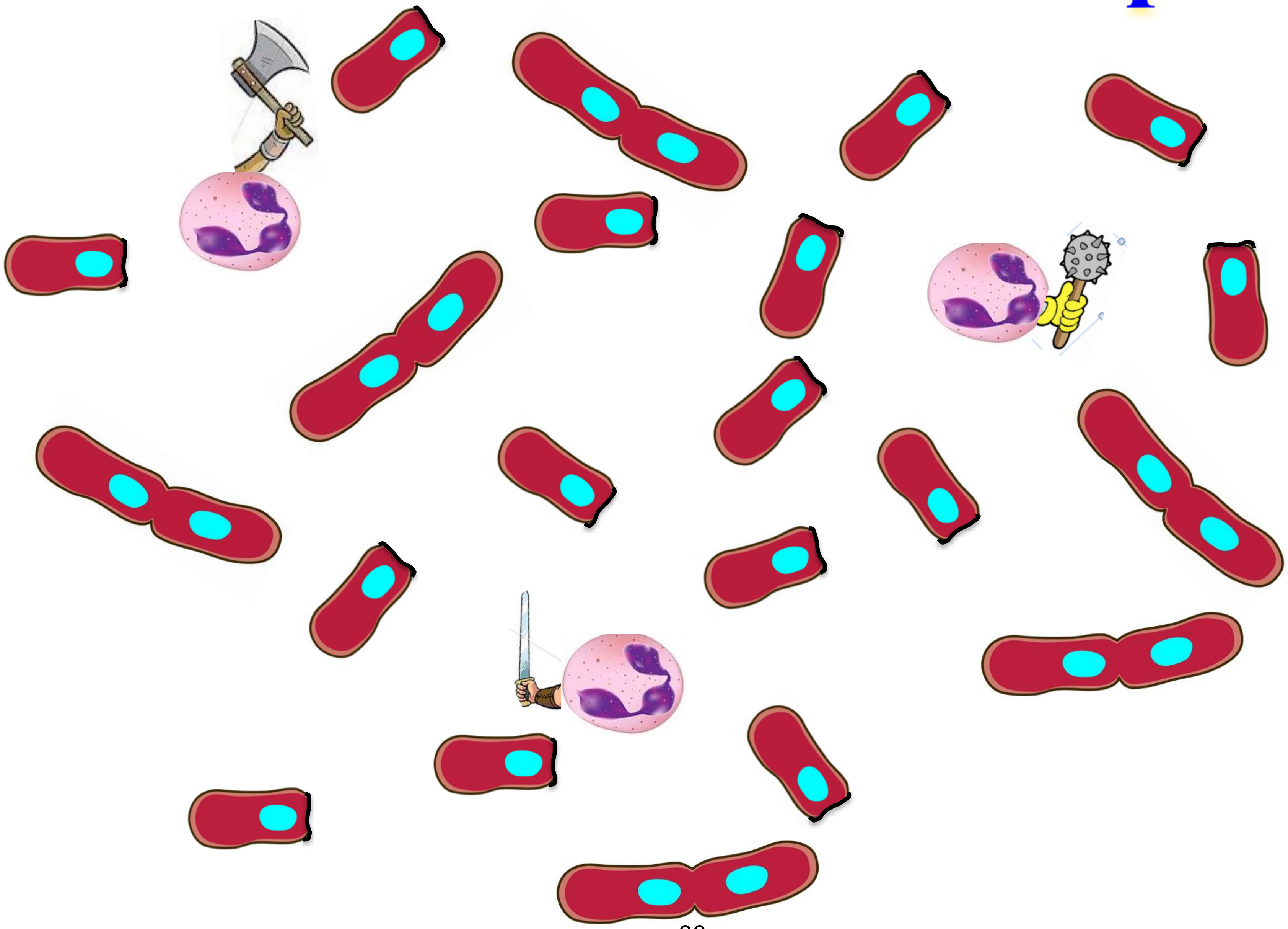


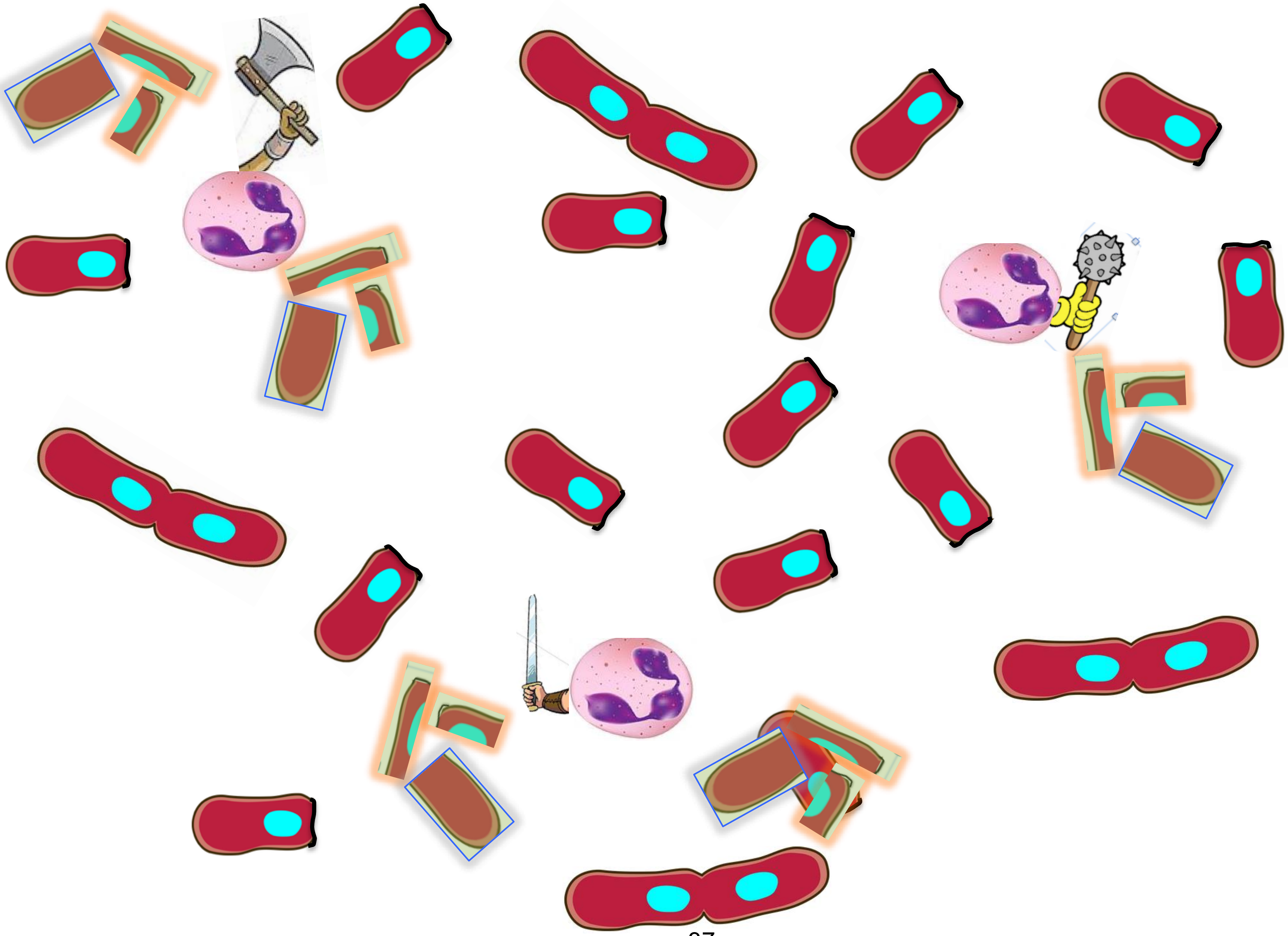
Infection Cleared

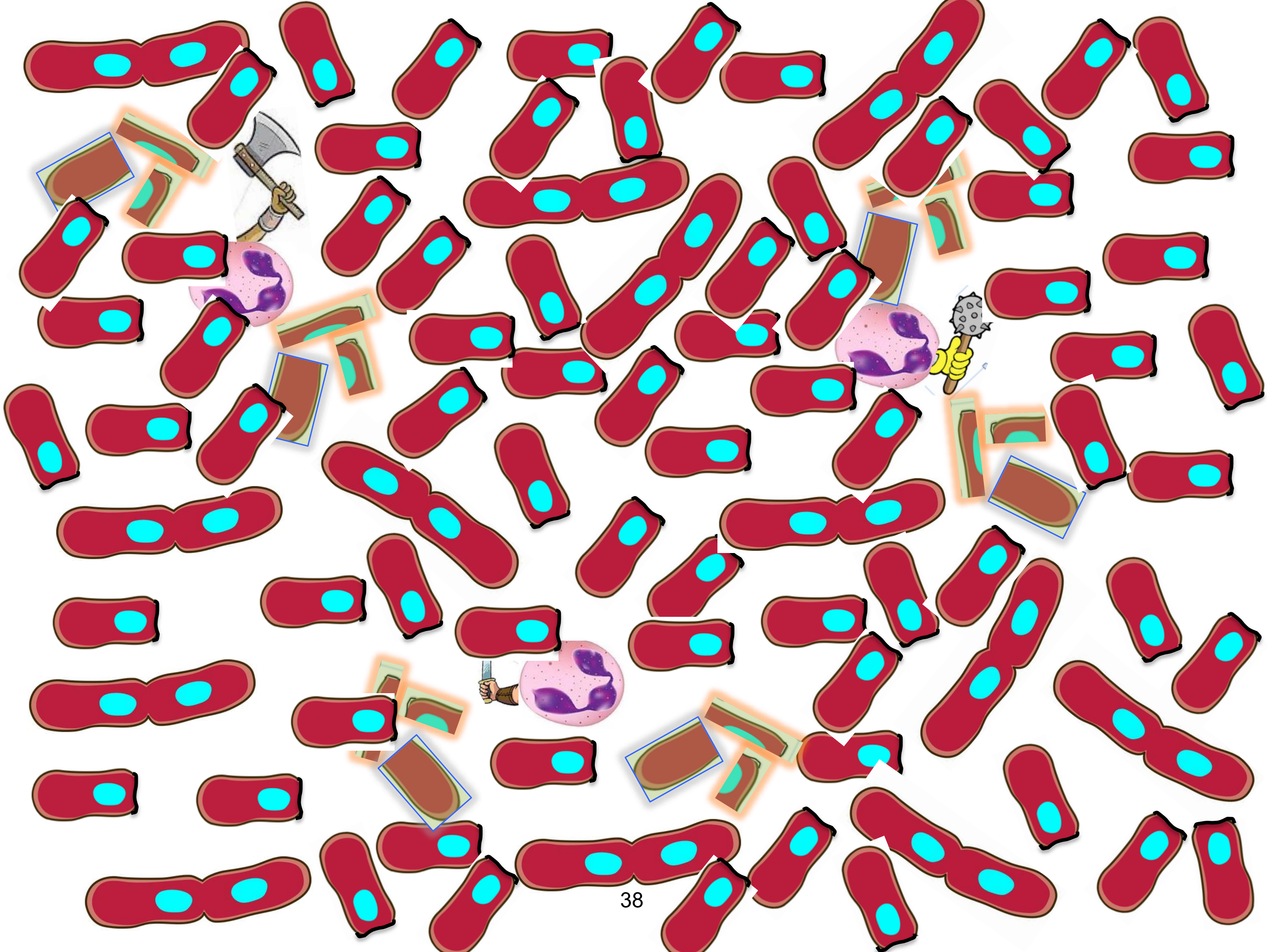


Bacterial Infection

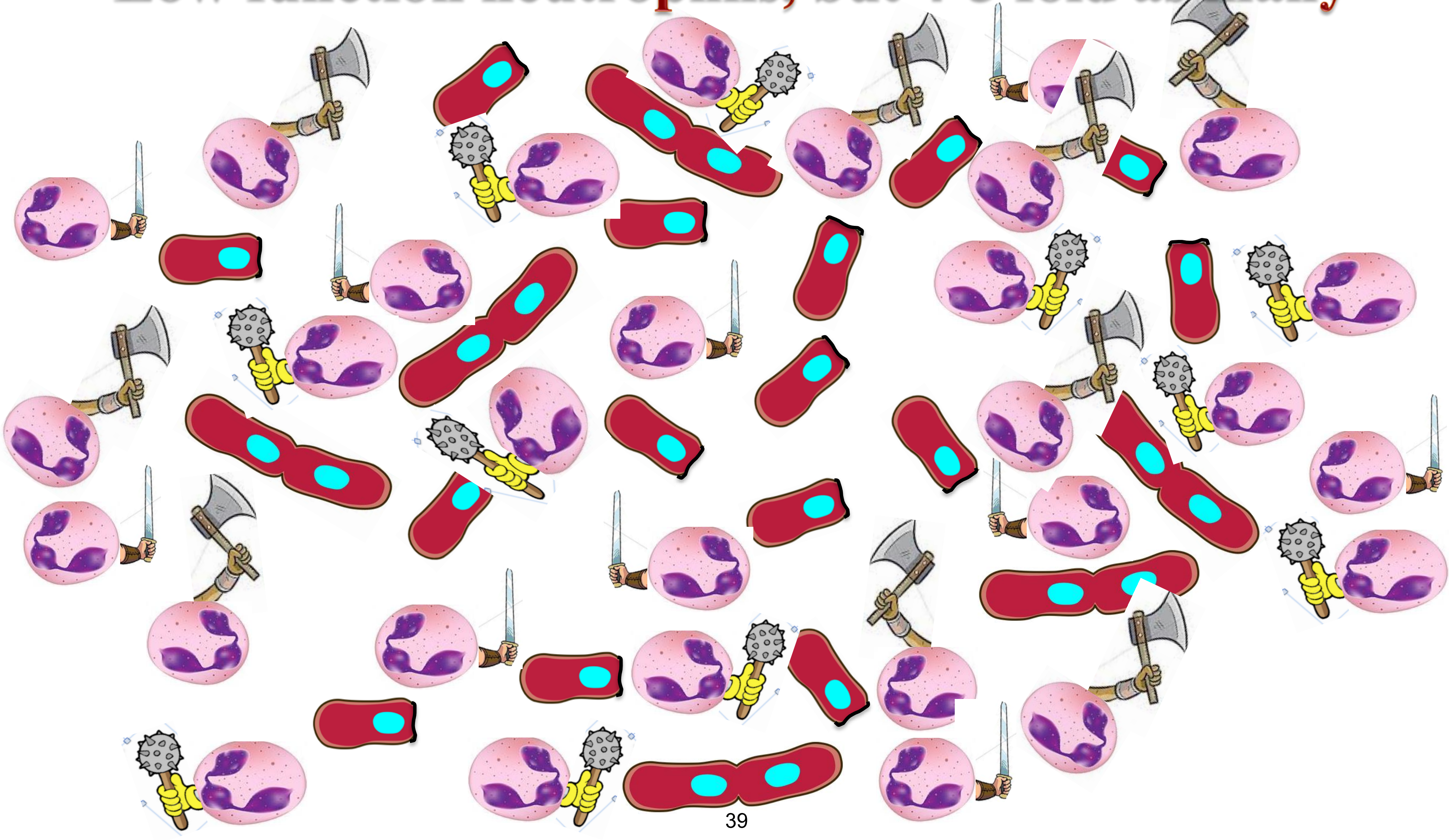
Less Functional Neutrophils







Low function neutrophils, but 4-5 fold as many



Low function neutrophils, but 4-5 fold as many

Infection Cleared Eventually!?

BUT …. DURING CHRONIC INFLAMMATION THE COW EXPERIENCES

DECREASED DMI

- MORE KETOSIS/ FATTY LIVER
- LESS RUMEN FILL= LESS ABOMASAL CONTRACTION
- LESS PROTEIN INTAKE → MORE MUSCLE LOSS

GREATER # BACTERIA TO KILL → MORE ENDOTOXINS

- AFFECTS LIVER FUNCTION
- INCREASED FATTY ACIDS RELEASE FROM ADIPOSE
- LOW GRADE HYPOCALCEMIA
- DECREASED INSULIN SENSITIVITY
- REDUCED BLOOD TO HOOF →MORE LAMENESS

TISSUE DAMAGE DURING MASTITIS OR METRITIS

- GREATER DAYS OPEN
- LESS MILK PRODUCTION

Anti-Inflammatory drugs for fresh cows

NSAIDS given shortly after calving may improve milk production and reduce culling of cows

Timing of administration?

How long to treat?

Which drugs are legal to use in fresh cows??

Possible negative effects???

Study	NSAID	Start	Duration	Milk Production	OTHER
Trevisi & Bertoni 2008	Aspirin IV	Day 1	5 days	13% increase, p<0.05	
Farney et al., 2013	Salicylate in water	Day 1	7days	Primiparous down 8%, p=0.08 2nd lact – no effect 3 + lact – up 21%, p<0.01	
Carpenter et al., 2016	Meloxicam Salicylate	12-36 hrs	3days	Multiparous - up with both NSAIDS	
Shock et al., 2018	Meloxicam	Day 1	Once	Multiparous up , p=0.03	Lower risk of being culled OR= 0.46
Schmitt et al., 2023	TD Flunixen meglumine	24-36 hr	Once	Primiparous up , p =0.08 Multiparous down , p <0.01	Tendency to reduce culling risk
Barragan et al., 2020	Aspirin bolus	3-5 days	Every 12 hr for 4 trts	Increased 1.8 kg/d	Culling, health, not Improved
Barragan et al., 2020b	Aspirin bolus	<12 h	2nd dose 12 hr	Increased 1.6 kg/d	
Newby et al., 2017	Flunixen meglumine	At calving	2 doses	decreased milk by 1.6 kg/day for first 14 days	Increased RP and metritis, still birth
Shwartz et al., 2019	Flunixen meglumine	Day 1	3 days	No effects	
Carpenter et al., 2018	Salicylate	12-36 hr	3 days	Multiparous – no effect	

Negative Energy & Protein Balance

What is the problem?

What are we trying to do with dry cow diets?

What are we trying to do with fresh cow diets?

Lactation & Energy Sources

- Humans and rats – adjust by consuming more diet; little mobilization of body fat
- Seals, whales – don’t eat at all so 100% reliant on body reserves!!
- **Cow = intermediate!!**

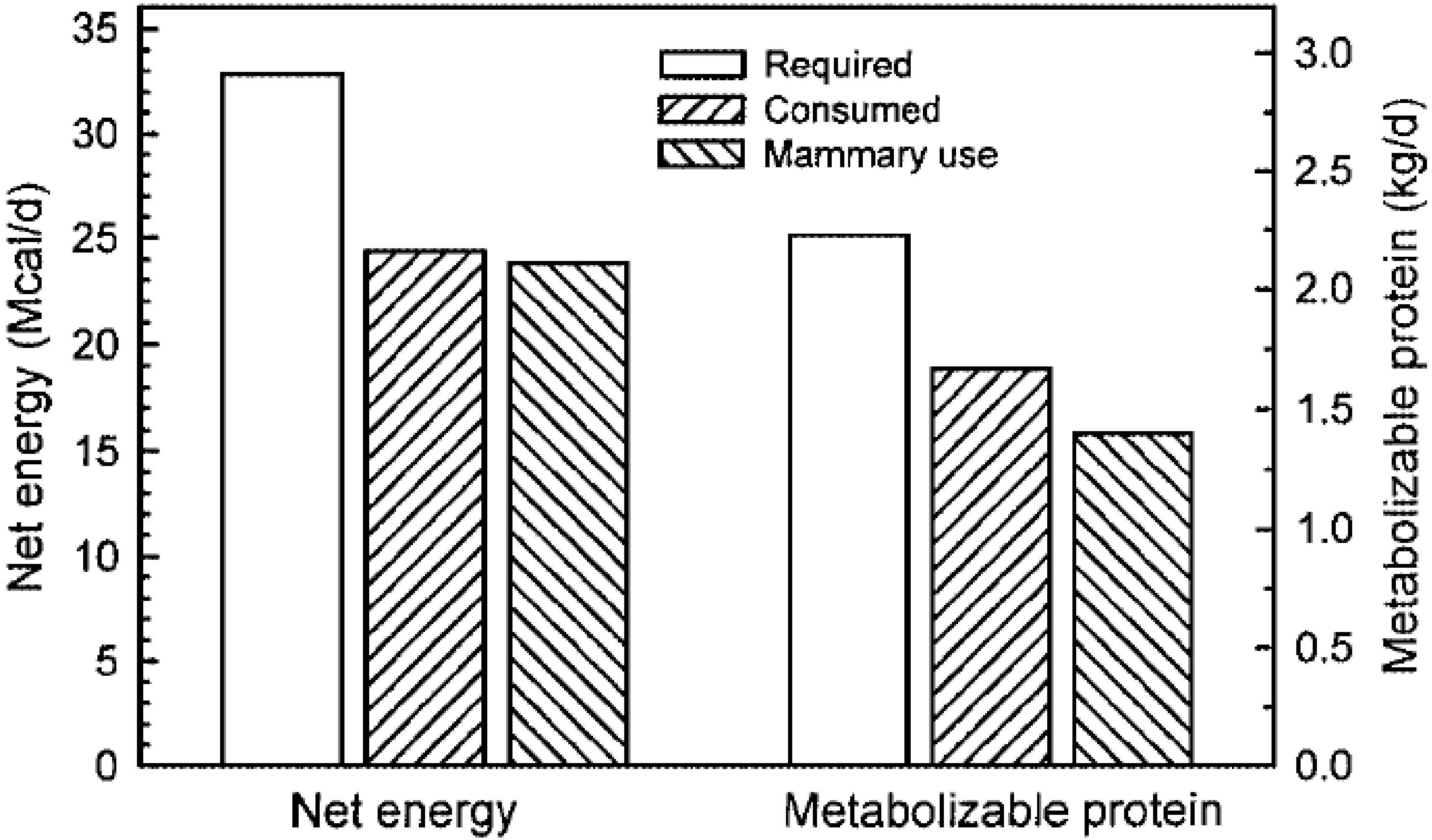


Figure 1. Calculations of amounts of NE_L and metabolizable protein required, consumed, and utilized by lactating mammary gland of healthy dairy cows at 4 d postpartum. Adapted from Bell (11).

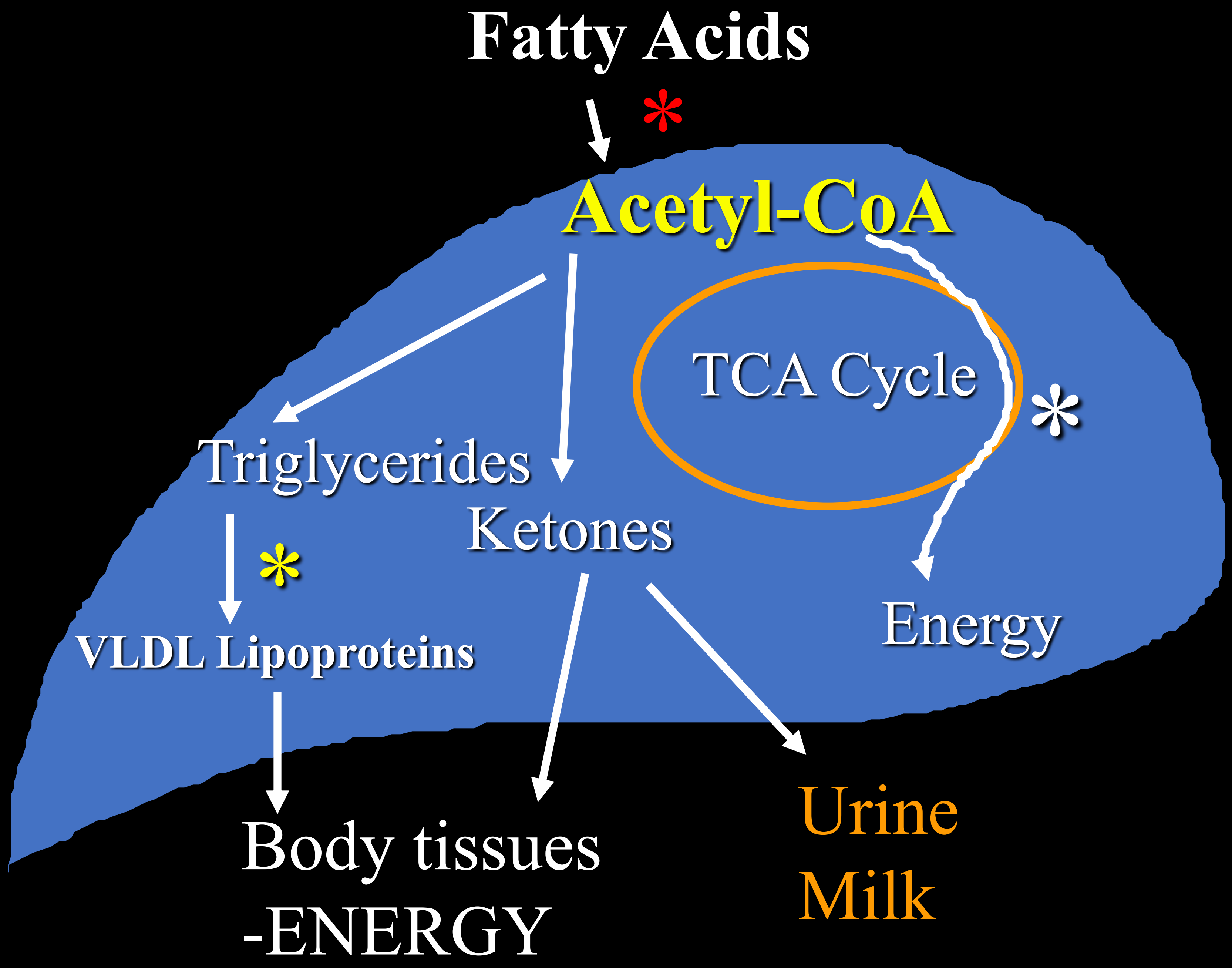
Energy balance

Nadir reached at 10-18 DIM

(Beam & Butler, 1998)

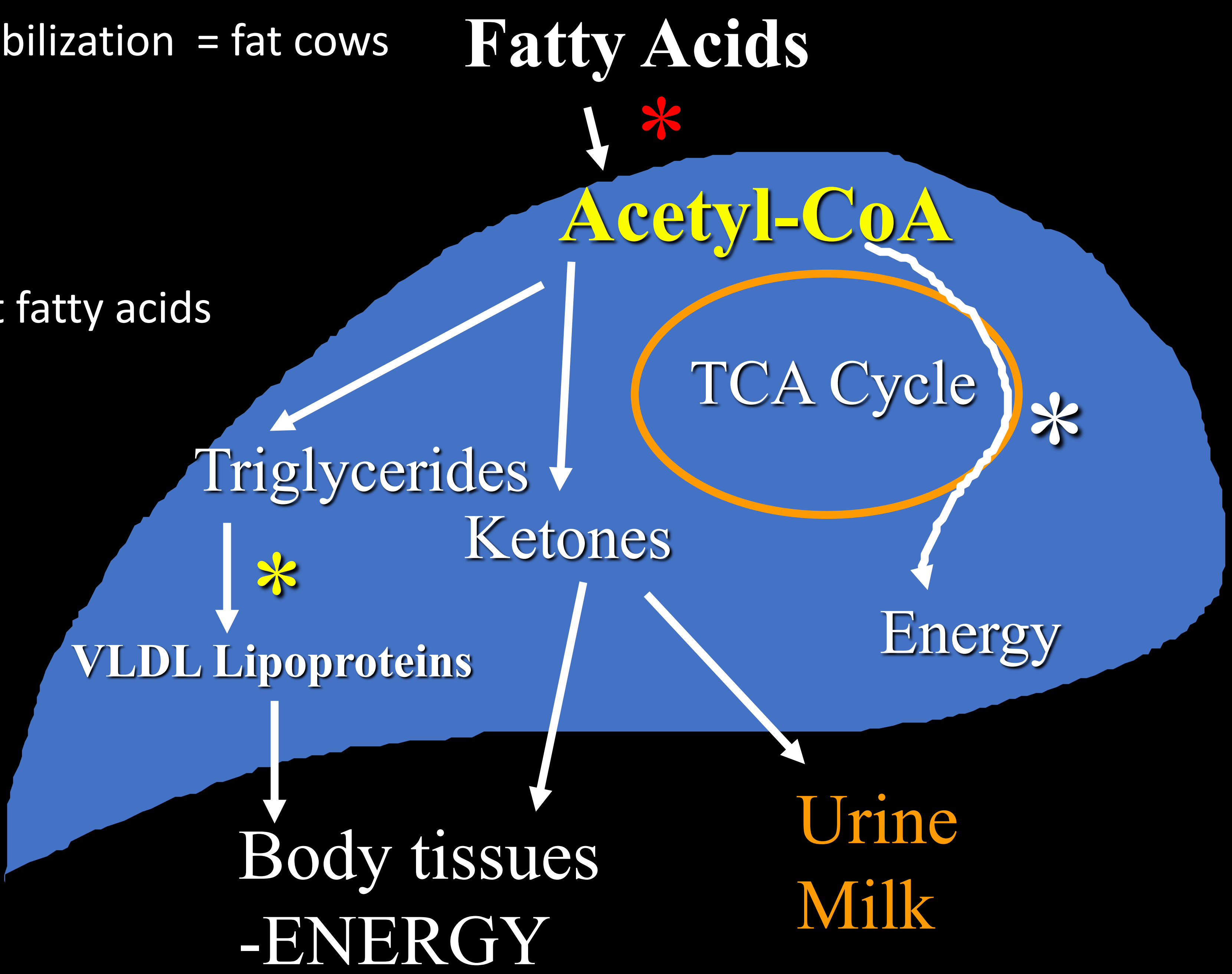
Positive balance reached around 45 days

(Grummer & Rastani, 2003)


Fatty Acids
*
Acetyl-CoA
TCA Cycle
*
Triglycerides
Ketones
*
VLDL Lipoproteins
Energy
Body tissues
-ENERGY
Urine
Milk

* Excessive Fat mobilization = fat cows

* Failure to export fatty acids
= Fatty Liver



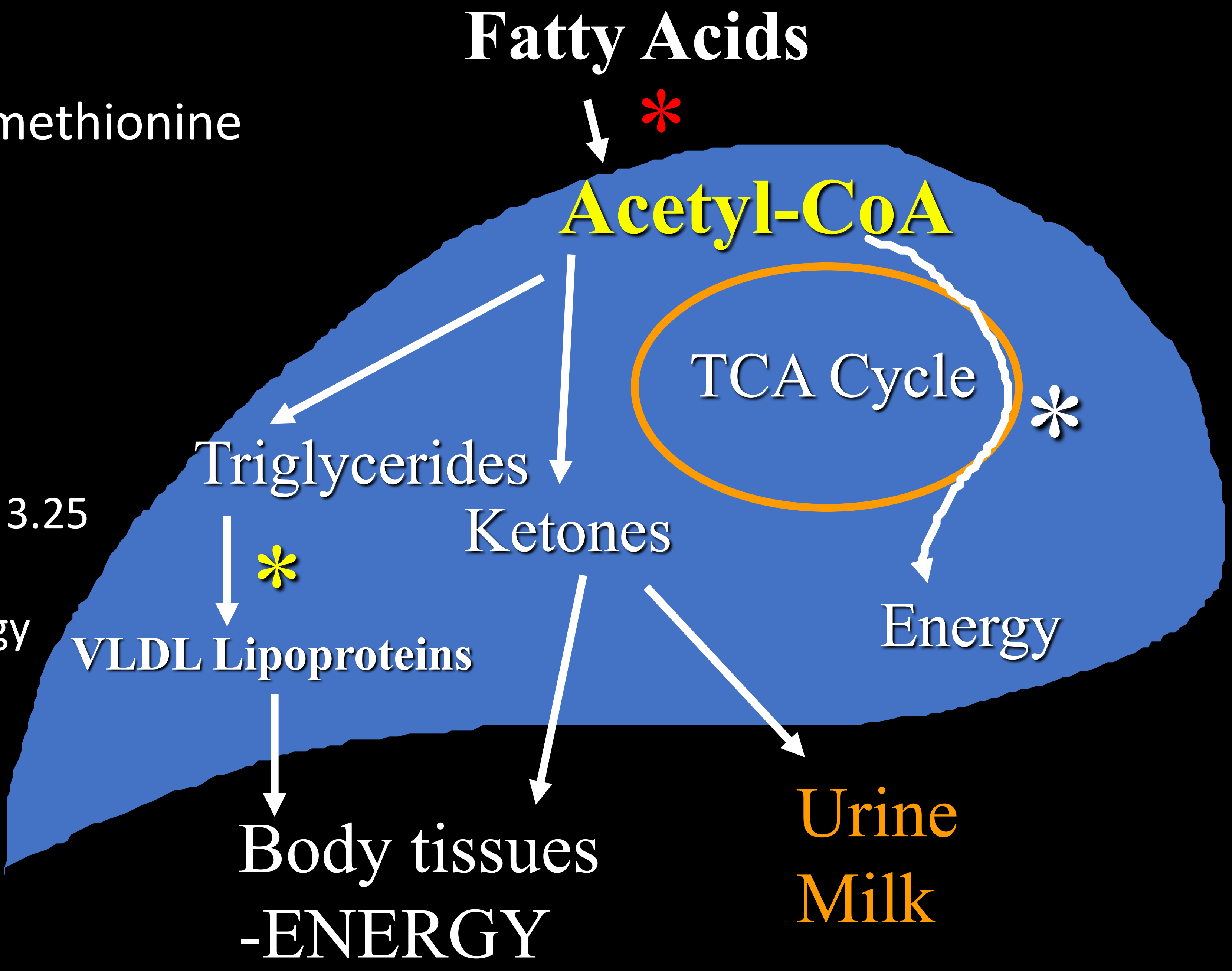
* Choline and methionine

* Niacin

* Thin cows BCS < 3.25

Controlled energy close-up diets

Higher protein Fresh cow diets



Why won't fresh cows that are desperate for energy and protein eat??

Hepatic Oxidation Theory – Mike Allen, Michigan State

Fats released from body stores are oxidized in liver to produce energy to support production of glucose and amino acids needed for lactation.

But during this process ATP (energy) builds up in liver.

Nerves within the liver interpret the high ATP levels as a liver that has plenty of energy and sends signals to the brain that the liver is full and to STOP EATING!!

“HIGH STRAW” Diets Pre-Partum

Adequate ENERGY diets have .58 - .62 Mcal NE/lb

Based on straw or other mature forage and some corn silage.

Once farms figure out how to chop into mixer these diets are generally *easier to manage* on the farm

Intake of 26-34 lbs /day (mature cows) providing 15 Mcal NE or more per day!

MUST increase metabolizable protein above 1200 g / day.

Heifer diet about 15% protein

Multiparous cow diet about 12% protein with some RUP.

Keep body condition scores 3.25 or below!!

Fat leaving body stores too quickly, especially before calving, reduces dry matter intake.

But if body condition score falls below 2.75, the cow may not have the energy needed for peak milk production.

Keep body condition scores 3.25 or below!!

Fat leaving body stores too quickly reduces dry matter intake.

But if body condition score falls below 2.75, the cow may not have the energy needed for peak milk production.

HOW???

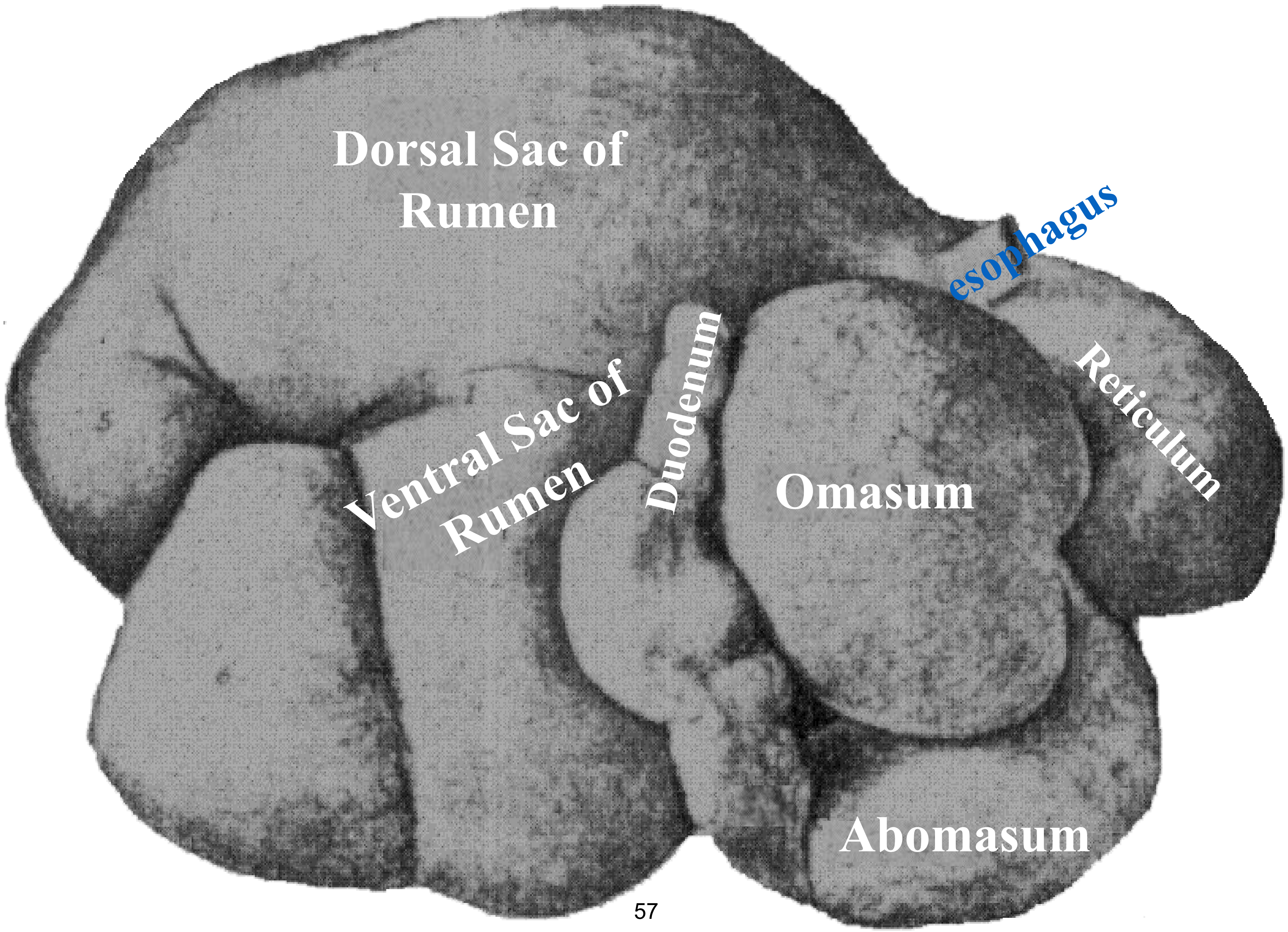
Get aggressive with breeding. Start thinking of designating DNB if still open by day 140 in milk.

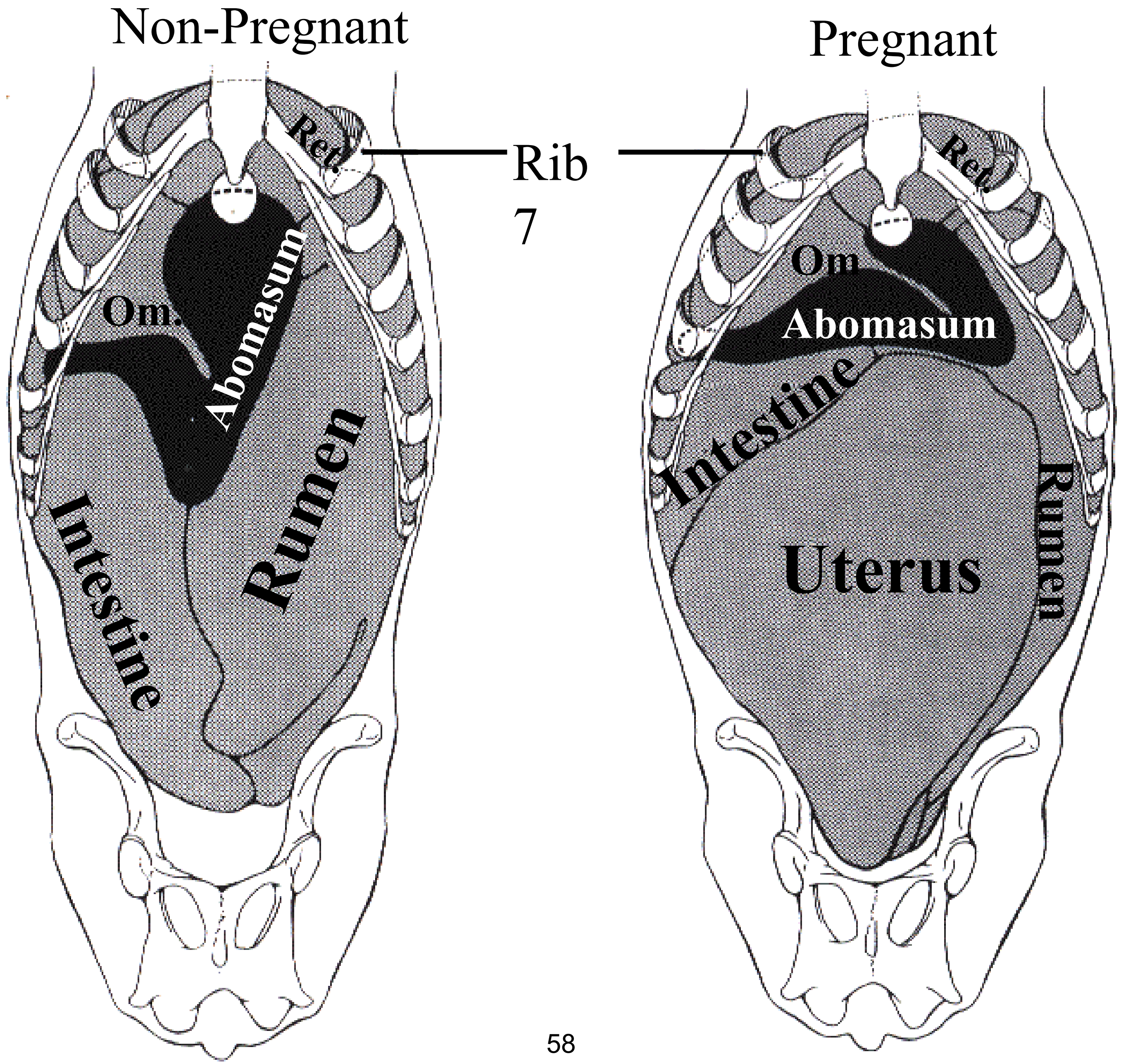
- sexed semen brings in good heifers.
- SYNCH programs have raised preg rate from 17-20% being good in 1990 to 26-30 found on many farms today.
- Price of beef!

Displacement of the abomasum

Etiology

1. Anatomical
   - "normal" vs pregnant position
   - vacuum left after calving
2. Physiological
   - abomasal atony prevents gas expulsion leading to distension and displacement.
     - hypocalcemia
     - high grain feeding around calving
     - loss of rumen "raft"


Dorsal Sac of
Rumen
esophagus
Ventral Sac of
Rumen
Duodenum
Reticulum
Omasum
Abomasum


Non-Pregnant
Pregnant
Rib
7
Ret.
Abomasum
Om.
Intestine
Rumen
Ret.
Om
Abomasum
Intestine
Uterus
Rumen

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      -loss of rumen "raft"

Chewing activity elicited by straw vs long hays.

Feed stuff	NDF	Min/Kg DM	Min/Kg NDF
Ryegrass-1	48	53	111
Alfalfa	49	61	125
Ryegrass-2	65	90	139
Ryegrass-3	68	104	152
Oat straw	79	143	195

From Mertens JDS 80: 1463, 1997

Displaced abomasum-hypocalcemia

Daniel (1983) reported a linear relationship between Plasma Ca concentration and the rate and strength of rumen and abomasal contractions.

	Plasma Ca	amplitude	rate/min
abomasum	10.4 ± .84	31.7 ±13	2.26 ± .69
	4.8 ± 1.0	16.5 ± 1	.62 ± .80
rumen	10.0 ± .88	14.7 ± 2.6	1.13 ± .31
	5.2 ± .92	8.9 ± 1.9	0.59 ± .17


No More Milk Fever!!!

Effects of # days in close-up pen

’

↑ **Milk 195 lb for each day cows were in close-up pen up to day 18.**
Robinson and Moorby, Hoard’s Dairymen , March 2001

↑ **Milk 261 lb for each day heifers were in close-up pen up to day 28.**
Robinson and Moorby, Hoard’s Dairymen , March 2001

Cows calving within 9 days of a pen move had 6 fold increase in becoming ill from a metabolic disease.

Corbett R. AABP, 2007

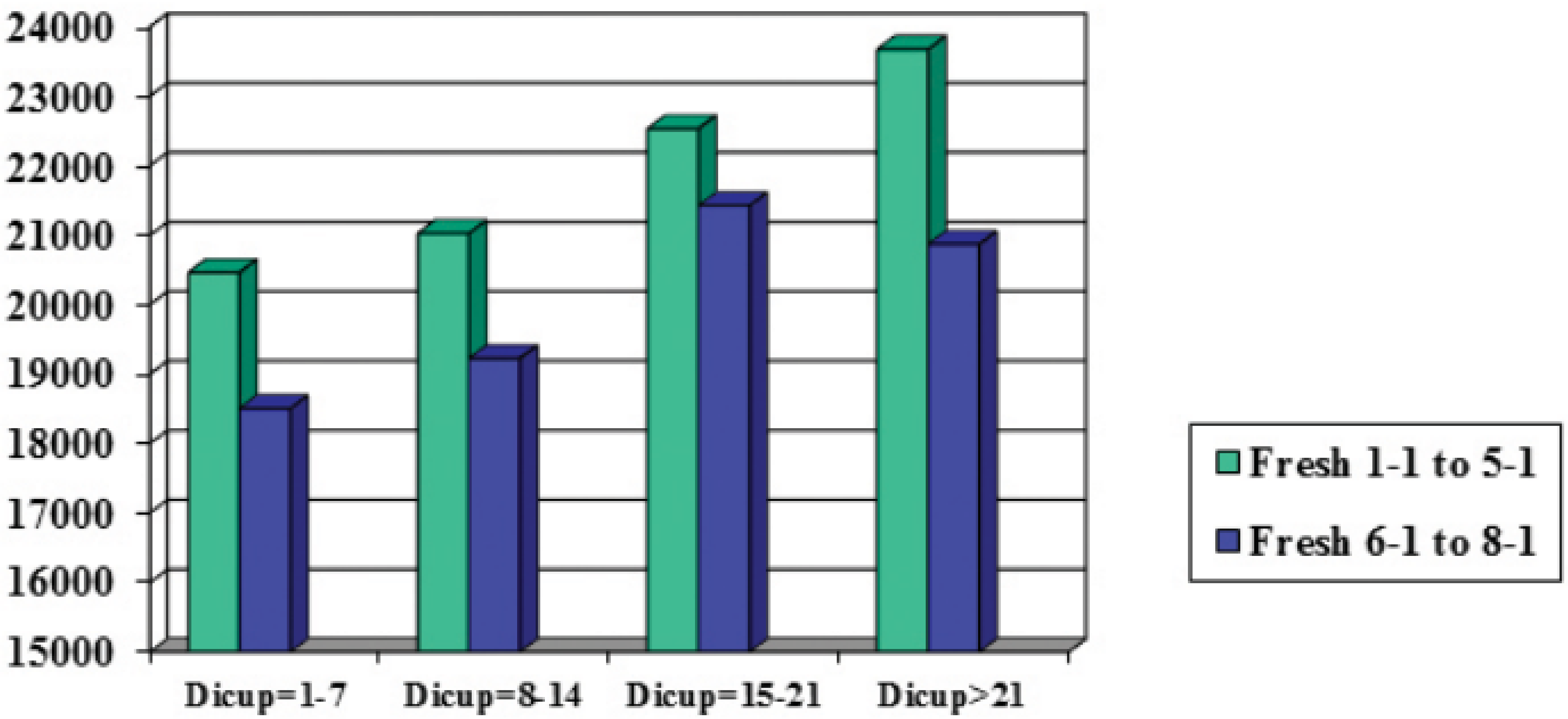
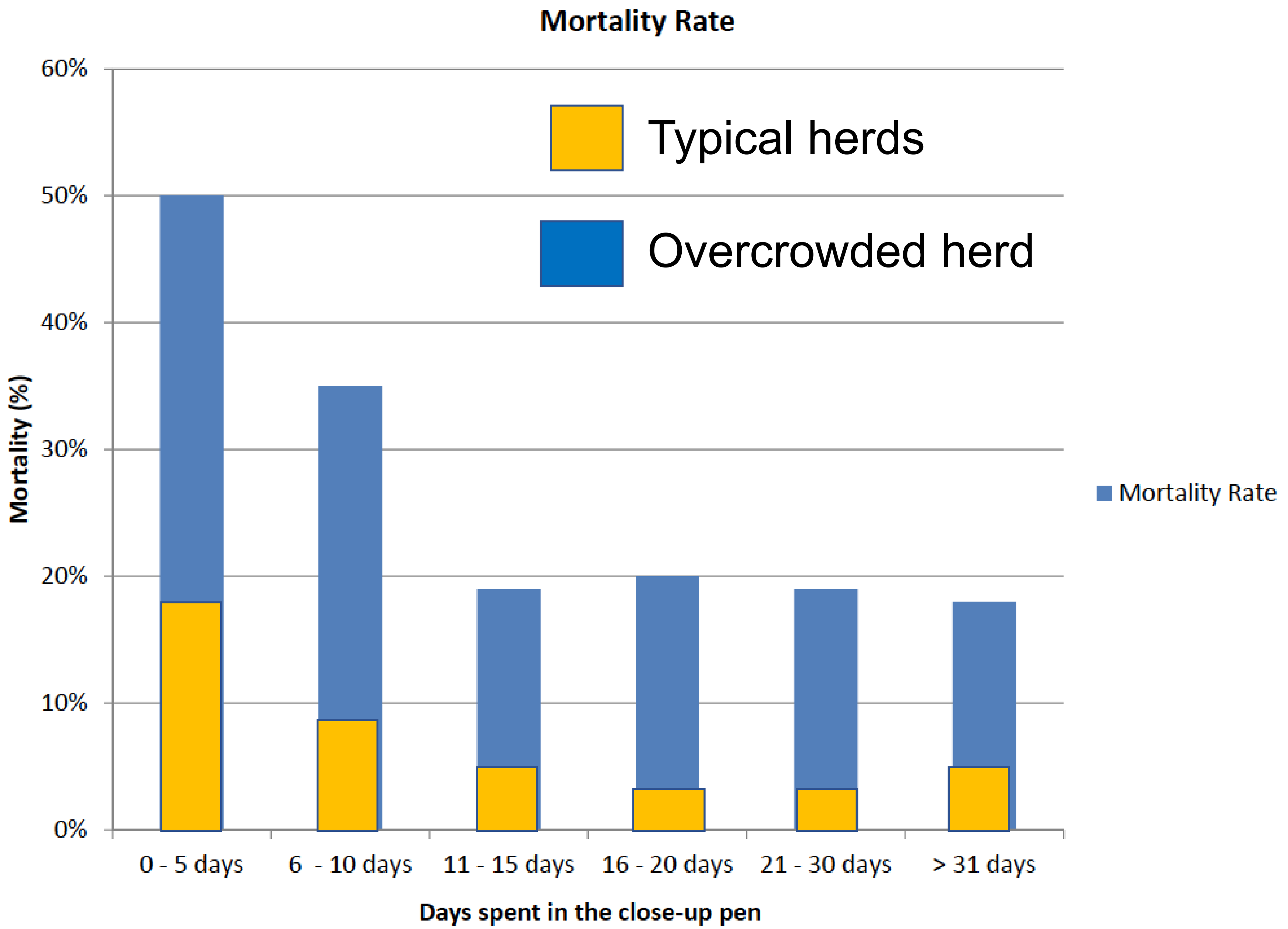


Figure 1. Milk production of cows categorized by days in the close up pen (Dicup).

Corbett R 2013 Penn State Dairy Symposium



Coetzee and Goff, 2015 personal observations

Hormone Changes of transition cows affect hoof health

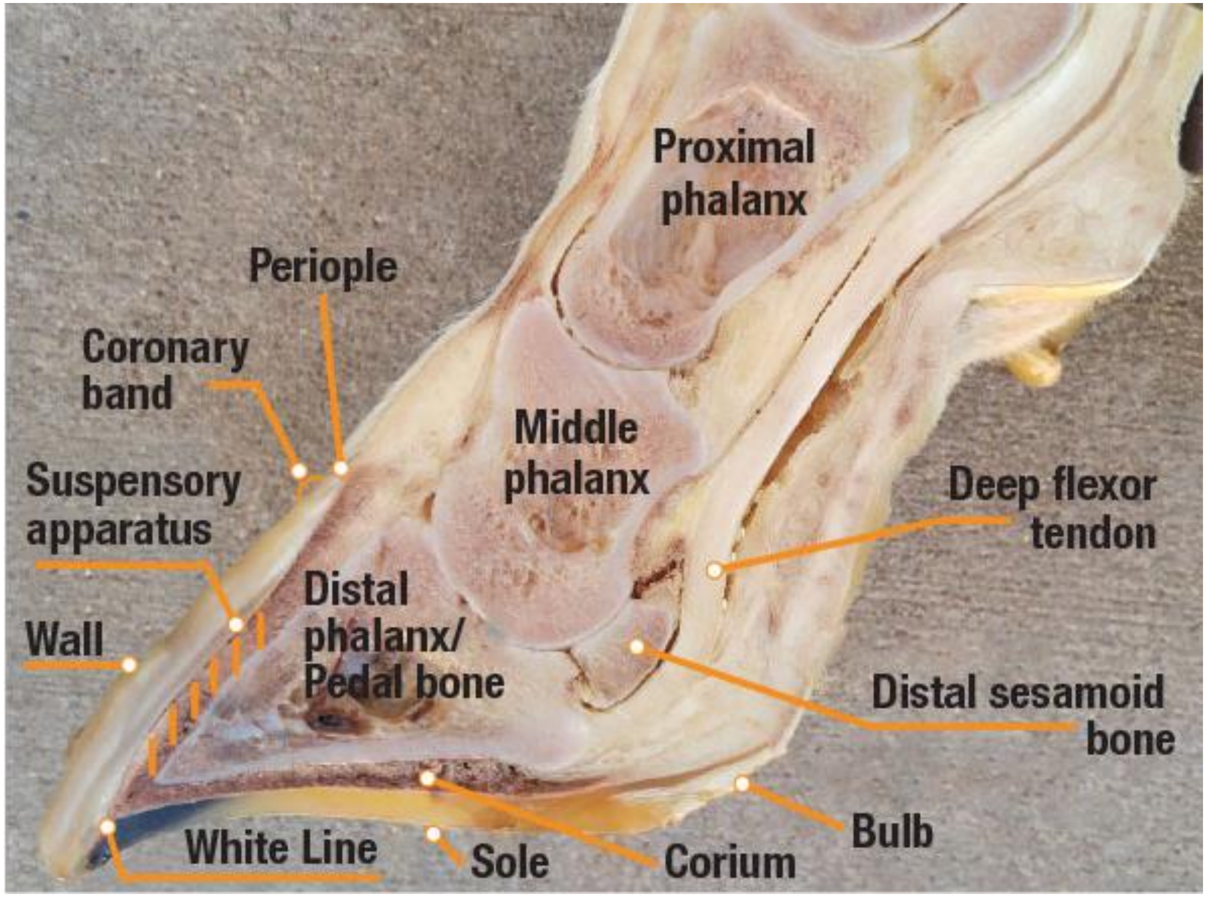
Several days prior to calving relaxin and estrogen concentrations rise.

Cortisol can be very high in challenged cows (dystocia, hypocalcemia, etc)

Relaxin causes collagen fiber breakdown of digital extensor and flexor tendons of foot as well as suspensory apparatus collagen.

P3 sinks.

Cortisol and estrogen decrease keratinization of epidermis of sole and hoof wall



Digital Cushion – fat pad to protect corium from trauma

As BCS decreases, so does thickness of Digital Cushion

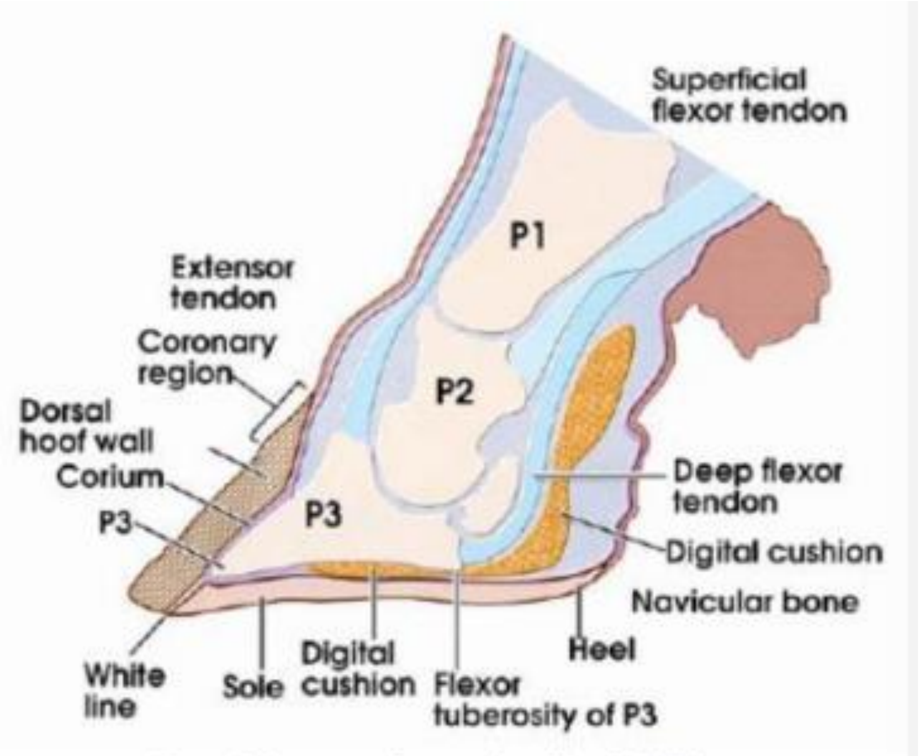
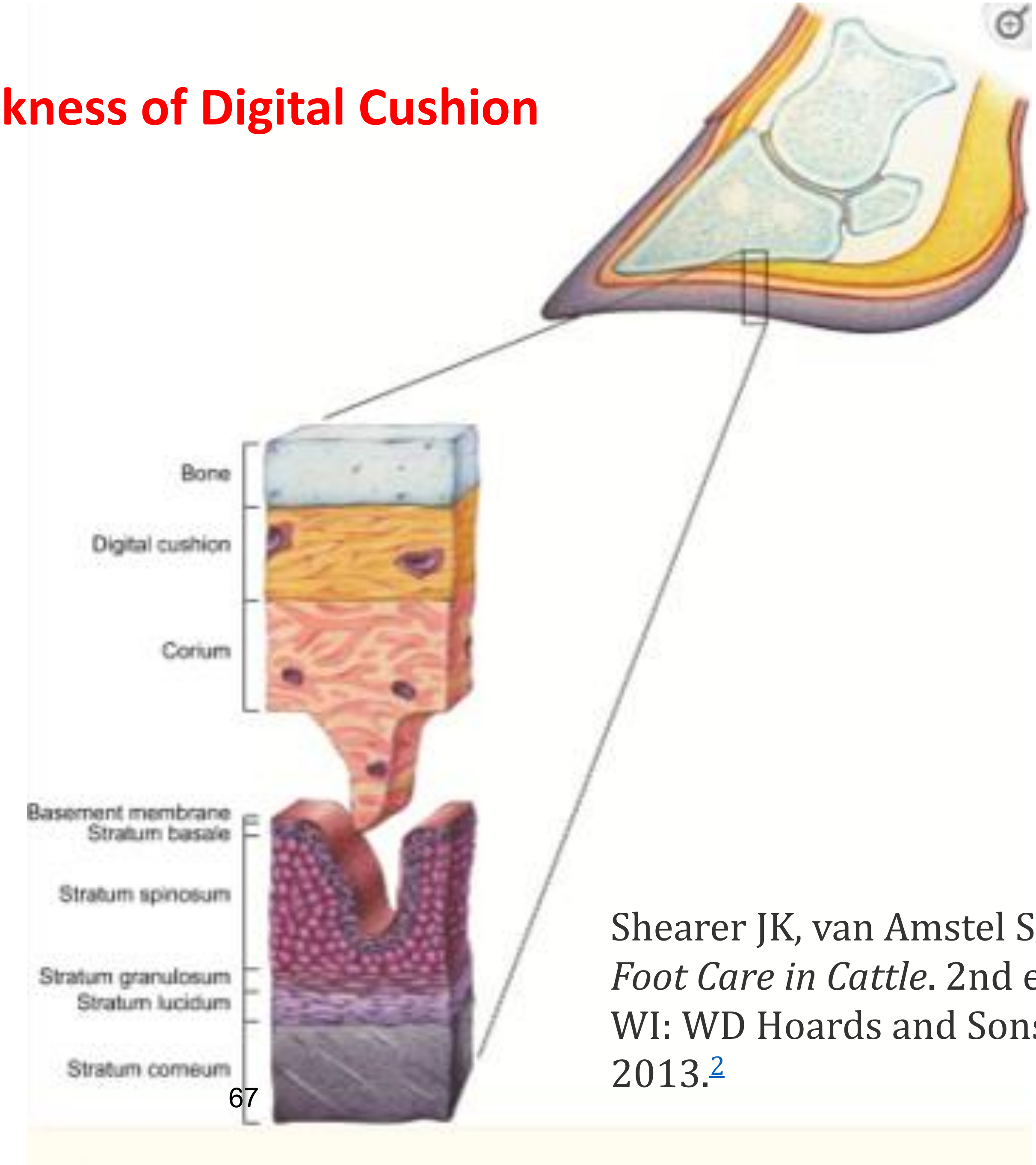
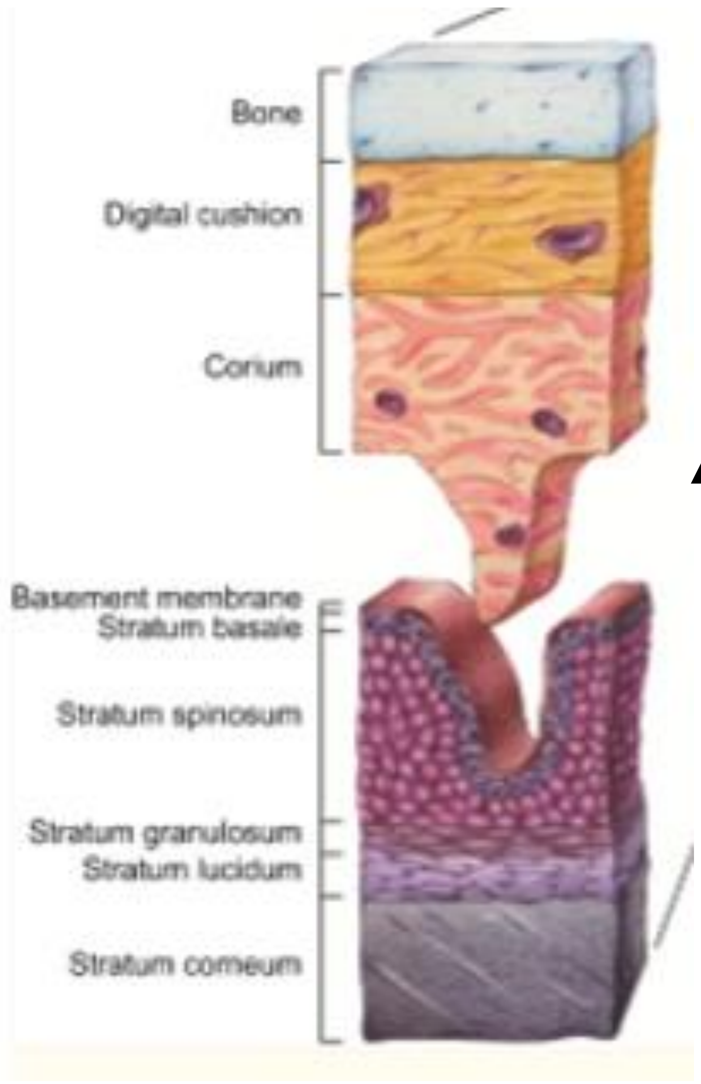


Figure 2: Anatomy of a cow claw (Gooch 2003)



Shearer JK, van Amstel SR. *Manual of Foot Care in Cattle*. 2nd ed. Ft Atkinson, WI: WD Hoards and Sons Company; 2013.[2]

When P3 sinks and Digital Cushion fat is lost the corium is under greater pressure from walking on hard, uneven surfaces.



Body weight

↑ Pressure →

Hard Surface

Disrupt diffusion of nutrients from corium to epidermis layers
=Poor keratinization

Build up of transudate within sole corium (yellow or reddish streaking).
Causes separation of Corium (dermis) from sole and white line (epidermis) and lame cow 5-9 weeks later!!!!

Shearer JK, van Amstel SR. *Manual of Foot Care in Cattle*. 2nd ed. Ft Atkinson, WI: WD Hoards and Sons Company; 2013.[2]

Lameness in Transition Cow

Pregnant and fresh cows should not be searching for a place to lay down!!

- no overcrowding

Sand or dry pack bedding best. Provide support to P3 so it does not bear as much weight.

Avoid making sharp turns- pulls corium from epidermis

Avoid fat dry cows- excess weight and will lose more BCS in early lactation.

Nutrition and the Distal Foot

Negative protein balance for first 2-3 weeks after calving likely slows replacement of corium dermis and sole/ wall epidermis.

Higher MP for fresh cows = higher RUP, added bypass methionine and lysine

Methionine (spare cysteine for keratin) and Biotin for harder keratinized epidermis

Keratin is 6-16% cystine – more = harder (Banasaz and Ferraro, 2024)

Avoid hypocalcemia – inhibits differentiation of keratinocytes.(Bikle, 2012)

Zinc – vital to keratinization process,

-Zn Hydroxychloride reduced # Treponemes in feces (Wenner et al., 2022)

Se – too much interferes with keratinization. Sulfur amino acids = strong disulfide bonds in keratin, Se-amino acids = fewer disulfide bonds within keratin= weaker hoof

Vitamin E – to fight oxidative stress associated with laminitic inflammation

Fresh Cow Diets – The Next Frontier

What's the matter with the high group TMR??

What changes should be made from the HIGH group TMR diet?

How long should they be fed??

Fresh Cow Diets – What I see practiced!

What’s the matter with the high group TMR??

- many farms put cows right on high group TMR,

- I prefer this if the farm cannot implement changes to the TMR described in the next sections

How long should "fresh cow diet" be fed??

Field observation- cows are fed restricted starch diets too long!!!

My Opinion - Healthy cows should be switched to High group TMR by~ 14 days in milk

Energy – higher or lower starch ? More or less forage?

Common practice to reduce starch or NFC in fresh cow diet and increase NFC (straw, forage)

Is this the correct approach?

study	Starch (NFC)	duration	Fresh DMI (kg)	ECM (kg/d)	OTHER
Rabelo et al 2003	41.1% (NFC) Vs 47.2 % NFC	21 d	15.35 16.45 P=0.10	38.5 40.4 NS	-2.5 Mcal/d Energy balance -3.25 Mcal/d Energy balance NS
McCarthey et al., 2015	20.9% Vs. 25.5%	21 d	14.8 15.6 NS	36.9 37.6 NS	-6.7 Mcal/d Energy balance -11.8 Mcal/d Energy balance P<0.001
Piantoni et al., 2015	17.6 % Vs. 24.2	29 d	20.8 23.6 P<0.01	56.8 55.1 NS	-0.95 BCS change -0.82 BCS change P<0.01
Haisan et al., 2021	25.1% Vs. 32.8%	20 d	18.0 17.4 NS	38.9 39.7 NS	* Better DMI, ECM, Serum Amyloid A if low starch had been fed prepartum

My take: Not much evidence there is a benefit to restricting starch in fresh cow diets BELOW WHAT YOU WOULD FEED TO HIGH GROUP COWS.

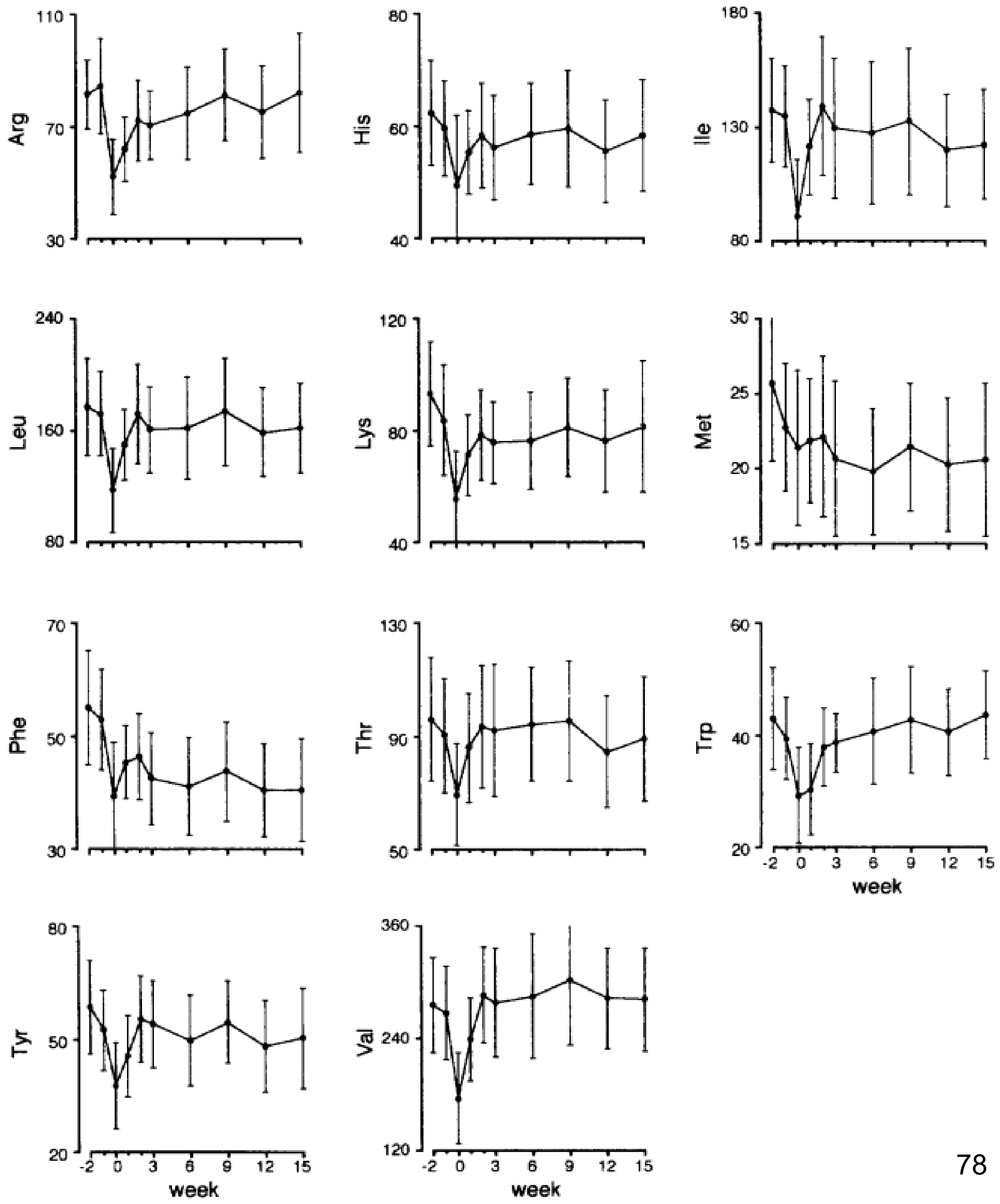
-especially if you are feeding more than 10 days!!

Higher starch (NFC) trend toward improved ECM, and DMI , Energy balance NOT generally improved

Negative Protein Balance??

-lasts 2-4 wks in early lactation

-Cows are estimated to lose as little as 17 and as much as 46 lbs protein in early lactation. Considering muscle is 72% water this amounts to loss of 60 to 164 lbs muscle mass lost.



Essential Amino Acid concentrations (UM) are low in transition cows for first 2 weeks of lactation. Longer for Methionine??

Meijer et al., JDS 1995

Study	Diet Protein	Duration	ECM kg/d	DMI kg/d	Metaboliz Prot balance g/d	Other
Amanlou et al., 2017	16.0% CP, 5% RUP 18.7% CP, 7% RUP 21.4% CP, 9% RUP	21 d	31.4 34.9 36.1	15.6 17.0 16.9	-440 -258 -127	Higher prot reduced BHBA and NEFA
Carder & Weiss 2020	16.3% CP 18.4% CP BP soy 17.4% CP Blood, AA	D 3-23	35.3 38.6 38.4	17.8 18.0 18.5	-343 -108 -115	3-methylhistidine Reduced
Tebbe & Weiss 2017	16.9 % CP 20.2 % CP, BP Soy 19.9% CP Soy ,canola,+ Lys, Met, His	25 d	46.1 48.7 51.1	19.0 18.6 20.1	-282 + 93 + 224	Showing cows, *heifers responded even better*

My Opinion -changes to make from the HIGH group TMR diet?

Energy – starch nearly same as high group, more straw, less silage → LDA prevention?

Protein – 20-21% CP And amino acid balanced!!

Fat - Don't add any!

Calcium – higher, 1.1-1.2% Ca

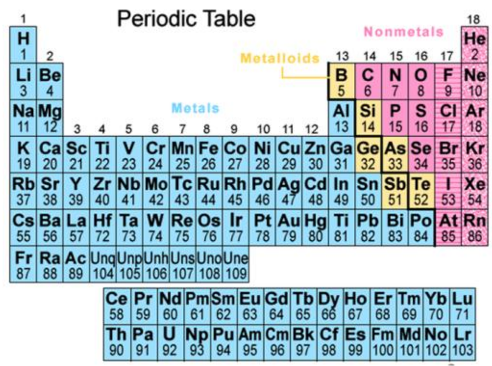
Magnesium – higher, 0.45-0.5% and **bioavailable** MgO, $MgOH_2$, $MgCO_3$

Vitamin E – higher, 3000-4000 IU /day

Effect of Trace Mineral Sources on Performance in Dairy Cows

José E.P. Santos
University of Florida





UF ANIMAL SCIENCES

CALIFORNIA ANIMAL NUTRITION CONFERENCE

Trace Minerals in Ruminant Nutrition

- ✓There are 7 trace minerals with established adequate daily intakes in the diet of ruminants
  - ✓Zn, Cu, Mn, Fe, I, Co, Se
- ✓Minimum adequate intakes have been established using the factorial approach for:
  - ✓Zn, Cu, Mn, Fe, I
- ✓The amounts of supplemental Co (0.2 mg/kg DM intake) and Se (0.3 mg/kg DM intake) are pre-established based on rumen microbial needs (Co) or based on maximum amounts that can be fed to cattle (Se)
  - ✓All Co and Se originate from the supplemental source unless you are in an area that has excess of Se in soils or have plants that accumulate Se
- ✓Other trace minerals are or might be essential, but inability to properly measure in feeds, lack of dose response data, and/or risk of toxicity make them to not be supplemented in diets of ruminants
  - ✓As, Cr, Cd, Fl, Mo, Ni, and Va

The Factorial Approach for Trace Mineral Adequate Intake

- ✓The factorial approach accounts for the expected needs of the animal:
  - ✓Maintenance needs: endogenous fecal and urinary losses, losses in tegument, and sweating
  - ✓Tissue accretion with losses in milk (milk yield and composition)
  - ✓Tissue accretion with gain of body tissues (body weight gain)
  - ✓Tissue accretion as pregnant uterus accretion
- ✓The daily needs for maintenance are often based on BW or DM intake
  - ✓Assumed that metabolic losses are a function of BW or a function of DMI (fecal losses)
- ✓The coefficient of absorption of the mineral
  - ✓Influenced by source of the trace mineral, amount fed, and presence of antagonists
  - ✓Most data are comparative to a source that has been evaluated in the past
    - ✓ E.g., if Cu absorption from $CuSO_4 \cdot 5H_2O$ is 5% and an organic trace mineral shows in a comparative experiment increased tissue incorporation (e.g., more liver Cu) or reduced fecal and urinary losses, then the coefficient of absorption might be increased relative to the 5% of Cu in $CuSO_4 \cdot 5H_2O$.
  - ✓Minerals are transported by specific proteins and their expression and activity in the GI tract are influenced by substrate availability: i.e., the coefficients of absorption are not constant! They are the best estimate given the data available.

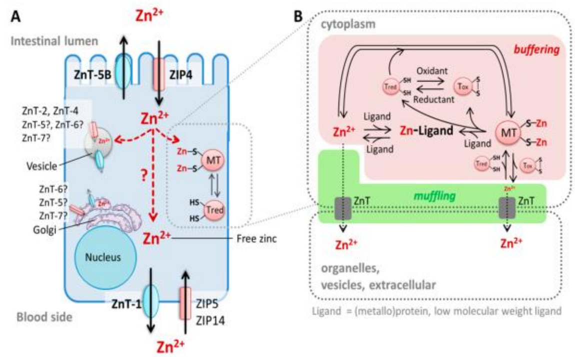
Trace Mineral Analyses and Sources

- ✓ Basal ingredients in the diet are major trace mineral sources and responsible for 30 to 60% of all trace mineral needs
  - ✓ Lack of routine analyses of some trace minerals (Co, I, Se) result in almost all trace mineral in the diet originating for supplemental sources
- ✓ Use inductively coupled plasma mass spectrometry (ICP-MS) to analyze minerals (Do not use results from NIR)
  - ✓ Supplement diets considering the concentrations in the basal ingredients
  - ✓ Remember NASEM values (dairy and beef) are suggested values based on the mean concentrations of minerals in tissues and the estimated coefficient of absorption
  - ✓ A sound recommended practice is to supplement to result in a final diet with 10 to 20% above NASEM guidelines
  - ✓ For many minerals, concentrations in diets of nonlactating animals will be greater than those in diets of lactating cows
    - ✓ A function of dry matter intake
- ✓ Mineral solubility
  - ✓ Sources that are more soluble tend to have greater coefficient of absorption
  - ✓ More soluble sources also are more reactive in the rumen (many free metal ions are bactericidal → Cu^{2+}, Zn^{2+}; interact with other minerals → Cu^{2+} and S^{2-} and Mo forming thiomolybdates
  - ✓ Oxides are often poorly absorbed in the GI tract of ruminants. Should be avoided.

Zinc Absorption and Transport

Mechanisms of Zinc absorption in the intestine

- Intestinal zinc absorption is mediated by the Zrt-, Irt-like protein (ZIP)4 (solute carrier (SLC)39A4), which imports ionic zinc from the lumen into enterocytes.
- Once in the enterocyte, ZnT-1 (SLC30A1), a basolateral membrane protein, exports zinc to the portal blood.
- The basolaterally localized transporters ZIP5 (SLC39A5) and ZIP14 (SLC39A14) complement these two transporters by importing zinc from the blood circulation into enterocytes.
- ZnT-5 variant B (SLC30A5B) localized at the apical membrane of enterocytes functions in a bidirectional manner, transporting both luminal zinc into enterocytes and cellular ions back into the lumen



Zinc Adequate Daily Intake

- ✓ NASEM suggested coefficient of absorption varies from 15 to 20%
  - ✓ Oxide is the least available source and should not be used
- ✓ Maintenance: 5 mg x DM intake (kg/d)
- ✓ Growth: 24 mg x daily BW gain (kg/d)
- ✓ Milk contains 4 mg of Zn/kg
  - ✓ Lactation: Milk yield x 4 mg
- ✓ Gestation: data available for pregnancies after 190 d
  - ✓ 0.017 x BW (kg)
- ✓ E.g., A 700 kg cow consuming 25 kg of DM daily, producing 40 kg of milk, gaining 0.1 kg of BW, and 100 days pregnant
  - ✓ Absorbable Zn = (25 x 5) + (0.1 x 24) + (40 x 4) = 287.4 mg/d
  - ✓ Assuming a 20% coefficient of absorption: Dietary Zn = 287.4/0.2 = 1437 mg/day
  - ✓ Suggested dietary concentration: (1.2 x 1437)/25 = 69 mg/kg of diet
    - ✓ Most diets of ruminants require supplemental Zn representing 40 to 60% of the daily intake

Zinc Deficiency and Toxicity

✓Deficiency:
- ✓Reduced growth due to decreased DM intake
- ✓Rough coat, loss of hair, and swelling of distal portion of limbs due to dermatitis
- ✓Loss of skin integrity (parakeratosis) with inflammation and secondary infections
- ✓Loss of epithelium integrity with parakeratosis of rumen epithelium
- ✓Impaired reproduction, reduced size of testes

✓Toxicity
- ✓Dietary Zn > 500 to 1,000 mg/kg DM
- ✓Changes in Zn content in liver or other tissues **do not** parallel Zn intake

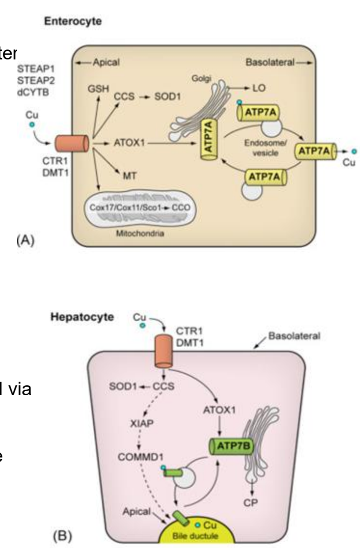
✓High dietary Zn affects Cu absorption

✓Adequacy
- ✓Serum or liver tissue for Zn analysis (rubber top in blood tubes can contaminate samples with Zn → use plastic top)

Copper Absorption and Transport

Mechanisms of Cu absorption in the intestine and hepatic uptake

- Divalent Cu^{2+} can be transported by the divalent metal transporter 1 (DMT1)
- Intestinal copper has to be reduced from Cu^{2+} to Cu^{+1} to be transported by the high-affinity copper transporter 1 (Ctr1).
- Reduction of Cu^{2+} is mediated by metalloreductase enzymes STEAP1, STEAP2 and dCYTB.
- Reduced Cu^{+1} can now be transported by the high-affinity Cu transporter 1 (Ctr1)
- Once in the enterocyte, Cu binds to numerous ligands and it is transferred to the Golgi and mitochondria
- Secretory vesicles from the Golgi are transported out of the cell via ATP7a (Cu^{1+}-transporting P-type ATPase) to the portal blood
- In portal blood, Cu is transported associated with proteins to the liver and other tissues
- Copper accumulates in hepatocytes



Copper Adequate Daily Intake

- ✓ Coefficient of absorption varies from 0.5 to 5%
  - ✓ Oxide is the least available source and should not be used
  - ✓ Cu absorption = $10^{(-1.153\ -0.0019\ x\ Mo\ -0.076\ x\ S\ -0.0131\ x\ S\ x\ Mo)}$ equation derived from data from sheep. *Not used by NASEM*
    - ✓ Where: absorption is %; Mo = dietary Mo mg/kg diet DM; S = dietary S in g/kg of diet DM

- ✓ Maintenance: 0.0145 mg x BW (kg)
- ✓ Growth: 2.0 mg x daily BW gain (kg/d)
- ✓ Milk contains 0.04 mg of Cu/kg
  - ✓ Lactation: Milk yield x 0.04 mg
- ✓ Gestation: data available for pregnancies after 90 d
  - ✓ 90 to 190 d = 0.0003 x BW (kg)
  - ✓ > 190 d = 0.0023 x BW (kg)

- ✓ E.g., a 700 kg cow consuming 25 kg of DM daily, producing 40 kg of milk, gaining 0.1 kg of BW, and 100 days pregnant
  - ✓ Absorbable Cu = (700 x 0.0145) + (0.1 x 2) + (40 x 0.04) + (700 x 0.0003) = 12.16 mg/d
  - ✓ Assuming a 5% coefficient of absorption: Dietary Cu = 12.16/0.05 = 243 mg/day
  - ✓ Suggested dietary concentration: (1.2 x 243)/25 = 11.7 mg/kg of diet
    - ✓ Most diets of ruminants require supplemental Cu representing 40 to 60% of the daily intake

Copper Adequate Daily Intake

- ✓Deficiency:
  - ✓ Loss of hair pigmentation (particularly around the eyes)
  - ✓ Diarrhea is a common sign (mucosal atrophy)
  - ✓ Anemia, bone fragility, poor growth, impaired reproduction, reduced killing ability of leukocytes
  - ✓ Increased susceptibility to bacterial and viral diseases (respiratory problems in growing animals and mastitis in lactating cows)

- ✓Associated with very low Cu diets (< 4 ppm) or antagonistic effects of Mo and S
  - ✓ S is reduced to sulfide in the rumen, and the latter combines with Mo to form thiomolybdate
  - ✓ Thiomolybdate forms insoluble complex with Cu in the rumen or blood: reduces Cu absorption and availability

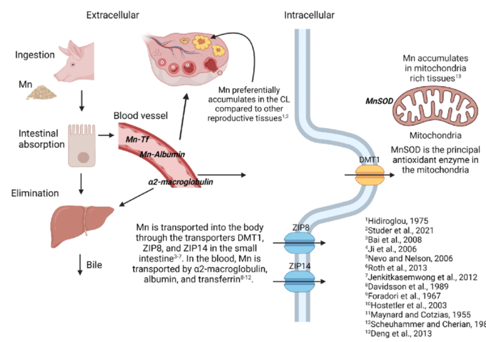
- ✓Risk of Toxicity
  - ✓ Dietary Cu > 25 mg/kg diet DM (particularly in Jersey cattle or sheep)
  - ✓ Liver Cu > 250 mg/kg wet tissue or > 750 mg/kg DM

- ✓Adequacy
  - ✓ Liver Cu is the best measure. Adequate Cu in liver tissue 50 to 200 mg/kg wet tissue (150 to 600 mg/kg DM)
  - ✓ Serum Cu is only useful if the animal is deficient in Cu

Manganese Absorption and Transport

Mechanisms of Mn absorption in the intestine

- Manganese is absorbed in the duodenum and jejunum mediated by the divalent metal ion transporter 1 (DMT1).
- Two other proteins, ZIP8 and ZIP14 are present in the duodenum and can transport Mn, but DMT1 mediates the majority of intestinal Mn absorption across the intestinal wall.
- Manganese in the blood is transported primarily proteins, 2-macroglobulin, albumin, and transferrin to the liver, which is the main storage site.



Studer et al. (2022) Anim. Reprod. Sci. 238:106924

Manganese Adequate Daily Intake

- ✓ Coefficient of absorption varies from 0.2 to 0.5%
  - ✓ Carbonate and oxide are the least available sources and should not be used
- ✓ Maintenance: 0.0026 mg x BW (kg)
- ✓ Growth: 2.0 mg x daily BW gain (kg/d)
- ✓ Milk contains 0.03 mg of Mn/kg
  - ✓ Lactation: Milk yield x 0.03 mg
- ✓ Gestation: data available for pregnancies after 190 d
  - ✓ 0.00042 x BW (kg)
- ✓ E.g., a 700 kg cow consuming 25 kg of DM daily, producing 40 kg of milk, gaining 0.1 kg of BW, and 100 days pregnant
  - ✓ Absorbable Mn = (700 x 0.0026) + (0.1 x 2) + (40 x 0.03) = 3.22 mg/d
  - ✓ Assuming a 0.4% coefficient of absorption: Dietary Mn = 3.22/0.004 = 805 mg/day
  - ✓ Suggested dietary concentration: (1.20 x 805)/25 = 39 mg/kg of diet
    - ✓ Most diets of ruminants require supplemental Mn representing 40 to 50% of the daily intake

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Nutrient Physiology, Metabolism, and Nutrient-Nutrient Interactions

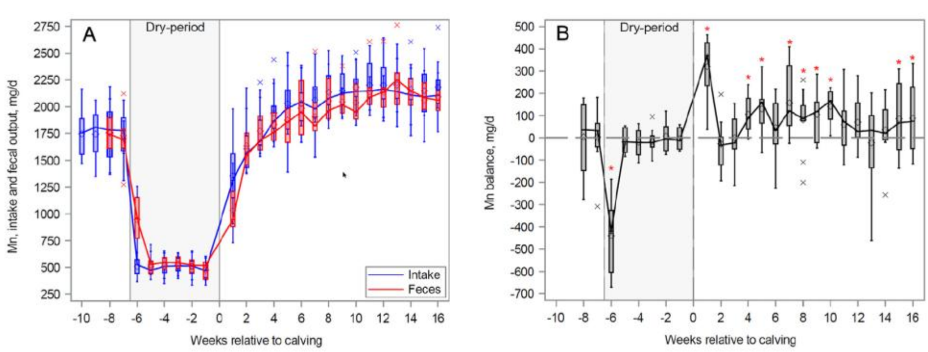
Zinc, Copper, and Manganese Homeostasis and Potential Trace Metal Accumulation in Dairy Cows: Longitudinal Study from Late Lactation to Subsequent Mid-Lactation

Jean-Baptiste Daniel[1,*], Daniel Brugger[2], Saskia van der Drift[3], Deon van der Merwe[3,4], Nigel Kendall[5], Wilhelm Windisch[6], John Doelman[1], Javier Martín-Tereso[1]

- ✓ 12 Holstein cows from 10 wk prepartum to 16 wk postpartum
- ✓ Trace mineral balance measured weekly

	Diets	
Item	Dry	Lactation
CP, % DM	12.7	17.2
Forage NDF, % DM	49.9	32.2
Starch, % DM	20.7	24.7
Crude fat, % DM	2.7	3.5
Ca, % DM	0.30	0.70
P, % DM	0.23	0.36
Mg, % DM	0.26	0.33
K, % DM	1.39	2.03
Na, % DM	0.01	0.16
Cl, % DM	0.24	0.72
S, % DM	0.14	0.25
Fe, mg·kg^{-1} DM	123	260
Zn, mg·kg^{-1}DM	**61**	**132**
Mn, mg·kg^{-1}DM	**37**	**90**
Cu, mg·kg^{-1}DM	**11**	**23**
Mo, mg·kg^{-1}DM	1.1	1.2

Manganese Intake, Fecal Excretion and Balance

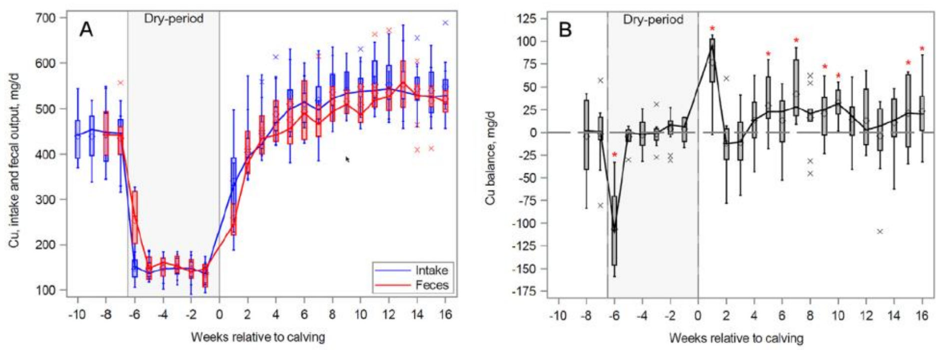


Note the drop in mineral balance once cows moved from the lactating to the dry cow diet

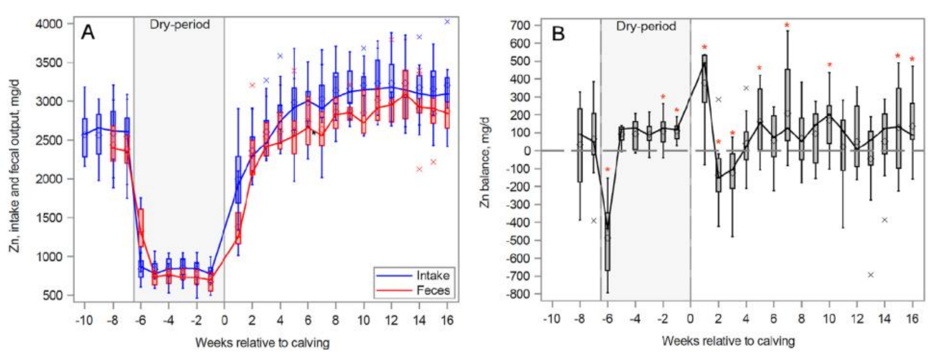
Note the increase in mineral balance once cows moved from the dry cow diet to the lactating diet

Suggests effects on regulation of mineral transport in the gut as the cow moved from high to low or low to high intake

Copper Intake, Fecal Excretion and Balance



Zinc Intake, Fecal Excretion and Balance



Content of Trace Minerals is More Variable and Analyses are Less Frequent

Samples of **corn silage** analyzed by Dairy One from 2000 to 2013

	Samples	Mean	SD	CV
CP, %	233,640	8.28	1.06	12.7%
NDF, %	239,116	43.68	6.00	13.7%
Starch, %	197,674	31.82	7.59	23.9%
Trace minerals				
Zn, mg/kg	45,195	27.32	97.14	355.6%
Cu, mg/kg	45,216	6.57	3.71	56.5%
Mn, mg/kg	45,189	31.18	19.32	62.0%
Co, mg/kg	224	0.88	0.69	78.7%

Dairy One database http://www.dairyone.com/Forage/FeedComp/MainLibrary.asp

Industry Typically Feeds Trace Minerals in Excess of Needs

100 eastern Canadian commercial dairies

Trace mineral, mg/kg DM	NASEM 2021 (50 kg/d MY)	Average ± SD	1st Percentile	99th Percentile
Copper	11	17 ± 5	10	34
Manganese	32	65 ± 18	27	123
Zinc	62	76 ± 21	33	144

Duplessis et al. (2021) J. Dairy Sci. 106:4030-4041

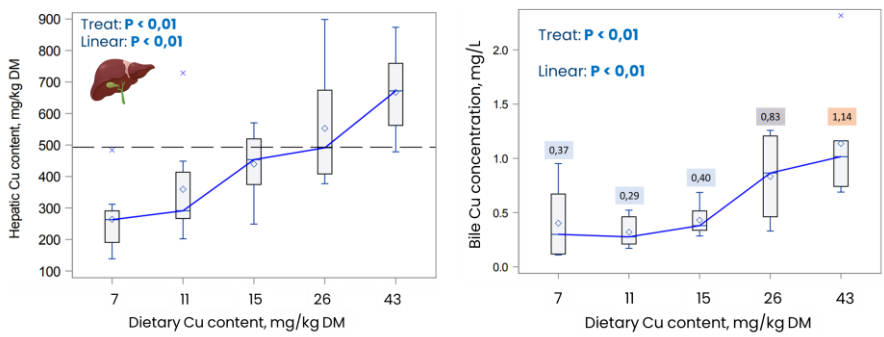
39 California dairy farms

Trace mineral, mg/kg DM	NASEM 2021 (50 kg/d MY)	Median	10th Percentile	90th Percentile
Copper	11	18	10	31
Manganese	32	73	48	106
Zinc	62	74	51	103

Castillo et al. (2013) J. Dairy Sci. 96:3388-3398

Some Trace Minerals Accumulate in Tissues Over Time

Hepatic Cu and biliary Cu concentrations



N = 8 bulls/Trt

Daniel and Martín-Tereso (2025) J. Dairy Sci. 108:8410-8427

Trace Minerals

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

Ionic Cu^{2+} is bactericidal

e.g.,

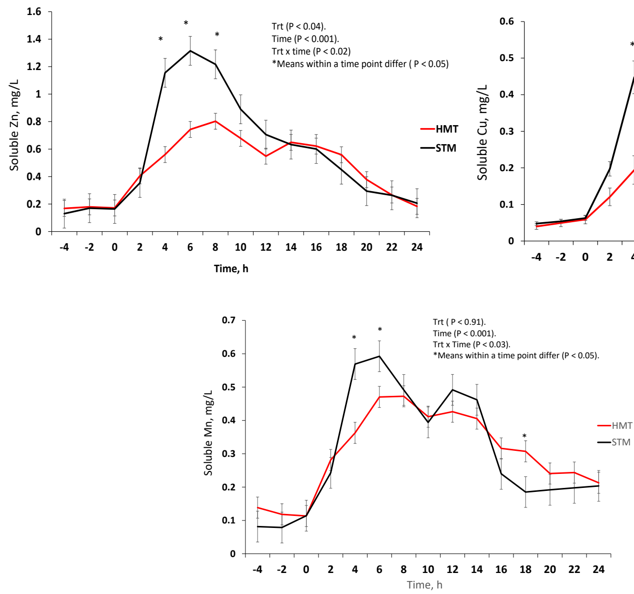
$$CuSO_4 \cdot 5H_2O \xrightarrow{\text{In solution}} Cu^{2+} + SO_4^{2-} + 5H_2O$$

Ionic Zn^{2+} is bactericidal

e.g.,

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

Solubility of Different Sources of Trace Minerals



Guimarães et al. (2022) Animal 16:100500

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

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

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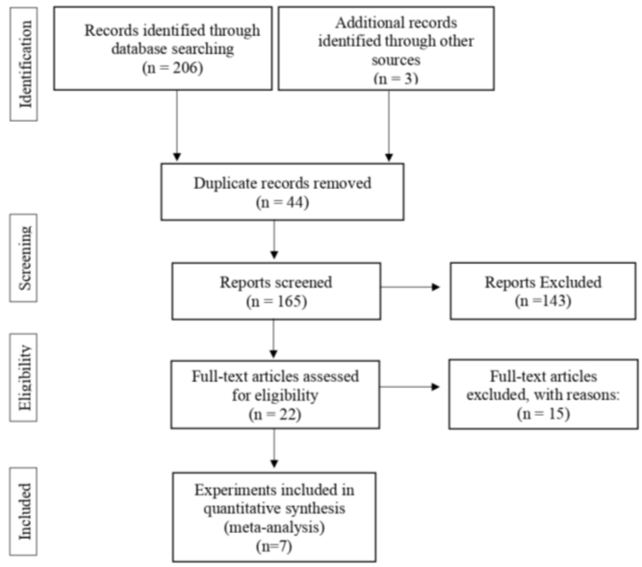
[1]Department of Animal Science, Michigan State University, East Lansing 44824
[2]Micronutrients USA LLC, Indianapolis, IN 46231

- ✓ **Inclusion criteria:** Digestibility analysis, study design, cattle type, mineral intake, days on treatment, diet NDF%, etc. and the main outcomes extracted were DM digestibility, NDF digestibility, and DMI (kg/d or % of body weight).
- ✓ **Statistical analysis:** Mixed-effects model meta-analysis to estimate overall effect sizes of hydroxy versus sulfate TM.

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

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

PRISMA Diagram For Searching and Screening the Literature



Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

Data Used for the Meta-Analysis

Table 1. List of references used in the meta-analysis

Reference	Cows, n	EU,[1] n	Breed	Design[2]	Treatments, n
Yasui et al. (2014)	38	38	Holstein	CRD	2
Faulkner and Weiss (2017a)	18	35	Holstein	LSD	4
Metcalf (2018)	6	12	Holstein	LSD	2
Miller et al. (2020)	14	56	Holstein	LSD	4
Daniel et al. (2020)	52	207	Holstein	LSD	4
Harvatine (2024)	16	31	Holstein	LSD	2
Adeoti et al. (2025)	139	139	Holstein	RCBD	2

[1]EU = experimental units.

[2]CRD = completely randomized design; LSD = Latin square design; RCBD = randomized complete block design.

Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

Dietary Trace Mineral Content and Intake According to Treatment

Item	Treatment[1] STM	HTM	SEM	Difference[2]	SED[3]	*P*-value
Diet content, mg/kg						
Cu	20.1	20.1	0.8	0.01	0.08	0.89
Mn	71.2	75.4	0.2	4.1	0.2	< 0.001
Zn	90.3	90.7	6.1	0.5	0.4	0.19
Intake, mg/d						
Cu	494	500	27	6.8	5.6	0.23
Mn	1,754	1,872	95	118	22	< 0.001
Zn	2,235	2,272	213	37	24	0.13

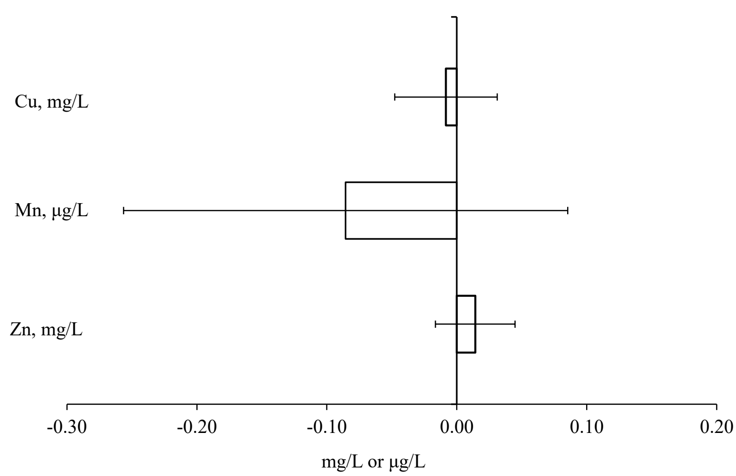
[1] STM = sulfate trace minerals; HTM =hydroxychloride trace minerals.

[2] Difference = effect size (HTM – STM).

[3] SED = standard error of the difference (SE of the effect size).

Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

Effect of Source of Trace Minerals on Concentrations of Cu, Mn, and Zn in Plasma



Effect size and 95% CI

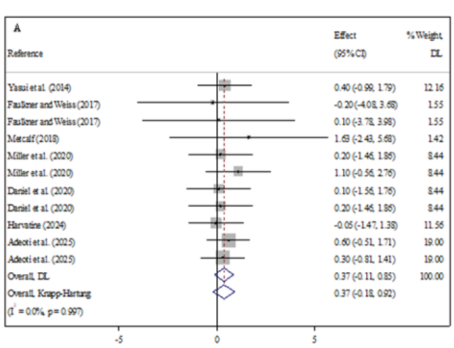
Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

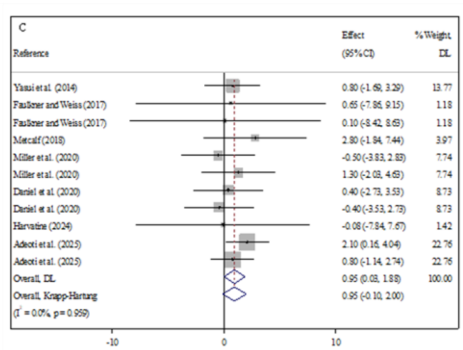
Effects of Sources of Trace Minerals on Intake and Yield of Milk

	Treatment					
Item	STM	HTM	SEM	Difference[1]	SED[2]	*P*-value
DMI, kg/d	24.5	24.9	0.9	0.37	0.28	0.19
Milk, kg/d	40.7	41.7	2.7	1.01	0.55	0.07
ECM, kg/d	40.8	41.9	1.9	1.10	0.55	0.04
ECM/DMI, kg/kg	1.68	1.71	0.05	0.025	0.019	0.19

Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

Forest Plots of the Effect of Source of Trace Minerals on DM Intake and Yield of ECM





Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

Effects of Source of Trace Minerals on Content and Yields of Milk Components

	Treatment					
Item	STM	HTM	SEM	Difference[1]	SED[2]	*P*-value
Content						
Fat, %	3.73	3.75	0.21	0.020	0.044	0.65
True protein, %	3.07	3.08	0.15	0.002	0.024	0.94
NEL, Mcal/kg	0.71	0.71	0.03	0.001	0.005	0.78
SCS	2.74	2.74	0.54	-0.004	0.151	0.98
Urea N, mg/dL	11.0	11.2	1.0	0.25	0.18	0.16
Yield						
Fat, kg/d	1.48	1.52	0.07	0.044	0.023	0.06
True protein, kg/d	1.22	1.25	0.05	0.031	0.016	0.06
NEL, Mcal/d	28.4	29.2	1.3	0.76	0.39	0.05

Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

Effect of Source of Trace Minerals on Measures of Energy Balance

	Treatment					
Item	STM	HTM	SEM	Difference[1]	SED[2]	*P*-value
BW, kg	643	646	11	3.7	6.8	0.59
BCS, 1 to 5	2.99	2.97	0.11	-0.02	0.05	0.71
Net energy						
Intake, Mcal/d	42.5	43.1	1.2	**0.64**	0.49	0.19
Balance, Mcal/d	1.3	1.1	1.2	-0.20	0.36	0.58

Cardoso et al. (2025) J. Dairy Sci. 108 (Suppl. 1):338-339

Treatments

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

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

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

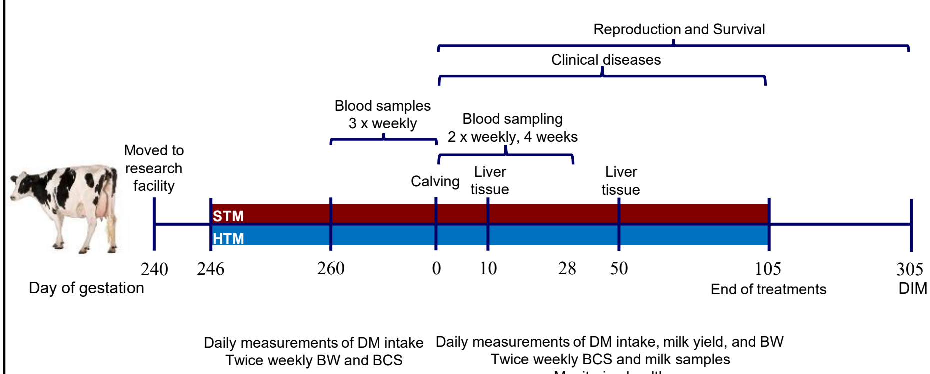
Prepartum

Postpartum

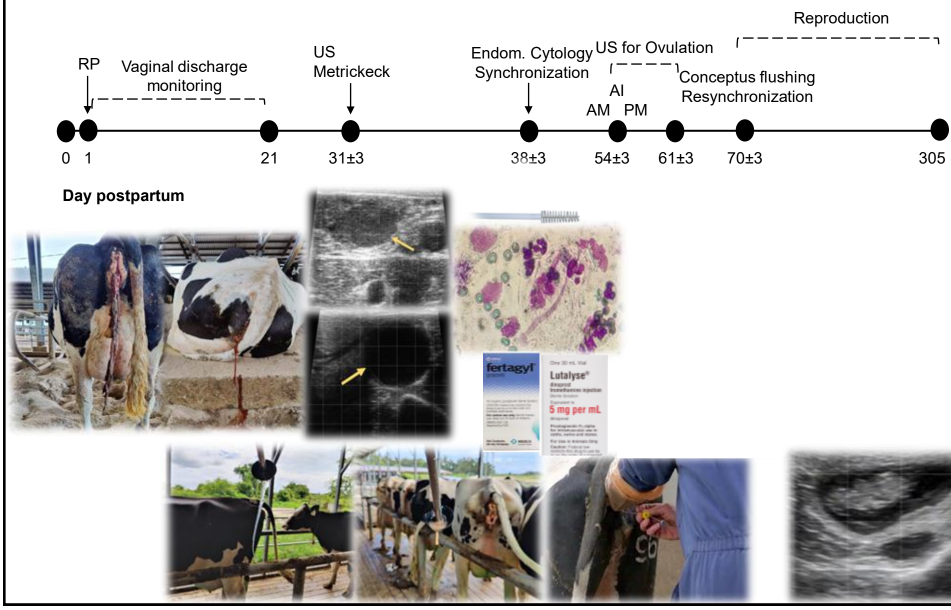
Adeoti et al. (2026) J. Dairy Sci. 109: accepted

Materials and methods

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



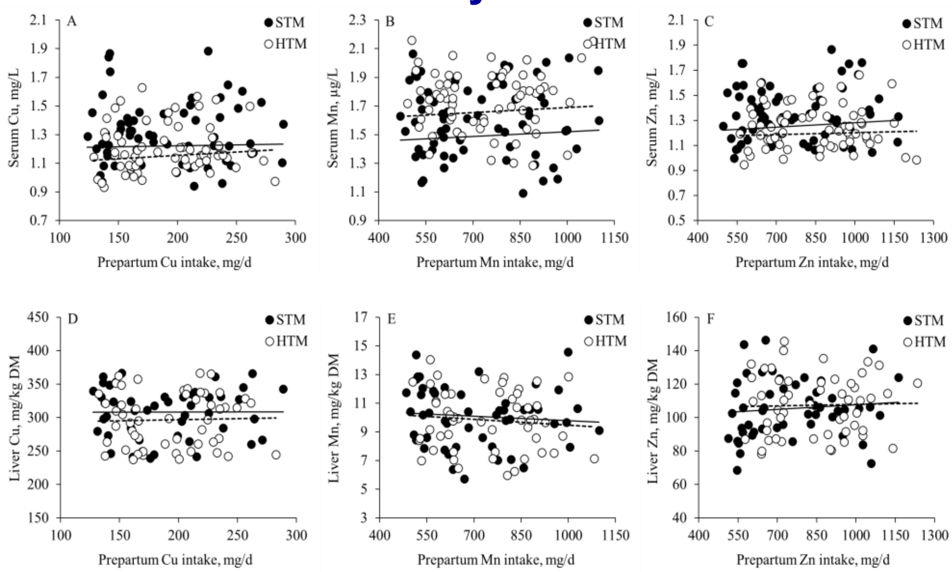
Materials and methods



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

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

Intake and Tissue Contents of Trace Minerals in Dairy Cows



Adeoti et al. (2026) J. Dairy Sci. 109: accepted

Colostrum Yield and Composition

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

Adeoti et al. (2026) J. Dairy Sci. 109: accepted

Risk of diseases in the first 105 DIM

	Treatment			
Item	STM (n=70)	HTM (n=71)	AOR (95% CI)[1]	*P*-value
RFM, %	11.5 ± 6.3	3.8 ± 2.3	0.30 (0.13-0.74)	0.01
Milk fever,[2] %	1.1 ± 1.3	1.3 ± 1.3	1.12 (0.06-19.7)	0.94
Mastitis,[2] %	1.4 ± 1.0	0	---	0.49
DA,[2] %	1.4 ± 1.4	1.4 ± 1.4	0.99 (0.06-16.8)	0.99
Ketosis, %	6.4 ± 2.9	5.7 ± 2.8	0.89 (0.25-3.26)	0.86
Lameness, %	6.7 ± 3.1	1.2 ± 1.3	0.18 (0.02-1.58)	0.12

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

Sarwar et al. (2026) J. Dairy Sci. 109: accepted

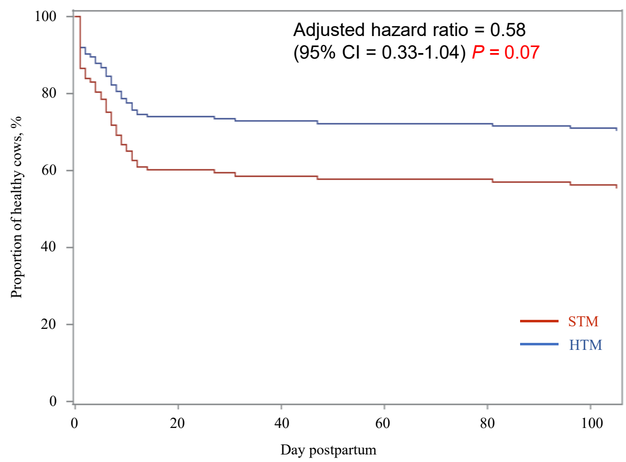
Risk of diseases in the first 105 DIM

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

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

Sarwar et al. (2026) J. Dairy Sci. 109: accepted

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



Sarwar et al. (2026) J. Dairy Sci. 109: accepted

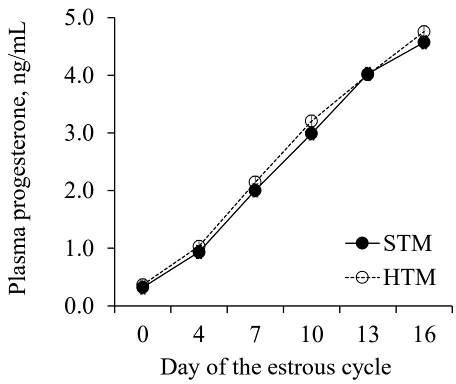
Effect of source of trace minerals on ovarian responses and conceptus development in dairy cows

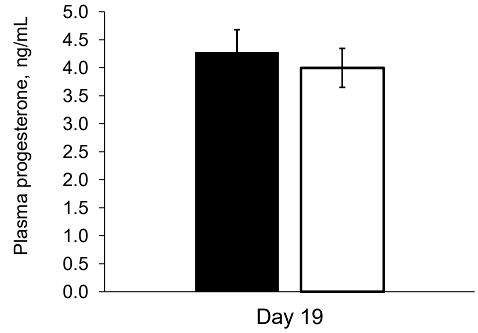
Item	Treatment			
	STM (n=70)	HTM (n=71)	AOR (95% CI)[1]	*P*-value
Cyclic by 38 d postpartum, %	62.2 ± 9.2	59.3 ± 8.3	0.89 (0.44-1.80)	0.73
Synchronized ovulation, %	82.7 ± 4.8	93.0 ± 3.7	2.77 (0.77-9.97)	0.12
Ovulatory follicle, mm	12.7 ± 0.5	13.4 ± 0.4	---	0.18
Luteal area d 7, mm^2	344 ± 21.8	386 ± 18.7	---	0.08

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

Sarwar et al. (2026) J. Dairy Sci. 109: accepted

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





Sarwar et al. (2026) J. Dairy Sci. 109: accepted

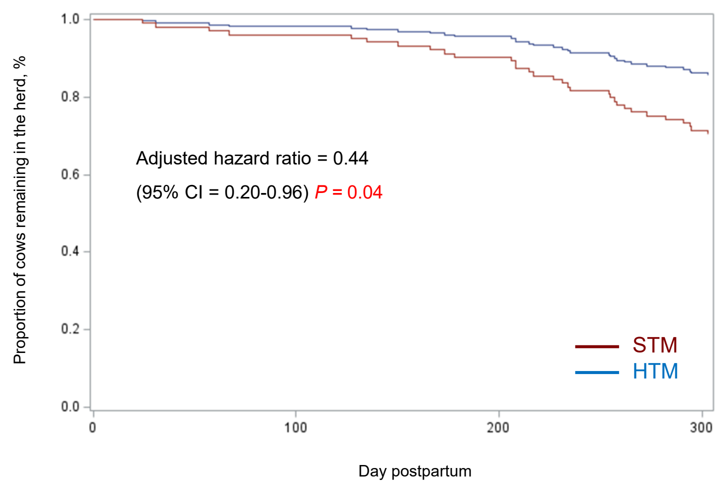
Effect of source of trace minerals on reproduction in dairy cows

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

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

Sarwar et al. (2026) J. Dairy Sci. 109: accepted

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



Sarwar et al. (2026) J. Dairy Sci. 109: accepted

Summary

- ✓ In the meta-analysis, feeding HTM increased the yields of milk, fat, and protein, which increased the yield of ECM by 1.1 kg/d
  - ✓ The increment in yield of ECM was caused primarily by the additional NEL intake (0.64 Mcal/d)
- ✓ In the FL experiment, replacing sulfate sources of Zn, Cu and Mn with hydroxychloride sources of the same trace minerals:
  - ✓ Increased yield of ECM and tended to increase the yield of colostrum with no changes in the composition of colostrum.
  - ✓ Reduced morbidity
  - ✓ Tended to improve reproduction

Acknowledgements

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ANIMAL SCIENCES

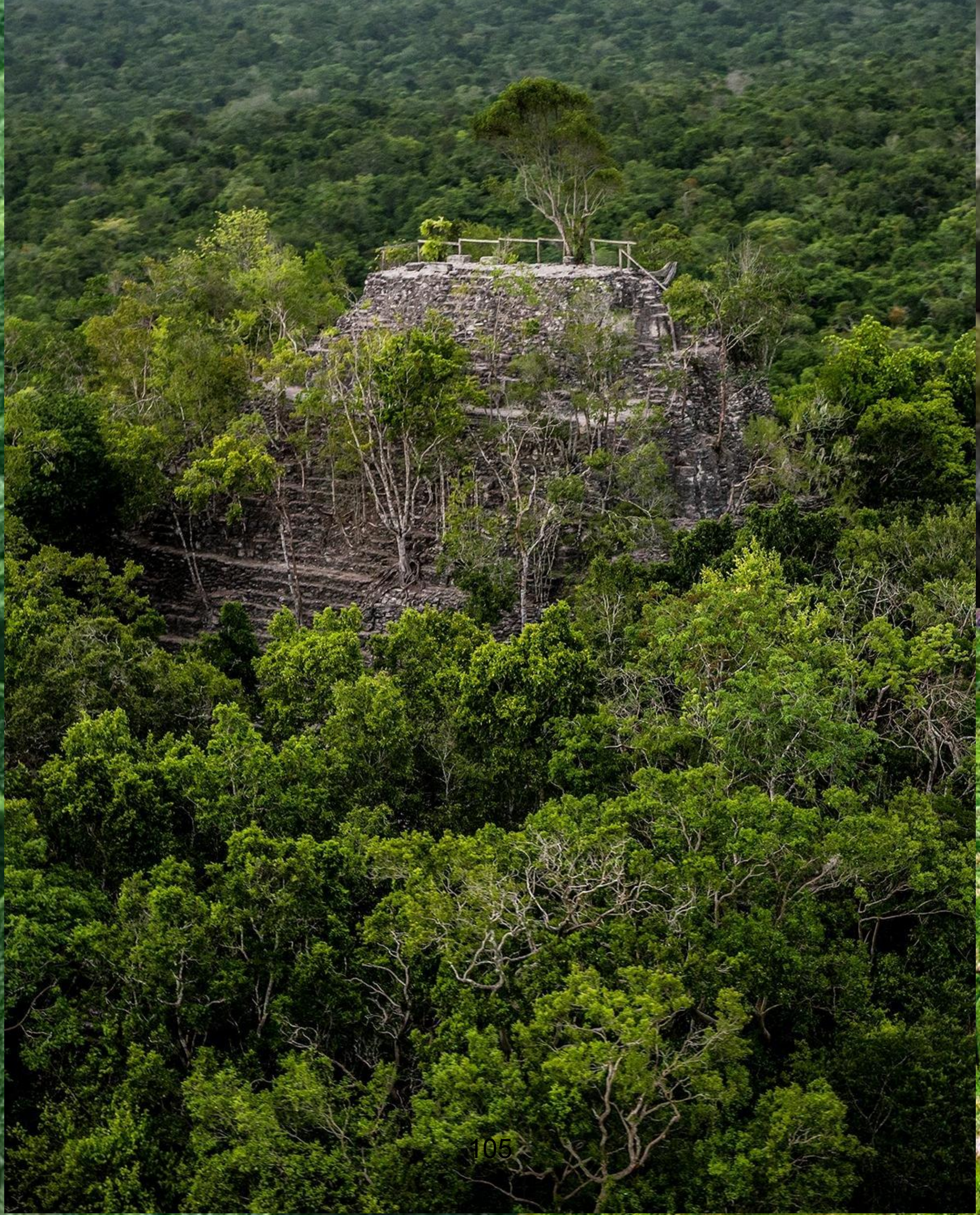
Discovery of Phytotechnologies for improving resilience of the modern dairy cow: a physiological perspective

Emma Wall, PhD

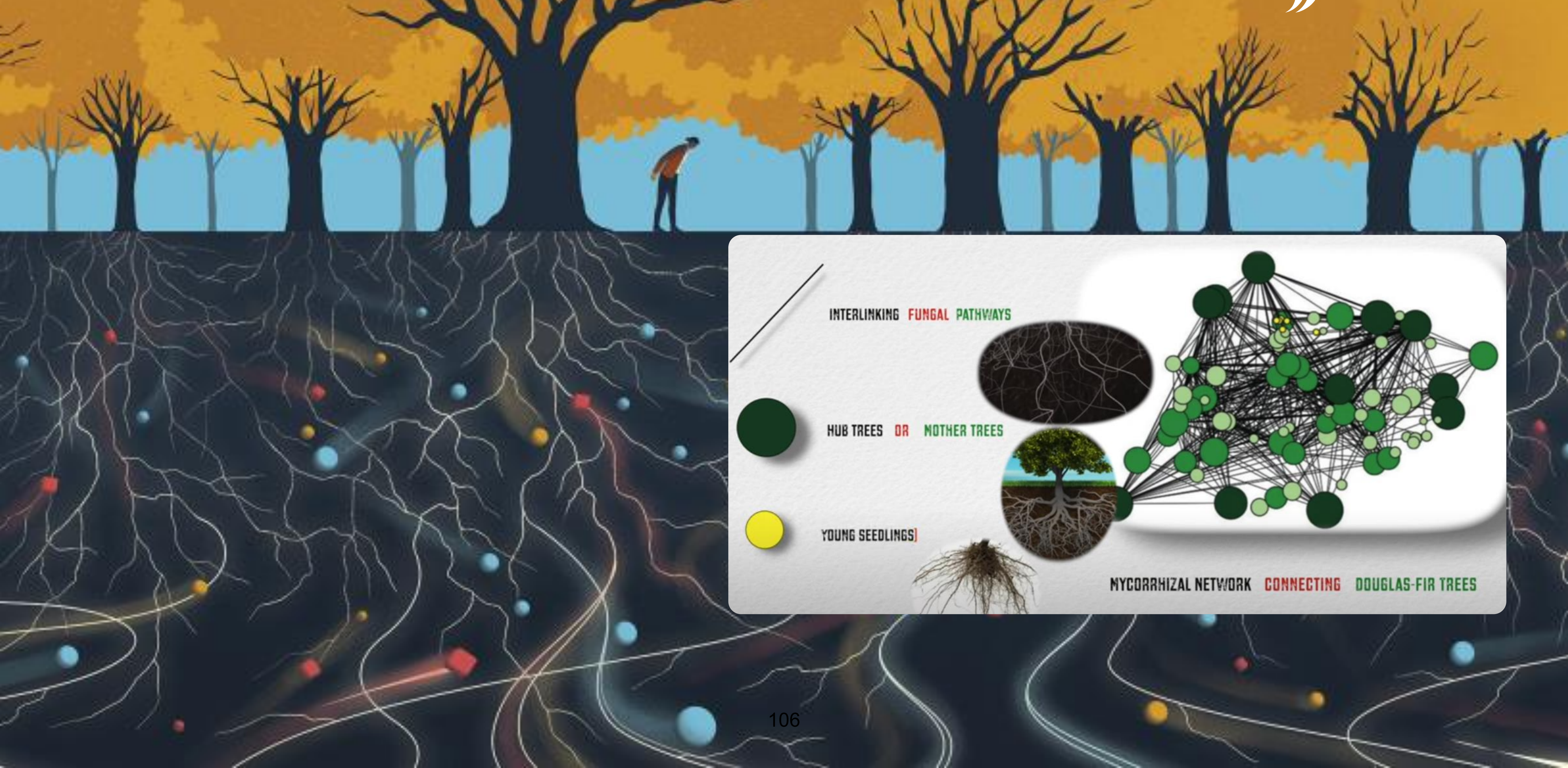
Life finds a way: when nature reclaims abandoned places

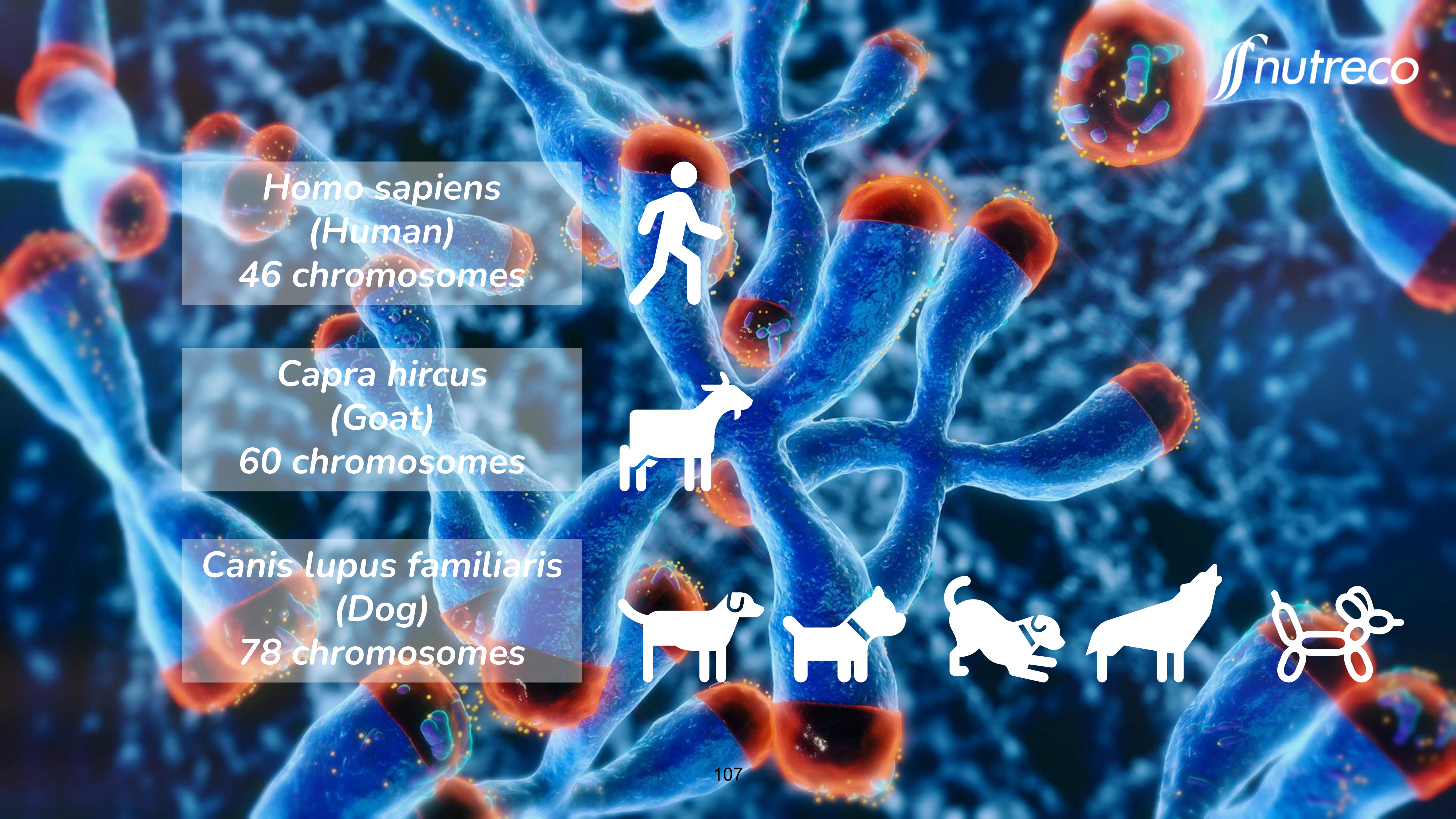
What happens to a human environment when all the people leave? Nature takes it back.

By Hayley Bennett
Published: July 20, 2020 at 8:23 am



Dr. Simard et al., Nature 1997

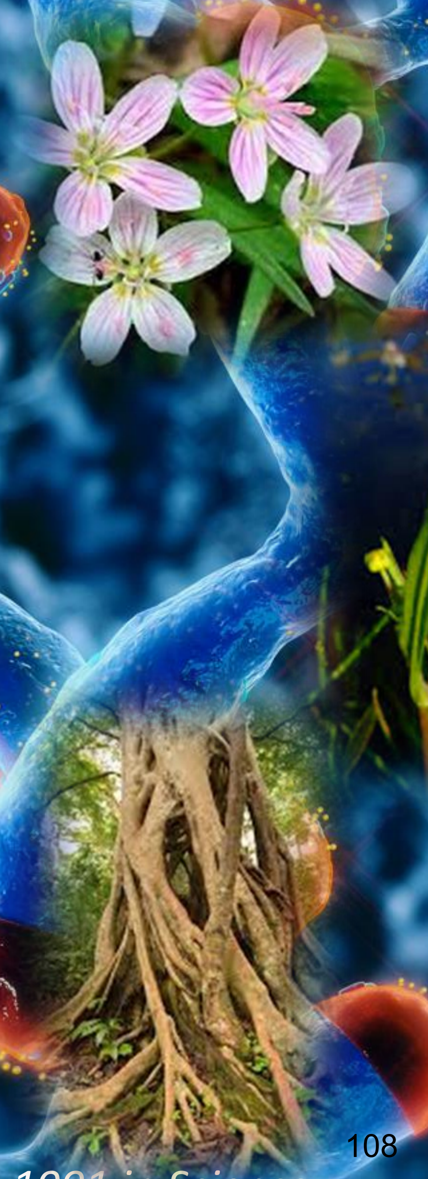



Homo sapiens
(Human)
46 chromosomes
Capra hircus
(Goat)
60 chromosomes
Canis lupus familiaris
(Dog)
78 chromosomes

Claytonia virginica
(Virginia spring beauty)
12 chromosomes

Ranunculus flammula
(Lesser spearwort)
16 chromosomes

Ficus aurea
(Strangler Fig Trees)
26 chromosomes



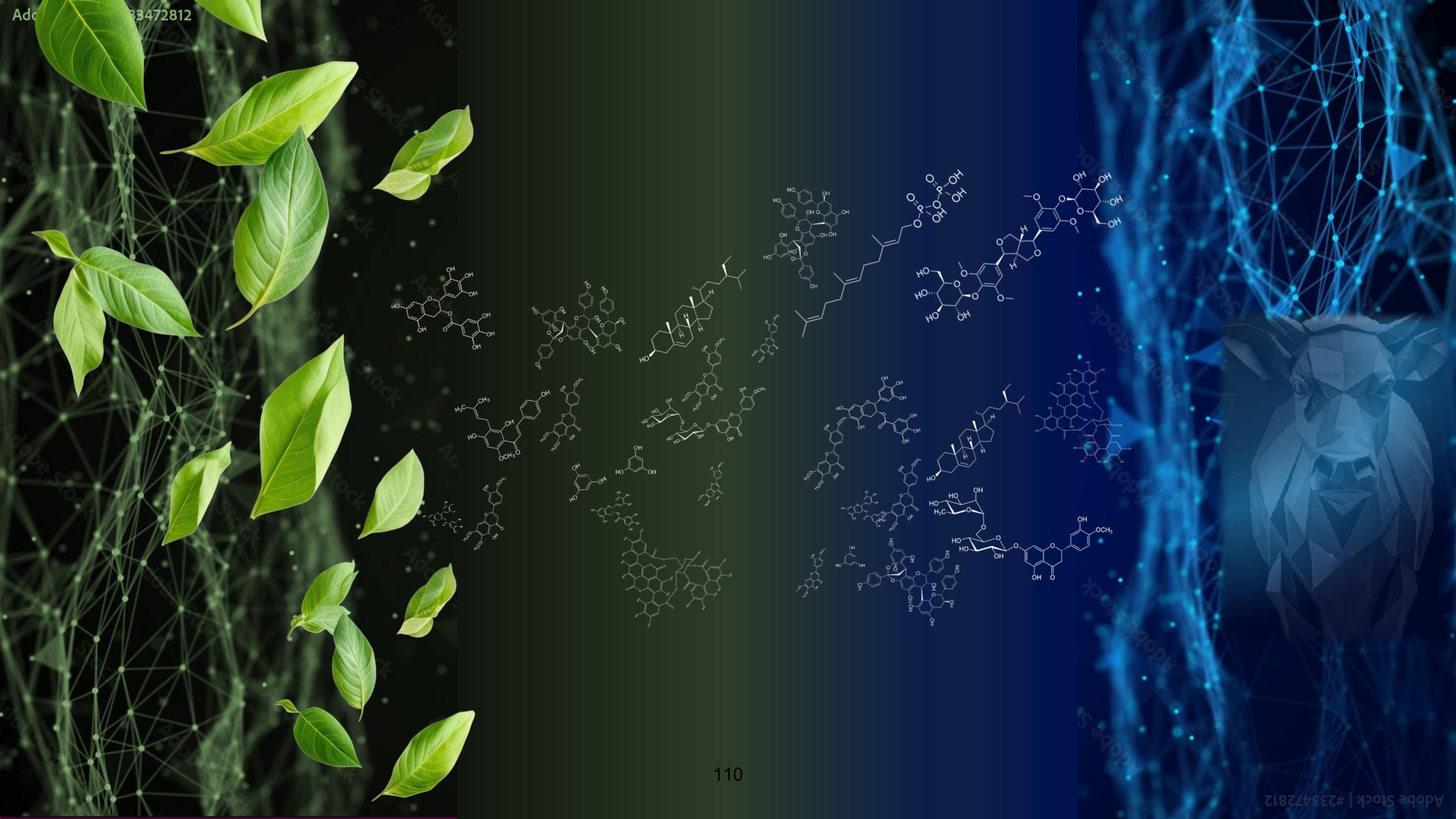
Chromosome N
from 12 to 191*

Gene absent in some parts of the plants

On 14 trees, 13 are genotype mosaics.
13 trees included at least 45 genetic individuals (genetic Mosaics)
In 7 of the trees, each sampled branch was different **

* Source: Lewis, 1970 in Science; ** Thomson, 1991 in Science

Plants have a highly successful evolutionary strategy.
They cannot run; they are agile, highly adaptable experts in chemistry.
Since they co-evolved with animals, they communicate with them and directly impact physiology.



Phytotechnologies for resilience

Animals know the power of plants

Cows on grass prefer herbs as a side dish

Scientists from Aarhus University have studied a selection of herbs and their potentially beneficial effects in cows.

Grazing cows do not just automatically move to the next patch of grass for their meal. If possible, they will choose a meal containing different kinds of herbs.

https://www.allaboutfeed.net

Nutritional Intuition: Why Grass-Fed Cattle Need Biodiversity

BY CHRIS BAGGOTT
DECEMBER 5, 2024 · 3 MIN READ

https://tynerpondfarm.com/blogs/uncategorized/nutritional-intuition-why-grass-fed-cattle-need-biodiversity

Phytotechnologies for resilience

Animals know the power of plants

biomolecules

MDPI

Review

Zoopharmacology: A Way to Discover New Cancer Treatments

Eva María Domínguez-Martín [1,2], Joana Tavares [1], Patrícia Ríjo [1,3] and Ana María Díaz-Lanza [2,*]

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check for updates

Received: 5 May 2020; Accepted: 22 May 2020; Published: 26 May 2020

Abstract: Zoopharmacognosy is the multidisciplinary approach of the self-medication behavior of many kinds of animals. Recent studies showed the presence of antitumoral secondary metabolites in some of the plants employed by animals and their use for the same therapeutic purposes in humans.

Phytotechnologies for resilience

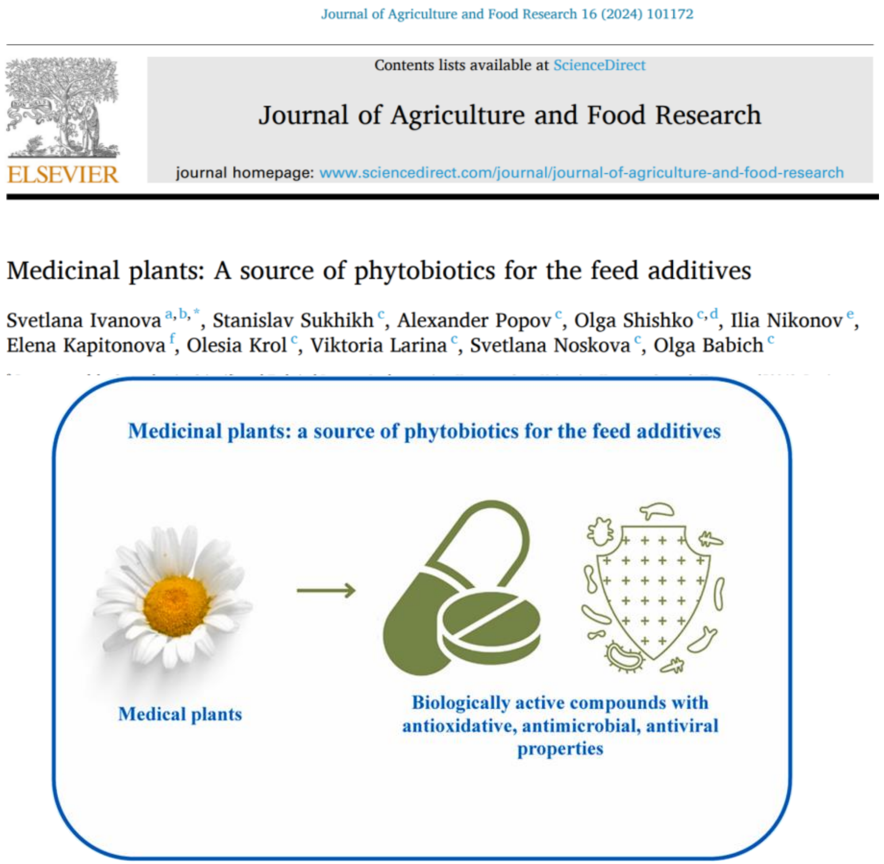
Status quo: silver-bullet solutions

Nearly all “phytogenics” on the market were developed using this approach

- Reductionist, pharmaceutical lens
- Antimicrobial properties
- Replacement of antibiotics

There are a few effective solutions, but we face significant challenges:

- **Inconsistent efficacy**
- **Regulatory problems**
- **Customer/market fatigue**
- **Limited candidate pool; few new products**


Journal of Agriculture and Food Research 16 (2024) 101172

Contents lists available at ScienceDirect

Journal of Agriculture and Food Research

journal homepage: www.sciencedirect.com/journal/journal-of-agriculture-and-food-research

ELSEVIER

Medicinal plants: A source of phytobiotics for the feed additives

Svetlana Ivanova[a,b,*], Stanislav Sukhikh[c], Alexander Popov[c], Olga Shishko[c,d], Ilia Nikonov[e], Elena Kapitonova[f], Olesia Krol[c], Viktoria Larina[c], Svetlana Noskova[c], Olga Babich[c]

As needs changed → forced to fit


> Trop Anim Health Prod. 2017 Dec;49(8):1663-1668. doi: 10.1007/s11250-017-137
Epub 2017 Aug 11.

The effects of supplementing Acacia mearn
extract on dairy cow dry matter intake, mil
production, and m
pasture

> J Dairy Sci. 2020 Mar;103(3):2

Effects of feedin
extract on lactat

Ruchita Khurana [1], Tassilo Brand

> Anim Biotechnol. 2021 Jun;32(3):36

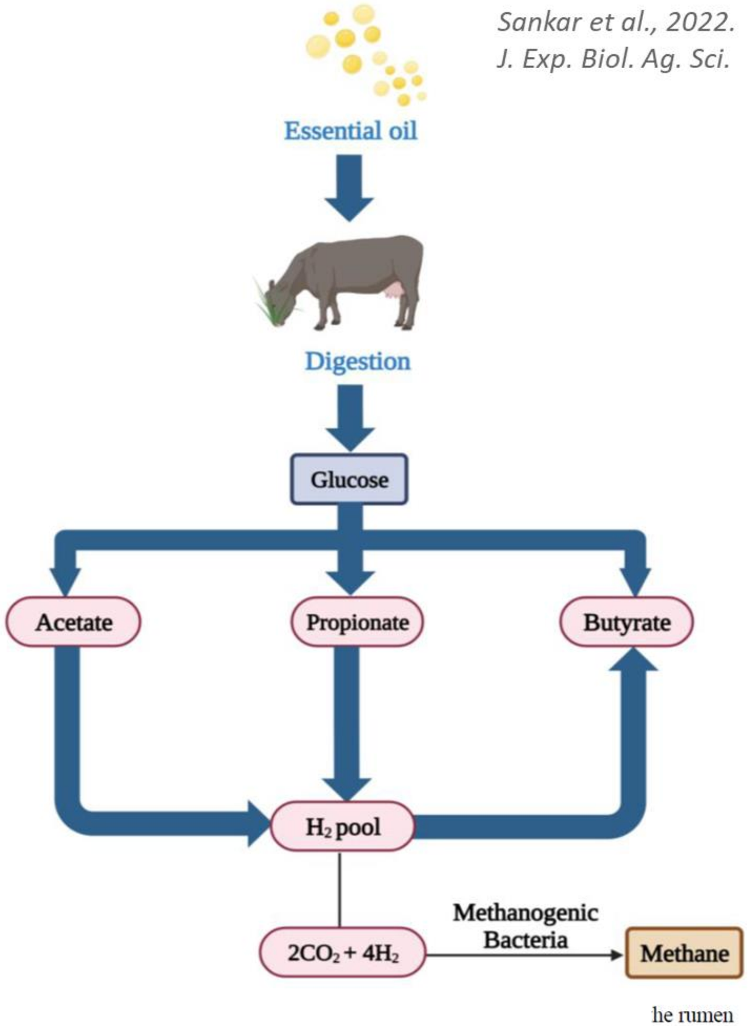
Effects of pomegran
post-ruminal *in vit*
inoculum of the dai

Mohammad Javad Abarghuei [1], Yousef Rouzbehan [1], Abdelfattah Zeidan Mohamed Sa
Mohammad Javad Zamiri [3]

> Food Funct. 2023 Jan 3;14(1):94-111. doi: 10.1039/d2fo02751h.

Dietary citrus flavonoid extract improves
performance through modulating rumen
and metabolites in dairy cows

Shiqiang Yu [1], Liuxue Li [1], Huiying Zhao [1], Shuyue Zhang [1], Yan Tu [2], Ming Li
Yuchao Zhao [1 3], Linshu Jiang [1]



Sankar et al., 2022.
J. Exp. Biol. Ag. Sci.

Most "phytogenics" for ruminants are focused on modifying the rumen.
Very few focus on the physiology of the animal → opportunity gap.

Phytotechnologies for resilience

Status quo: silver-bullet solutions

Review > J Dairy Sci. 2017 Jul;100(7):5974-5983. doi: 10.3168/jds.2016-12341. Epub 2017 Apr 5.

Host-mediated effects of phytonutrients in ruminants: A review

J Oh [1], E H Wall [2], D M Bravo [2], A N Hristov [3]

Most "phytogenics" for ruminants are focused on modifying the rumen.
Very few focus on the physiology of the animal → opportunity gap.

Phytotechnologies for resilience

Summary

- The impact of plants on animal physiology:
    - is real
    - is powerful
    - is misunderstood & under utilized in ruminant nutrition
- Using a physiological approach to Discovery, we:
    - Respect the power of plants
    - Respect observation even when we can’t explain it
    - Let the animals tell us what the value is
    - Bring that value to industry
- Let’s look at some examples

Phytotechnologies for resilience

Examples we will review

- Passive immunity
- Adaptive immunity
- Liver health

No mention of specific plants, actives, phytochemicals, or receptors.

Because that's not the point!

The point is to appreciate the powerful response of animals to plants and the opportunity that comes with it.

PASSIVE IMMUNITY

NUTRECO'S
GARDEN OF THE FUTURE

Passive Immunity

Importance of Immunoglobulins

> J Dairy Sci. 2020 Aug;103(8):7611-7624. doi: 10.3168/jds.2019-17955. Epub 2020 May 21.

Consensus recommendations on calf- and herd-level passive immunity in dairy calves in the United States

J Lombard [1], N Urie [2], F Garry [3], S Godden [4], J Quigley [5], T Earleywine [6], S McGuirk [7], D Moore [8], M Branan [2], M Chamorro [9], G Smith [10], C Shivley [2], D Catherman [11], D Haines [12], A J Heinrichs [13], R James [14], J Maas [15], K Sterner [16]

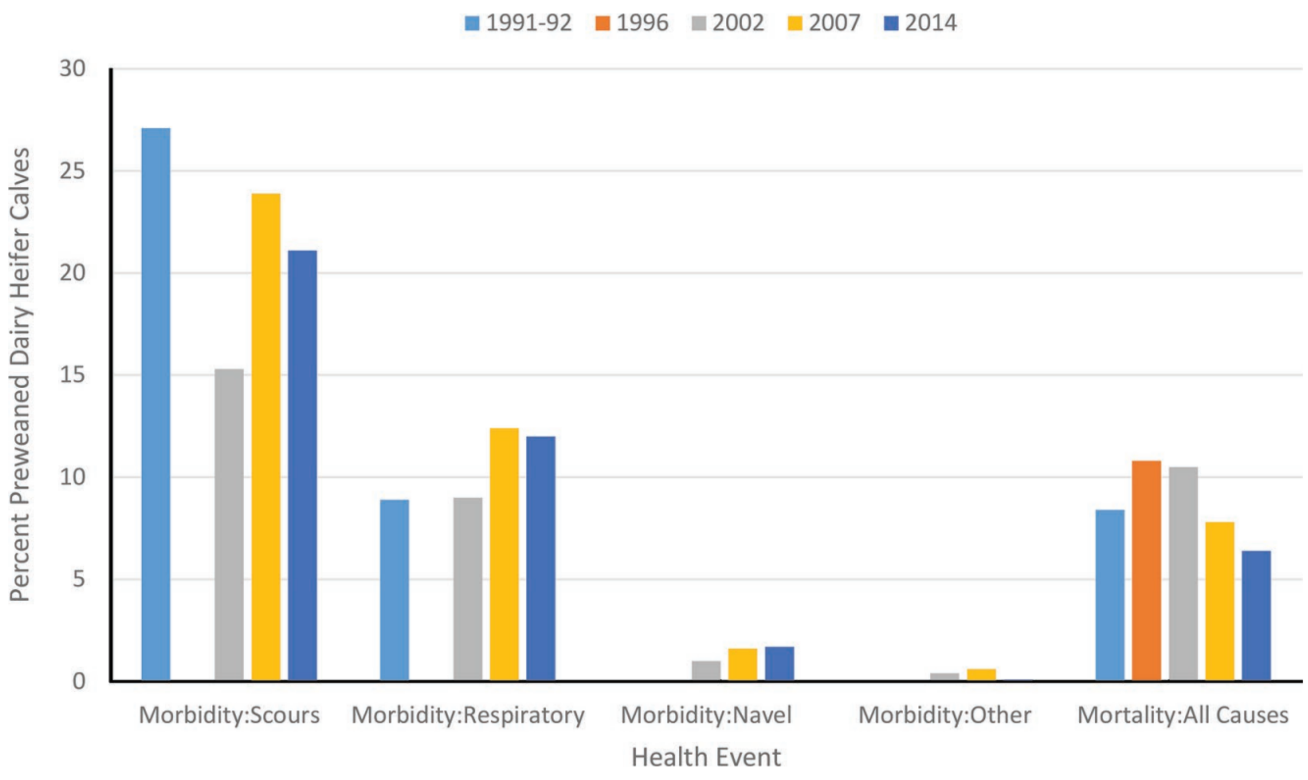
*"…The current standard for categorizing dairy calves with successful passive immunity or failure of passive immunity has been used for **more than 35 yr**."*

*"…recent studies have described reduced **morbidity** in calves to be associated with serum **IgG levels higher than what has been traditionally recommended**."*

Lombard et al., J. Dairy. Sci. 2020

Passive Immunity

Importance of Immunoglobulins



Lombard et al., J. Dairy. Sci. 2020

Passive Immunity

Importance of Immunoglobulins

TPI category	Serum IgG category (g/L)
Excellent	≥25.0
Good	18.0–24.9
Fair	10.0–17.9
Poor	<10.0

IgG level (g/L)	Model predicted, percent (95% CI)	
	Morbidity	Mortality
8.0	41.3 (34.6–48.8)	8.2 (6.2–10.7)
14.0	37.8 (31.8–44.3)	6.6 (5.3–8.2)
21.5	33.6 (28.2–39.5)	5.0 (4.1–6.2)
27.0	30.6 (25.2–36.6)	4.1 (3.1–5.4)

How can we further improve passive immunity (other than management)?

WE NEED TO FOCUS ON THE PHYSIOLOGY.

Lombard et al., J. Dairy. Sci. 2020

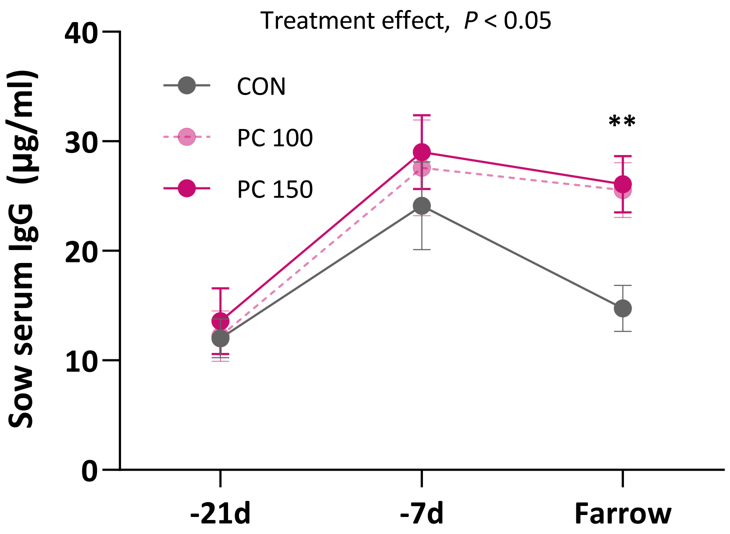
Passive Immunity

Importance of Immunoglobulins

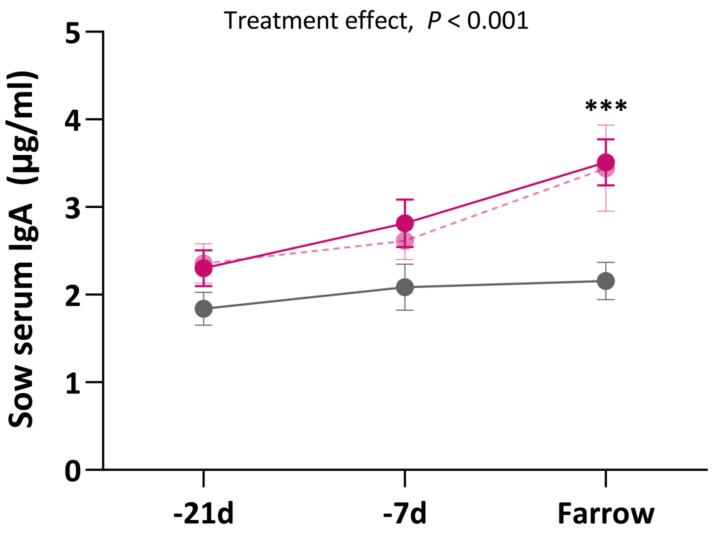
Passive Immunity

Improving passive transfer with PhytoComplex

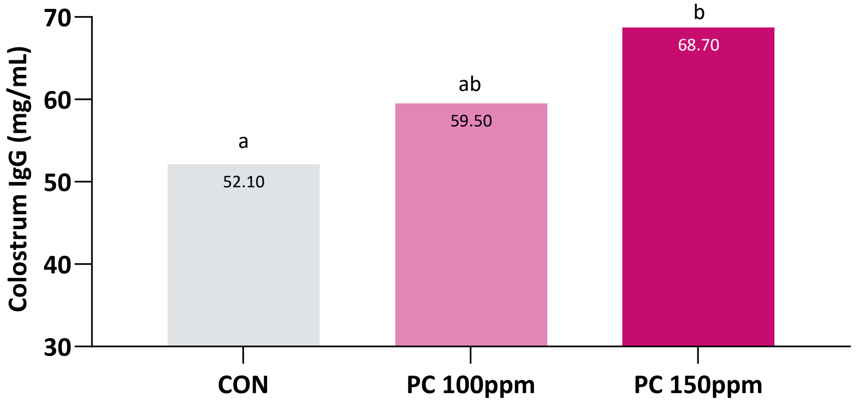
SOW SERUM - IgG



SOW SERUM - IgA

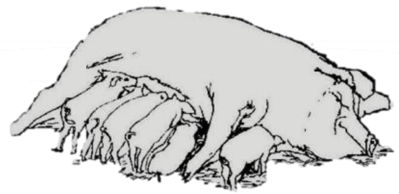


COLOSTRUM - IgG



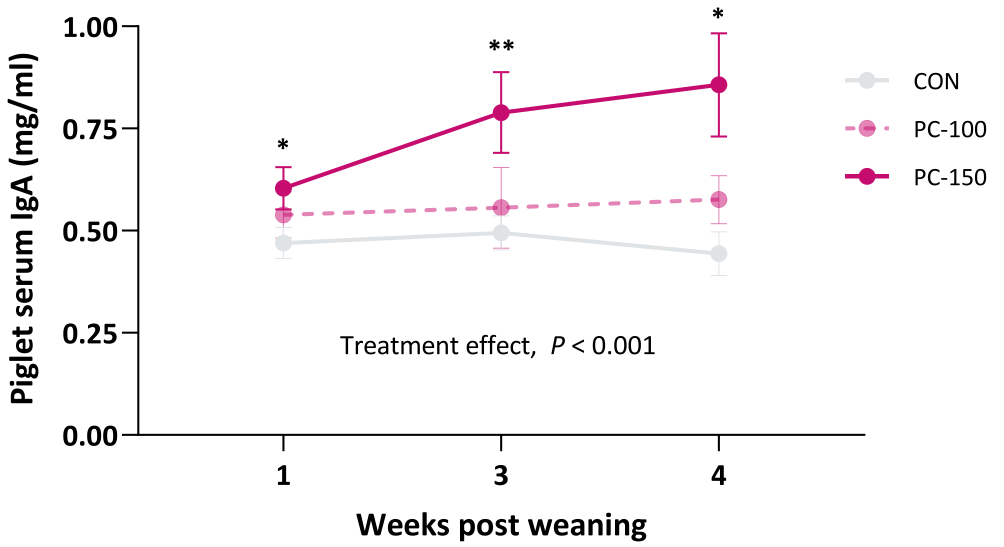
Van de Ligt et al., J. Anim. Sci Vol. 102, Suppl. S2. 2024; doses are in ppm

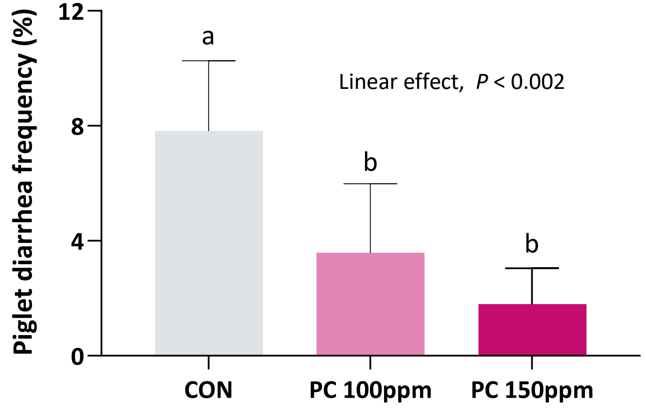
Passive Immunity

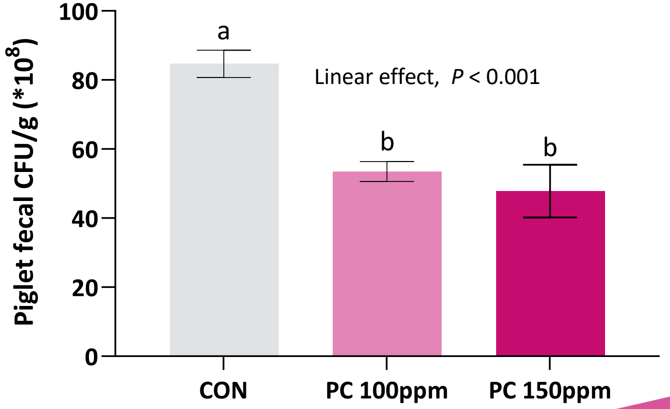


Improving passive transfer with PhytoComplex

PIGLET SERUM - IgA







*Treatments administered to **<u>sows only</u>**; a,b = P < 0.05*

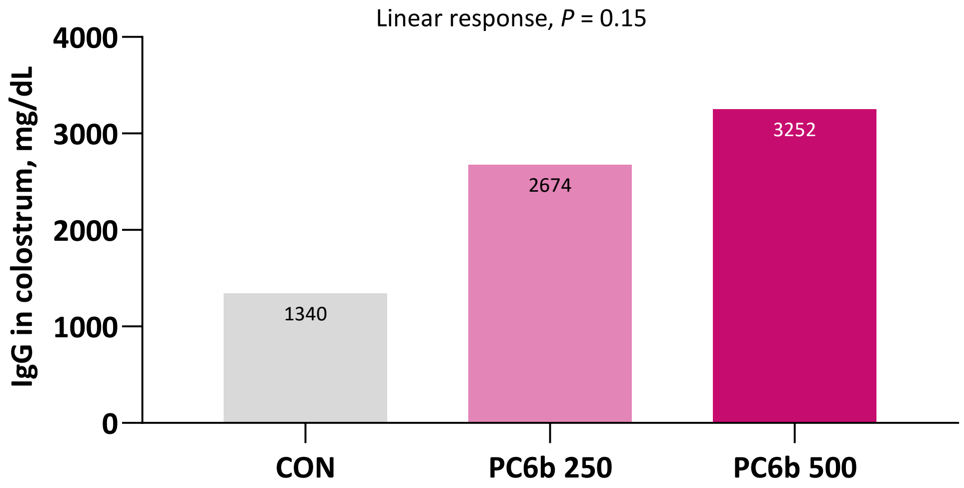
Van de Ligt et al., J. Anim. Sci Vol. 102, Suppl. S2. 2024; doses are in ppm

Passive Immunity

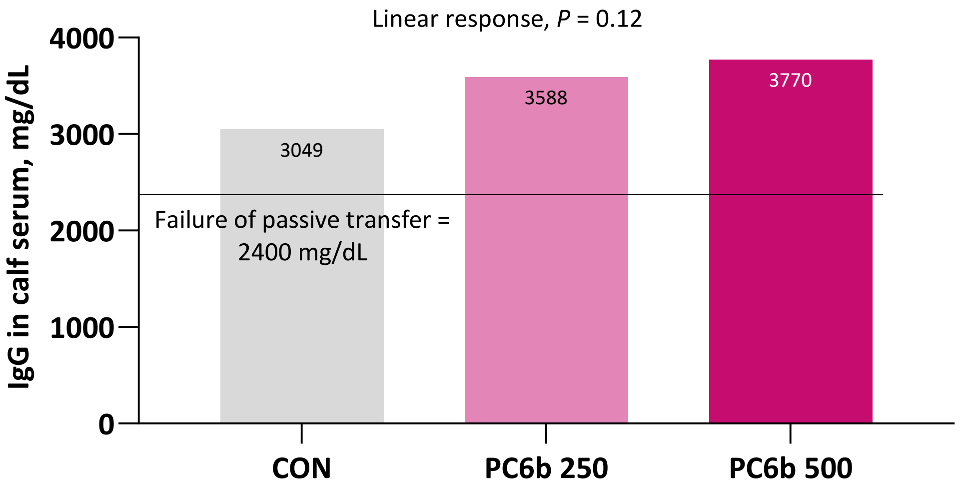
Improving passive transfer with PhytoComplex

STUDY 1

COLOSTRUM - IgG



CALF SERUM - IgG



Beef cows supplemented from d-30 to 56 of lactation; ***doses are in mg/head/d***

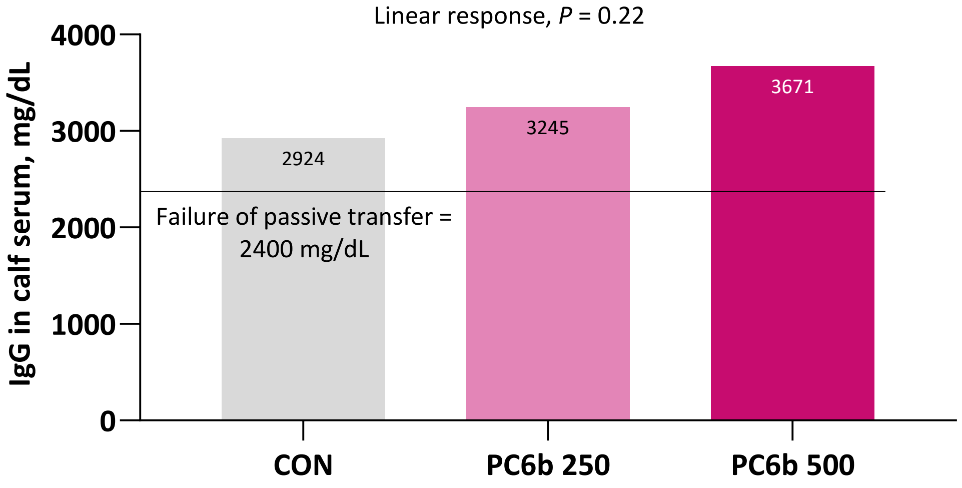
Ezzell et al., J. Anim. Sci *(submitted)*

Passive Immunity

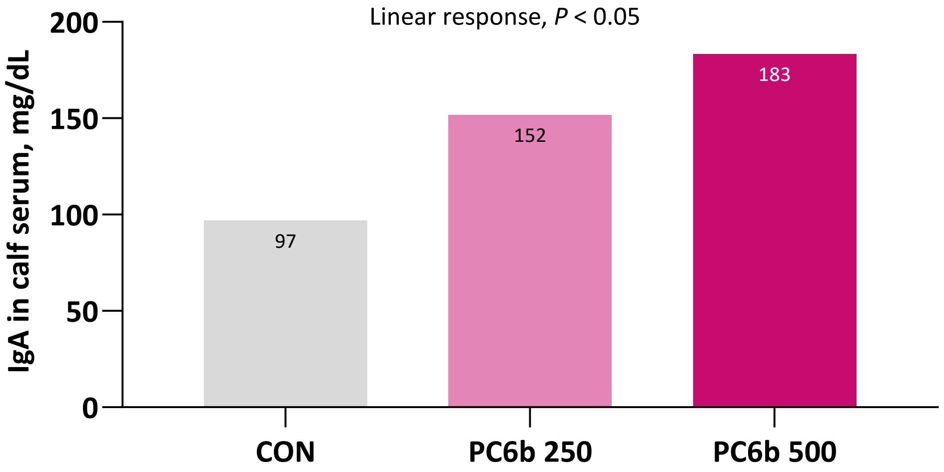
Improving passive transfer with PhytoComplex

STUDY 2

CALF SERUM - IgG



CALF SERUM - IgA



Beef cows supplemented from d-30 to 56 of lactation; ***doses are in mg/head/d***

Jardon et al., Vet. Sci. 2025

South Dakota State University

Fytera® | Lacteco

Passive Immunity

Improving passive transfer with PhytoComplex

	CON	PC6b 250	PC6b 500	*P*-value
Calf serum*				
IgG, mg/dL	2986[a]	3417[a]	3721[b]	0.03
IgA, mg/dL	214[a]	256[ab]	276[b]	0.10
Calf ADG, kg				
d0 to weaning**	0.795[a]	0.855[b]	0.845[b]	0.11
Calf BW, kg				
birth	31.5	30.5	32.5	0.85
d56	85.5[a]	88.7[ab]	91.8[b]	0.04

*blood samples taken 24-48h after birth; **d 200-205; a,b = means in the same row are different, $P < 0.05$
Beef cows supplemented from d-30 to 56 of lactation; ; doses are in mg/head/d

Improved passive immunity with PhytoComplex translated into increased body weight

Fytera® | Lacteco

Pooled analysis (unpublished)

Passive Immunity

Summary

- Current benchmarks for passive transfer are outdated
- We need more refined approaches to improving passive immunity in calves
- We can directly impact passive immunity with Phytotechnologies during transition:
  - Increased Ig production by the dam
  - Increased Ig levels in calf serum
  - → Improved health & growth performance (beef)
- Studies ongoing for dairy application (Carlyn)

Dr. Carlyn Peterson

ADAPTIVE IMMUNITY

NUTRECO'S GARDEN OF THE FUTURE

Adaptive Immunity

Cryptosporidiosis is globally endemic

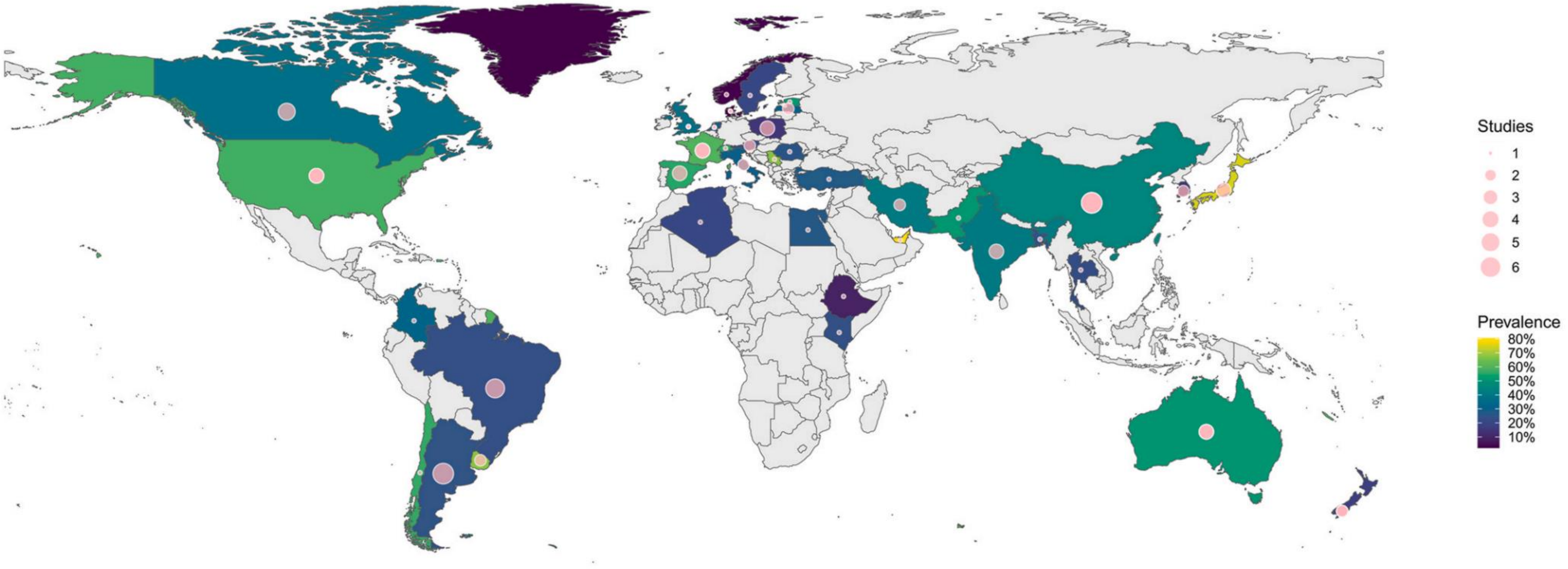


Fig. 1. Global prevalence of *Cryptosporidium* spp. in calves. Estimation of *Cryptosporidium* spp. prevalence in calves and the number of studies per country.

Buchanan et al., Curr. Res. Parasitol. & Vector-Borne Dis. 2025

Adaptive Immunity

Cryptosporidiosis & coccidiosis remain top causative pathogens in calves

Table 2
Distribution of trials by age category (<15 days, 16–30 days, 31–59 days, and >60 days) and primary targeted etiological agent.

Age Category (days)[1]	Targeted Etiological Agent	Trials (n)	Age at AMU (days)[2] Average	Min	Max
≤ 15	Cryptosporidium spp.	25	3.3	0.0	14.0
	Eimeria spp.	2	3.0	3.0	3.0
	Escherichia coli	2	2.0	1.0	3.0
	Unspecified agent	4	3.1	1.0	7.0
30–59	Eimeria spp.	10	45.6	31.0	58.0
	Salmonella Typhimurium	1	54.5	-	-
≥ 60	Eimeria spp.	14	81.9	60.0	129.0
	Salmonella Typhimurium	4	87.5	80.0	95.0

[1] No trials were reported for the age range of 16–30 days.
[2] Age at onset of antimicrobial drug administration.

WE NEED TO FOCUS CALF PHYSIOLOGY.

HOST-MEDIATED RESPONSES FOR PREVENTION & RESILIENCE.

Bernal-Cordoba et al., Prev. Vet. Med. 2025

Adaptive Immunity

Animals know the power of plants

Ruminant self-medication against gastrointestinal nematodes: evidence, mechanism, and origins☆

Juan J. Villalba[1,*], James Miller[2], Eugene D. Ungar[3], Serge Y. Landau[3], and John Glendinning[4]

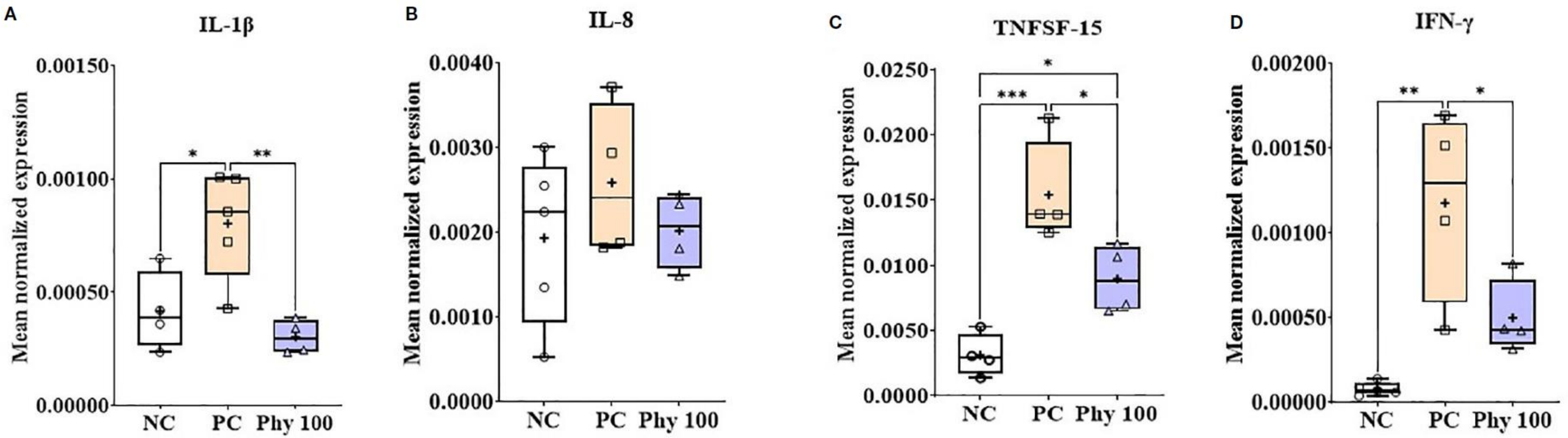
Sparrows use a medicinal herb to defend against parasites and increase offspring condition

Canchao Yang [1], Ping Ye [1], Juan Huo [1], Anders P. Møller [2], Wei Liang [1], William E. Feeney [3 4 5]

Adaptive Immunity

Coccidiosis

Host-mediated resilience with PhytoComplex



PhytoComplex reduces intestinal inflammation in broilers challenged with *Eimeria spp.*

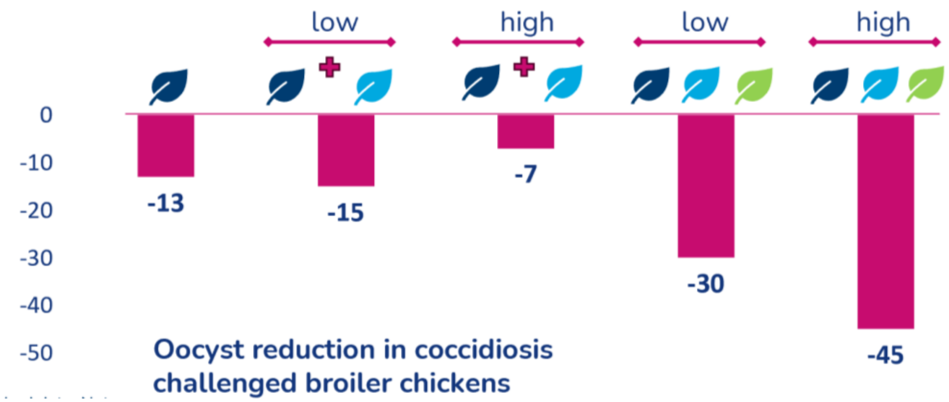
Park et al., Front. Immun. 2023; Park et al., Poultry. Sci. 2025

USDA Agricultural Research Service

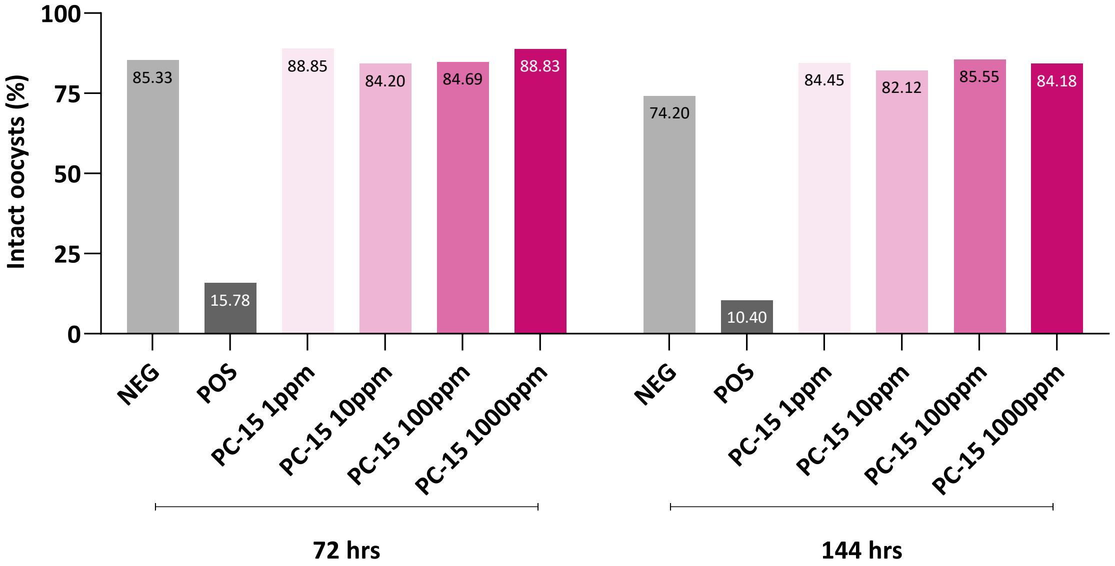
Adaptive Immunity

Coccidiosis

Host-mediated resilience with PhytoComplex



PhytoComplex reduces oocyst shedding in broilers challenged with *Eimeria spp.* …



Yet the PhytoComplex is not a coccidiostat

Park et al., Front. Immun. 2023; Park et al., Poultry. Sci. 2025

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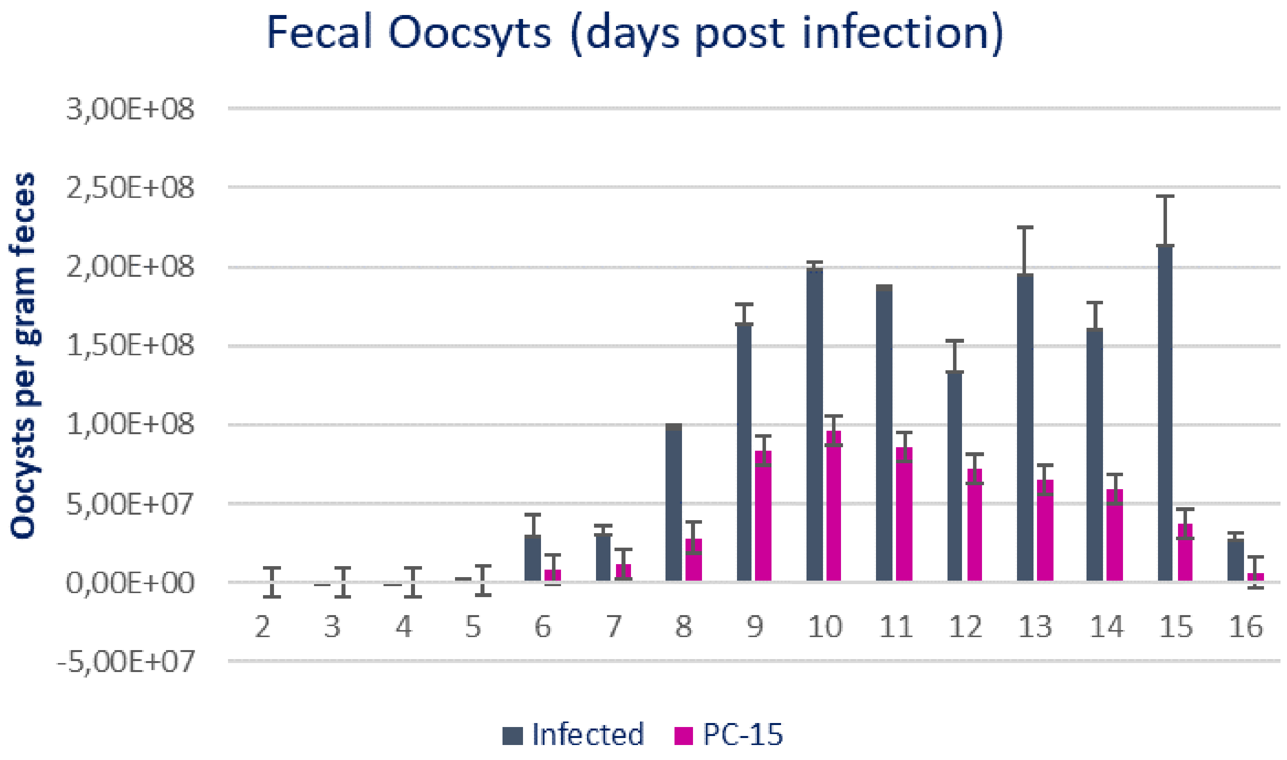
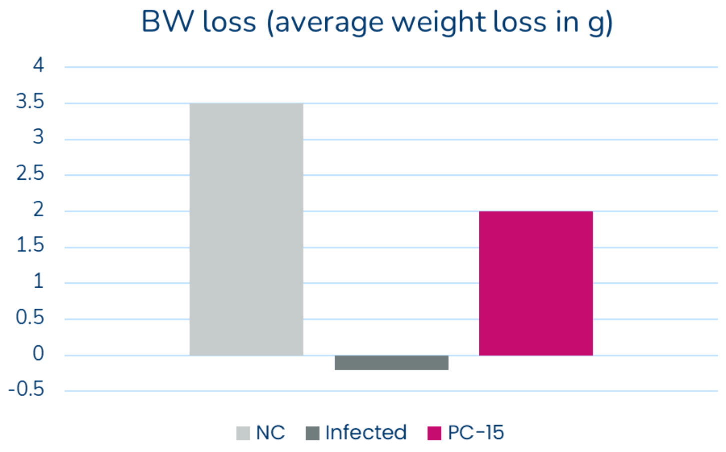
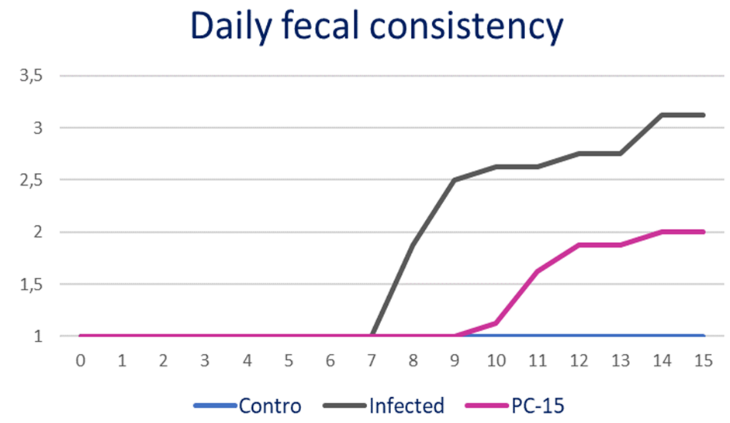
Adaptive Immunity

Cryptosporidiosis

Host-mediated resilience with PhytoComplex





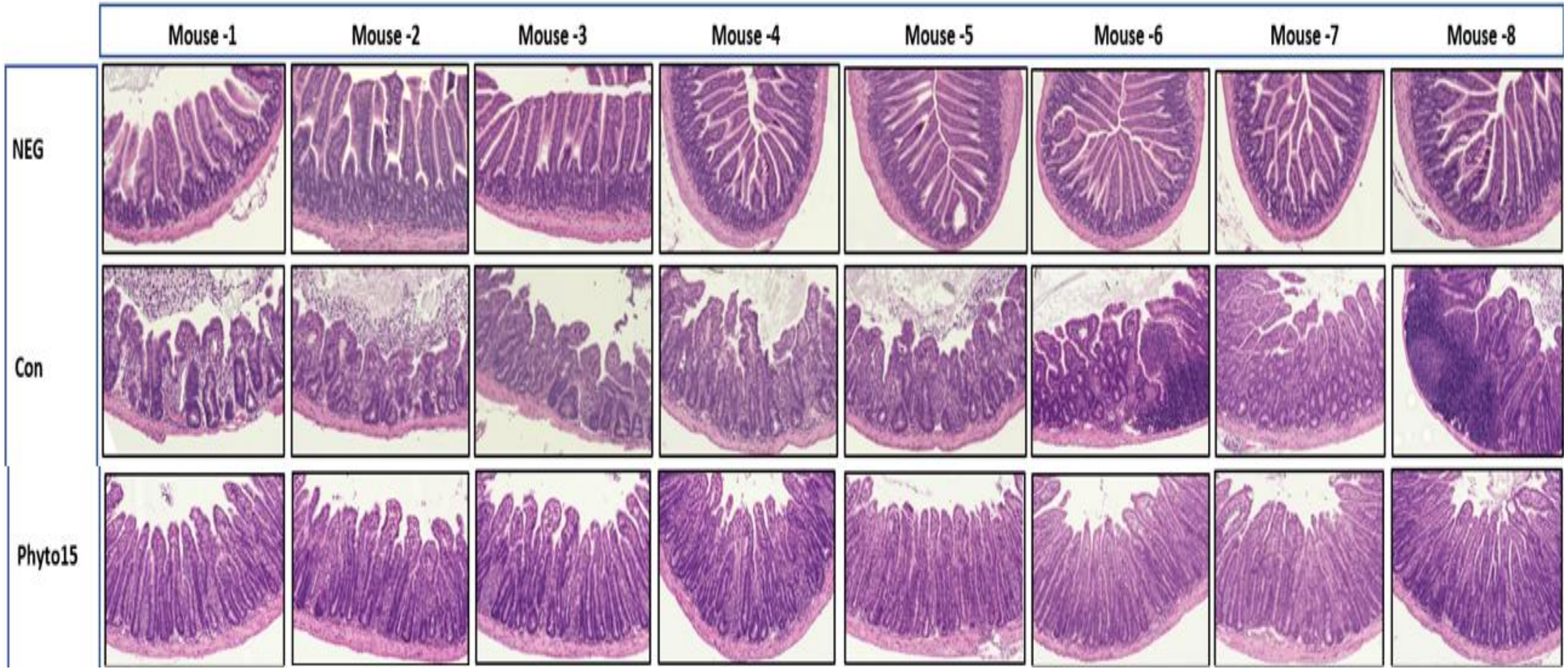


Mia et al., Front. Parasitol. (Submitted)

UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Adaptive Immunity

Host-mediated resilience with PhytoComplex



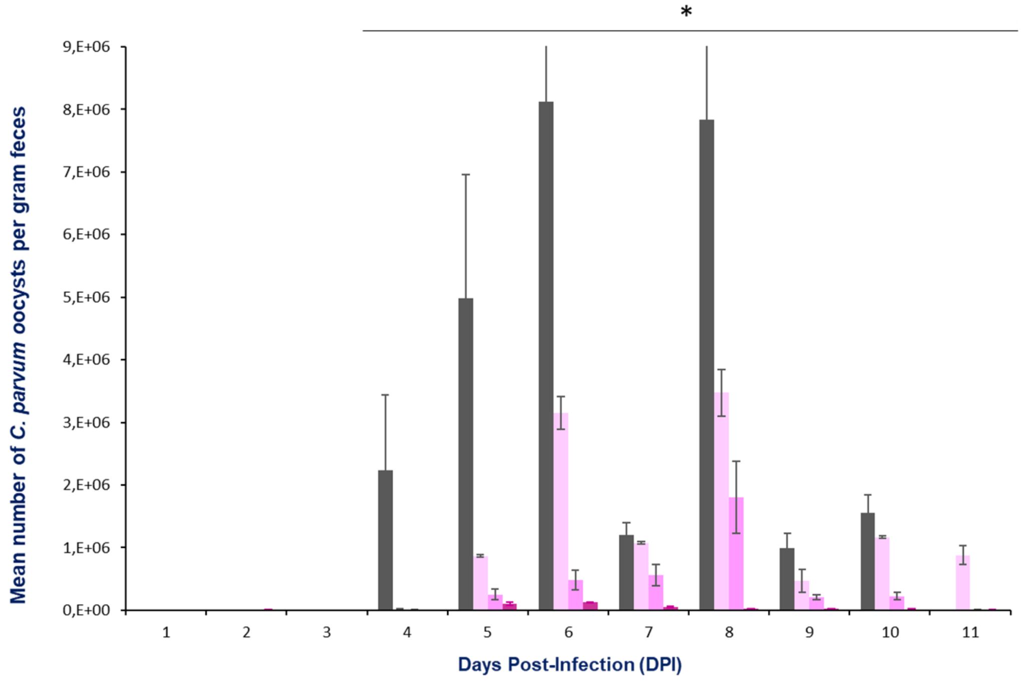
Mia et al., Front. Parasitol. (Submitted)

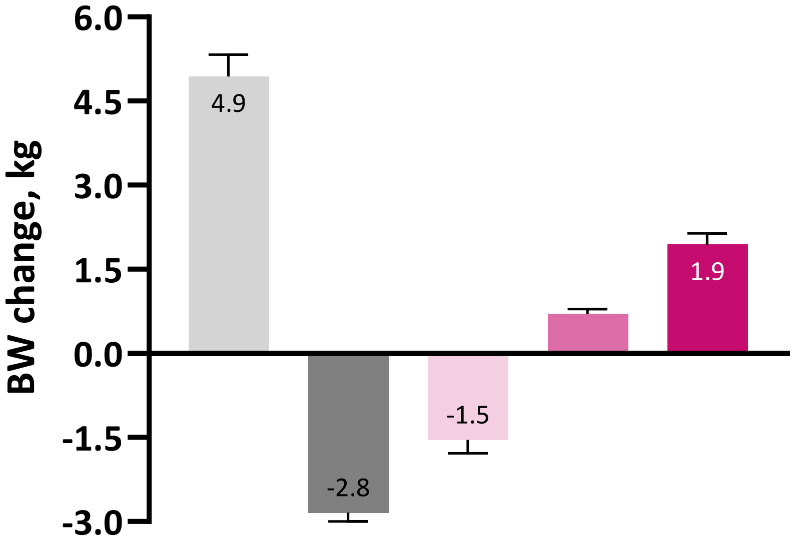
Adaptive Immunity

Cryptosporidiosis

Host-mediated resilience with PhytoComplex

STUDY 1 - CRYPTO





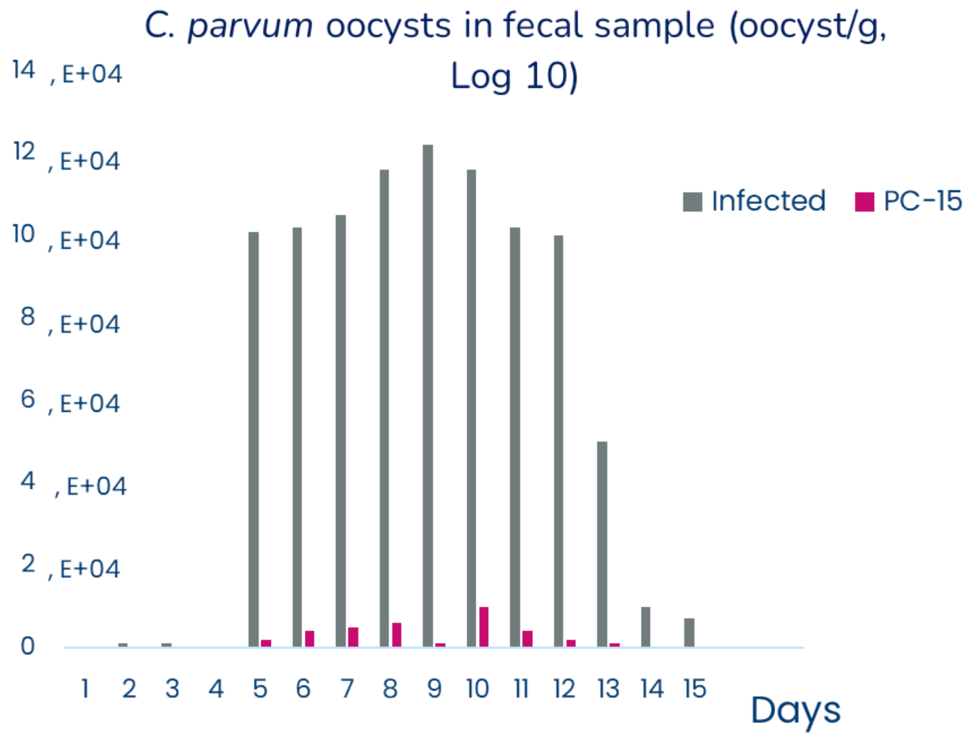
Seymour et al., 2026 ADSA

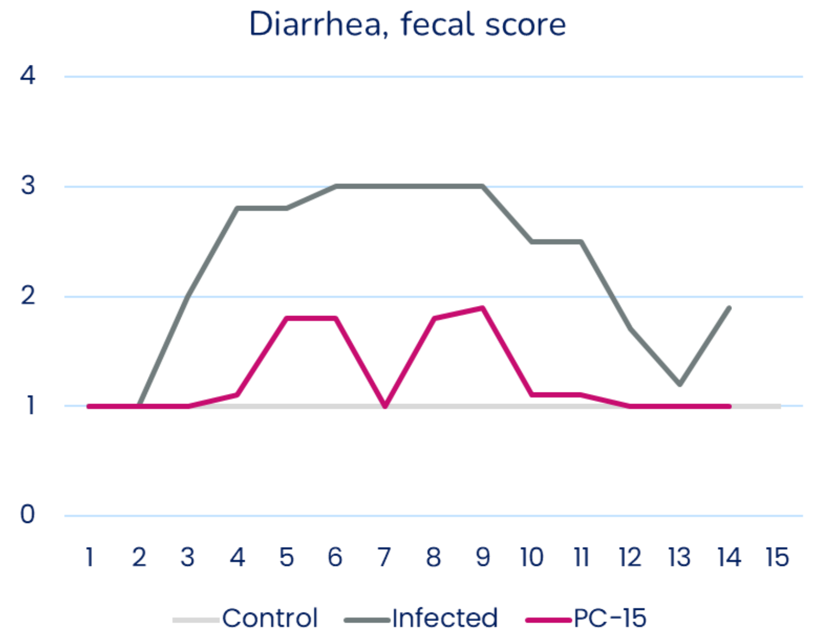
Adaptive Immunity

Cryptosporidiosis

Host-mediated resilience with PhytoComplex

STUDY 2 - CRYPTO





Seymour et al., 2026 ADSA

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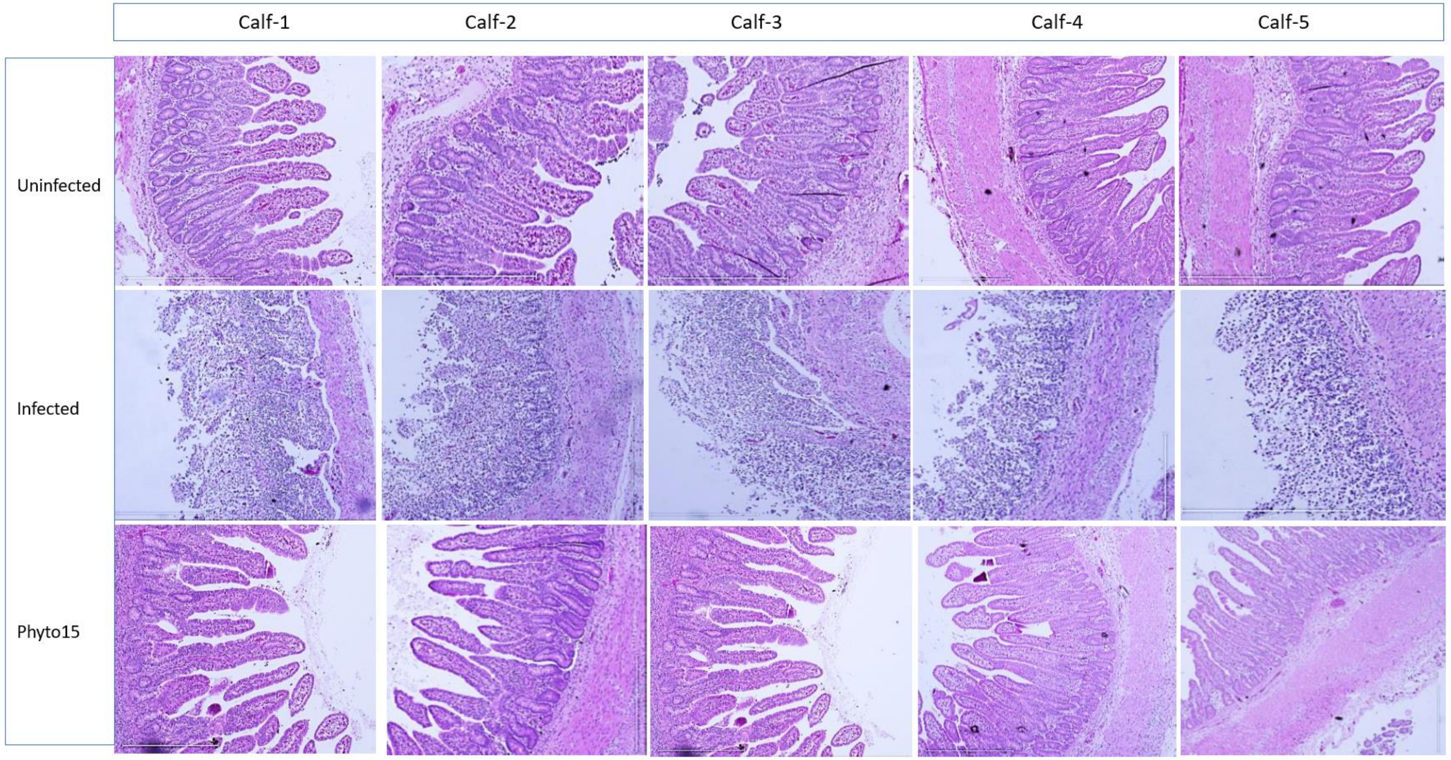
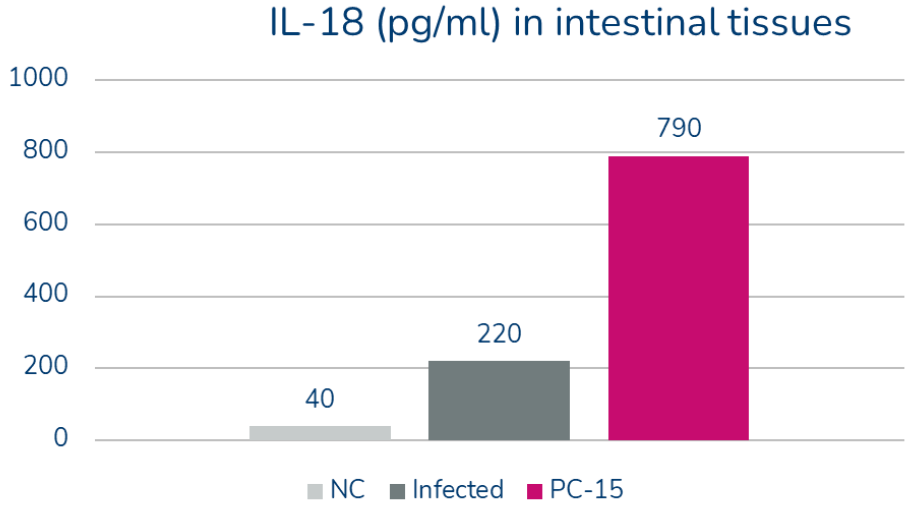
Adaptive Immunity

Cryptosporidiosis

Host-mediated resilience with PhytoComplex

STUDY 2 - CRYPTO





Seymour et al., 2026 ADSA

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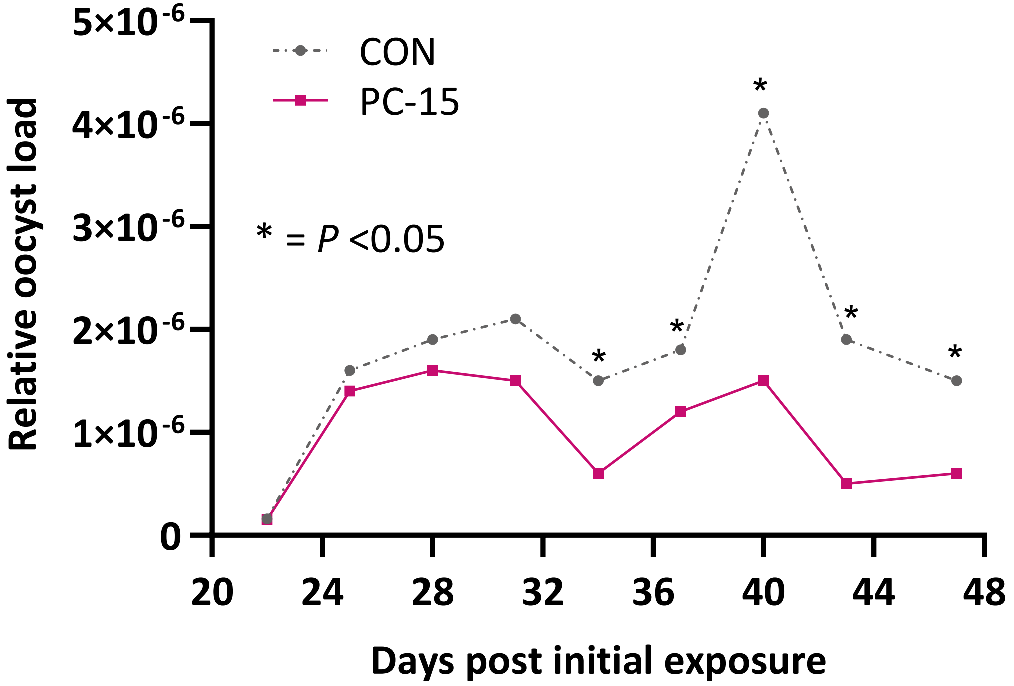
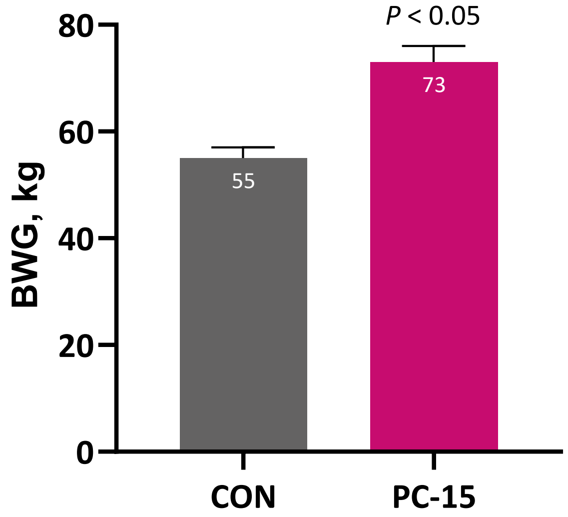
Adaptive Immunity

Coccidiosis

Host-mediated resilience with PhytoComplex

STUDY 3 - COCCI





New data (unpublished)

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Adaptive Immunity

Summary

- Calf scours are highly prevalent and crypto / cocci remain the main causative pathogens
- Rather than treatment, we need prevention approaches that target the animal
- We can improved host-mediated responses with Phytotechnologies:
  - Decreased inflammatory cytokines / improved Th1 immune responses
  - Prevention of intestinal damage
  - Decreased oocyst shedding
    - →Decreased spread of disease
    - → Improved health & growth performance

LIVER HEALTH

NUTRECO'S GARDEN OF THE FUTURE

Liver health

The target has changed!!

Living cow replica of 1960's genetics: **16L of milk/d**

Gigi in 2016: **93L of milk/d** for one year (**3X** the average milk yield for that time)

Connie today: record milk yield of **53L milk/d** over 14 year life (**191k L** of milk!!)

Hoards.com

Liver health

The target has changed!!

Review > Vet Clin North Am Food Anim Pract. 2022 Nov;38(3):433-446.
doi: 10.1016/j.cvfa.2022.07.004.

Liver Disorders Associated with Metabolic Imbalances in Dairy Cows

Pablo Pinedo [1], Pedro Melendez [2]

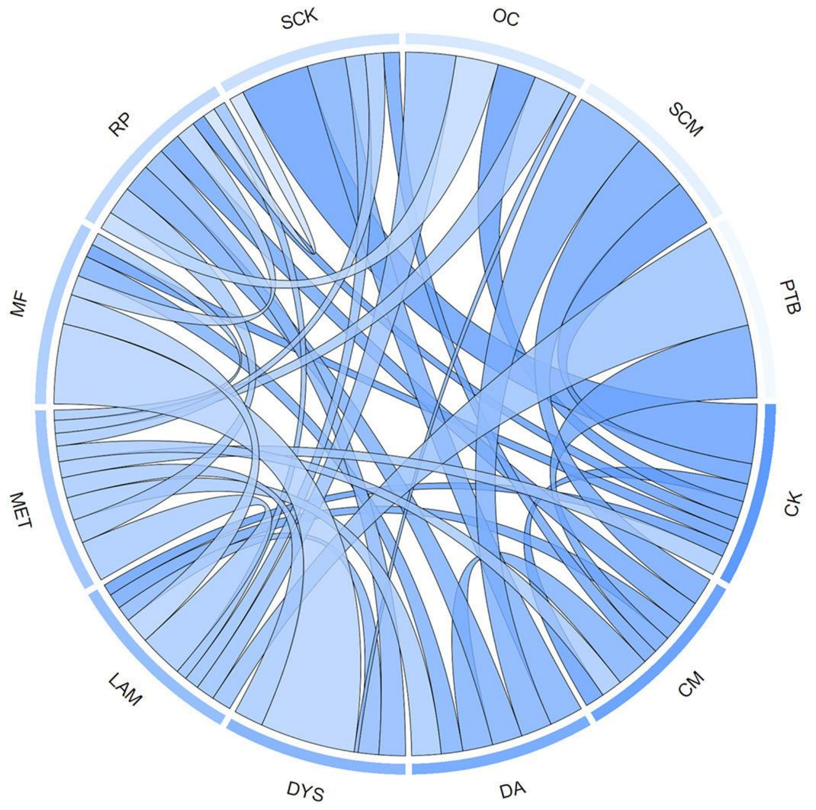
*“…the development of fatty liver has evolved over time, becoming a **more common and severe condition than it was 20 years ago**.”*

“…most cows have evolved to develop moderate to severe fatty liver regardless of feeding management.”

“…this makes them more susceptible to other diseases…”

Liver health

Metabolic disease is highly complex



The biggest impact on production losses are diseases that are prevalent, associated, and invisible.

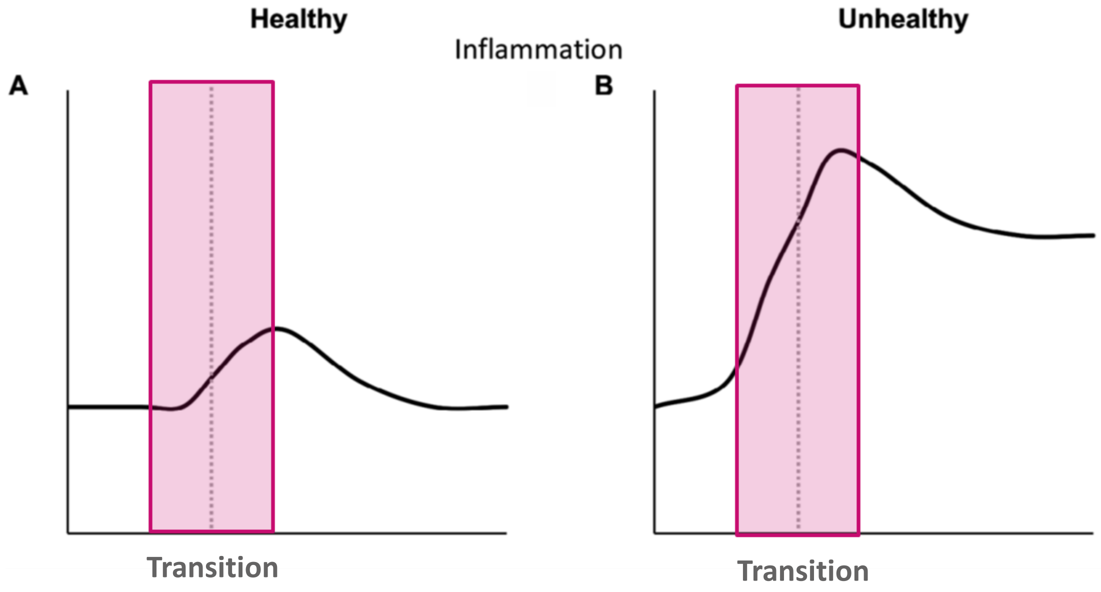
Silver bullet solutions are a pipedream

WE NEED TO TARGET HOST PHYSIOLOGY

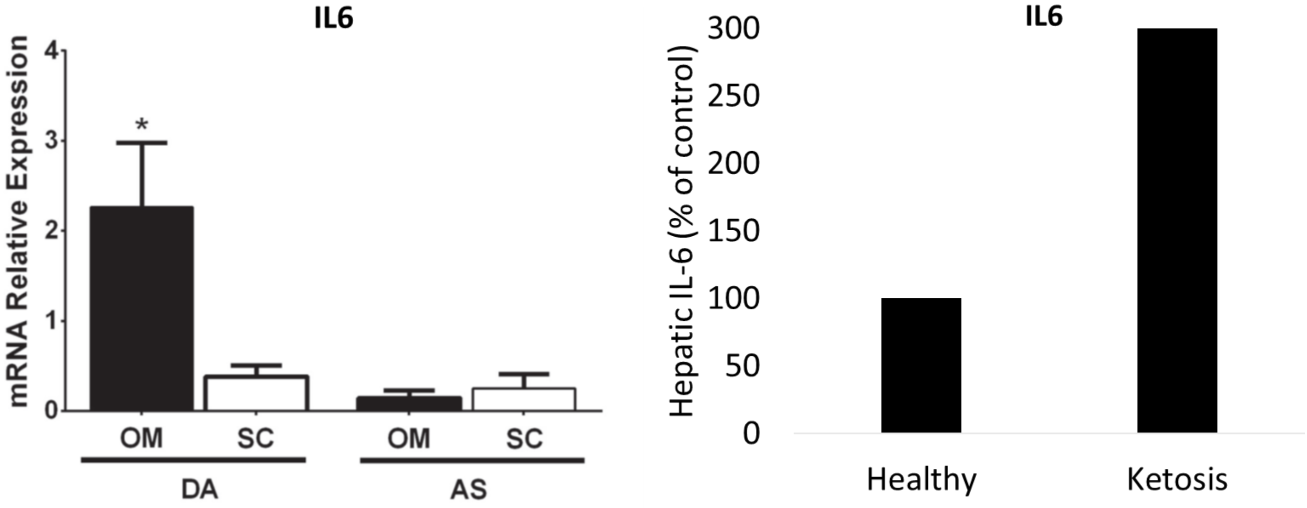
Rasmussen et al., 2024 J. Dairy Sci.

Liver health

The role of inflammation in metabolic disease



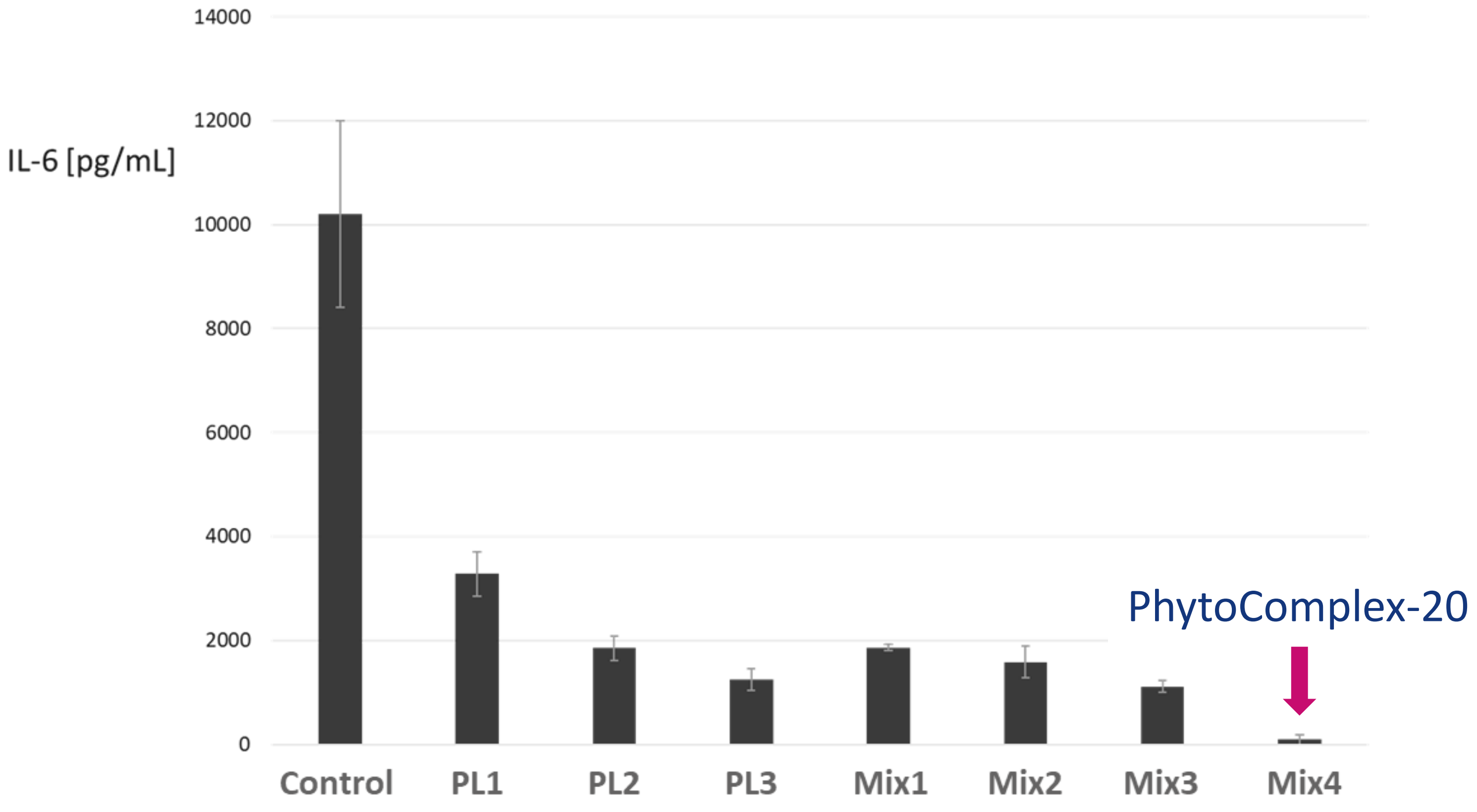
Horst et al., 2021. J. Dairy Sci.



Contreras et al., 2015. J. Dairy Sci.; Loor et al., 2007. Phys. Genom.

Liver health

Decreasing inflammation with PhytoComplex

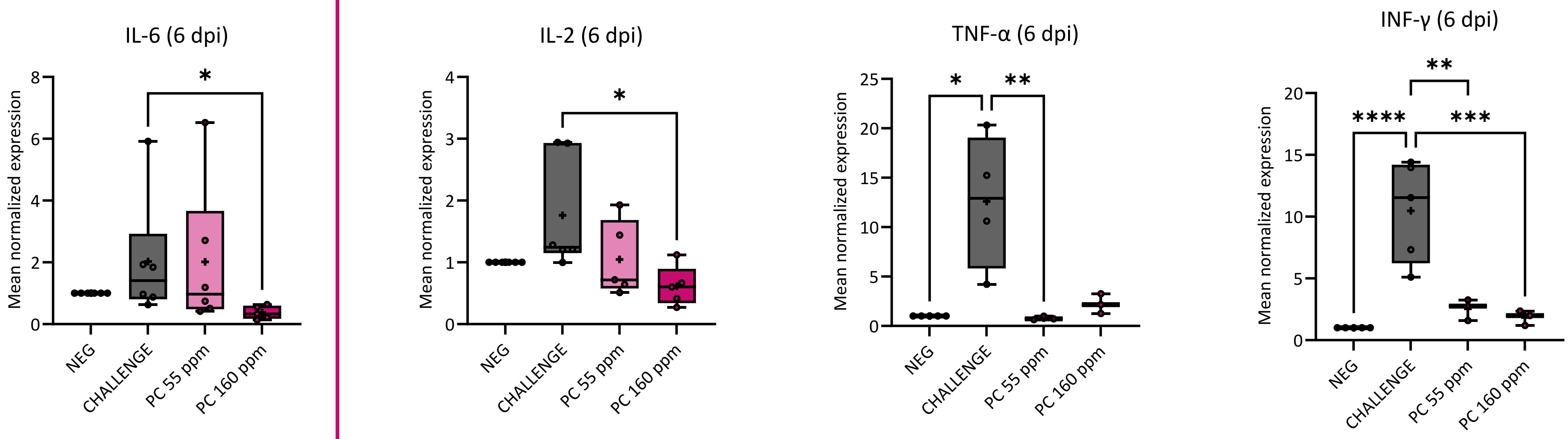


IL-6 production by LPS-stimulated macrophages. Unpublished data; NutEx trial T11

Liver health

Inflammation

Decreasing inflammation with PhytoComplex



Gene expression in hepatic tissue. Unpublished data; NutEx trial T81

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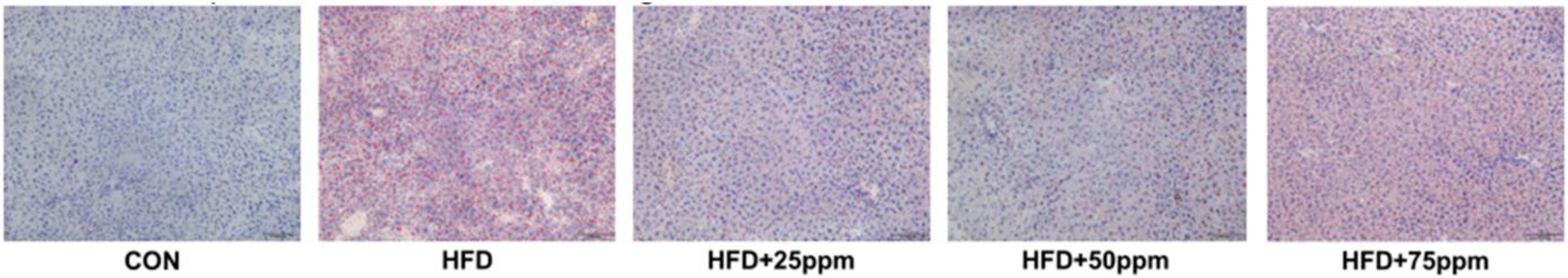
Liver health

Improving liver health with PhytoComplex

Histological Analysis of Liver Tissue

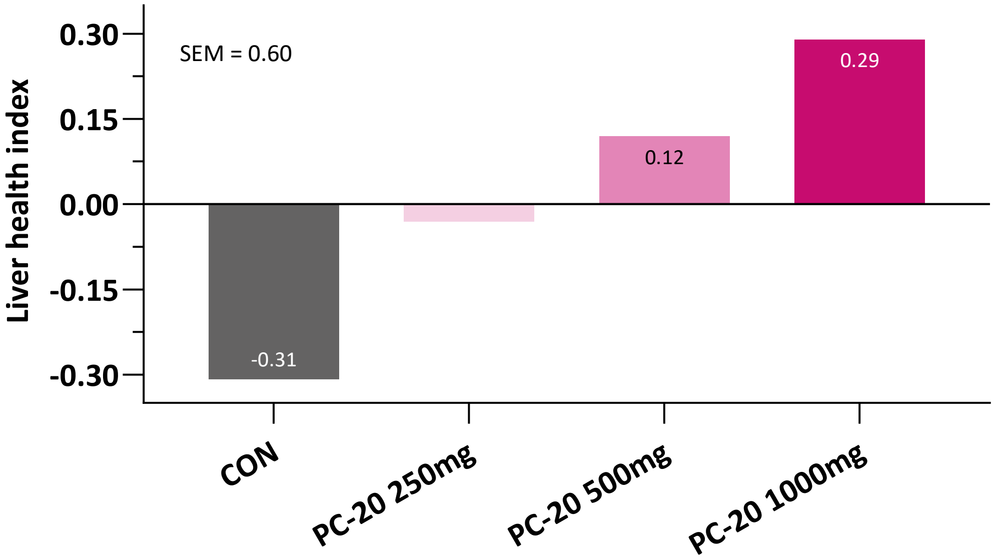
The next pictures show Hematoxylin–Eosin (HE) Staining.



H&E staining of liver tissue from mice fed a high fat diet. Unpublished data; NutEx trial T289

Liver health

Improving liver health with PhytoComplex

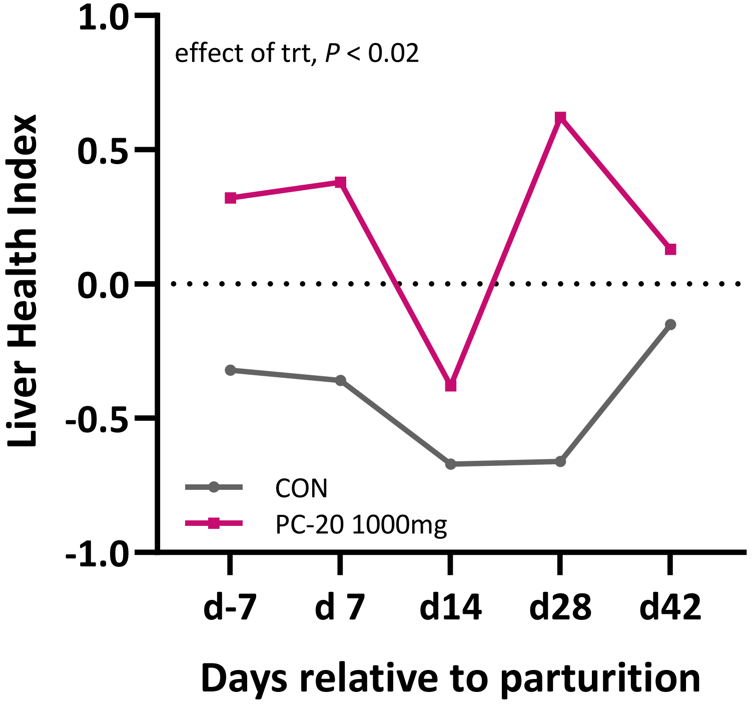


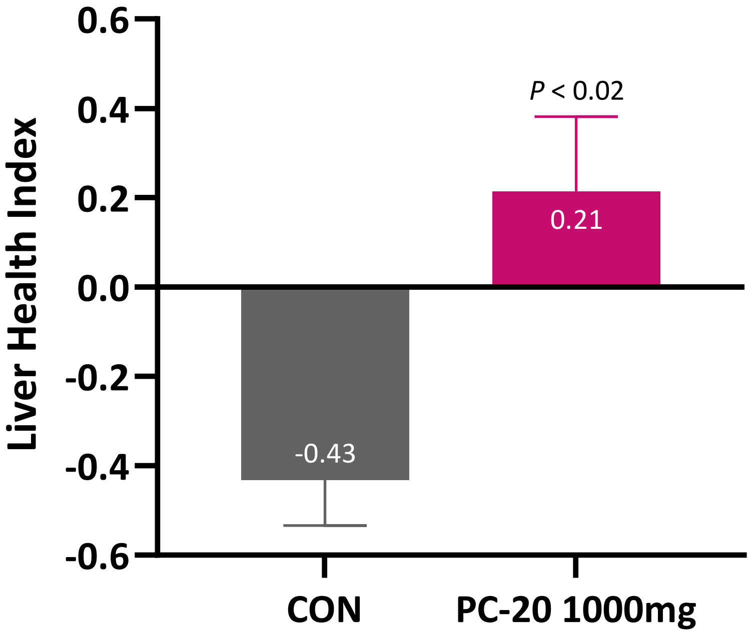
Liver health index in lactating dairy cows was calculated as described in Kerwin et al., 2022 J. Dairy Sci. (Cornell method)

Bourdeau et al., 2026 ADSA; doses are in mg/head/d

Liver health

Improving liver health with PhytoComplex





Metabolic disease, %		
Control	PC-20	*P*-value*
60.6	37.1	0.05

**Chi square test*

Bourdeau et al., 2026 ADSA; doses are in mg/head/d

Liver health

Summary

- Modern dairy cows are professional athletes; they walk a metabolic tight rope!
- Liver health is a critical component of metabolically healthy cows
- Liver health is highly complex and cannot be measured with a single marker nor targeted with a single compound
- We can target liver health and function holistically with Phytotechnologies:
  - Decreased hepatic inflammation
  - Decreased fatty liver
  - Improved liver health index
    - →Decreased incidence of metabolic disease

Phytotechnologies for resilience

Conclusions

- The impact of plants on animal physiology:
    - is real
    - is powerful
    - is misunderstood & under utilized in ruminant nutrition
- Using a physiological approach to Discovery, we:
    - Respect the power of plants
    - Respect observation even when we can't explain it
    - Let the animals tell us what the value is
    - Bring that value to industry
- We are only scratching the surface!

ACKNOWLEDGEMENTS

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Texas A&M University

Dr. Tryon Wickersham

University of Illinois Urbana-Champaign

Dr. William Witola

Dr. Jeff Heldt

JJ Degan

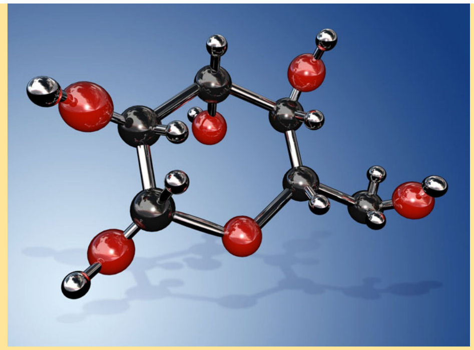
Dr. Chance Farmer

Dr. Maris McCarthy
(now at Phibro)

Selko

THANK YOU

NUTRECO'S
GARDEN OF
THE FUTURE



Udderly Dependent: Dairy Cows and Their Glucose Economy

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Dr. Alan Bell

Journal of Mammary Gland Biology and Neoplasia, Vol. 2, No. 3, 1997

Adaptations of Glucose Metabolism During Pregnancy and Lactation

Alan W. Bell[1,2] and Dale E. Bauman[1]

Increased glucose requirements of the gravid uterus during late pregnancy and even greater requirements of the lactating mammary glands necessitate major adjustments in glucose production and utilization in maternal liver, adipose tissue, skeletal muscle, and other tissues. In ruminants, which at all times rely principally on hepatic gluconeogenesis for their glucose supply, hepatic glucose synthesis during late pregnancy and early lactation is increased to accommodate uterine or mammary demands even when the supply of dietary substrate is inadequate. At the same time, glucose utilization by adipose tissue and muscle is reduced. In pregnant animals, these responses are exaggerated by moderate undernutrition and are mediated by reduced tissue sensitivity and responsiveness to insulin, associated with decreased tissue expression of the insulin-responsive facilitative glucose transporter, GLUT4. Peripheral tissue responses to insulin remain severely attenuated during early lactation but recover as the animal progresses through mid lactation. Specific homeorhetic effectors of decreased insulin-mediated glucose metabolism during late pregnancy have yet to be conclusively identified. In contrast, somatotropin is almost certainly a predominant homeorhetic influence during lactation because its exogenous administration causes specific changes in glucose metabolism (and many other functions) of various nonmammary tissues which faithfully mimic normal adaptations to early lactation.

KEY WORDS: Pregnancy; lactation; glucose metabolism; insulin responses; homeorhesis.

Regulation of Organic Nutrient Metabolism During Transition from Late Pregnancy to Early Lactation[1,2]

Alan W. Bell

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ABSTRACT: Conceptus energy and nitrogen demands in late pregnancy are mostly met by placental uptake of maternal glucose and amino acids. The resulting 30 to 50% increase in maternal requirements for these nutrients is met partly by increased voluntary intake and partly by an array of maternal metabolic adaptations. The latter include increased hepatic gluconeogenesis from endogenous substrates, decreased peripheral tissue glucose utilization, increased fatty acid mobilization from adipose tissue, and, possibly, increased amino acid mobilization from muscle. Within 4 d of parturition, mammary demands for glucose, amino acids, and fatty acids are severalfold those of the pregnant uterus before term. Even unusual postparturient increases in voluntary intake cannot satisfy this increased nutrient demand. Therefore, rates of hepatic gluconeogenesis and adipose fat mobilization are greatly accelerated. Concomitant changes in amino acid metabolism include increased hepatic protein synthesis and, possibly, decreased amino acid catabolism, and increased peripheral mobilization of amino acids. Insulin resistance in adipose tissue and muscle, developed during late pregnancy, continues postpartum; adipose lipolytic responsiveness and sensitivity to adrenergic agents are increased postpartum beyond their levels during late pregnancy. Before parturition, these homeorhetic adjustments may be coordinated with lactogenesis by increased secretion of estradiol and prolactin. Their amplification and reinforcement at and soon after parturition may be regulated mostly by somatotropin.

Key Words: Dairy Cows, Pregnancy, Lactation, Metabolic Adaptations, Homeorhesis

J. Anim. Sci. 1995. 73:2804–2819

Partitioning of Nutrients During Pregnancy and Lactation: A Review of Mechanisms Involving Homeostasis and Homeorhesis

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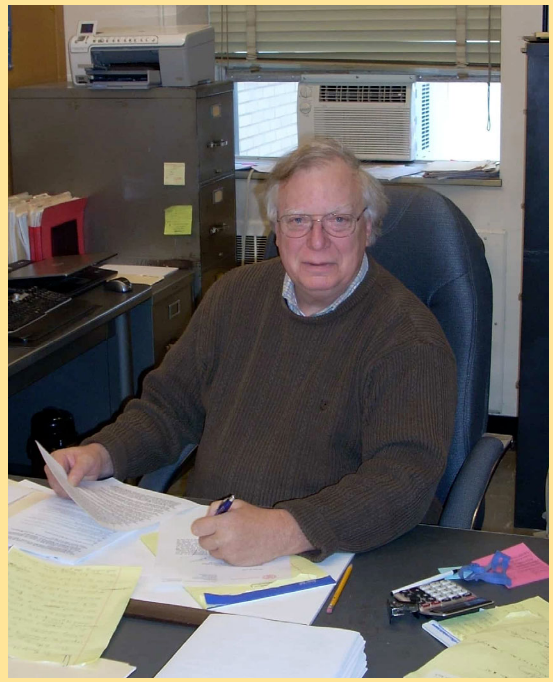
ABSTRACT

Control of metabolism during pregnancy and lactation involves two types of regulation—homeostasis and homeorhesis. Homeostatic control involves mainten-

tions and physiological processes in which food is transformed into body tissues and activities. In a broad sense the chemistry of life can be considered a cycle (Figure 1). Food is consumed, and, following digestion in the gut,

Introduced the Homeorhesis concept: uses glucose metabolism as the foundation



Dr. Dale Bauman

Dr. Bruce Currie

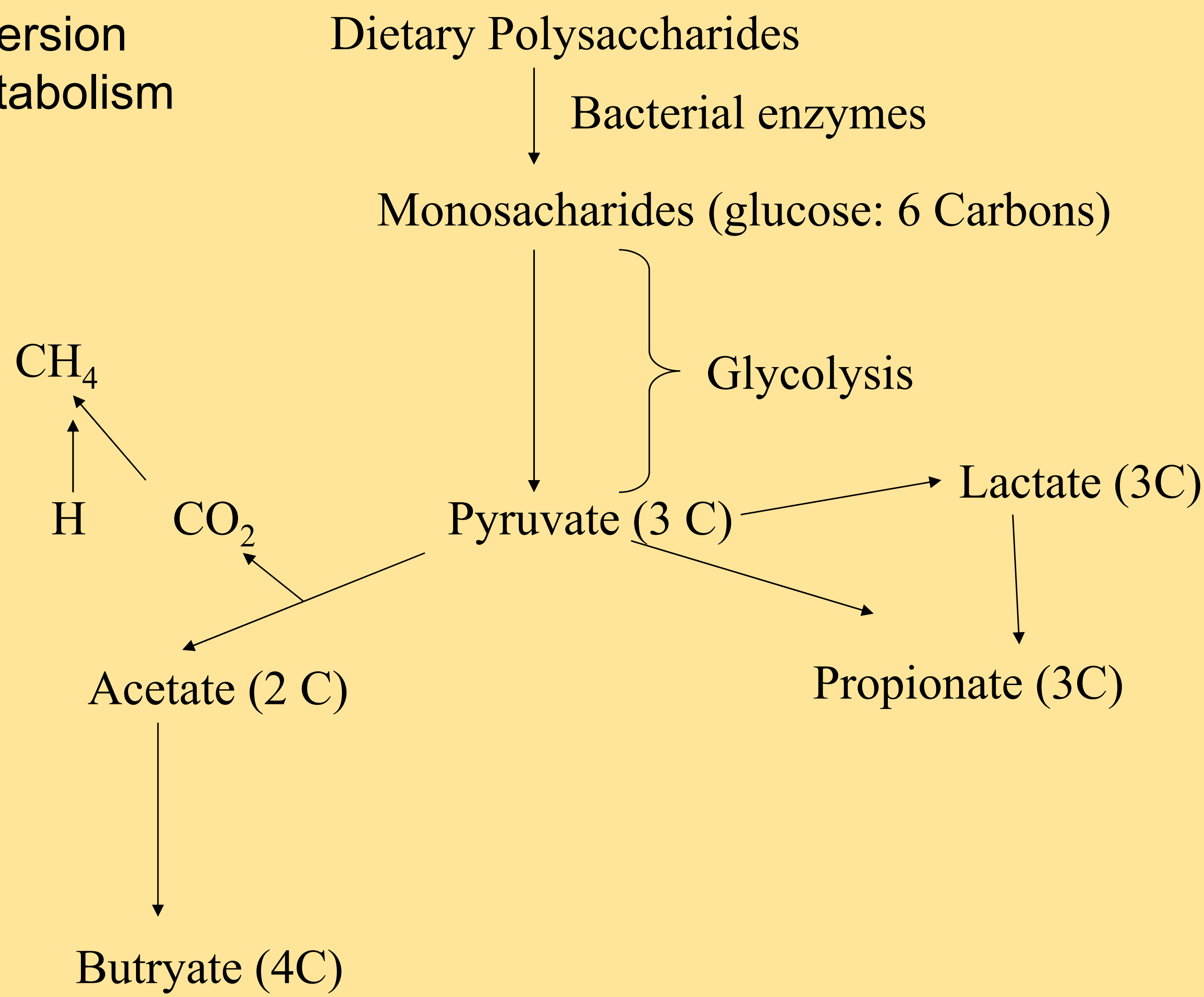
Friendly Reminder of Basic Ruminant Nutritional Physiology and Metabolism

Rumen Carbohydrate Metabolism

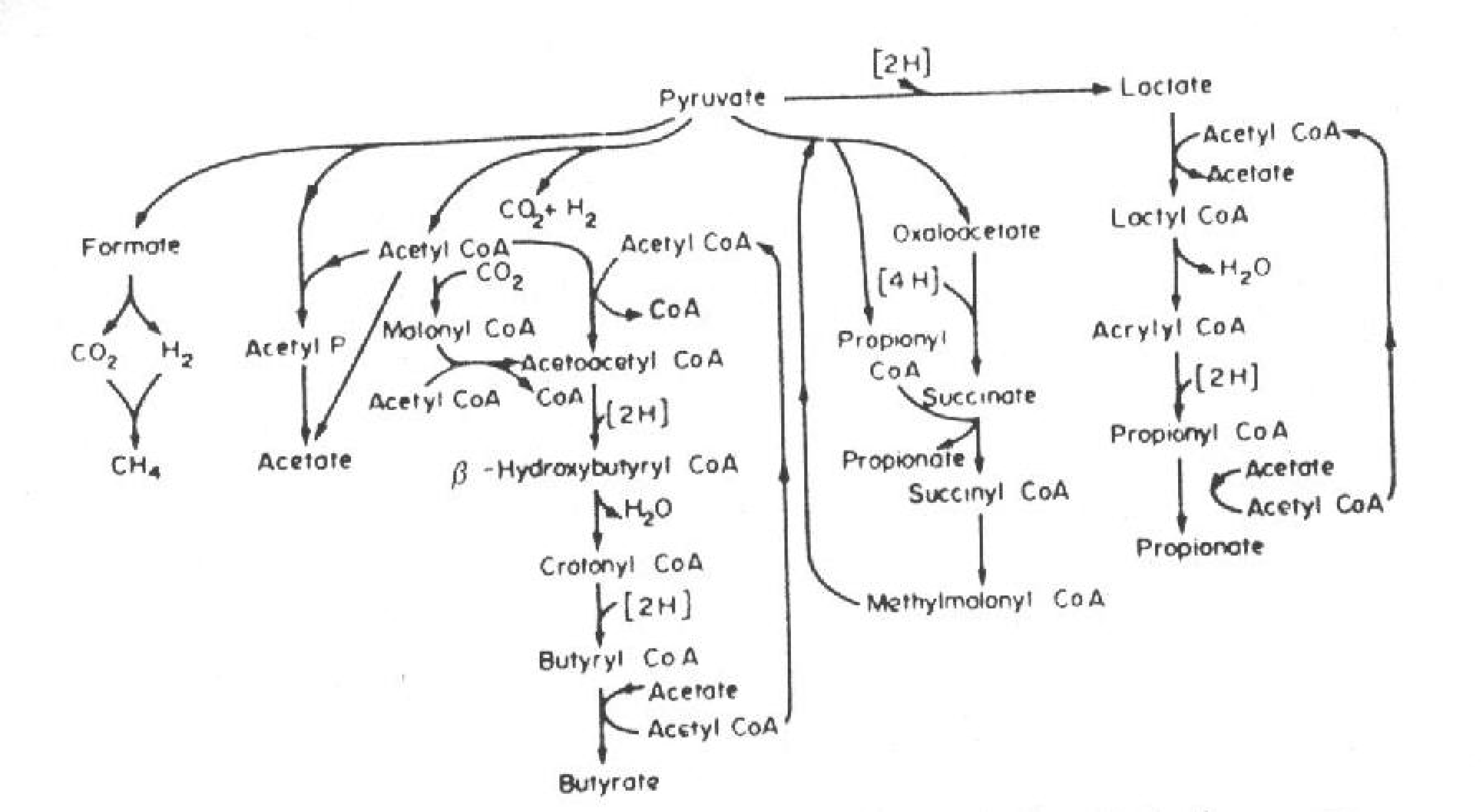
- Advantage: Can consume worlds most abundant organic compound (cellulose)
  - Increase digestibility
  - Microbes make all of their own amino acids and vitamins

- Disadvantage:
  - Lose energy as heat and CH_4
  - <u>Loss of dietary glucose</u>

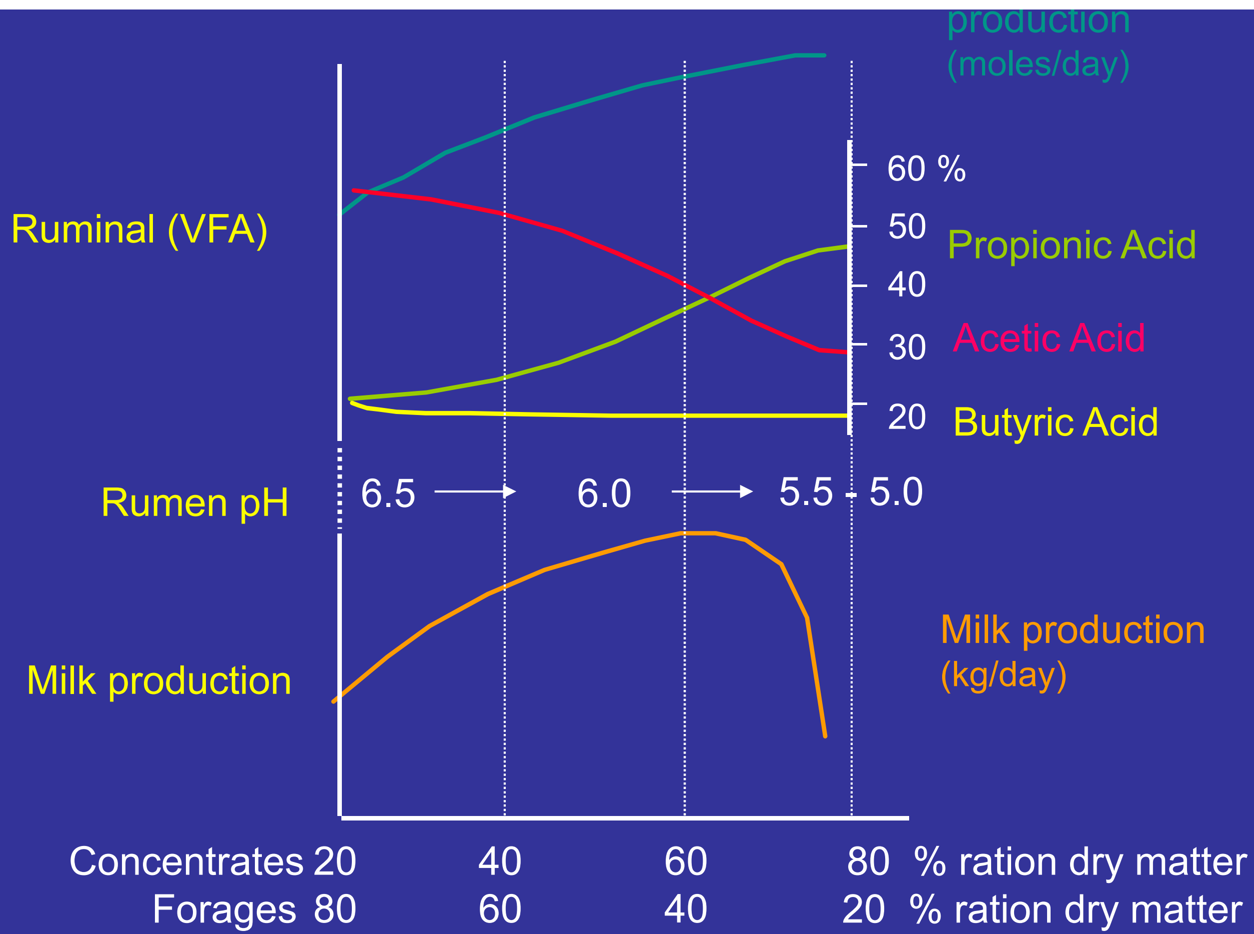
Undergraduate Version of Rumen CHO Metabolism



Graduate Student Version of Rumen CHO Metabolism



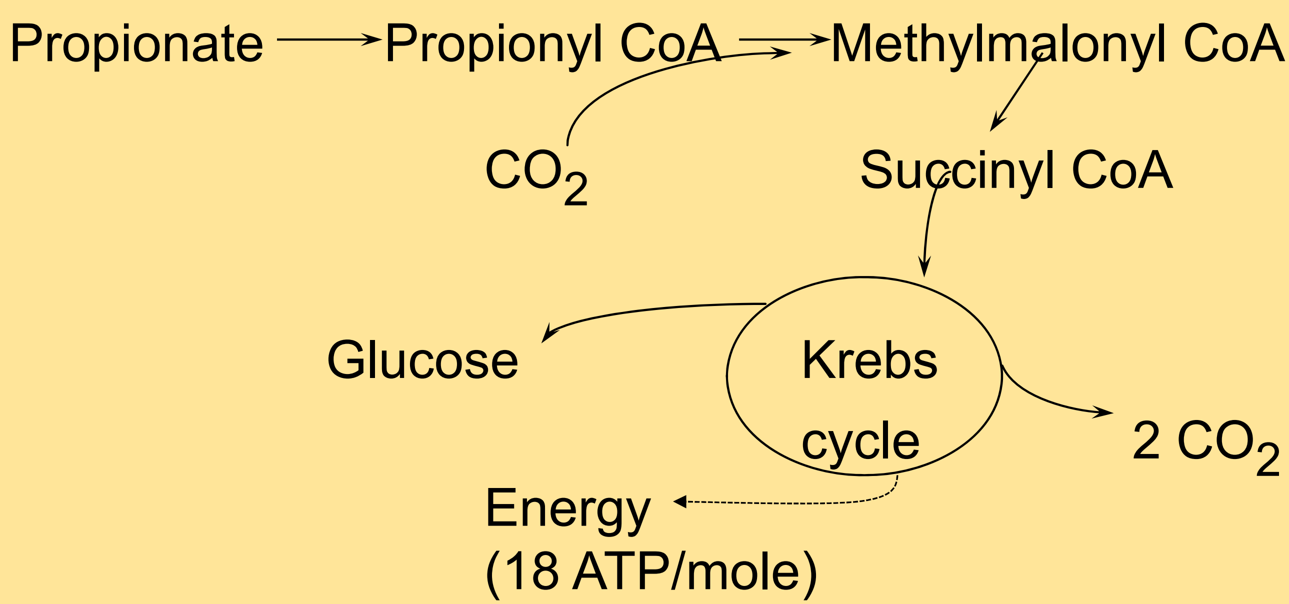
Increasing propionate production with grain comes at an economic cost and a rumen health concern



Propionate Utilization

- Absorbed through rumen wall
  - 2-5% converted to lactic acid by rumen enterocytes
  - 95-98% travels to liver
    - Converted to succinyl-CoA
      - Then converted to glucose (if in need of glucose)
      - ATP production: Oxidized to CO2 and H20
    - Very little escapes hepatic metabolism
      - Thus very low concentrations of propionate in systemic circulation

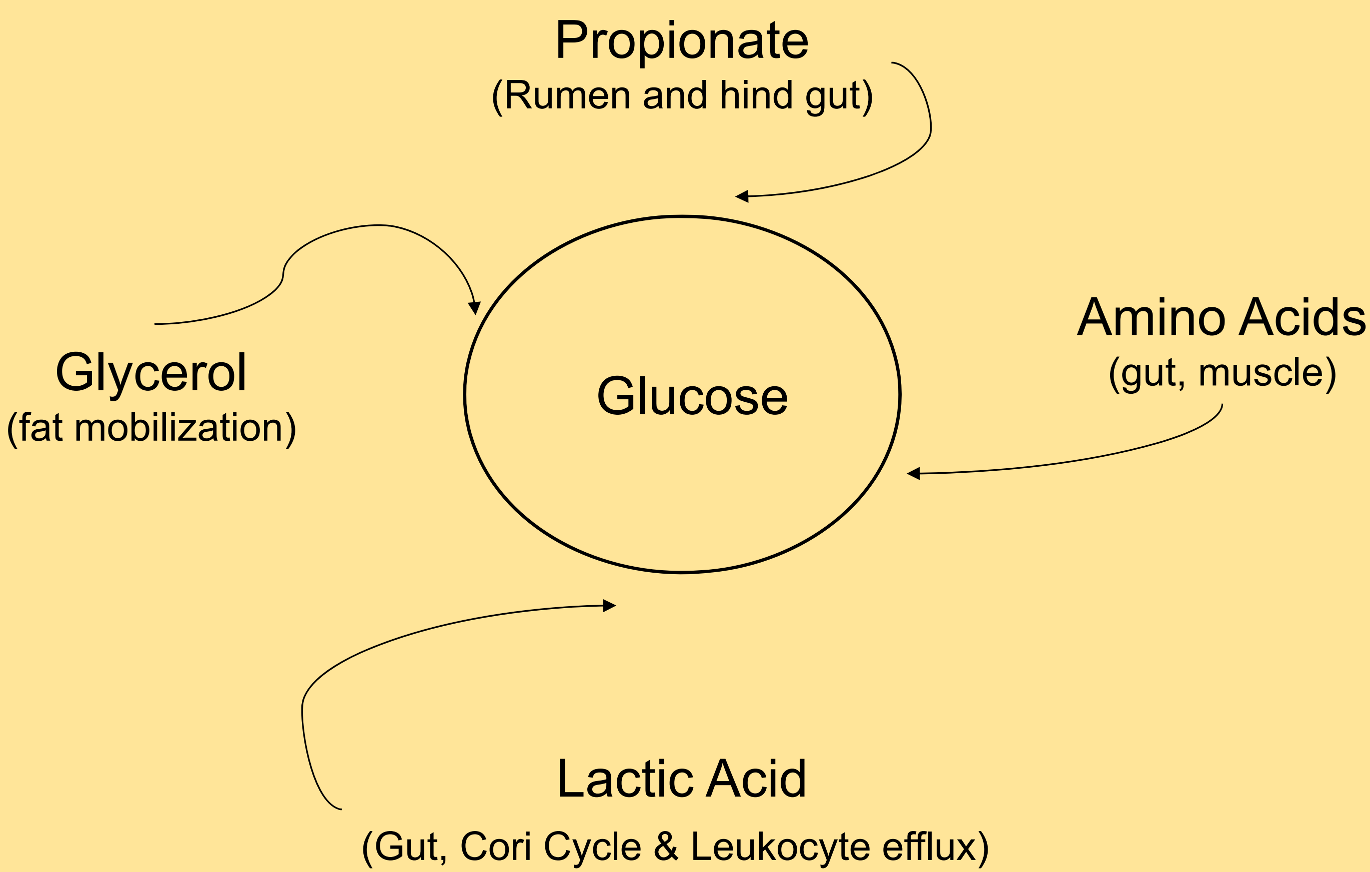
Hepatic Propionate Metabolism



Bioenergetic Benefits of Propionate

- 100% conservation of carbon
  - 1/3 of pyruvate's carbon is lost as CO_2 when converted into acetate
- ATP Generation
  - Propionate oxidation = 18 ATP: 6 ATP/carbon
  - Acetate oxidation = 10 ATP: 5 ATP/carbon
    - Oxidizing propionate is 20% more energetically efficient
- Only VFA that's a gluconeogenic precursor

Gluconeogenic Precursors



Glucose is a very diverse substrate

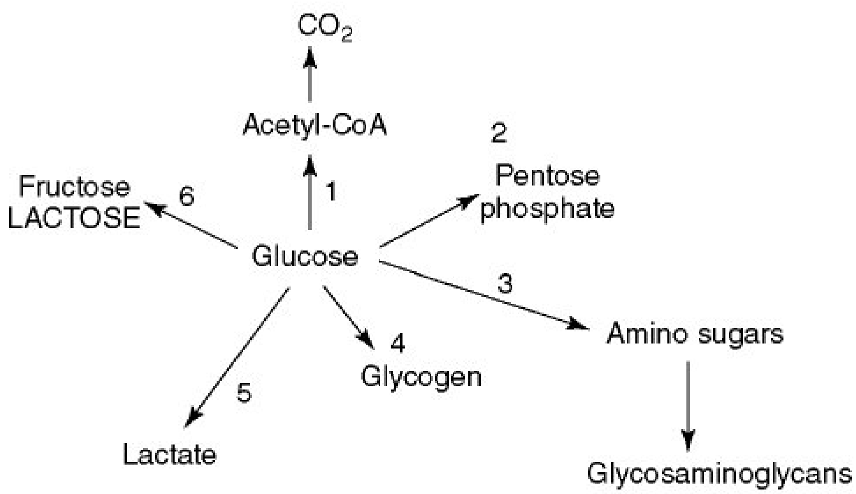


Figure 6.1 *Glucose is a substrate for several metabolic pathways.*
1. *Aerobic* glycolysis to form acetyl-CoA.
2. Pentose phosphate pathway.
3. Amino sugars to glycosaminoglycans (Appendix 6.2).
4. Glycogen synthesis.
5. *Anaerobic* glycolysis.
6. Formation of fructose and lactose.

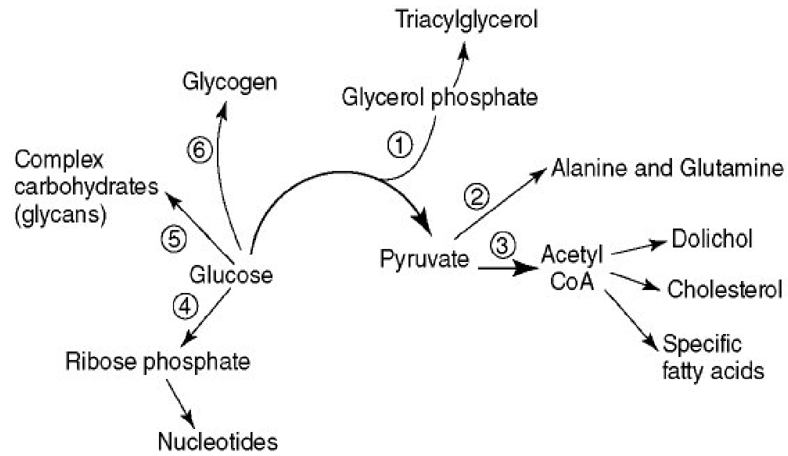
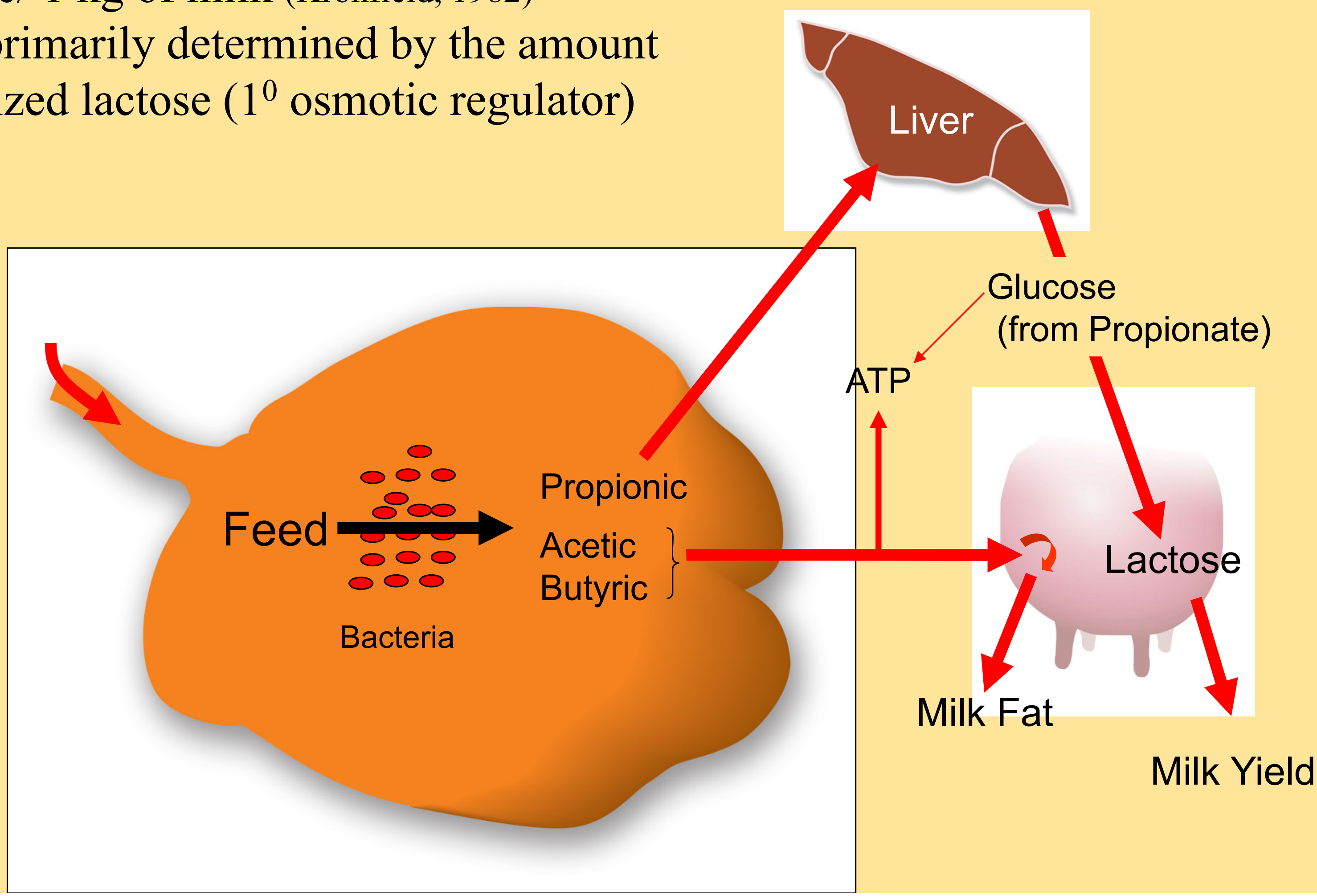


Figure 6.2 *Glucose and glycolytic intermediates as precursors for synthetic pathways.*
1. Glycerol phosphate for phospholipid and triacylglycerol formation.
2. Pyruvate for alanine and glutamine formation.
3. Pyruvate for acetyl-CoA which is precursor for several compounds (cholesterol, specific fatty acids, dolichol).
4. Glucose for ribose 5-phosphate (for formation of nucleotides).
5. Glucose for complex carbohydrate formation (e.g. glycans, glycoproteins, glycosaminoglycans, Appendix 6.2).
6. Glucose for glycogen formation.

Glucose Metabolism and Cell Types
All mammalian cells have glycolytic capacity

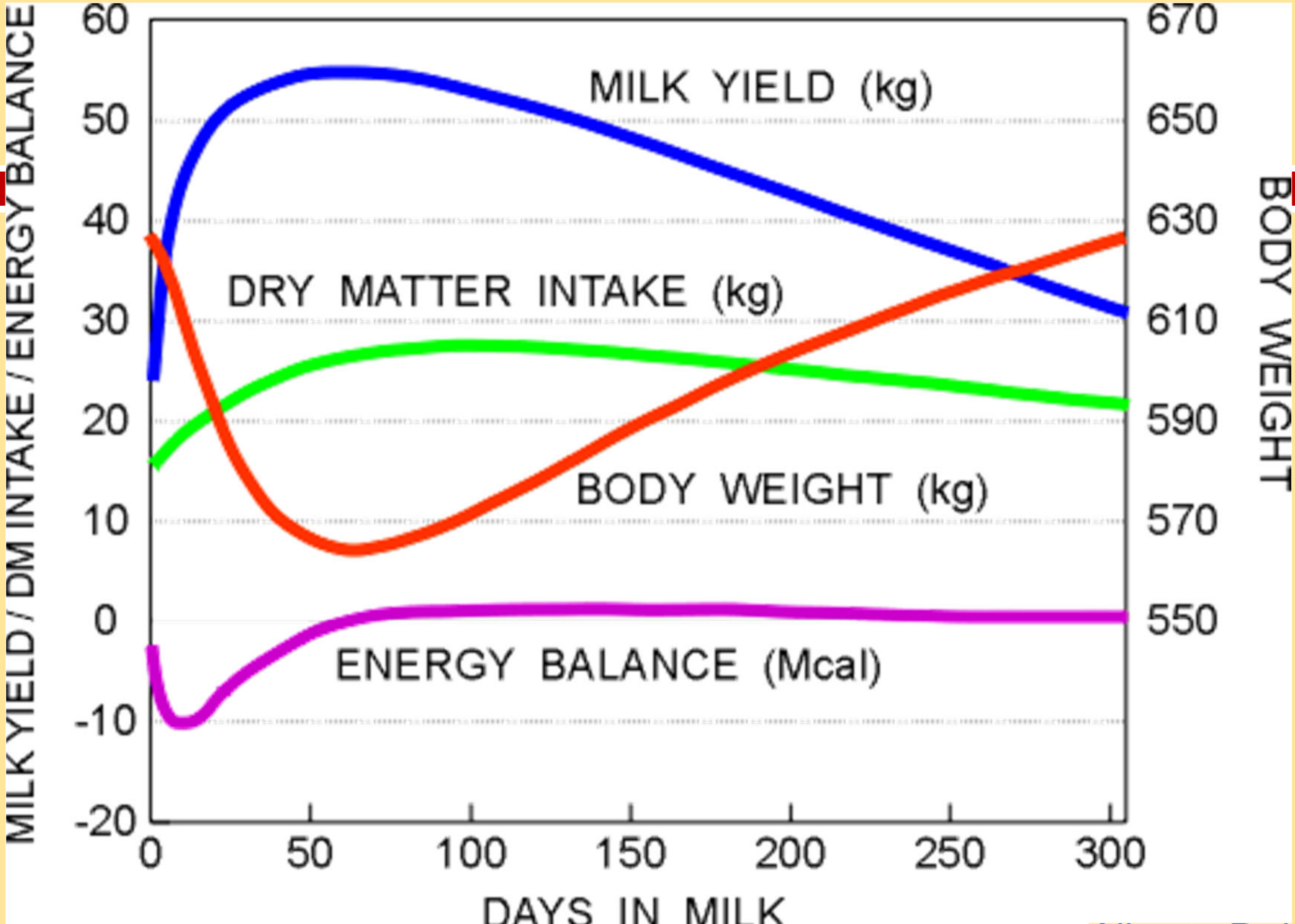
- Muscle
  - Completely oxidized
  - Glycogen storage
  - Lactate
- Cardiac muscle
  - Completely oxidized
  - Some glycogen storing capacity
  - Not lactate
- Red Blood Cells
  - Lactate
- <u>Mammary Epithelial</u>
  - Completely oxidized
  - Lactose synthesis
  - Reducing equivalents
- Liver
  - Completely oxidized
  - Glycogen storage
  - Lactate
  - Fatty acid synthesis
  - Amino acid synthesis
- Brain
  - Completely oxidized
- Adipocytes
  - Completely oxidized
  - Partially oxidized for G3P
  - Fatty acid synthesis

Glucose is primarily made from propionate
Lactose is made from glucose
72 g of glucose/ 1 kg of milk (Kronfield, 1982)
Milk yield is primarily determined by the amount of synthesized lactose (1^0 osmotic regulator)



- 150 lbs milk/day = 68.2 kg milk/day

- 68.2 kg milk * 72 g glucose/kg milk = 4.91 kg of glucose (10.8 lbs)



Alberta Dairy Management

Change in Energy Requirements Following Calving

NE_L (MJ/d) requirements double

It's likely impossible for any animal to upregulate appetite 2-fold within 2 days

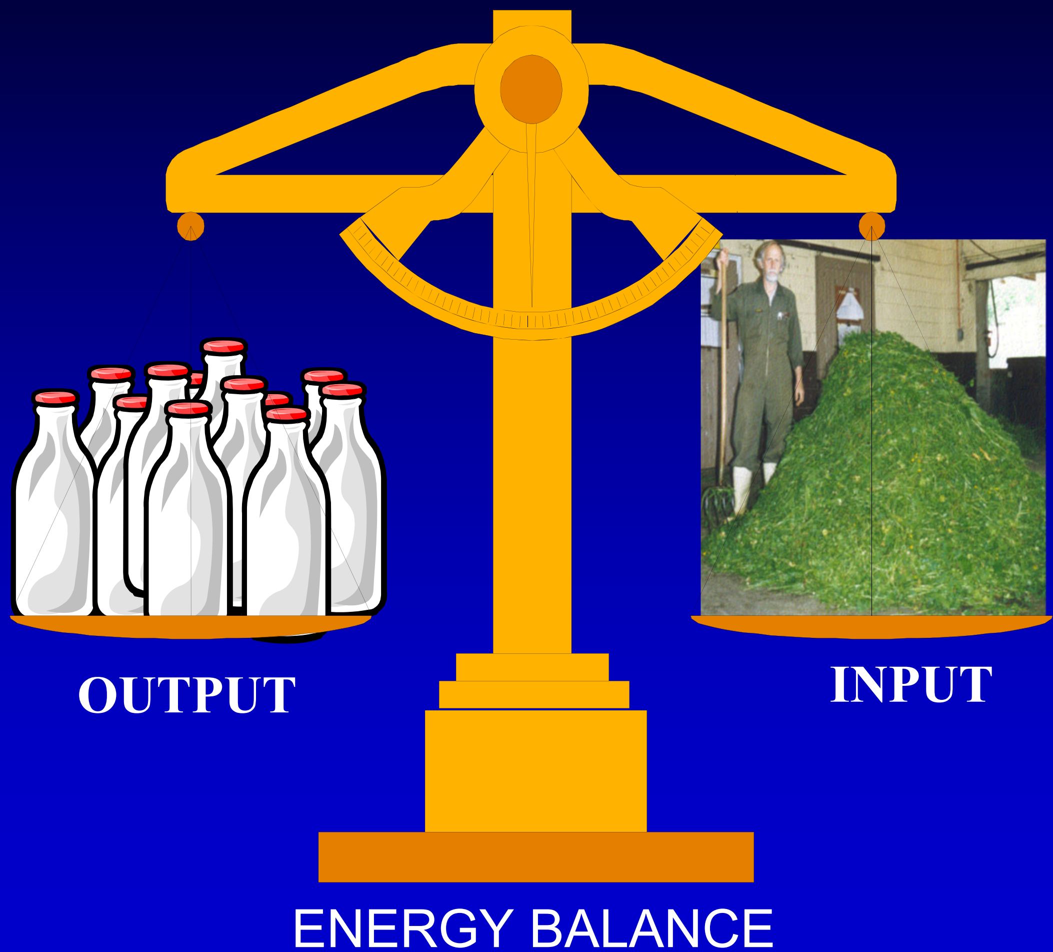
	725-kg multiparous		570-kg primiparous	
Function	-2 d	+2 d	-2 d	+2 d
Maintenance	46.9	42.2	38.9	35.6
Pregnancy	13.8	---	11.7	---
Growth	---	---	7.9	7.1
Milk production	---	78.2	---	62.3
Total	60.7	120.4	58.5	105.0

Calculated from National Research Council (2001). Assumes precalving body weight for Holstein cows with average decrease for calf and fluid loss at calving, milk production of 25 kg/d for multiparous cow and 20 kg/d for primiparous cow, and milk containing 4% fat for each.

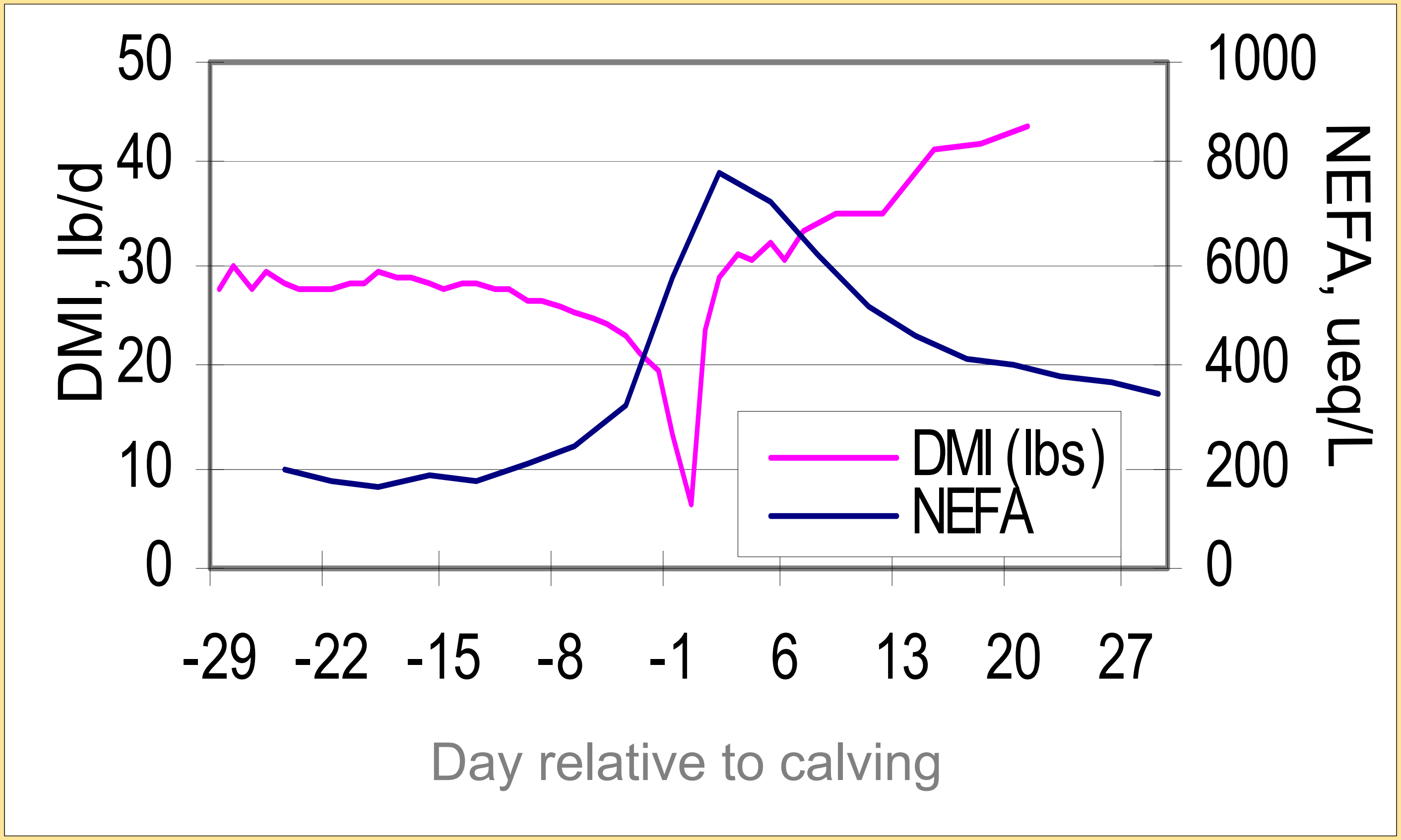
Energy Balance

EBAL = Feed Intake – (Maintenance ($BW^{0.75}$) + Milk Production (yield and composition))

Especially fat!



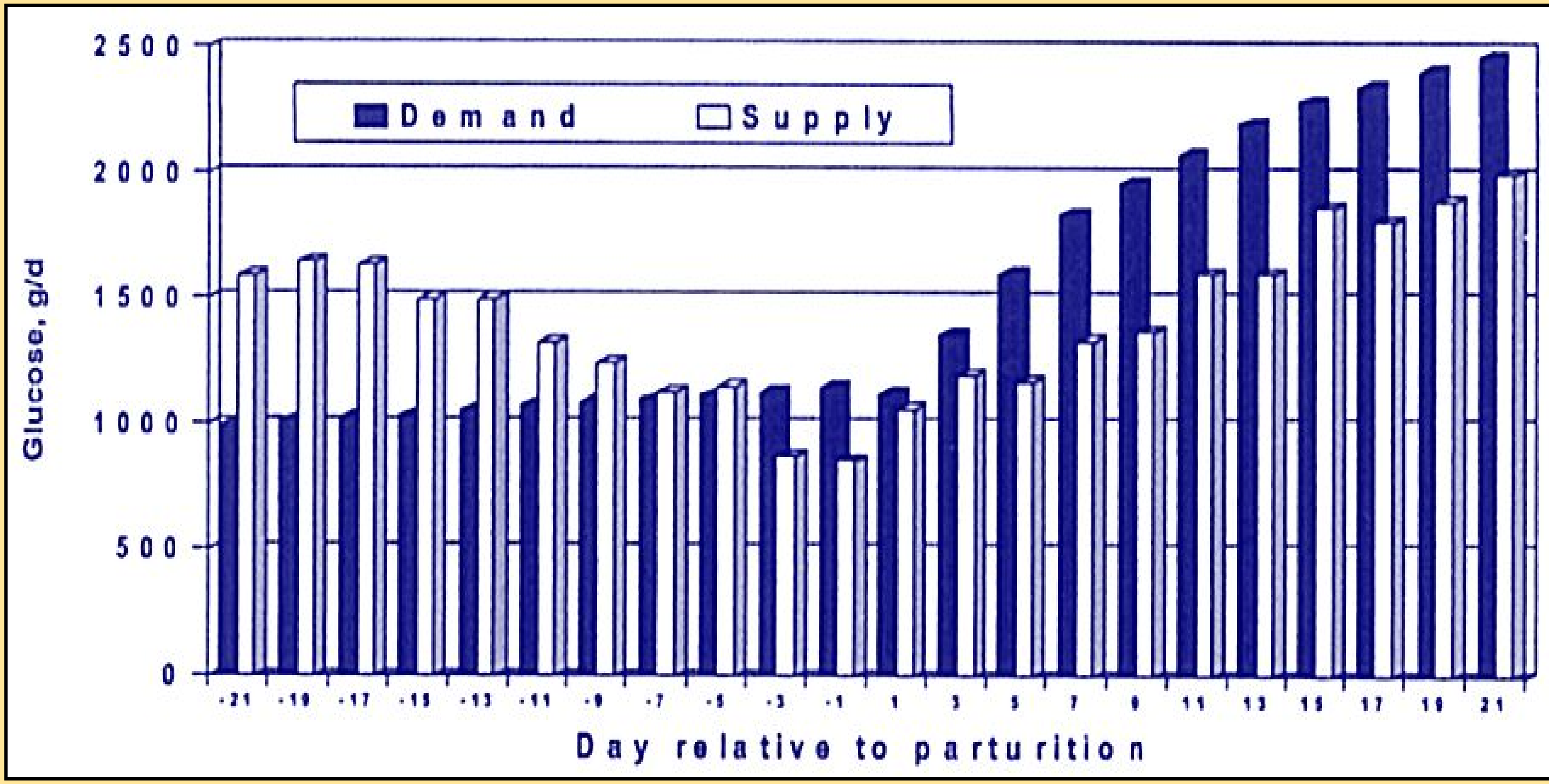
Feed Intake and Adipose Mobilization During the Transition Period



Burhans and Bell, 1998

Glucose demand vs. supply during the periparturient period

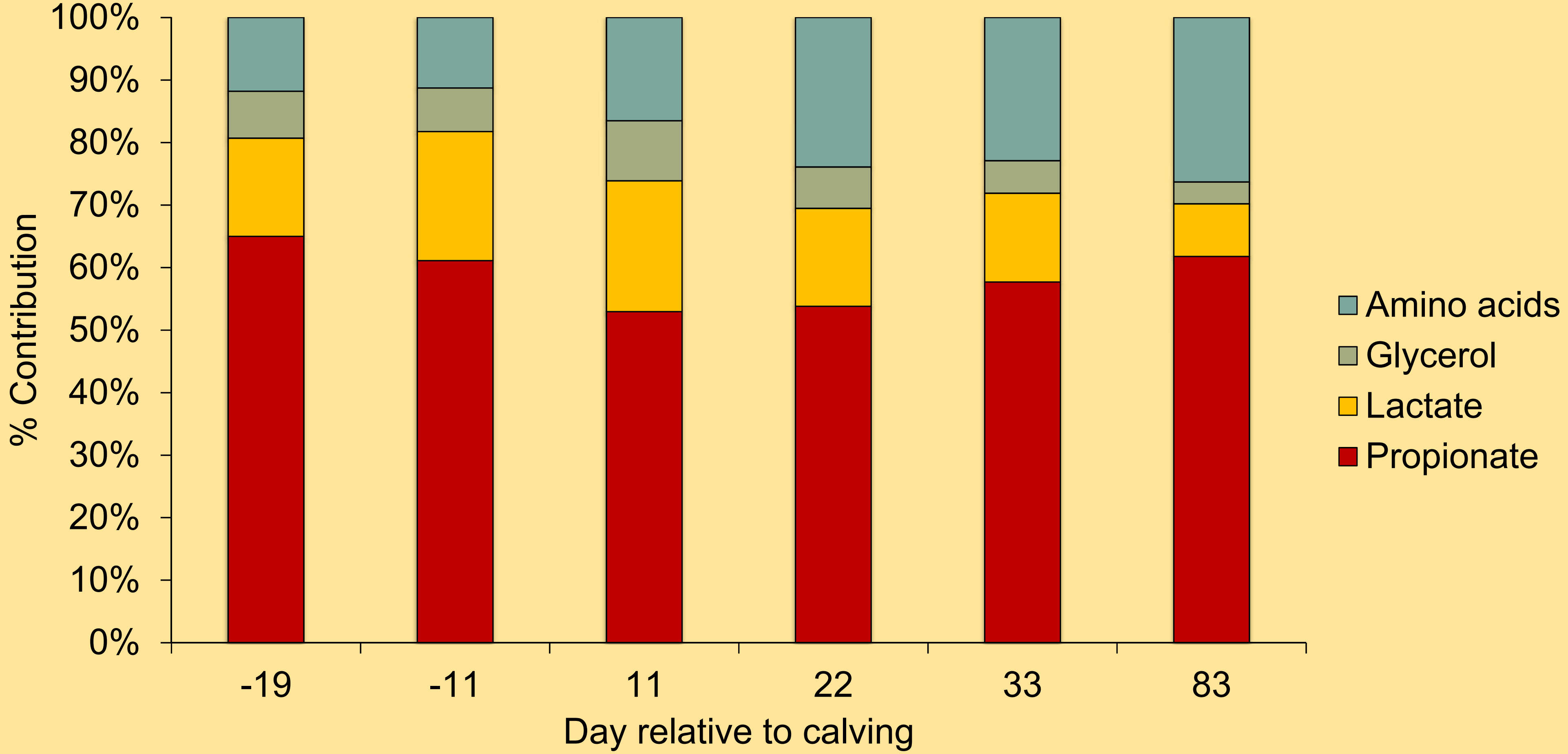
2.5 X!!



After calving glucose supply is less than demand by 500 g/d

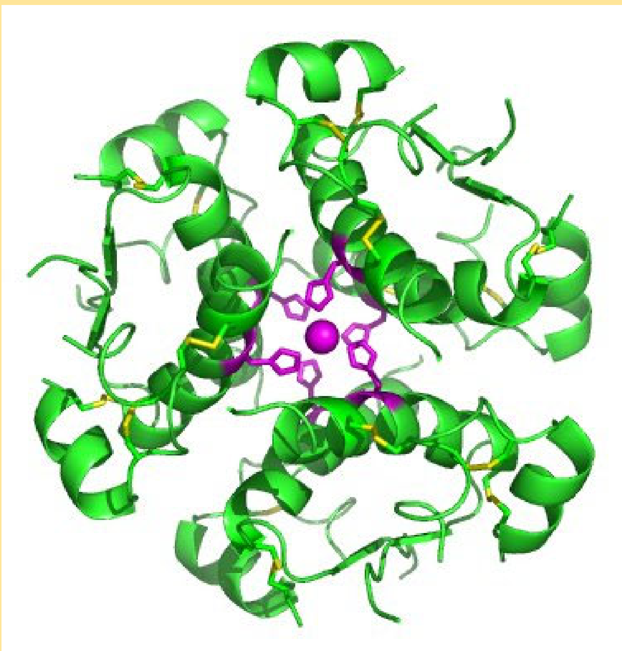
Piepenbrink, M. S., and T. R. Overton. (2000). J. Dairy Sci. 83(Suppl. 1):257.(Abstr.)

Precursor Contribution to Hepatic Glucose Production



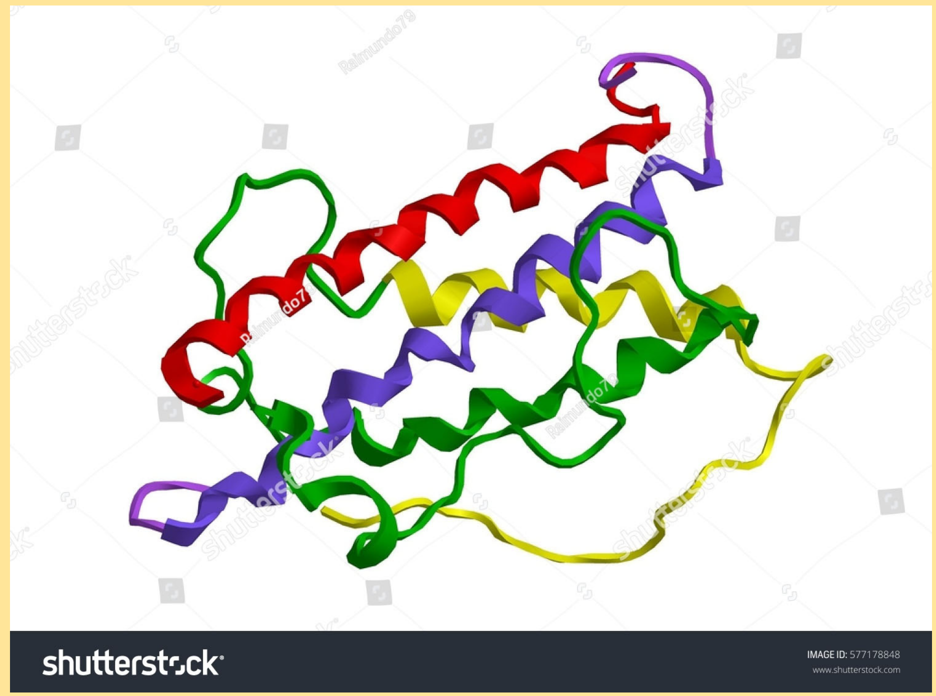
Reynolds et al., 2003: J. Dairy Sci. 86:1201–1217

Endocrine Control of Nutrient Partitioning



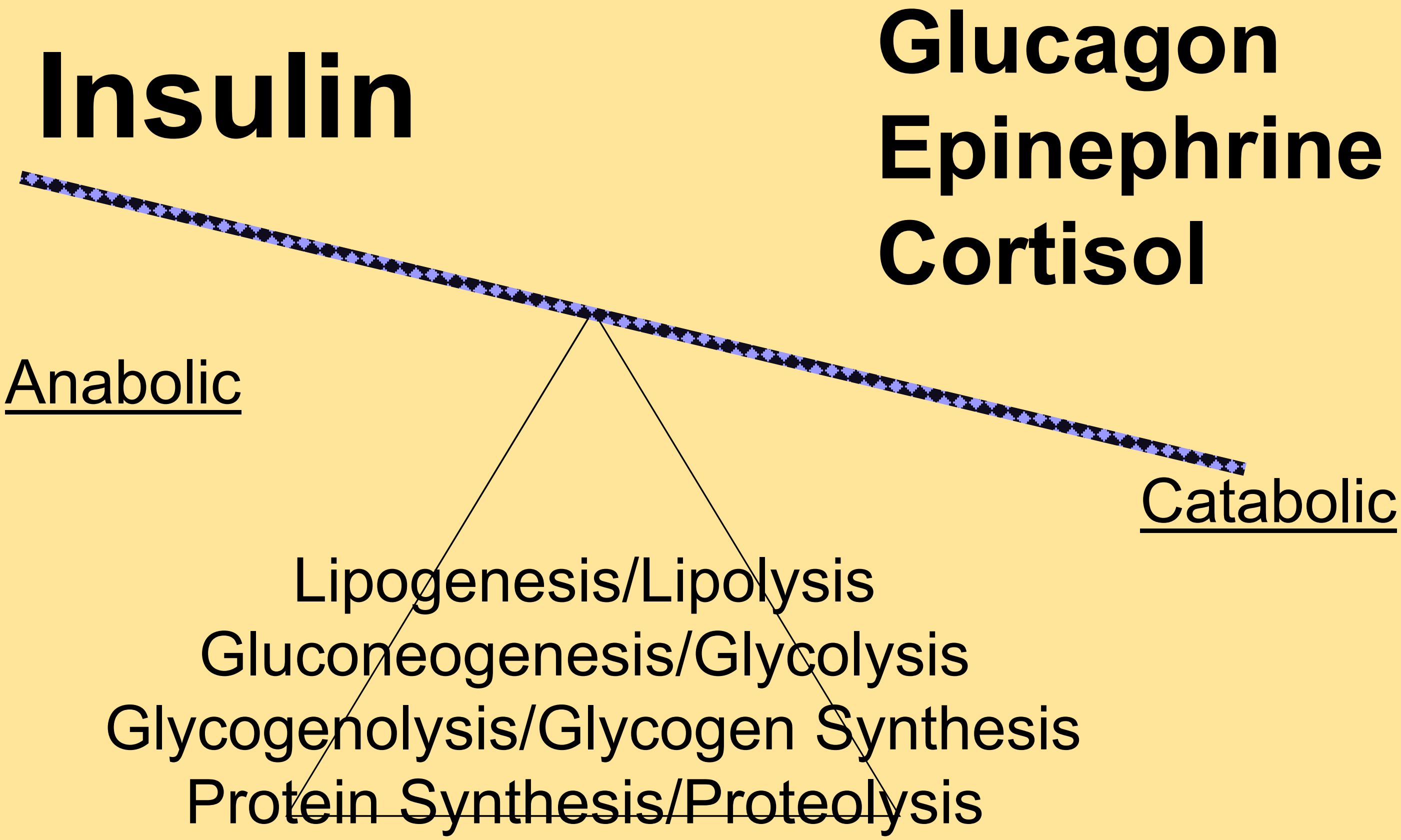
Insulin

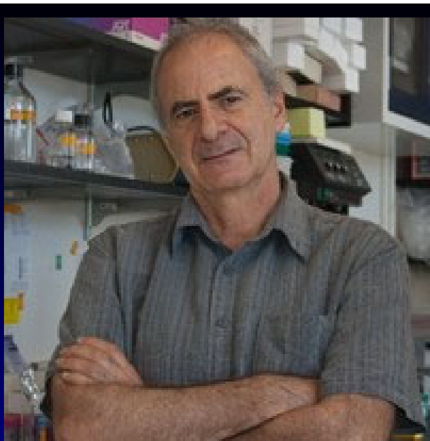
https://howmed.net/pathology/structure-of-insulin/



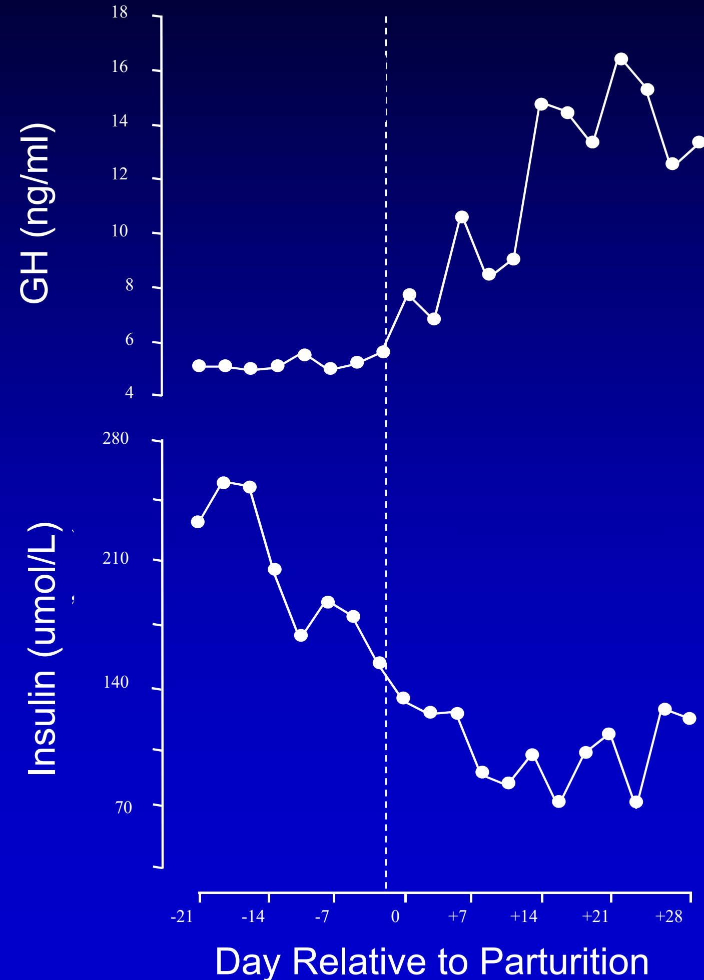
Somatotropin

Nutrient Coordinators



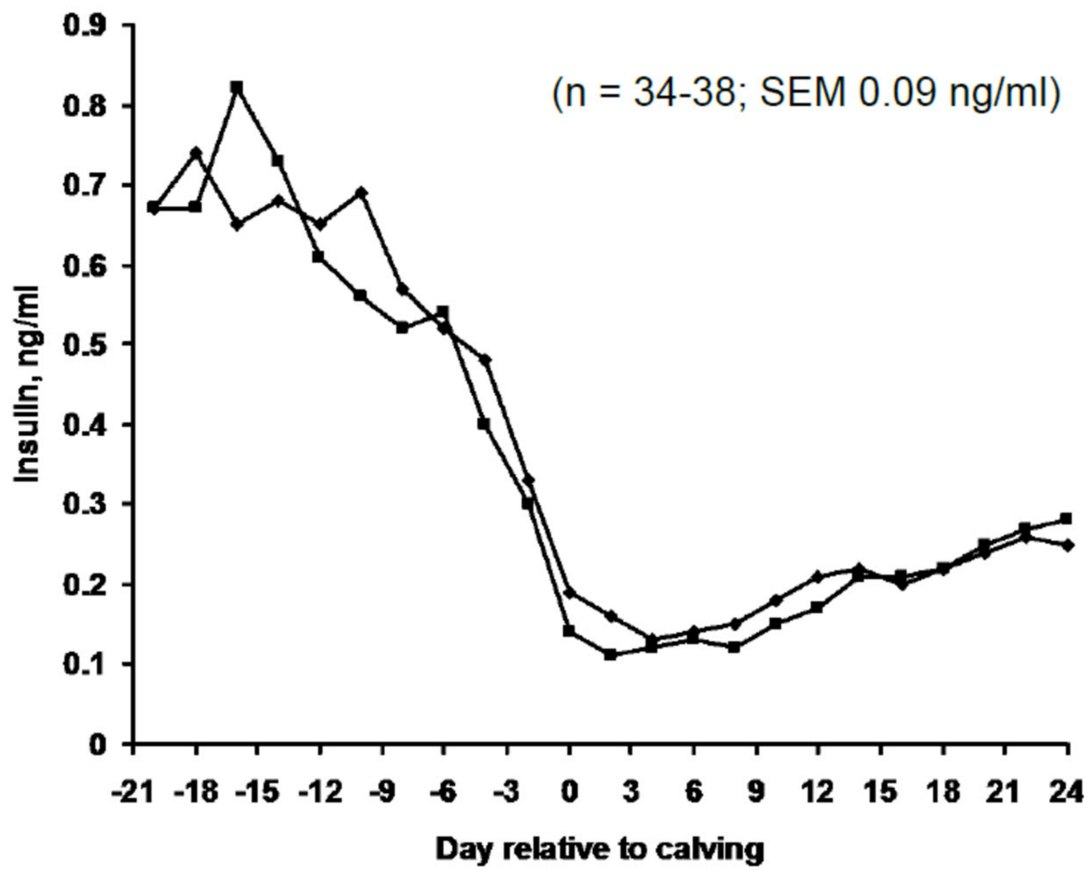


Profiles of plasma GH and insulin during the transition period



Rhoads et al. 2004

Periparturient Insulin Concentration



Smith, 2006

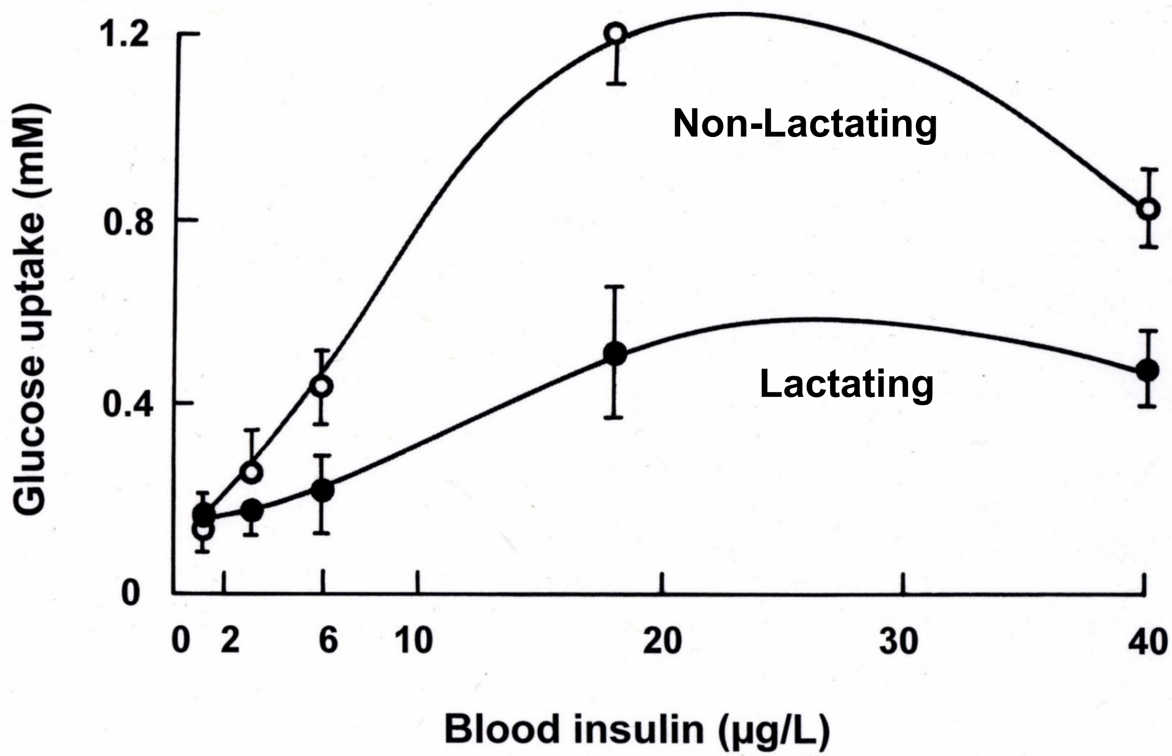
Periparturient Insulin Dynamics

- Decreased insulin secretion

- AND decreased insulin action
  - Increased "insulin resistance" at peripheral tissues
    - Skeletal muscle (largest glucose sink prior to lactation)
    - Adipose tissue

- Mammary gland's glucose uptake is mostly* insulin independent
  - *Dr. John Cant's (U of Guelph) 2024 ADSA seminar indicates that the mammary' s glucose use may be partially insulin dependent

Muscle Glucose Utilization

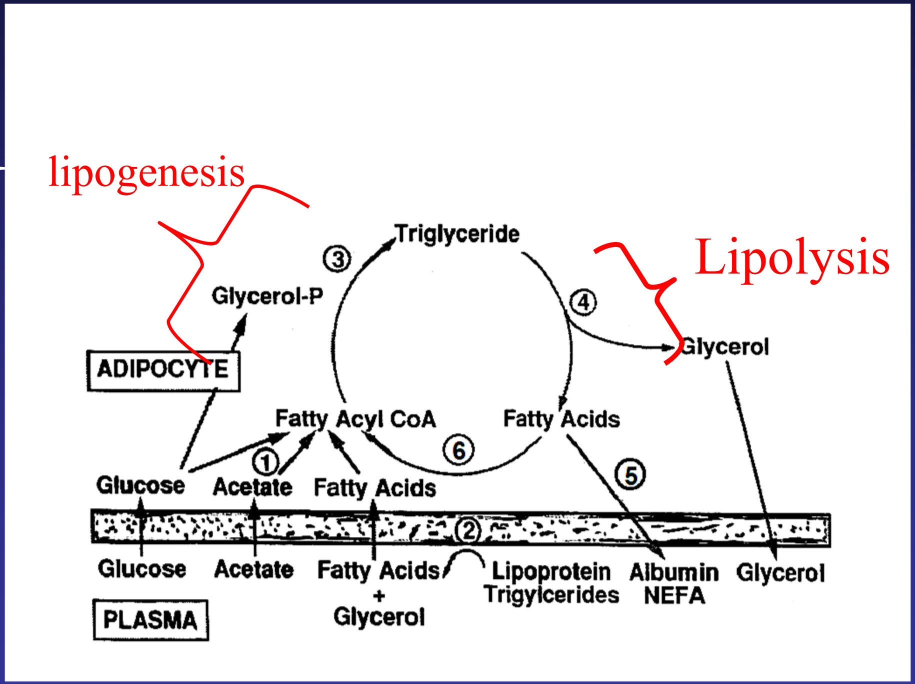


Bauman, 2004

Intracellular Triglyceride Review

Stimulator:
Insulin

Inhibitors:
GH
Epinephrine
Glucagon

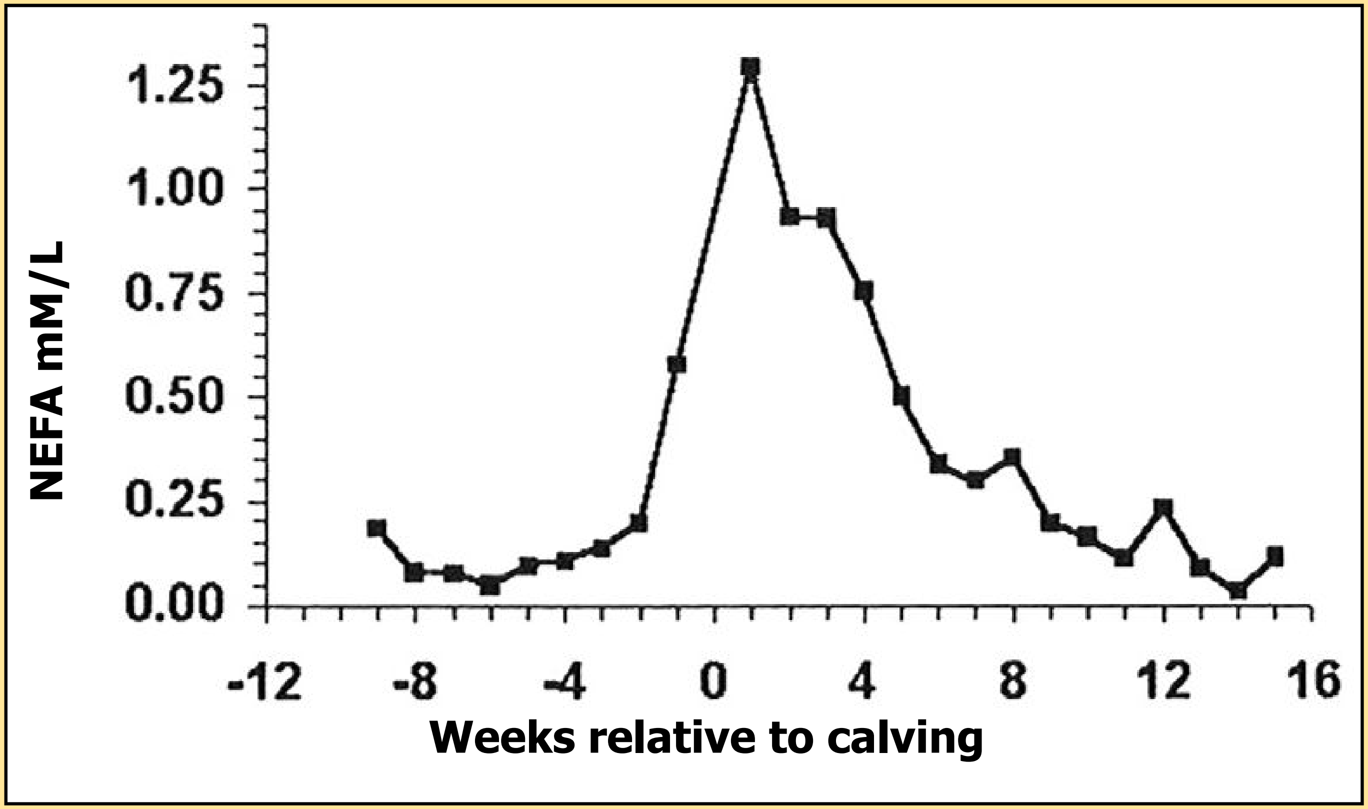


Stimulator:
GH
Epinephrine
Glucagon

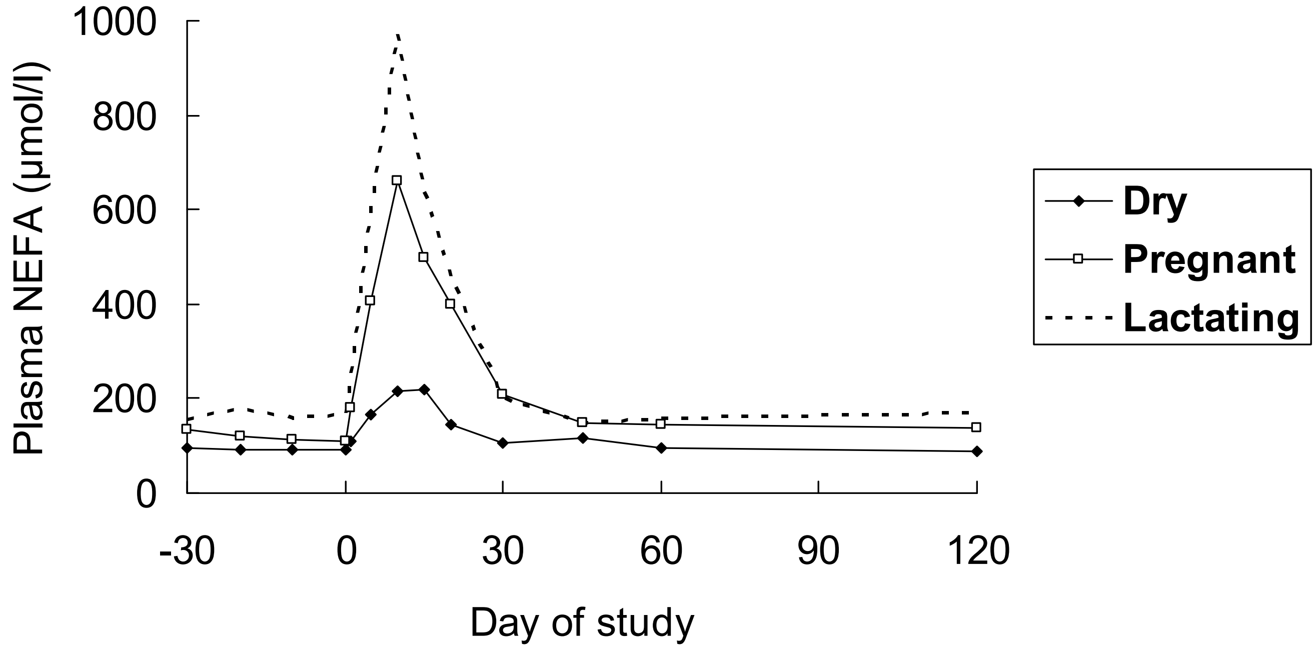
Inhibitor:
Insulin

Bauman et al., 1985

Periparturient Basal Circulating NEFA



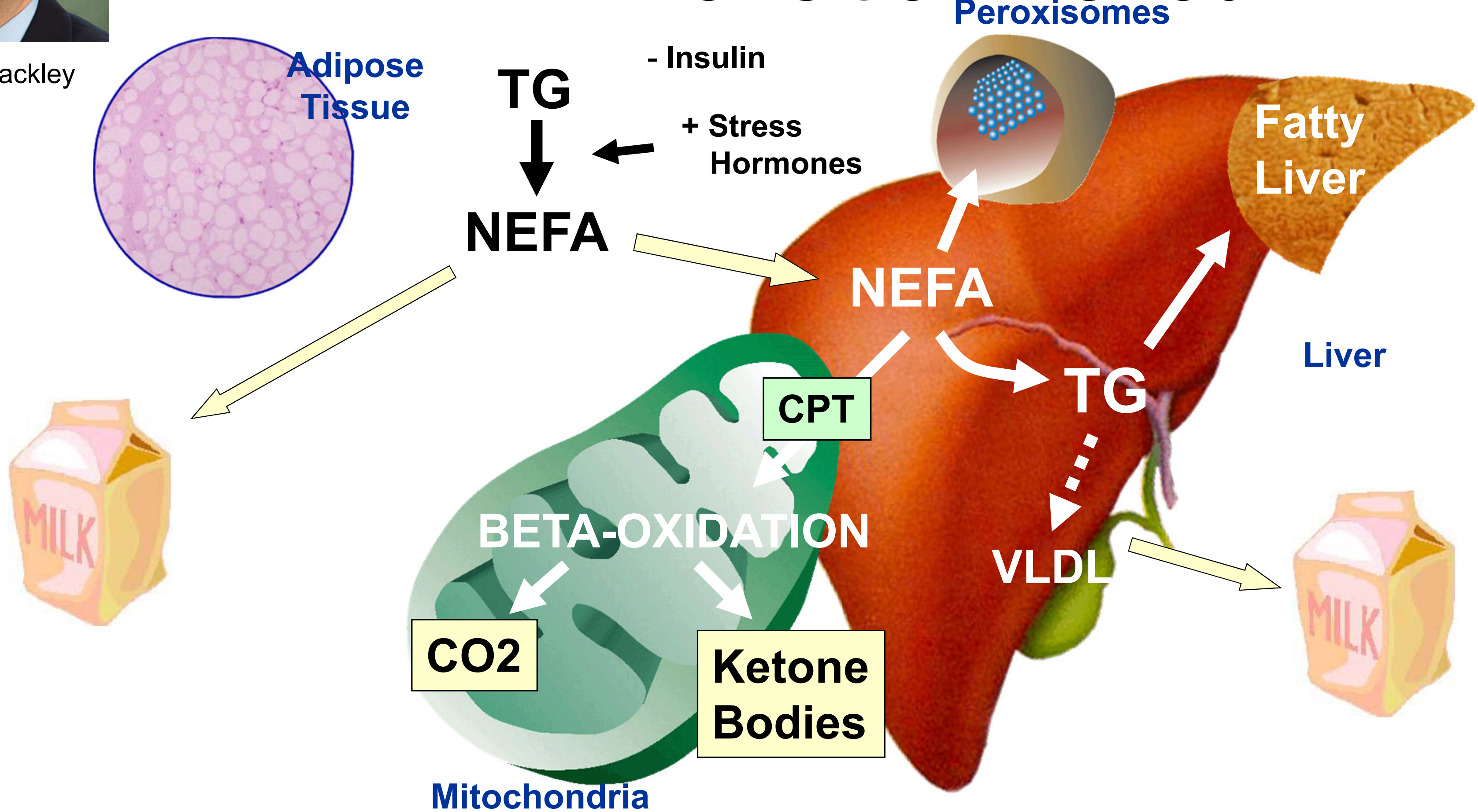
NEFA Response to Epinephrine Changes with Physiological State

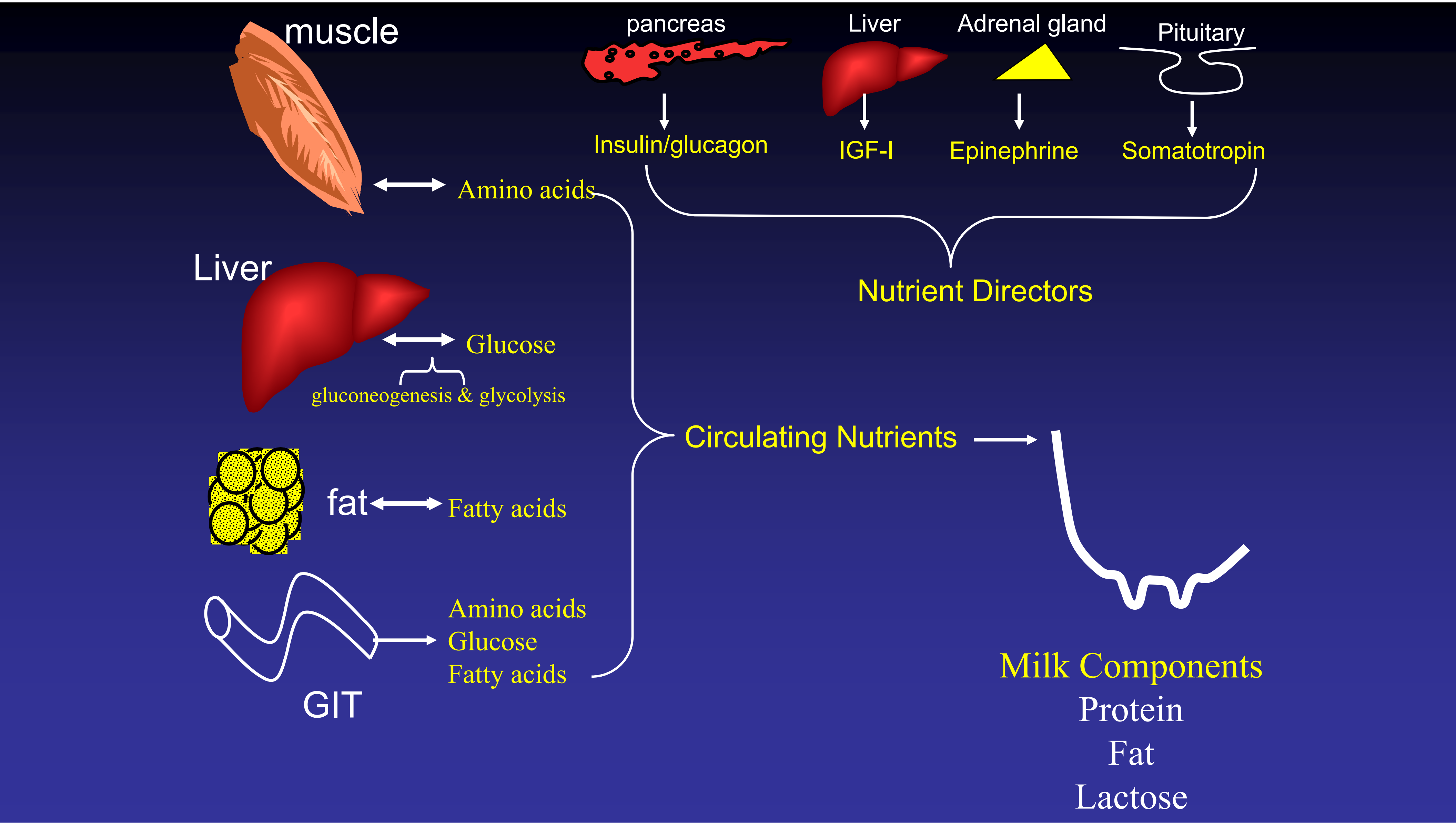


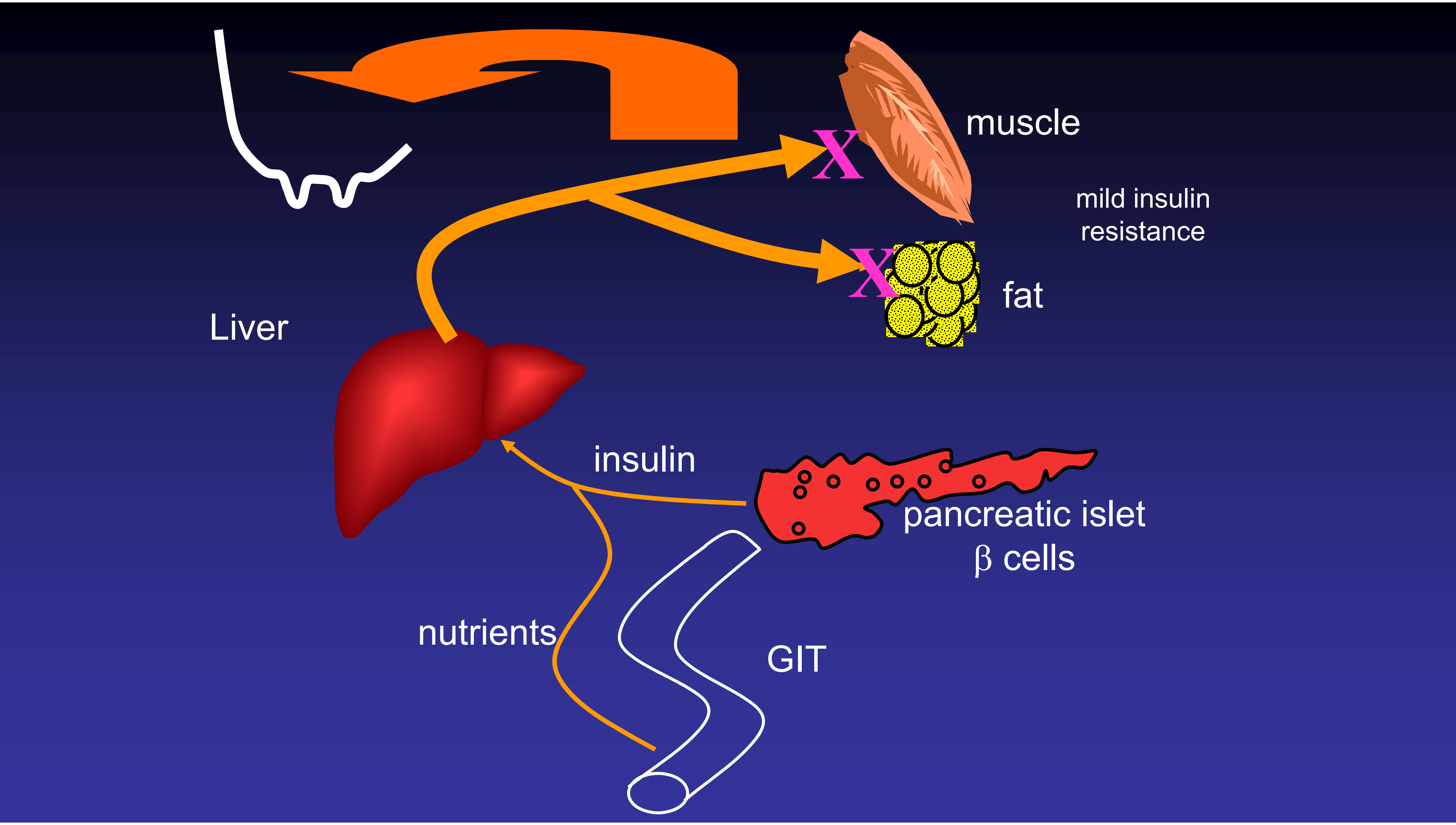
Sechen et al., 1990

Lipid Metabolism During the Transition Period

Dr. Jim Drackley




muscle
Amino acids
Liver
Glucose
gluconeogenesis & glycolysis
fat
Fatty acids
GIT
Amino acids
Glucose
Fatty acids
pancreas
Insulin/glucagon
Liver
IGF-I
Adrenal gland
Epinephrine
Pituitary
Somatotropin
Nutrient Directors
Circulating Nutrients
Milk Components
Protein
Fat
Lactose

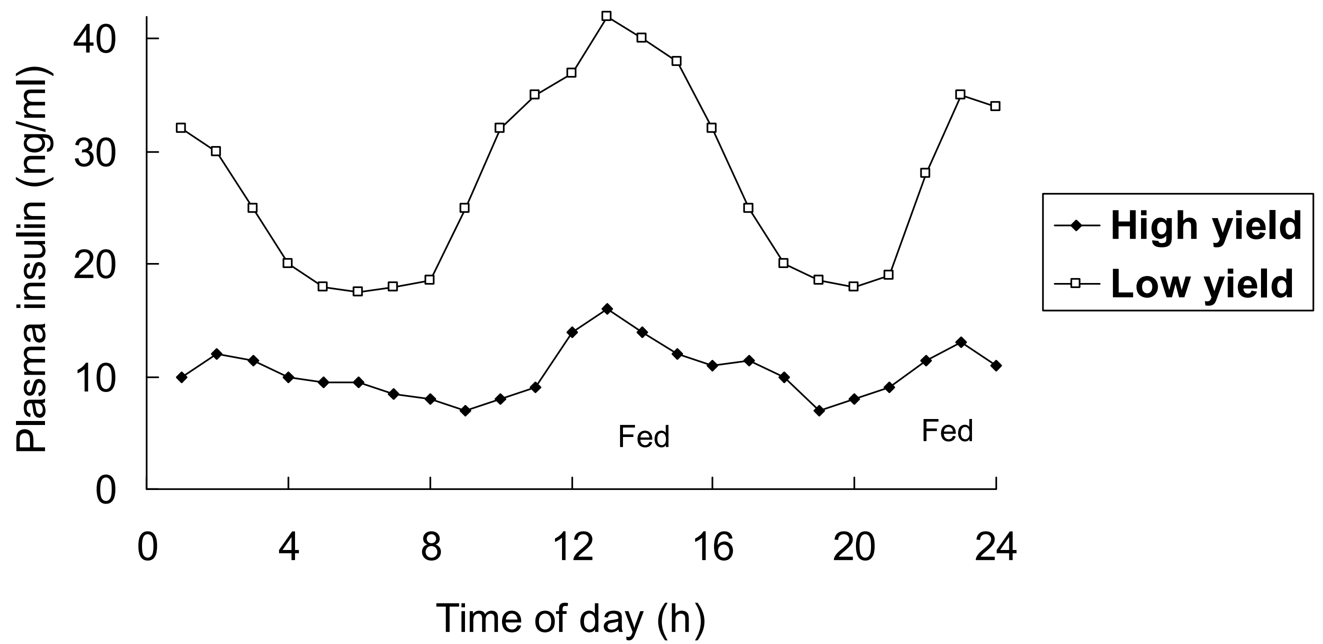

muscle
mild insulin
resistance
fat
Liver
insulin
pancreatic islet
β cells
nutrients
GIT

Insulin and Nutrient Trafficking

- Causes nutrients to be taken up by muscle and adipose tissue
  - Glucose
  - Amino Acids
  - Fatty Acids

- Prevents tissue catabolism/mobilization
  - “Locks” fatty acids and AA in adipose and muscle

High yielding cows have low insulin concentrations



Bines and Hart,1982

DEPRESSION OF MILK SECRETION DURING INSULIN ADMINISTRATION [1]

D. S. KRONFELD, G. P. MAYER, J. McD. ROBERTSON, AND FIORA RAGGI
School of Veterinary Medicine, University of Pennsylvania, Kennett Square

SUMMARY

Long-acting insulin was injected intramuscularly twice a day into two cows. Their daily milk yield and plasma glucose concentration both decreased. Glucose was then infused intravenously while the insulin injections were continuing. When the plasma glucose was restored to a normal level, the milk secretion returned to the pretreatment rate. These observations suggest that hypoglycemia is a more direct cause of hypogalactia than is insulin.

Depression of milk secretion after insulin administration was observed in goats as early as 1923 (7). Eight years later, Gowan and Tobey (5, 6) found that withholding food from cows would lower the milk production, increase the fat percentage, and decrease the lactose concentration, with a concurrent fall in blood glucose concentration. These effects of fasting were not noticeably affected by administration of parathyroid hormone or by phloridzin, but were intensified by insulin. Indeed, insulin administered to one nonstarved cow induced similar effects. The decline in milk lactose was attributed by Gowan and Tobey to the low blood sugar level, while the fall in milk yield was attributed to a decrease in available energy.

Insulin acting directly on mammary cells would not be expected to diminish the energy available for milk secretion, nor the availability of precursors for synthesis of milk constituents. Added in vitro, insulin increases the metabolism of glucose and acetate in mammary slices taken from lactating rats but not in slices from sheep (1). This was taken to reflect the ruminant's utilization of acetate rather than glucose as a precursor of acetyl-CoA in mammary lipogenesis, assuming that the primary action of insulin is on carbohydrate metabolism and that the in vitro conditions were suitable for the sheep slices to respond. In

does this occur when insulin is given but also in association with hypogalactia in ketotic cows. Jasper (10) found the prolonged hypoglycemia due to exogenous insulin was accompanied by many clinical signs similar to those seen in ketotic cows. These did not include a fall in milk production, because one cow was dry and the other almost so. Finally, Hardwick et al. (8) found that the perfused goat's udder required glucose in the perfusate in order to secrete, and that the rate of secretion varied directly with changes in the perfusate glucose concentration in the range 0 to 300 mg/100 ml.

The present experiments aim to test whether insulin-induced hypoglactia is a direct effect of insulin on the udder or an indirect effect due to hypoglycemia. Cows were given insulin, and when the milk yield fell, glucose was given intravenously in addition to the insulin.

EXPERIMENTAL PROCEDURE

The cows were milked at 6 AM and 4 PM, and the milk weighed to one-tenth of a pound. Jugular blood samples were collected in fluoride tubes each day between 10 AM and NOON. The blood was centrifuged at 2,500 rpm for 30 min and the packed cell volume recorded. The plasma was tested for acetone bodies with nitroprusside (1). Plasma glucose concentra-

Kronfeld et al., 1963 JDS

Effect of Insulin on Yield and Composition of Milk of Dairy Cows

G. H. SCHMIDT
Animal Husbandry Department, Cornell University, Ithaca, New York

Abstract

Short-acting insulin injections into lactating Holstein cows resulted in a decrease in milk production, milk lactose percentage, and blood glucose levels, and an increase in the percentage composition of milk fat and protein. The casein expressed as a percentage of the total protein remained the same during the insulin treatment as compared to the pretreatment period. Phlorizin caused a decrease in milk production, a slight increase in milk fat percentage, but no change in the milk protein percentage. Infusion of glucose with the insulin injections restored the milk yield to near-normal levels and caused the milk protein percentage to return to the pretreatment levels. The milk fat percentage remained elevated during the glucose infusion. Increases in milk fat and protein percentages during insulin treatment cannot be explained entirely by a decrease in the volume of milk.

Insulin is known to have a depressing effect on the level of blood glucose and milk production in dairy cows. Gowen and Tobey (3) found that the fasting of cows resulted in a decrease in milk production, a decrease in lactose percentage of the milk, a fall in blood glucose, and an increase in the milk fat percentage. Insulin intensified these results and insulin administration to one normal cow gave results similar to those of fasting. It also increased the nitrogen content of the milk. Rook et al. (11) infused insulin into two lactating cows for 12 and 15 hr and found it to cause a decrease in milk yield and lactose percentage and an increase in the percentages of milk fat, total protein, and casein. Kronfeld et al. (7) found that insulin injections lowered the milk production of cows. Intravenous injection of glucose along with the insulin restored a normal milk yield and these authors concluded that the lowered milk production was a result of the hypoglycemia and not of the insulin per se. Chemical composition of the milk was not reported.

It has been shown that insulin in vitro enhances the incorporation of labelled amino acids into isolated rat diaphragm [summarized by Manchester and Young (10)], epididymal fat pad (5); liver slices (6); perfused heart, heart slices, and rat mammary gland (14). The insulin effect on amino acid incorporation into rat diaphragm protein occurred in the absence of glucose or an oxidizable substrate in the media (8, 13), and the amino acid incorporation was not increased as the glucose concentration of the media was increased. Wool and Manchester (14) showed that the insulin effect on amino acid incorporation into the proteins of heart slices, epididymal fat pads, and rat mammary glands required glucose or some oxidizable substrate to be added to the incubation media.

The purpose of these experiments was to obtain further information on the effect of insulin injections on the yield and composition of milk of dairy cows.

Received for publication January 17, 1966.

Experimental Procedure

The insulin used in these experiments was short-acting insulin (Insulin injection, Regular Iletin, Eli Lilly and Co.) and this was administered subcutaneously. Composite night and morning milk samples were taken and analyzed for milk fat (Babcock method), milk protein (Kjeldahl nitrogen multiplied by 6.38), and milk lactose (4). Jugular blood samples were taken at regular intervals and analyzed for blood glucose by the Nelson-Somogyi method (4) in Experiments I, II, and V. The glucose oxidase method (2) was used in Trials III and IV. Cows were milked twice daily and fed hay and silage free choice. The amount of grain fed was based on their previous production and was not changed during the trials.

Experiment I. Six first-calf Holstein heifers in early lactation were divided into three groups. One group received 0.25 USP unit of insulin per kg of body weight twice daily after each milking. A second group received 0.35 unit per kg body weight after each milking, and a third group received 0.5 unit/kg body weight after the morning milking only. The insulin was injected for four days and this was preceded and followed by seven-day control periods. Milk samples were collected for two days each during the treatment period and the pre- and post-treatment periods. Blood samples were taken once during each period.

Experiment II. The same six cows used in Experiment I were used a month later for

Abstract

Short-acting insulin injections into lactating Holstein cows resulted in a decrease in milk production, milk lactose percentage,

Schmidt, J. Dairy Sci. 1966

J. Dairy Sci. 102:1473–1482
https://doi.org/10.3168/jds.2017-14029

Association of peripartum plasma insulin concentration with milk production, colostrum insulin levels, and plasma metabolites of Holstein cows

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Department of Population Medicine and Diagnostic Sciences, Cornell University, Ithaca, NY 14853-6401

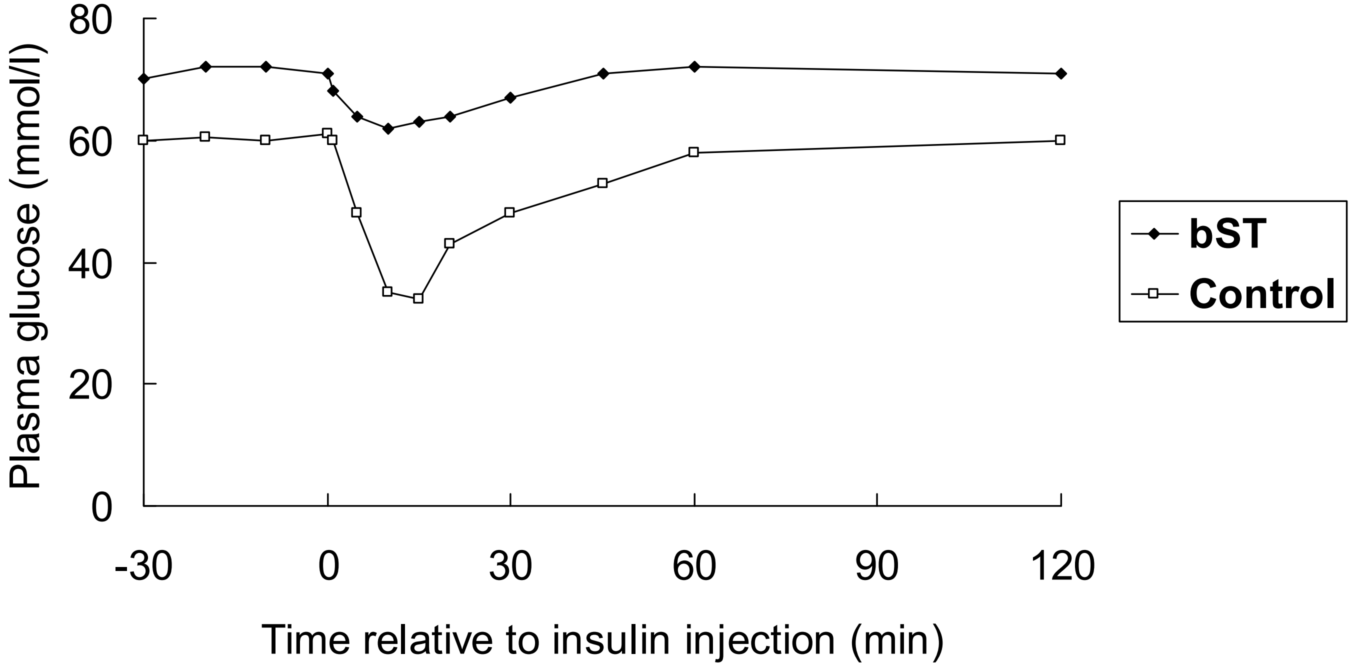
ABSTRACT

The main objective of this study was to assess associations between plasma insulin concentration around parturition and production in Holstein cows. Primiparous and multiparous cows (n = 267) were enrolled.

d 10, L-INS = 44.09 ± 0.73 vs. H-INS = 40.55 ± 0.68 kg). We conclude that low plasma insulin concentration during early lactation is associated with higher milk yield in the long term.

Key words: insulin, milk production, nonesterified fatty acid, β-hydroxybutyrate

rbST decreases the glucose response to insulin

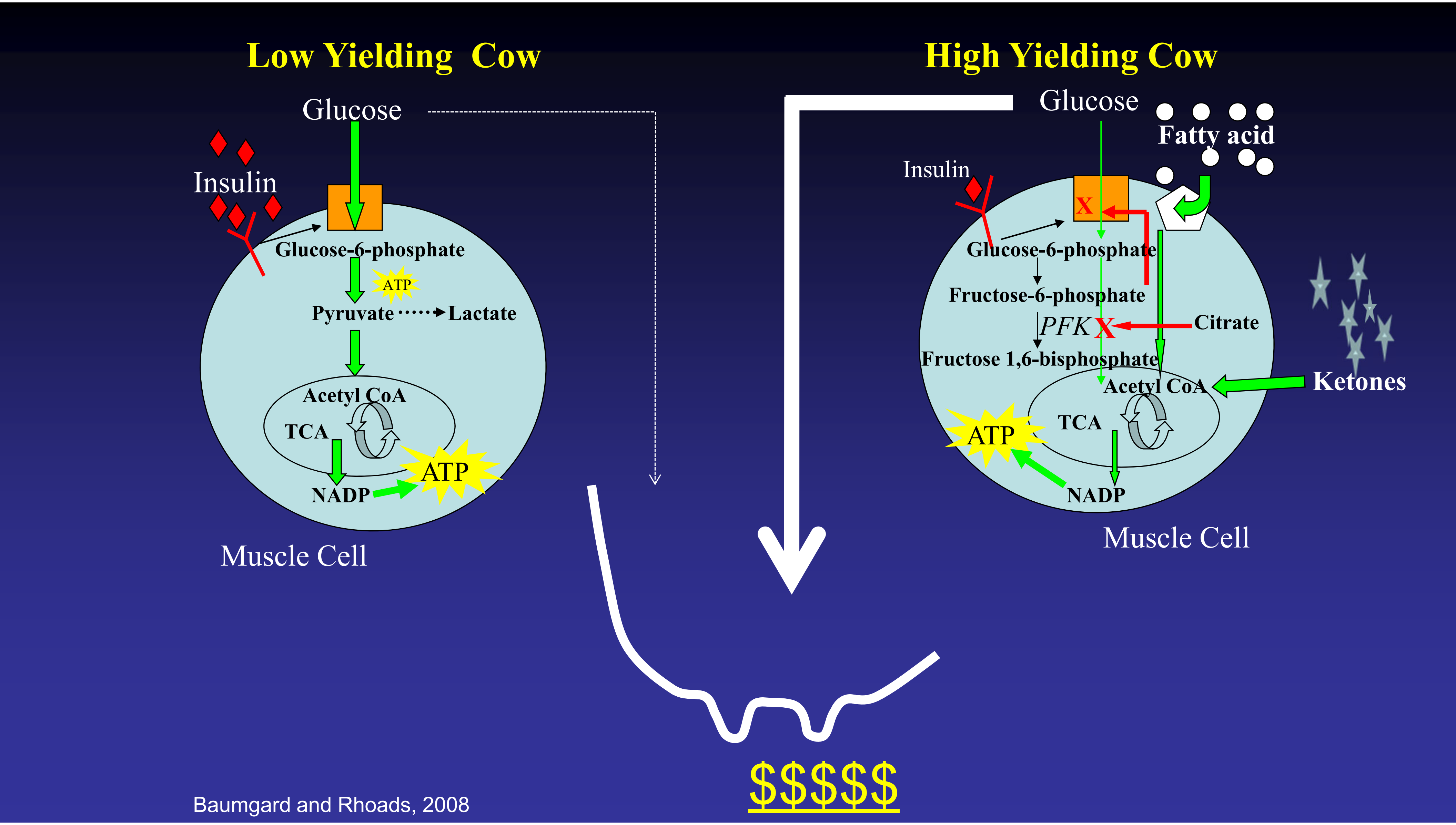


Sechen et al., 1990

“Glucose Sparing”

- Reprioritization of fuel selection at systemic tissues (muscle and adipose)
  - Decrease dependence on glucose
  - Increased reliance on NEFA, ketones, VFA, and amino acids

- “spares” glucose for the mammary gland



Low Yielding Cow
Glucose
Insulin
Glucose-6-phosphate
ATP
Pyruvate
Lactate
Acetyl CoA
TCA
ATP
NADP
Muscle Cell
High Yielding Cow
Glucose
Fatty acid
Insulin
X
Glucose-6-phosphate
Fructose-6-phosphate
PFK
X
Citrate
Fructose 1,6-bisphosphate
Acetyl CoA
Ketones
TCA
ATP
NADP
Muscle Cell
$$$$$
Baumgard and Rhoads, 2008

Insulin Resistance in Dairy Cows

Jenne D. De Koster, DVM, Geert Opson

KEYWORDS

- Insulin resistance • Dairy cow • Glucos
- Pregnancy and lactation • Adipose tiss

KEY POINTS

- Insulin plays a pivotal role in the glucose r
- The glucose metabolism of ruminants is ch trations and a low insulin response of the
- The effect of insulin on the glucose metab the pancreas and the insulin sensitivity of
- A state of insulin resistance may develop a and pathologic processes, which may decreased insulin responsiveness.

COWS ARE RUMINANTS AND POSSESS A

The glucose metabolism is of major inte vitally important cell types (erythrocytes on glucose as the only energy substrate levels within normal physiologic ranges i that of other mammals, the glucose m low peripheral glucose concentrations[2–4] tissues.[3,5–7] The glucose metabolism is glucose and glucogenic precursors in th hormones. Within the ruminants, dairy c glucose metabolism. The massive glucos sition between pregnancy and lactation an example of how intensive genetic sel schematic overview of the glucose metal

animals MDPI

Review

The Complex Interplay of Insulin Resistance and Metabolic Inflammation in Transition Dairy Cows

Kaixi Qiao [1], Renjiao Jiang [1], Ge
Geert Opsomer [3] and Qiang D

check for updates

Citation: Qiao, K.; Jiang, R.; Contreras, G.A.; Xie, L.; Pascottini, O.B.; Opsomer, G.; Dong, Q. The Complex Interplay of Insulin Resistance and Metabolic Inflammation in Transition Dairy Cows. *Animals* **2024**, *14*, 832.

Sim resi and acti infl infl dise met

Abs feta gluc as e infl ada a re

animals MDPI

Review

Metabolic Stress in the Transition Period of Dairy Cows: Focusing on the Prepartum Period

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Simple Summary: Complex pathwa around calving. These adaptations r fetal growth and the commencemen the development of clinical disease i focused on studying the metabolic c factors associated with postpartum c This review describes adaptive change off (40 to 60 days before parturition)

J. Dairy Sci. 107:9602–9614
https://doi.org/10.3168/jds.2023-24630

Unraveling metabolic stress response in dairy cows: Genetic control of plasma biomarkers throughout lactation and the transition period

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Insulin and Insulin Action

- Increased insulin action is not conducive for maximizing milk synthesis.
  - “anti” milk and “pro” fat hormone

J. Dairy Sci. 104:8380–8410
https://doi.org/10.3168/jds.2021-20330

Invited review: **The influence of immune activation on transition cow health and performance—A critical evaluation of traditional dogmas**

E. A. Horst, S. K. Kvidera, and L. H. Baumgard*
Department of Animal Science, Iowa State University, Ames 50011

- High mi … creased systemi …

- Insulin resistance during Type II Diabetes vs. Lactation
  - Metabolic disease vs. normal biology: The two aren’t similar

- IMO, “insulin resistance” is not an issue in ruminants and lactating dairy cows. It’s incorrect to compare insulin resistance in obese humans to cows.

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Invited review: The influence of immune activation on transition cow health and performance—A critical evaluation of traditional dogmas

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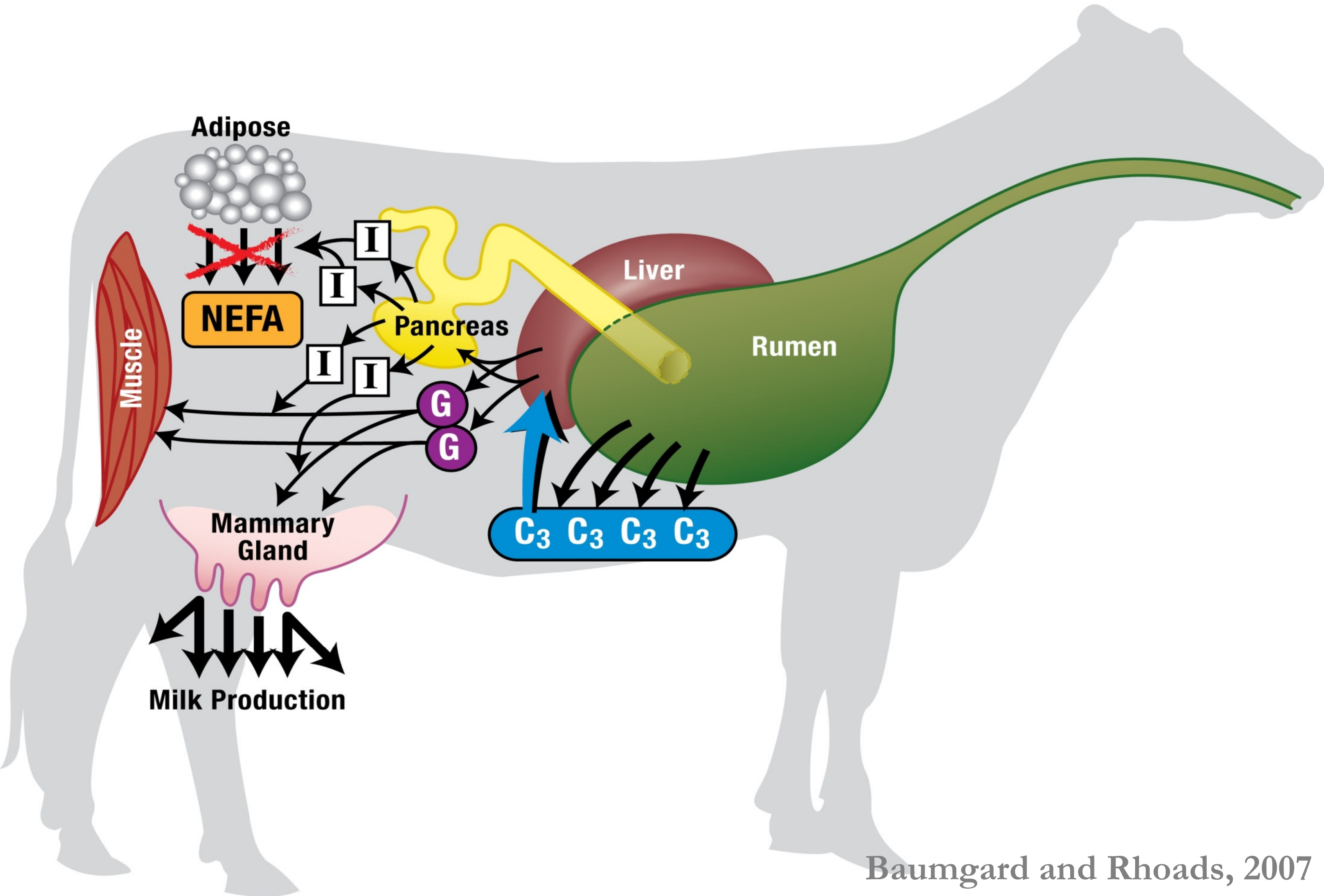
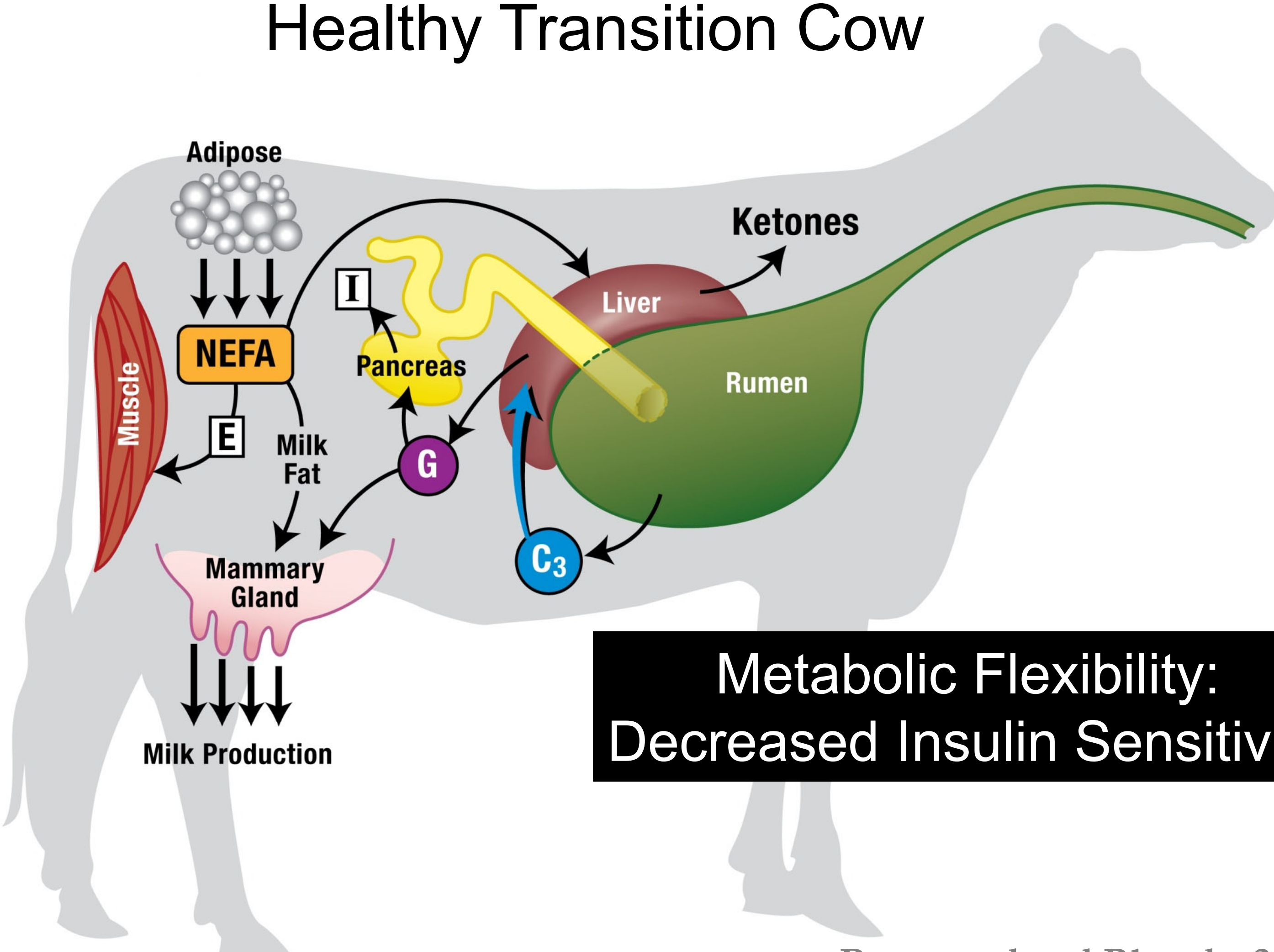
- Gestating cows are more insulin resistant than non-pregnant ones
- Lactating cows are more insulin resistant than non-lactating
- Higher yielding cows are naturally more insulin resistant
- rbST causes cows to be more insulin resistant

Well Fed….Mid-Late Lactation



Baumgard and Rhoads, 2007

Healthy Transition Cow



Metabolic Flexibility:
Decreased Insulin Sensitivity

Baumgard and Rhoads, 2007

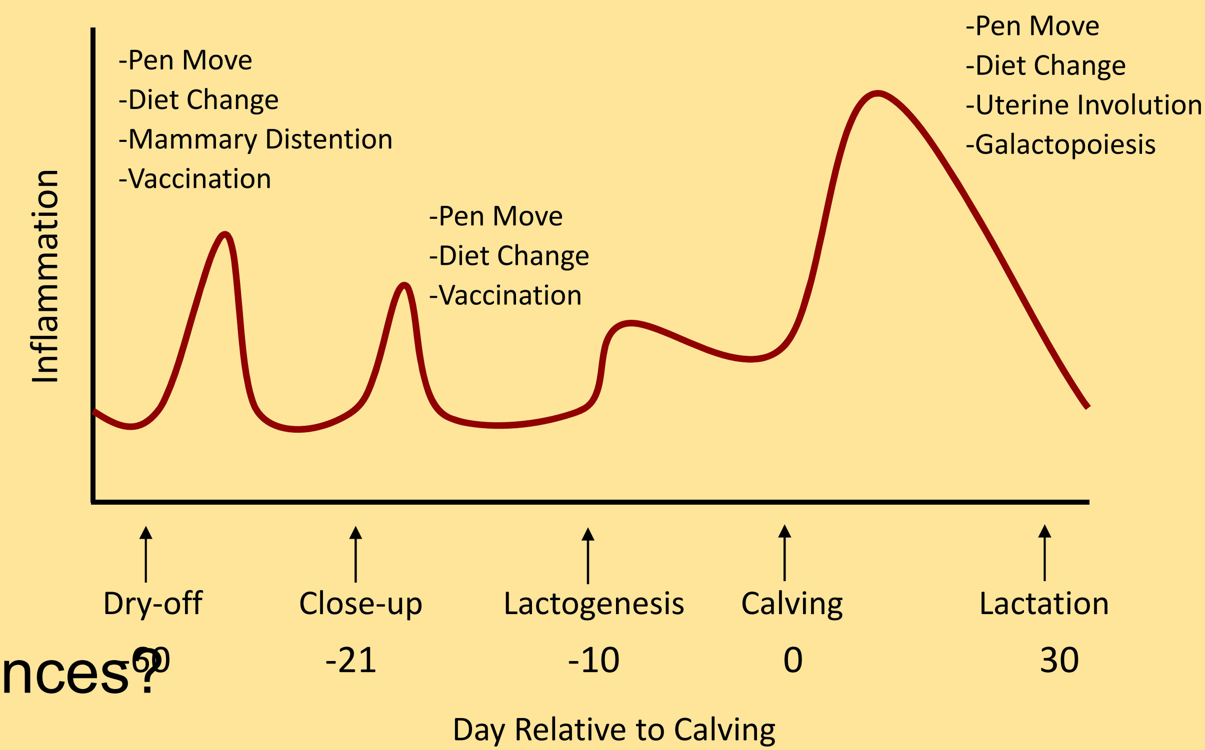
Inflammation in Transition Cows

- Observed in all cows

(Bertoni et al., 2008; Trevisi and Minuti, 2018)

- What is the source?
  - Mammary Gland
  - Uterus
  - Gastrointestinal tract

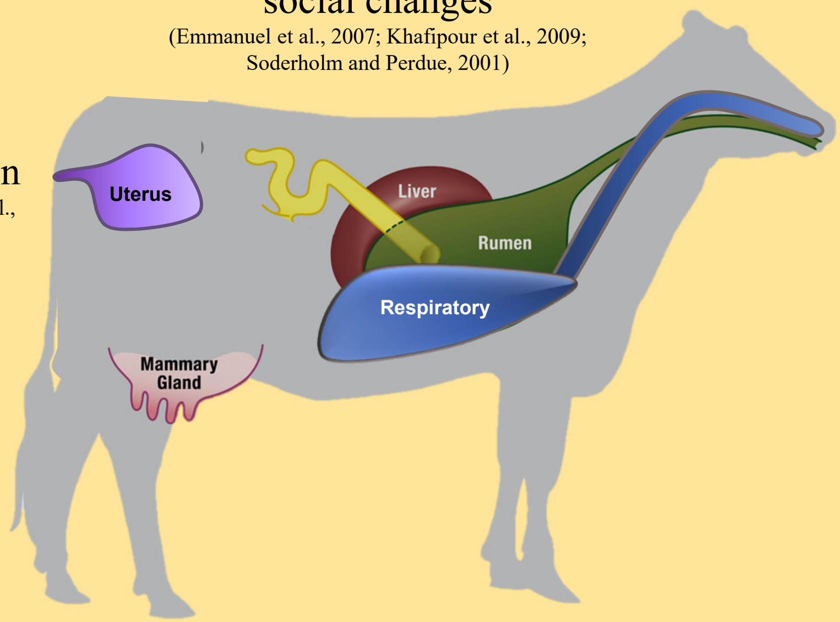
- What are the consequences?



Heightened risk of antigen insult in early lactation on multiple epithelia

Increased gut permeability via diet and social changes
(Emmanuel et al., 2007; Khafipour et al., 2009; Soderholm and Perdue, 2001)

Uterine bacterial contamination post-parturition
(Paisley et al., 1986; Földi et al., 2006; Norman et al., 2007; Sheldon et al., 2008)

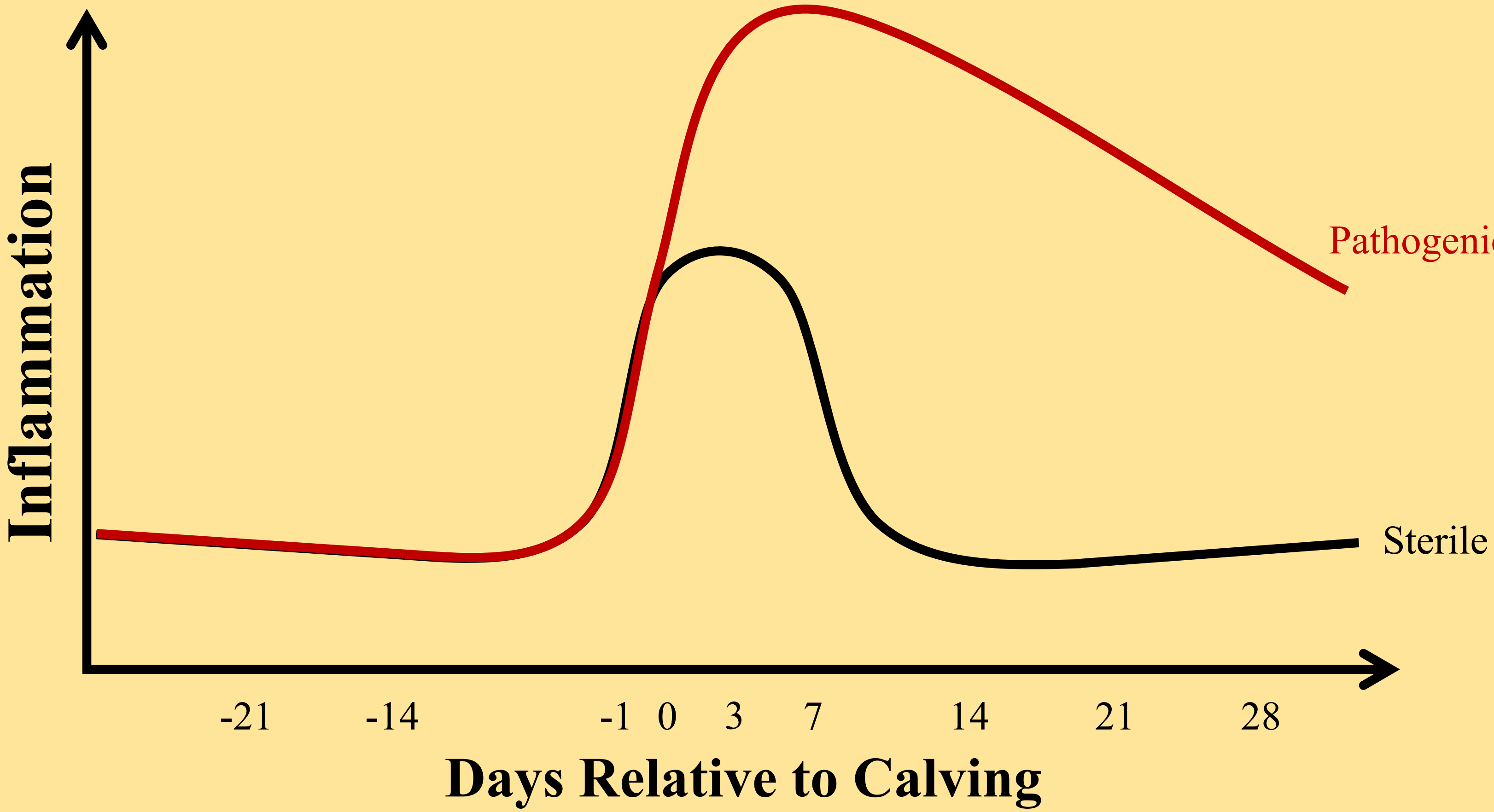


Lactogenesis and galactopoeisis
(Akers and Nickerson, 2011)

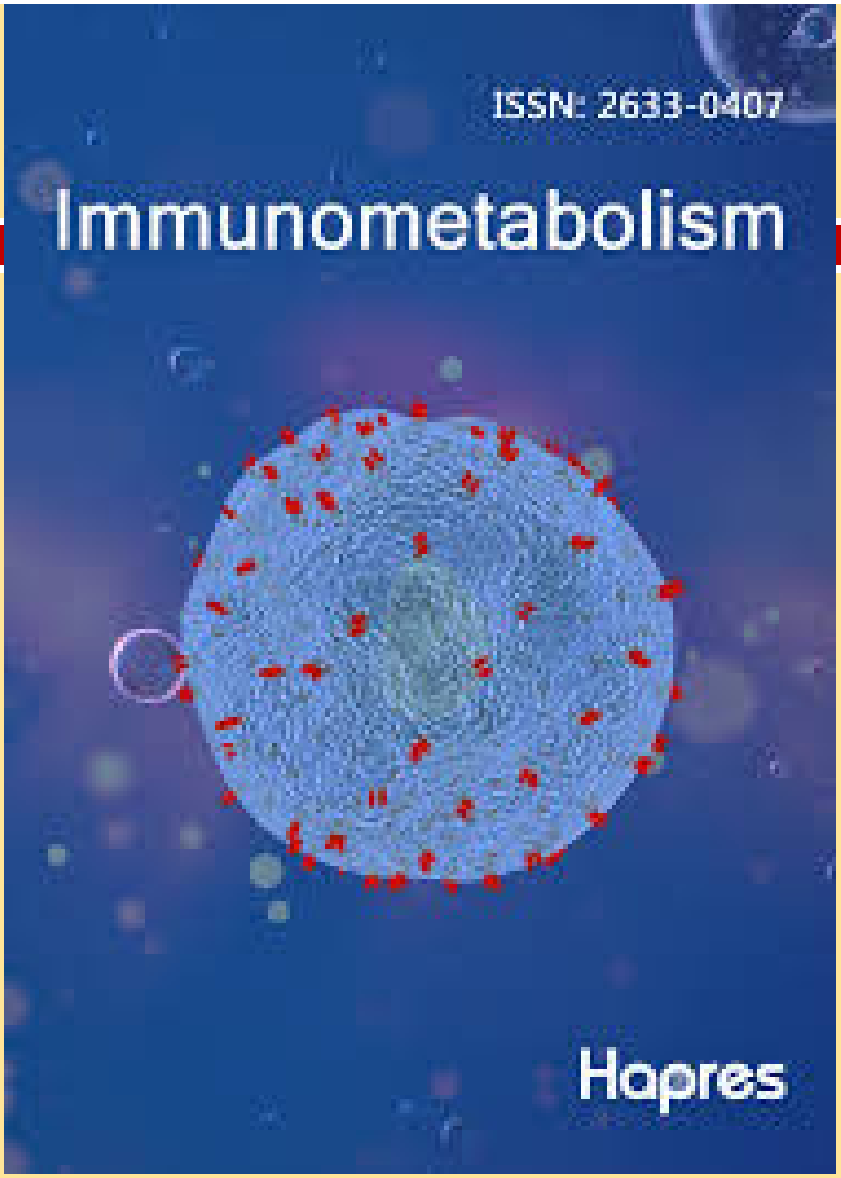
<u>Sterile Inflammation</u>
Parturition
Placenta Expulsion
Uterine Involution

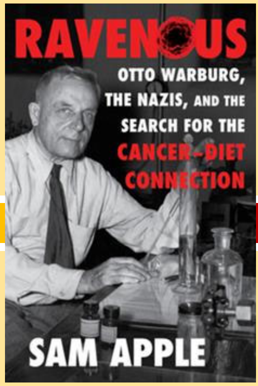
Julie Opgenorth

Transition Cow Inflammation

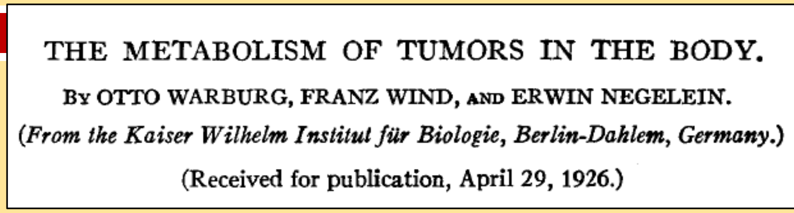


Bridget Buol


ISSN: 2633-0407
Immunometabolism
Hapres



Professor Dr. Otto Warburg



THE METABOLISM OF TUMORS IN THE BODY.

BY OTTO WARBURG, FRANZ WIND, AND ERWIN NEGELEIN.

(*From the Kaiser Wilhelm Institut für Biologie, Berlin-Dahlem, Germany.*)

(Received for publication, April 29, 1926.)

Stoffwechsel der weißen Blutzellen

Von OTTO WARBURG, KARLFRIED GAWEHN und AUGUST-WILHELM GEISSLER

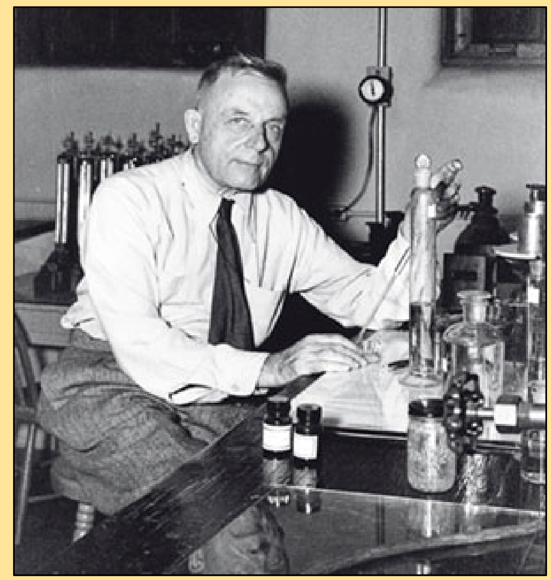
Aus dem Max-Planck-Institut für Zellphysiologie, Berlin-Dahlem

(Z. Naturforschg. **13 b**, 515—516 [1958] ; eingegangen am 21. Juni 1958)

Der „Krebsstoffwechsel" der normalen weißen Blutzellen, der vielfach, in der letzten Zeit z. B. von W. REMMELE und F. SEELICH [1], gefunden wurde, ist ein Artefakt infolge mechanischer und chemischer Schädigungen.

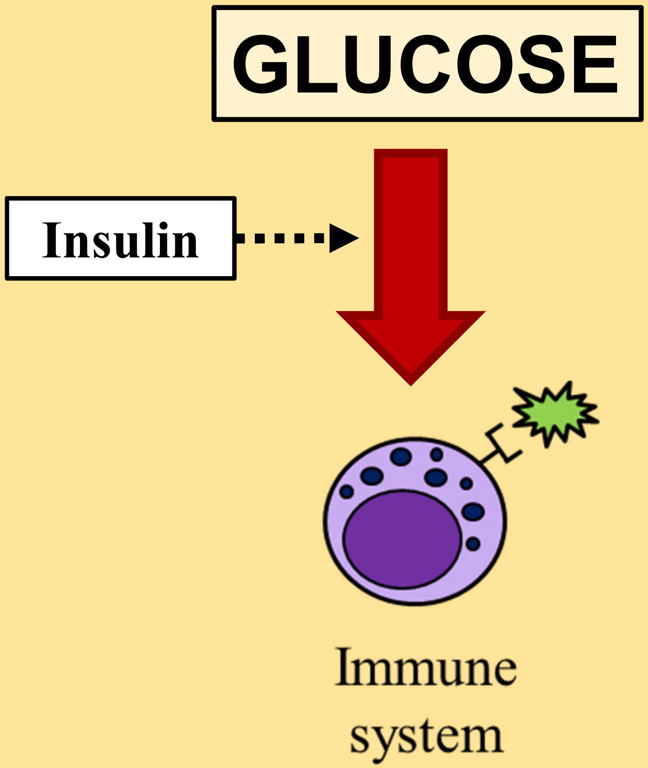
Translation: "Metabolism of "Leukocytes

- First recognized the unique metabolism of cancer cells (1927)
  - Large glucose consumers
  - Switch from oxidative phosphorylation → aerobic glycolysis
- Also observed activated lymphocytes become highly glycolytic (1958)
  - Wins 1931 Nobel Prize for these discoveries
- Mentored Hans Krebs, Hugo Theorell, Otto Meyerhoff
  - All three students went on to win Nobel Prizes
- Family friend with Albert Einstein (Nobel Prize winner)

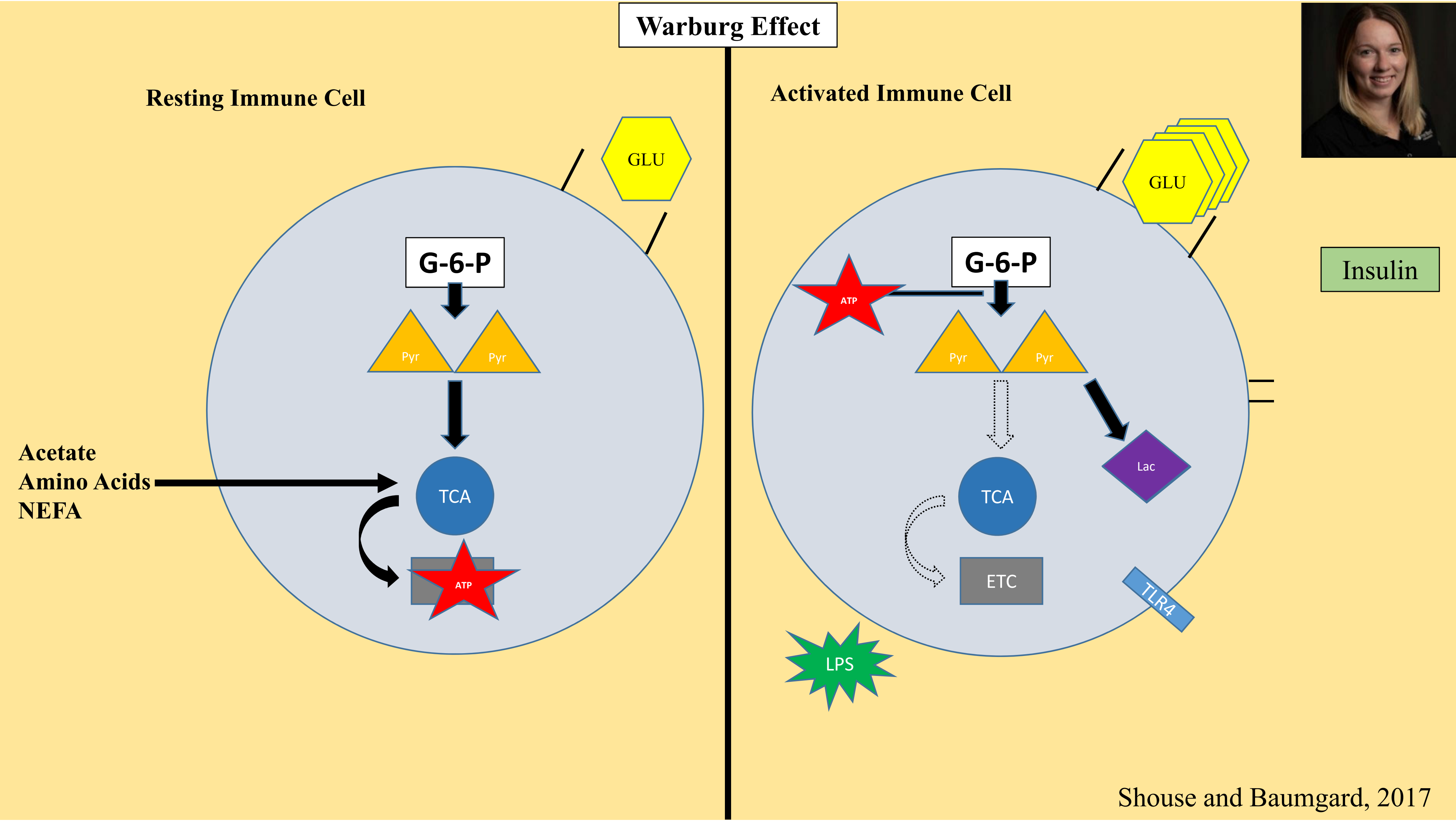


Immuno-Metabolism

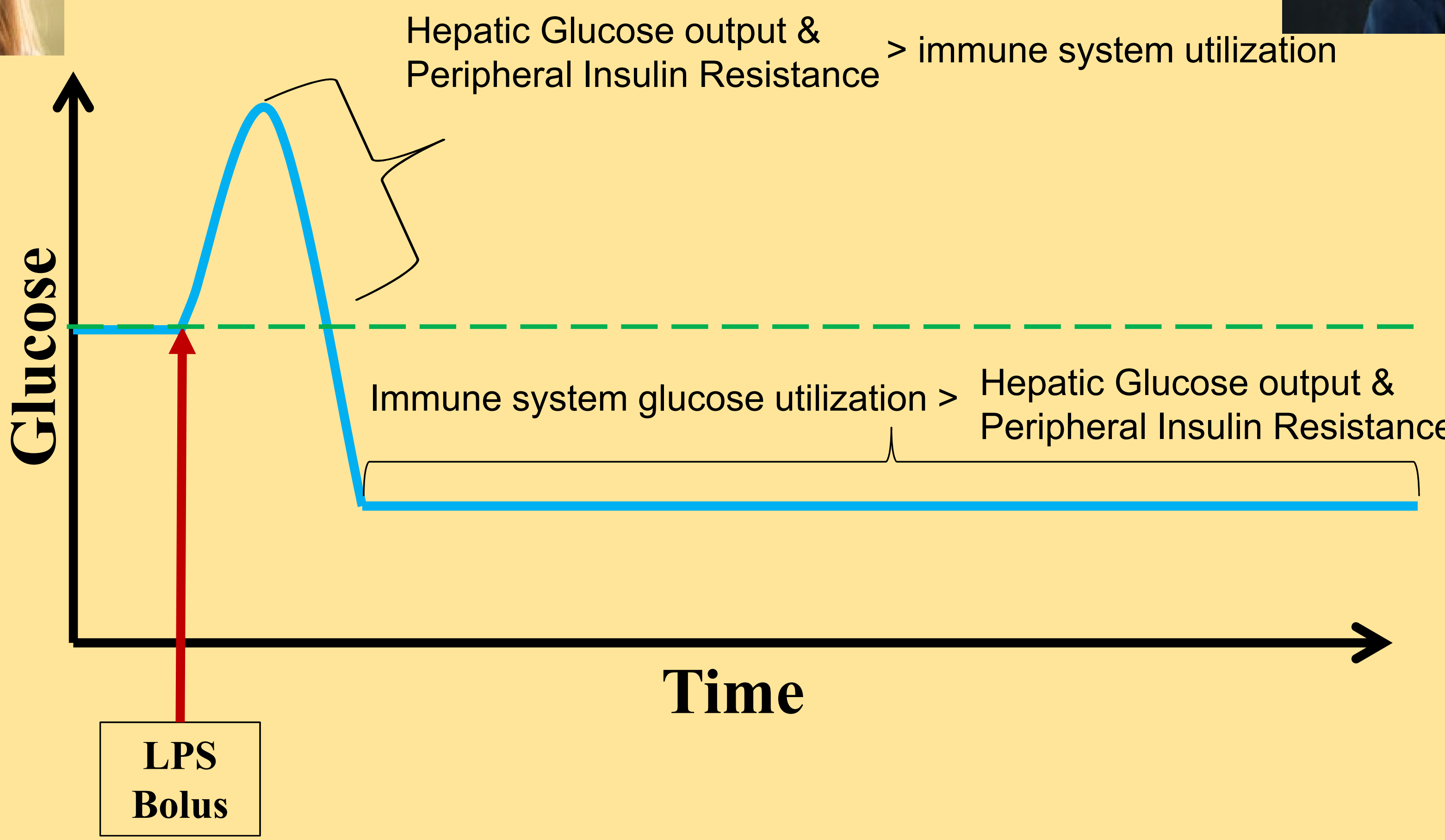
- Immune cells become obligate glucose utilizers when activated
  - Called “The Warburg Effect”
    - Leukocytes are insulin sensitive
      - Palsson-McDermott and O’Neill, 2013



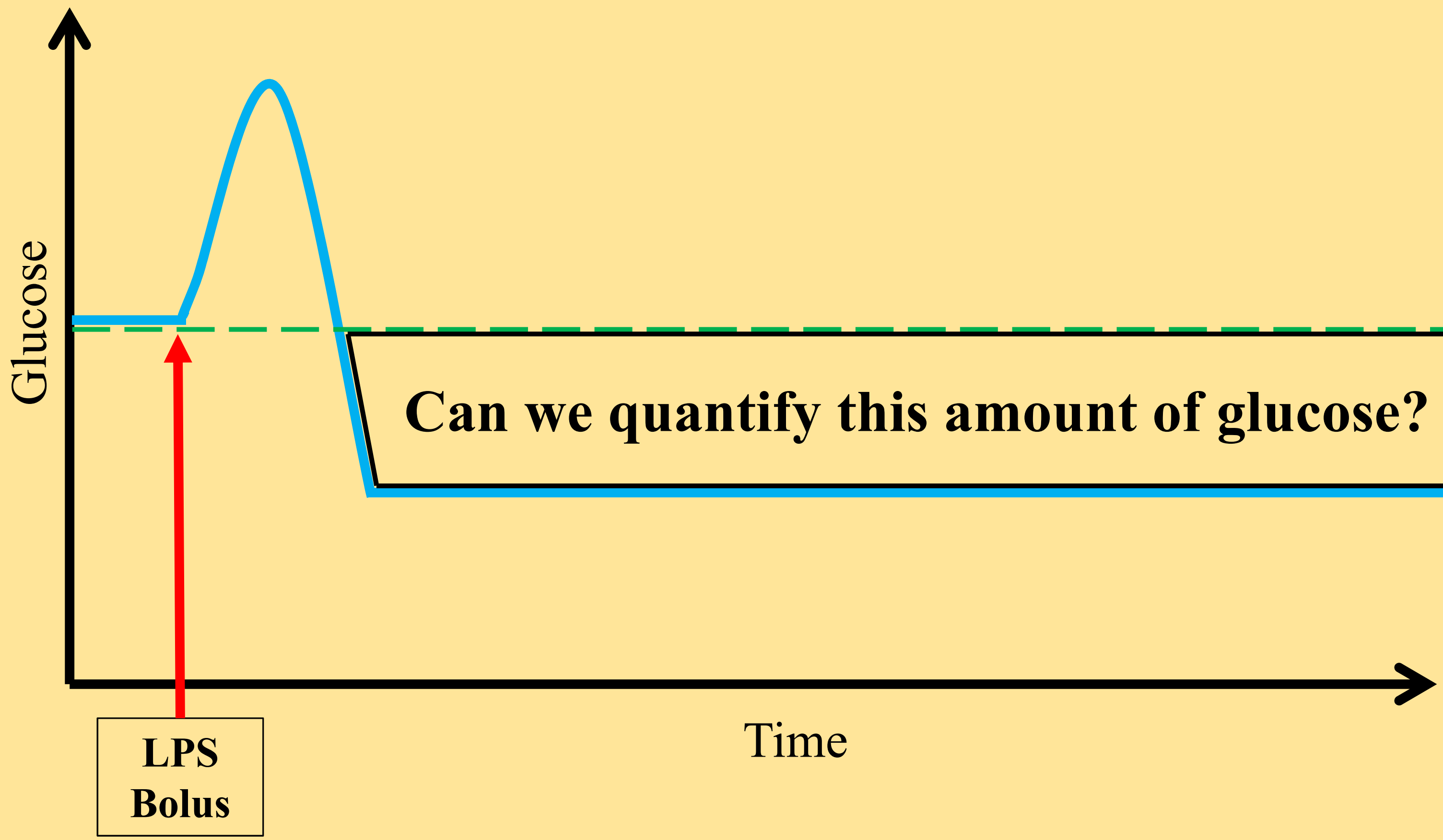
- Advantages of Warburg effect:
  - Rapid production of ATP
  - Synthesis of biomolecules (nucleotides, reducing equivalents, etc.)
  - Adaptation to hypoxic environment
  - Inflammatory signaling

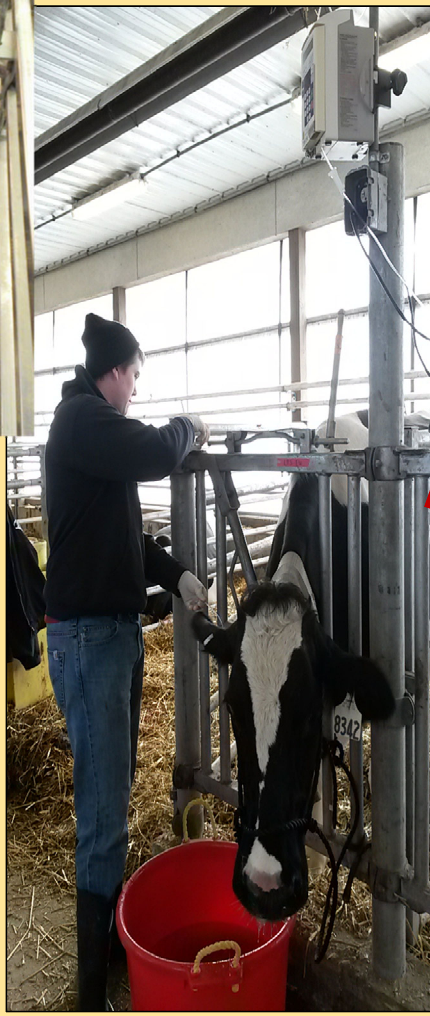

Warburg Effect
Resting Immune Cell
Activated Immune Cell
GLU
G-6-P
Pyr
Pyr
TCA
ATP
Acetate
Amino Acids
NEFA
GLU
G-6-P
ATP
Pyr
Pyr
Lac
TCA
ETC
TLR4
LPS
Insulin
Shouse and Baumgard, 2017

LPS Challenge & Blood Glucose



LPS Challenge and Blood Glucose

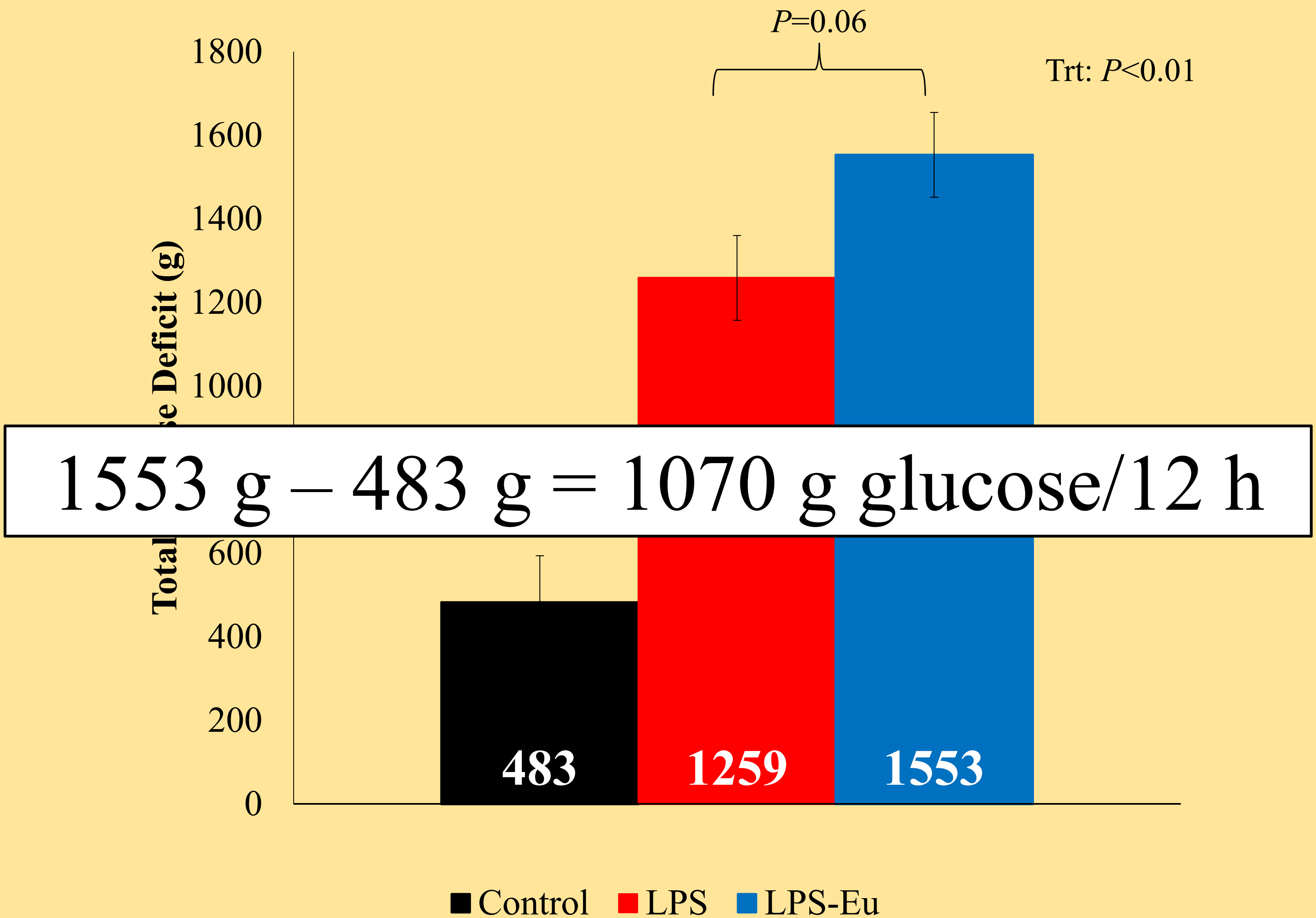




Cow # 8341 Target [Glu] Range: 61-67

Min	Blood Sample (✓)	[Glucose] (mg/dL)	Glucose ROI (mL/hr)	Tr (F)
60 (1 hr)	✓	96	0	101.3
70		84	0	
80		79	0	
90	✓	91	0	100.8
100		98	0	
110		116	0	
120 (2 hr)	✓	115	0	101.2
130		102	0	
140		87	0	
150	✓	68	0	100.9
160		49	50	
170		54	50	
180 (3 hr)	CBC/iStat/Urine ✓✓✓	55	75	100.7
190		56	75	

Kvidera et al., 2015



Kvidera et al., 2015

Study Limitations

- Glucose uptake by other tissues
  - ↓ insulin sensitivity in adipose
    - (Song et al., 2006, Shi et al., 2006, Poggi et al., 2007)

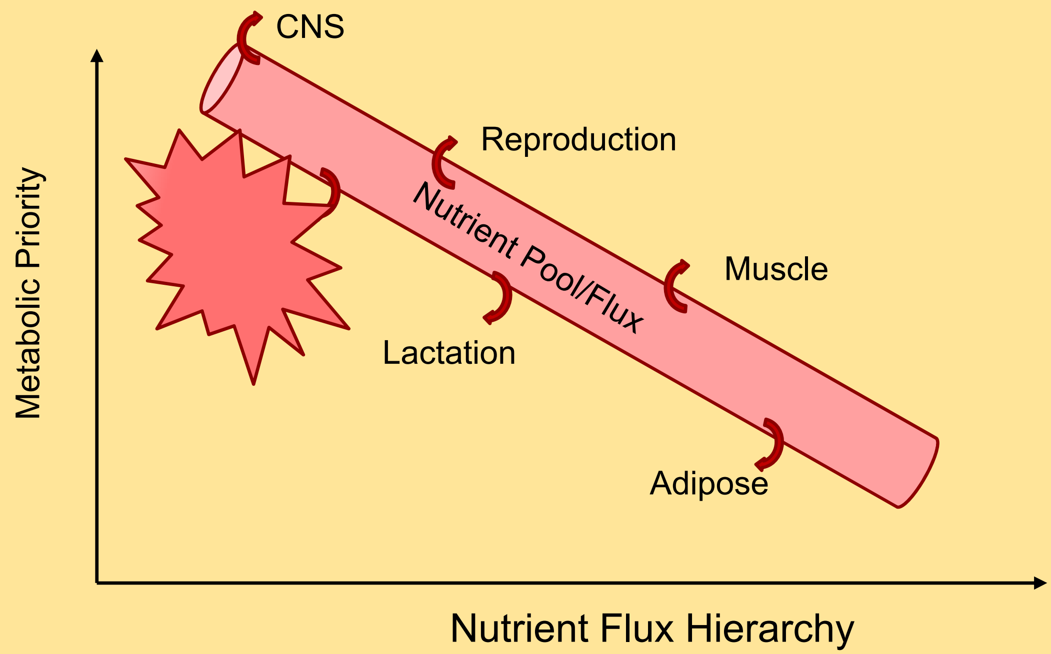
Conclusion: 1 kg/12 h is likely underestimated

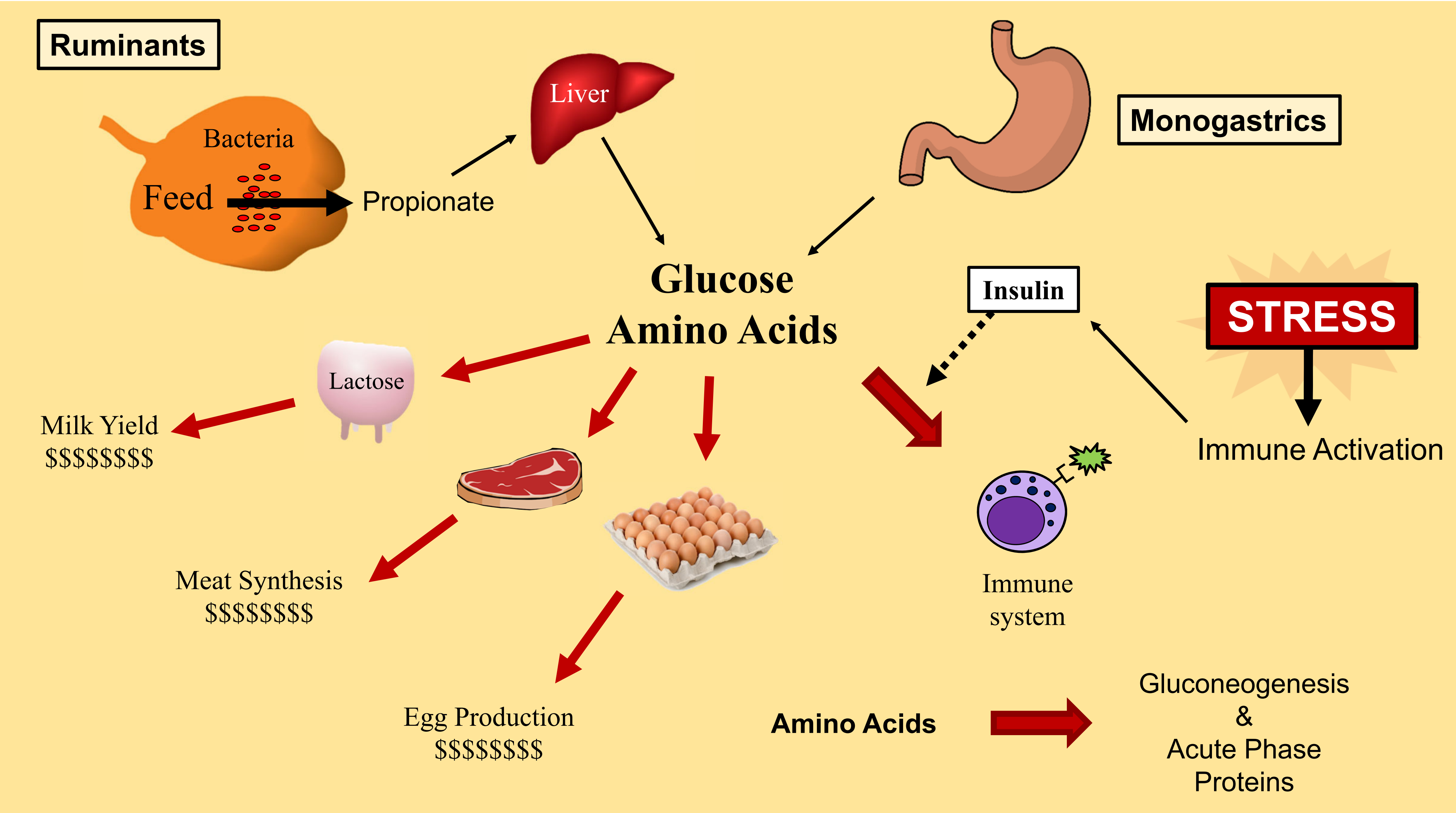
    - (White et al., 1987, Lang et al., 1989, 1990, 1992, Liang et al., 2013)

- Glucose output by liver
  - Increased
    - (Lang et al., 1993, McGuinness et al., 1993, Ling et al., 1994)

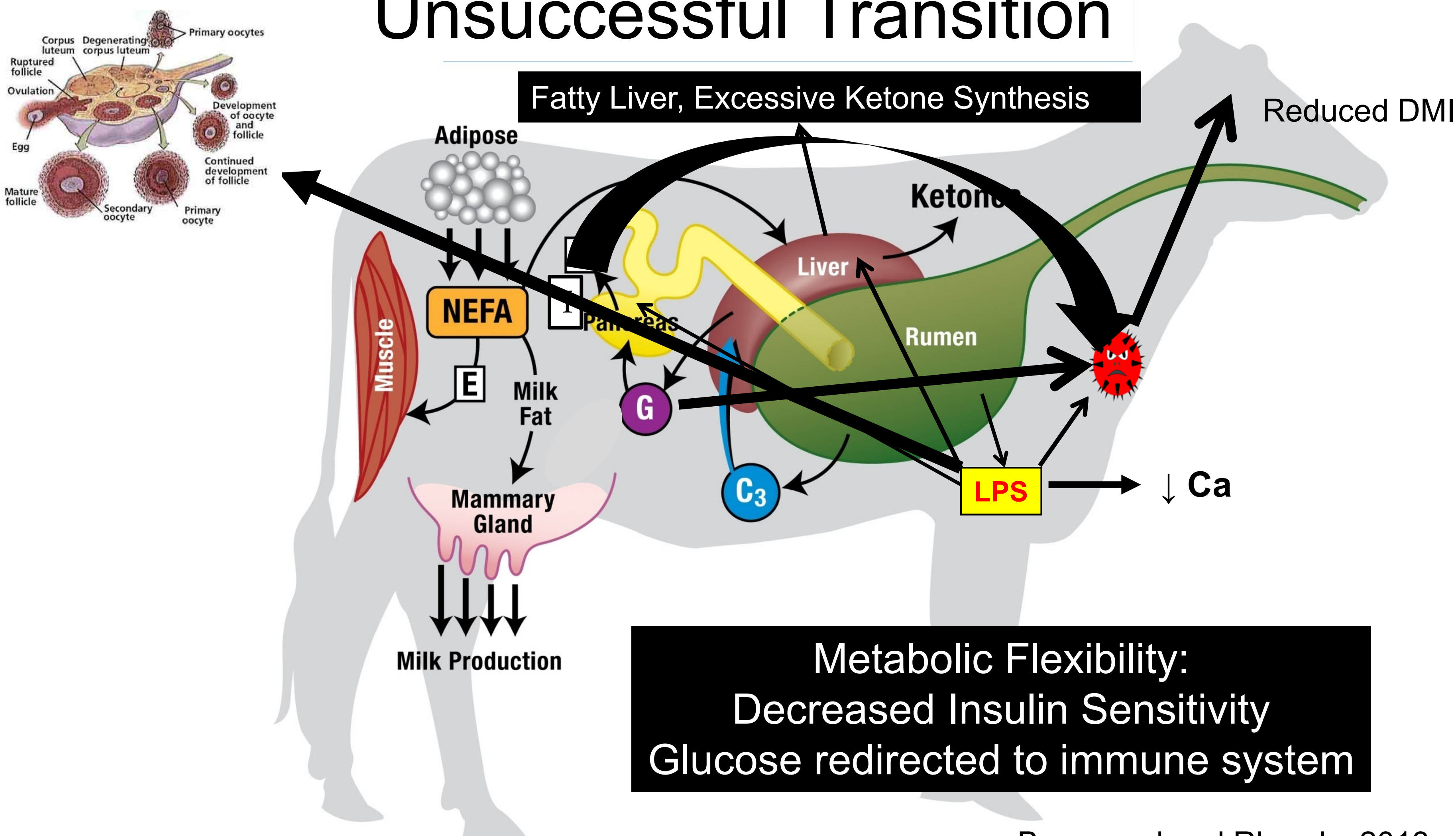
8.4 Mcal of energy!

Review: Coordination of Nutrient Partitioning




Ruminants
Bacteria
Feed
Propionate
Liver
Monogastrics
Glucose
Amino Acids
Insulin
STRESS
Lactose
Milk Yield
$$$$$$$$
Meat Synthesis
$$$$$$$$
Egg Production
$$$$$$$$
Immune Activation
Immune
system
Amino Acids
Gluconeogenesis
&
Acute Phase
Proteins

Unsuccessful Transition



Baumgard and Rhoads, 2013

Summary

- Periparturient glucose is gold
- Glucose is essential for milk synthesis AND the immune system
  - The immune system has a higher priority than the mammary gland
- Need to safely maximize rumen propionate and thus glucose production
- Insulin is the master metabolism regulator
  - Insulin resistance in the context of lactation is not pathological
  - Insulin resistance during Type II diabetes is pathological
- Preventing immune activation and the ensuing "pathogenic inflammation" is essential to maximizing milk yield

Acknowledgments

Funding Support

- USDA NRI/AFRI/NIFA
  - # 2005-35203-16041
  - # 2008-35206-18817
  - # 2010-65206-20644
  - # 2011-67003-30007
  - # 2014-67015-21627
  - # 2015- 10843
  - # 2017- 05931
  - # 2017- 10843
  - # 2019- 07859
  - # 2020- 02716
  - # 2021- 09507

United States Department of Agriculture

National Institute of Food and Agriculture

•Industry Partners

- ADM
- ASCUS
- Biomin
- Diamond V
- Elanco
- Idemitzu
- Micronutrients
- Novus
- Phileo Lesaffre
- TechMix
- Zinpro Inc.

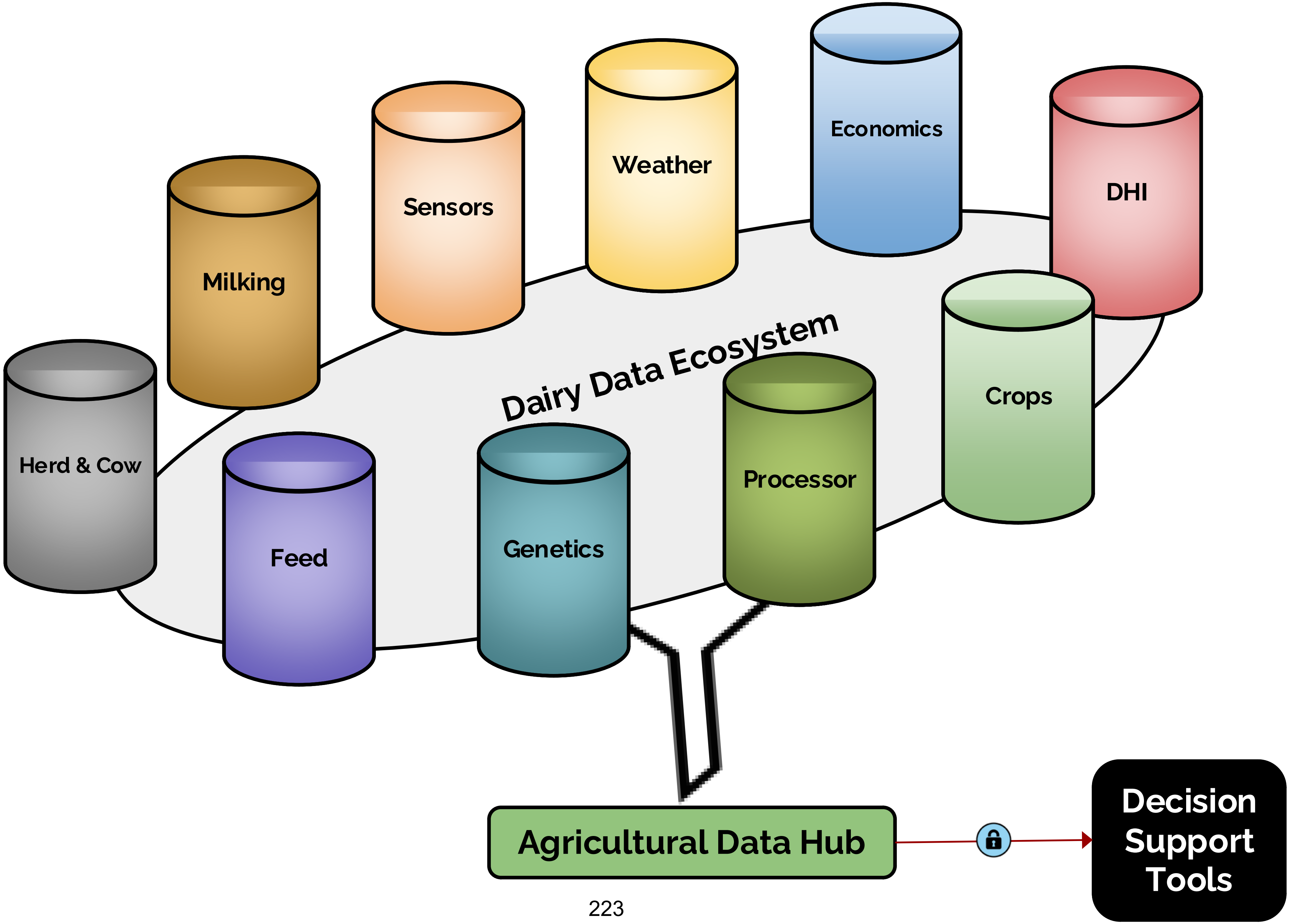
Alltech
BASF
Cargill
DPI Global
Grain States Soya
Kemin Inc.
Microaid
NutriQuest
Sherring Plough
United Animal Health
Zoetis

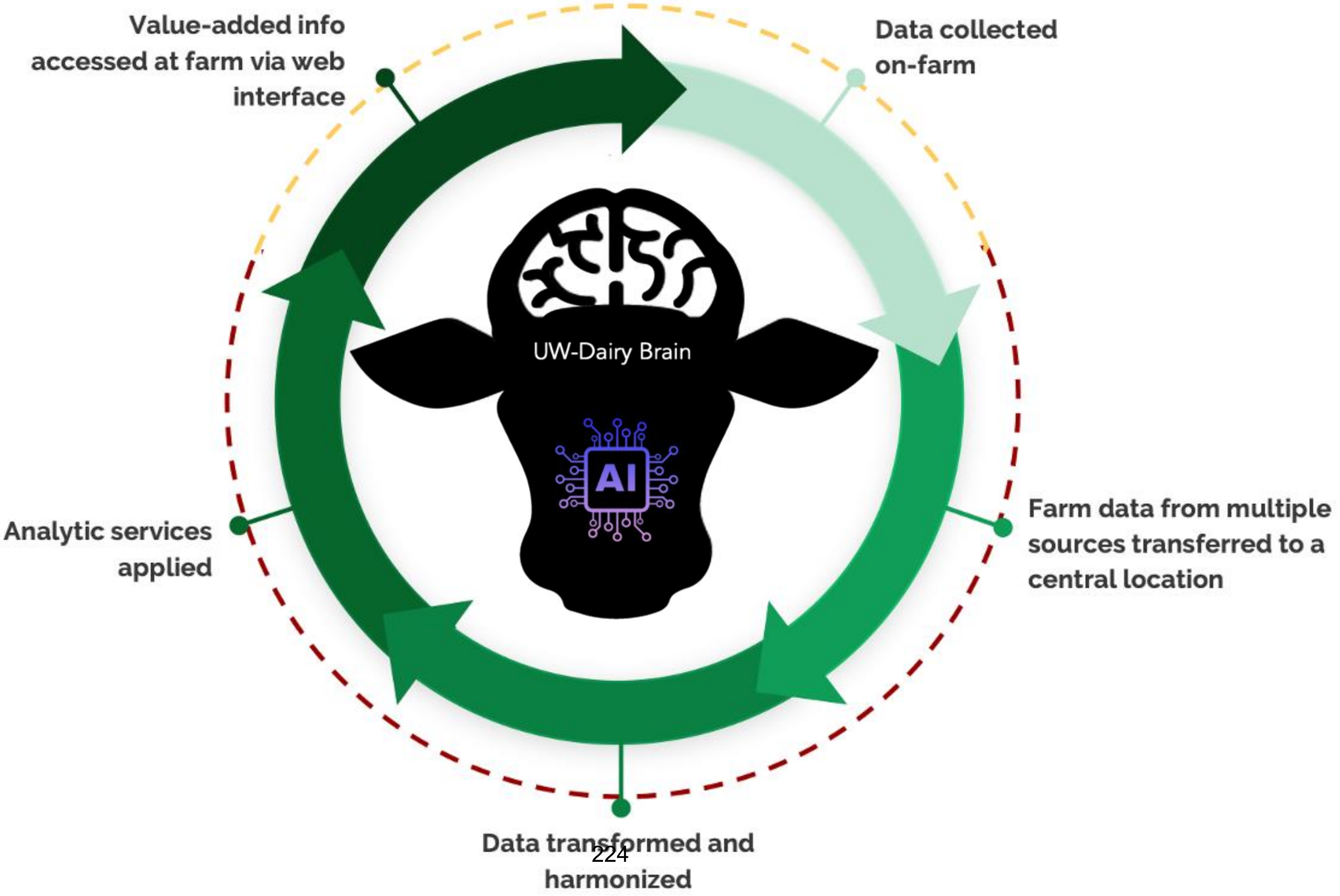

TRADITION OF
EXCELLENCE
IOWA STATE UNIVERSITY
COLLEGE OF AGRICULTURE & LIFE SCIENCES

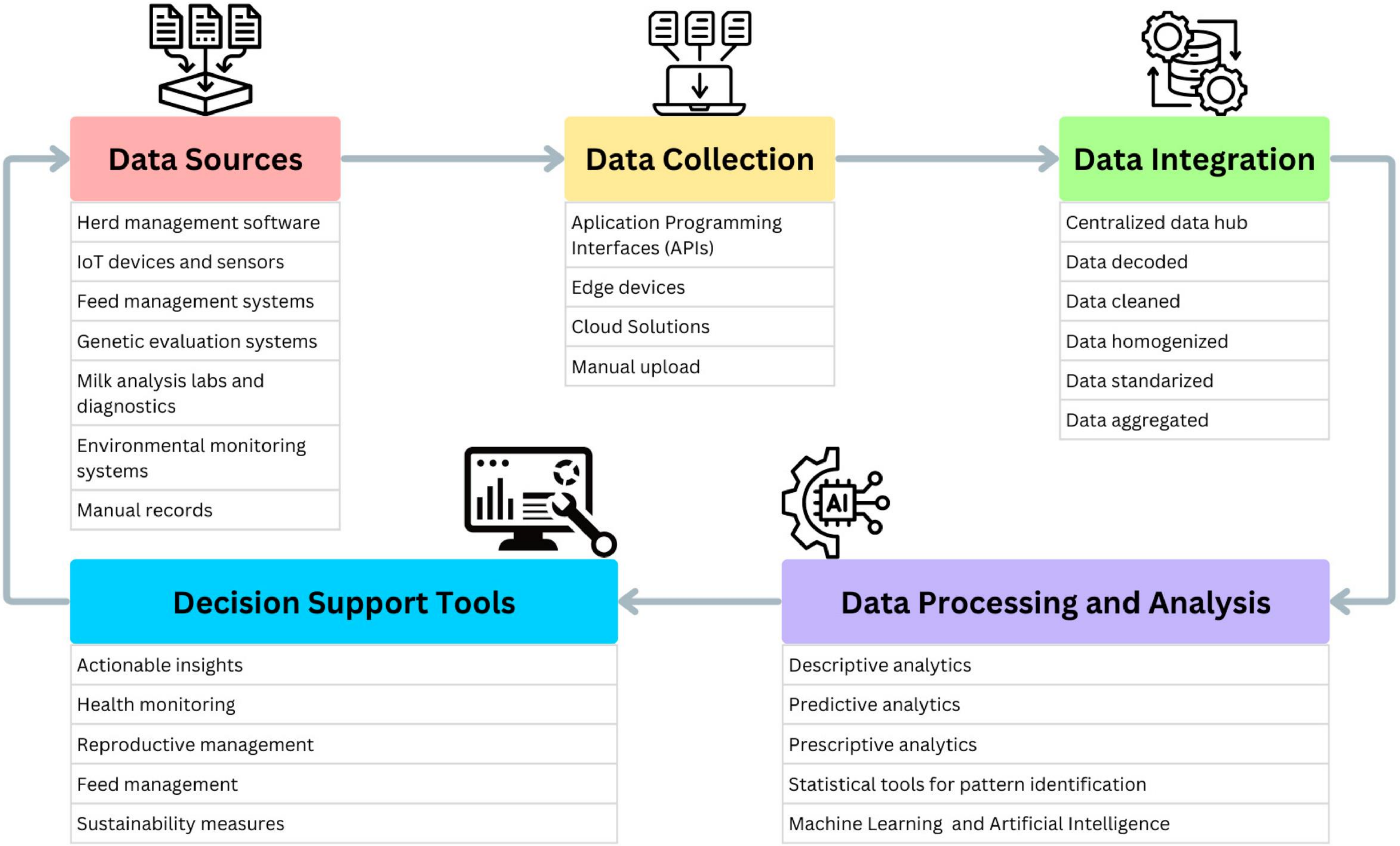
The Dairy Brain

A New Intelligence for Dairy Farming

Victor E. Cabrera

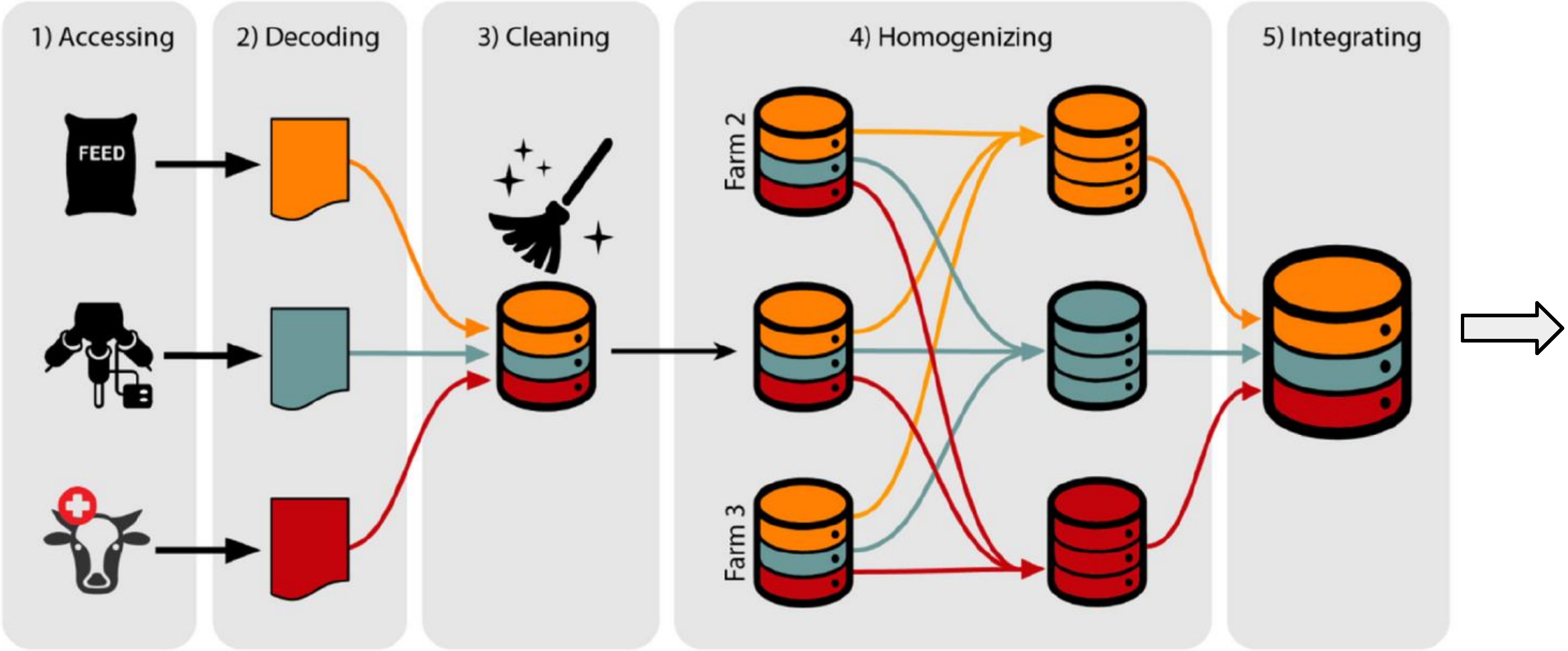

Milking
Sensors
Weather
Economics
DHI
Herd & Cow
Dairy Data Ecosystem
Crops
Feed
Genetics
Processor
Agricultural Data Hub
Decision Support Tools


Value-added info accessed at farm via web interface
Data collected on-farm
UW-Dairy Brain
AI
Farm data from multiple sources transferred to a central location
Analytic services applied
Data transformed and harmonized



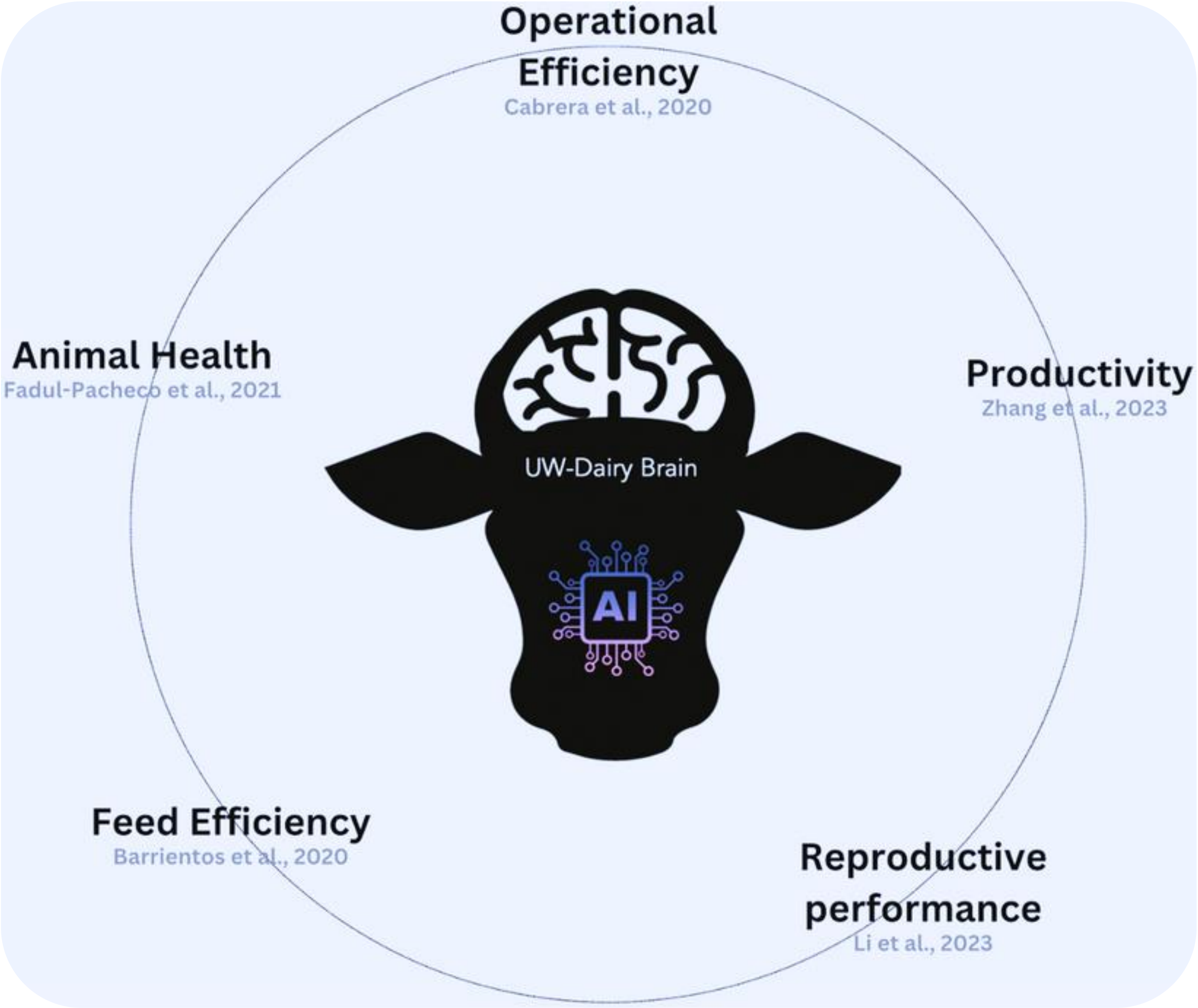
Cabrera et al., 2025

Data Integration

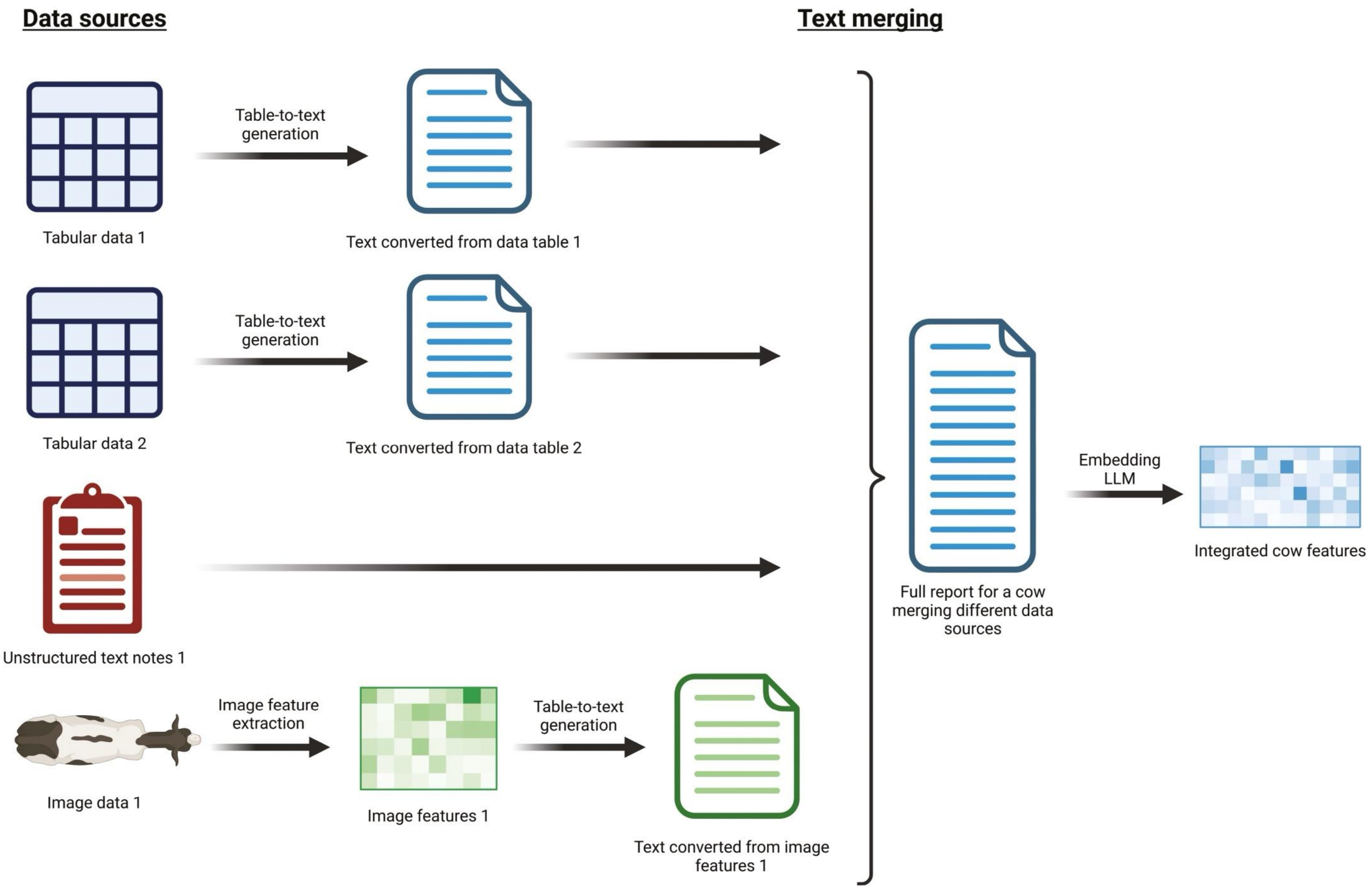


Wangen et al., 2021

Prescriptive Analytics

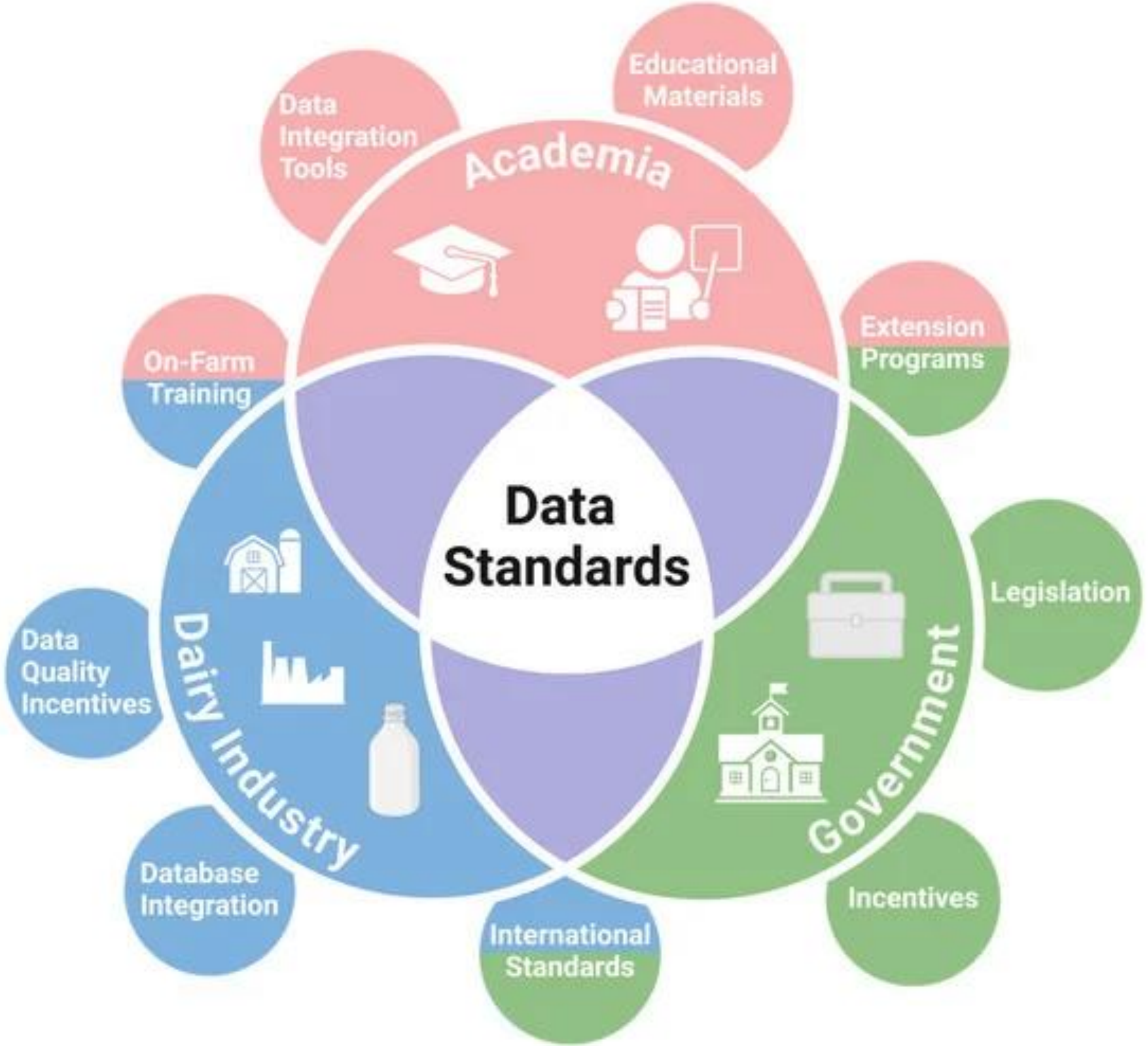


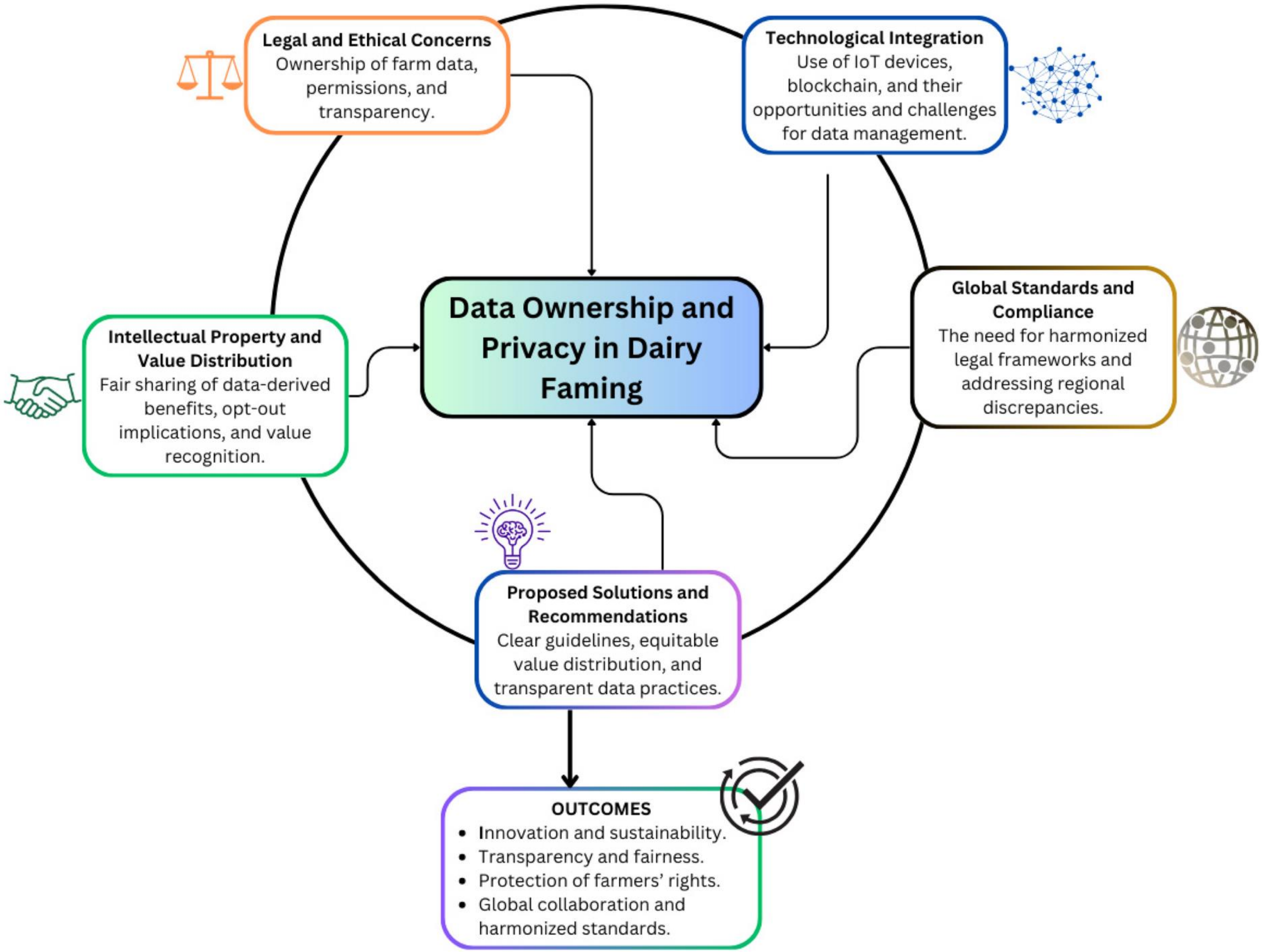
Cabrera 2025



Menezes et al., 2025

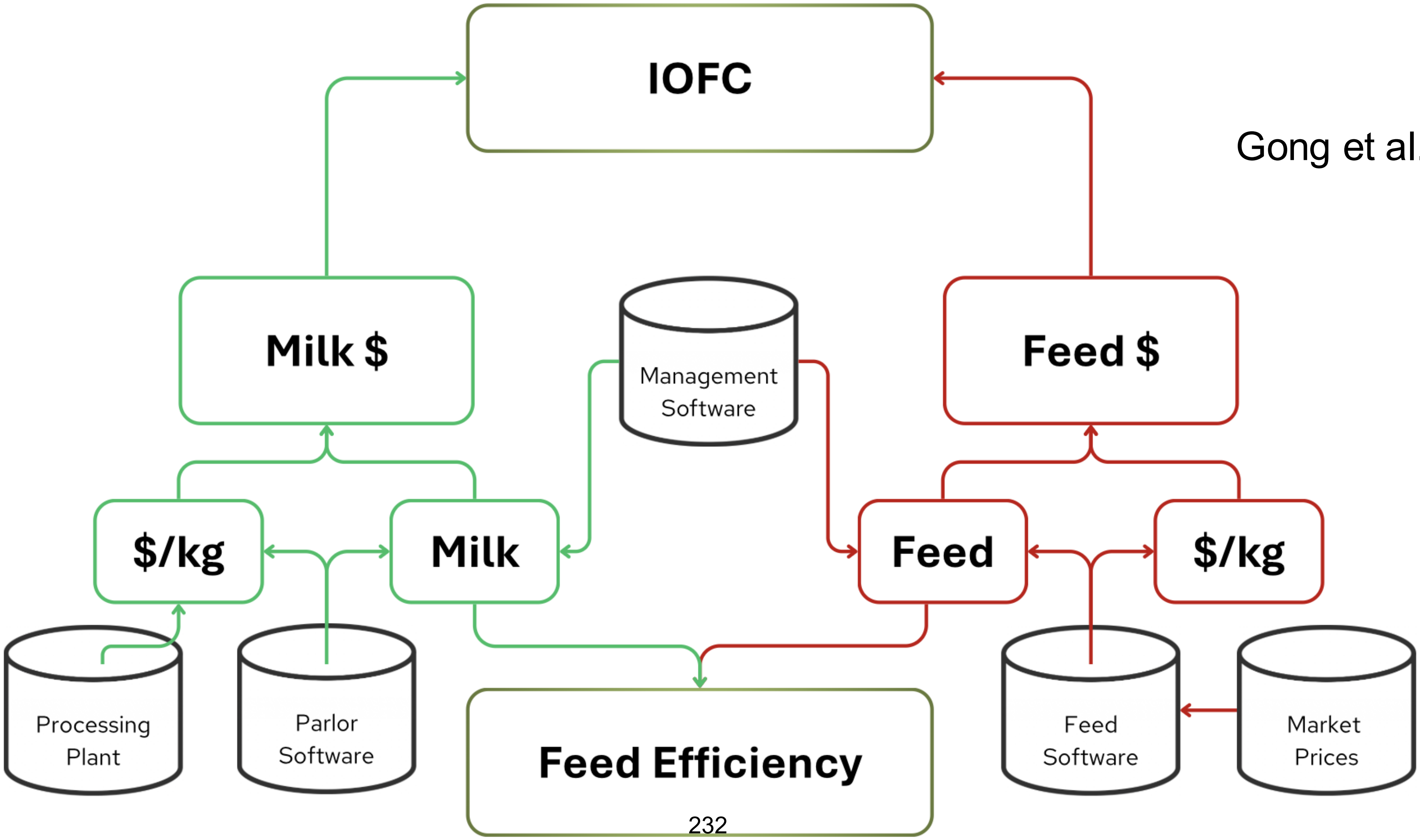
Baldin et al., 2025


Data Standards
Academia
Dairy Industry
Government
Data Integration Tools
Educational Materials
Extension Programs
Legislation
Incentives
International Standards
Database Integration
Data Quality Incentives
On-Farm Training

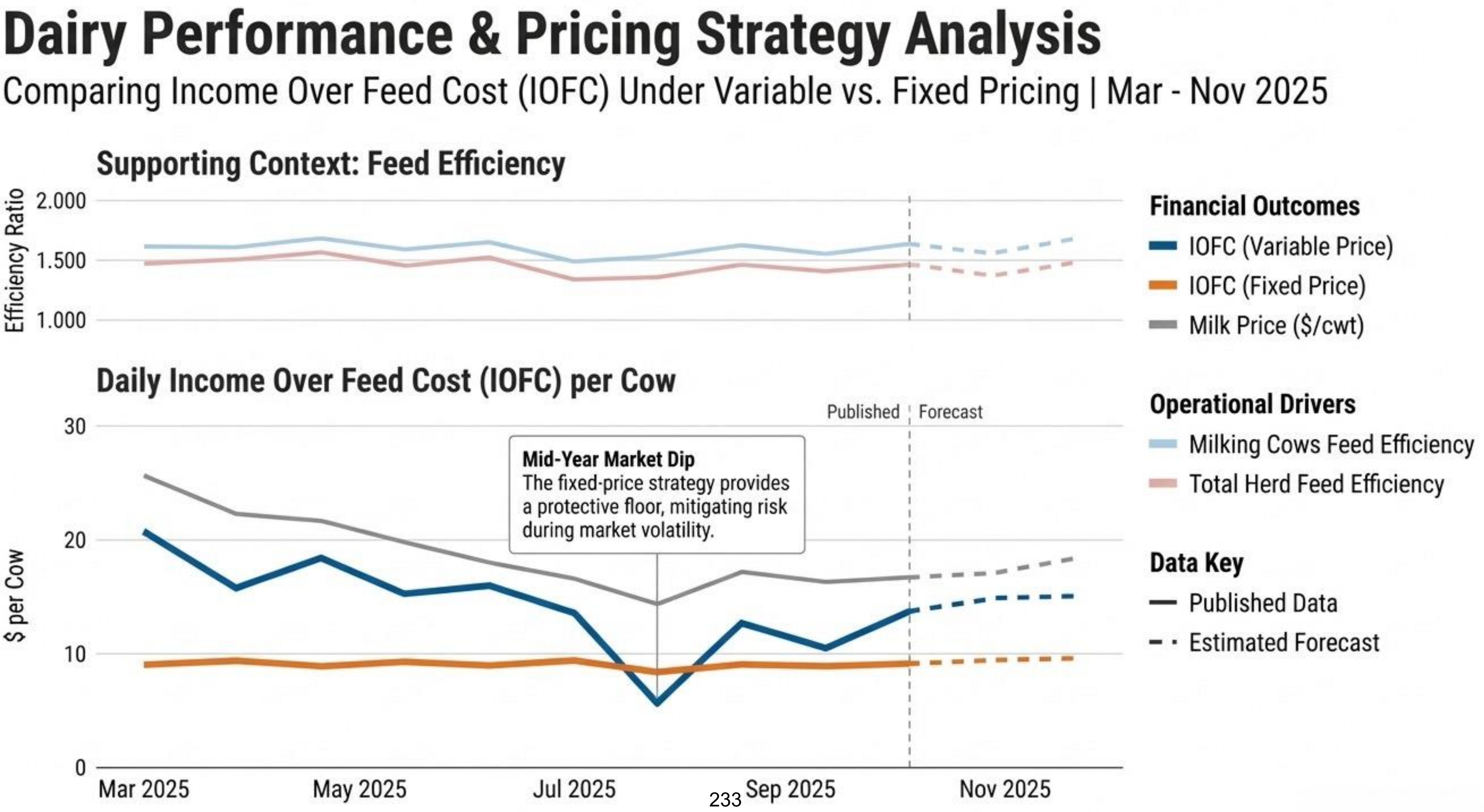


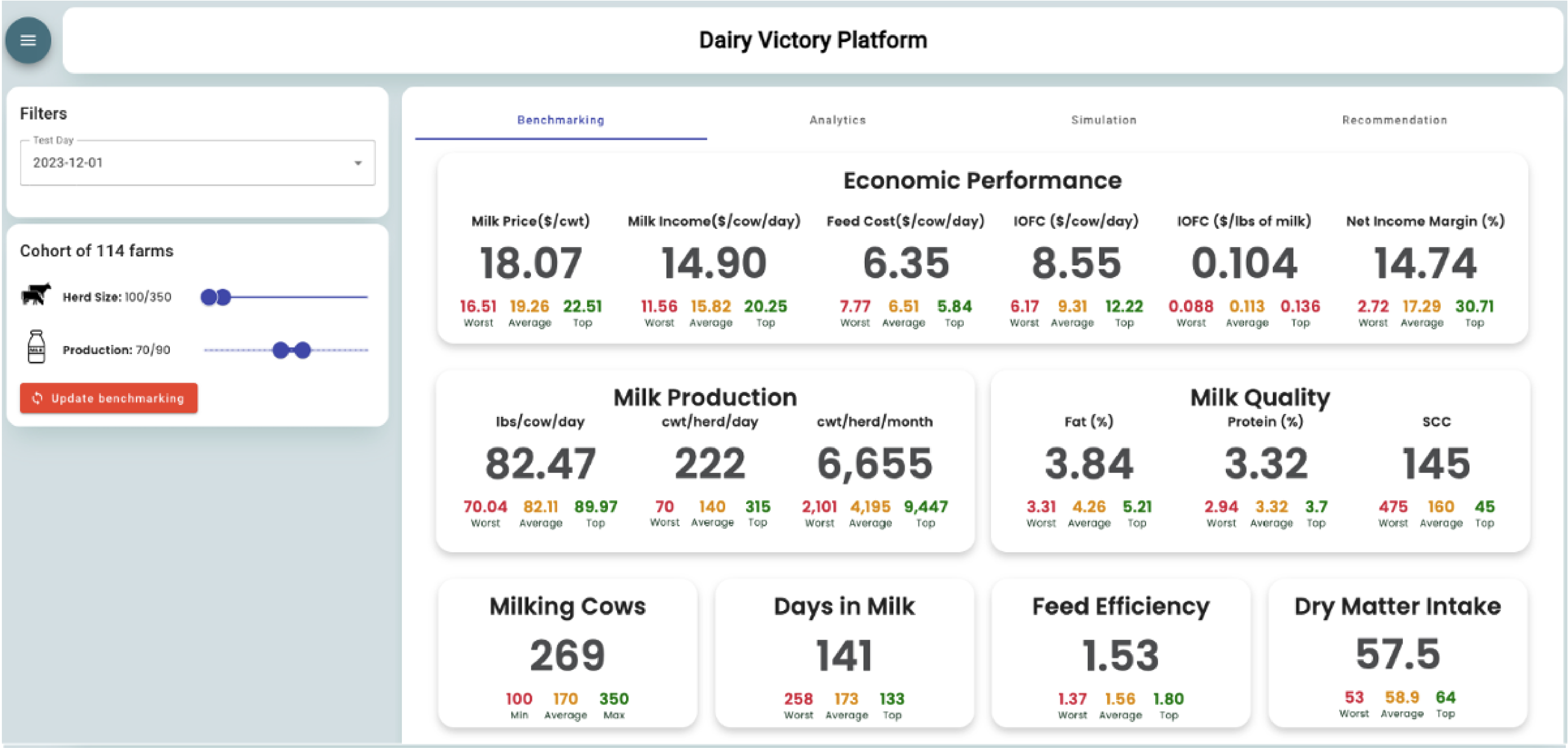
Barton et al., 2025

Monitoring Critical KPIs

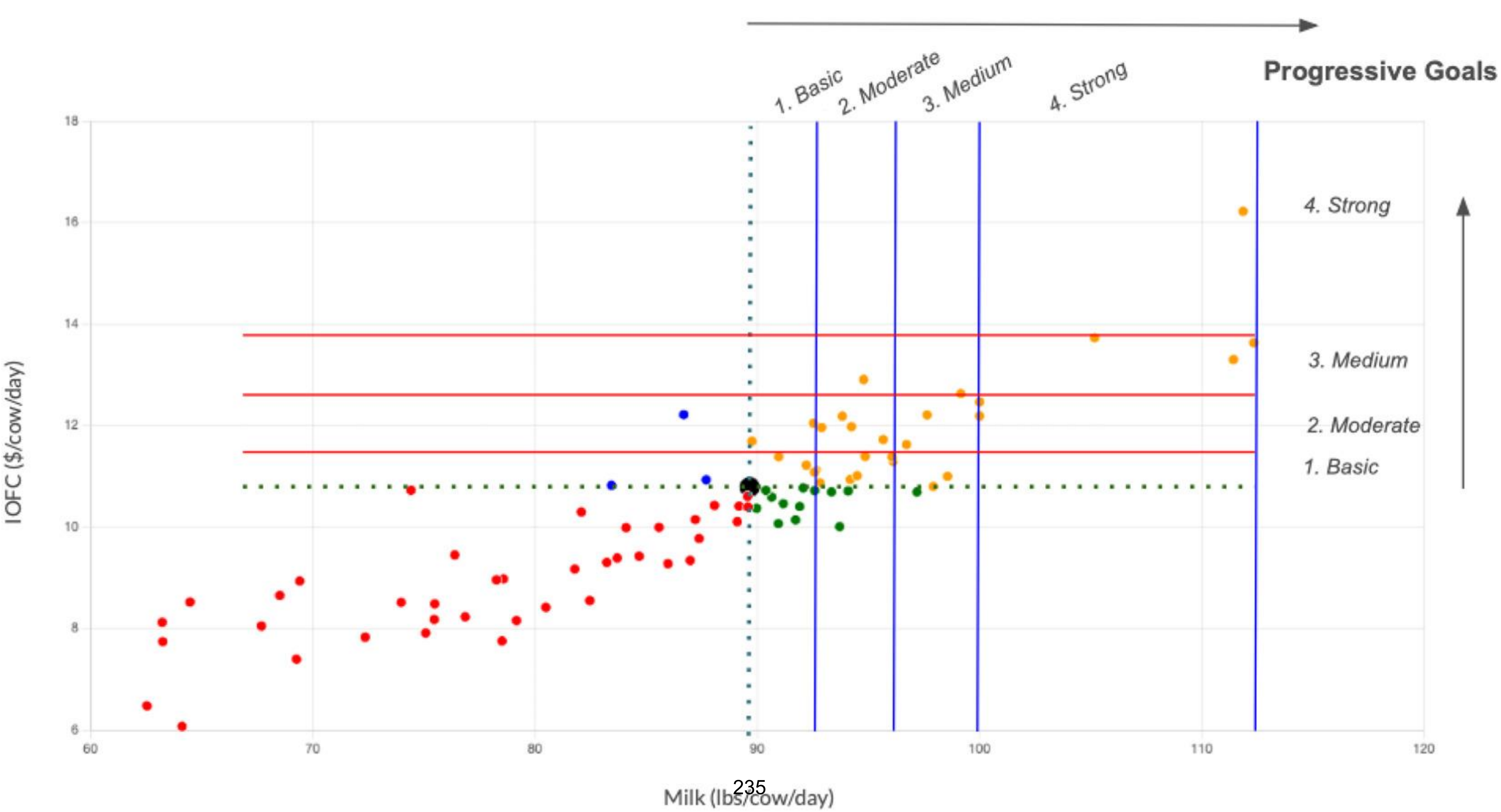


Gong et al., 2023

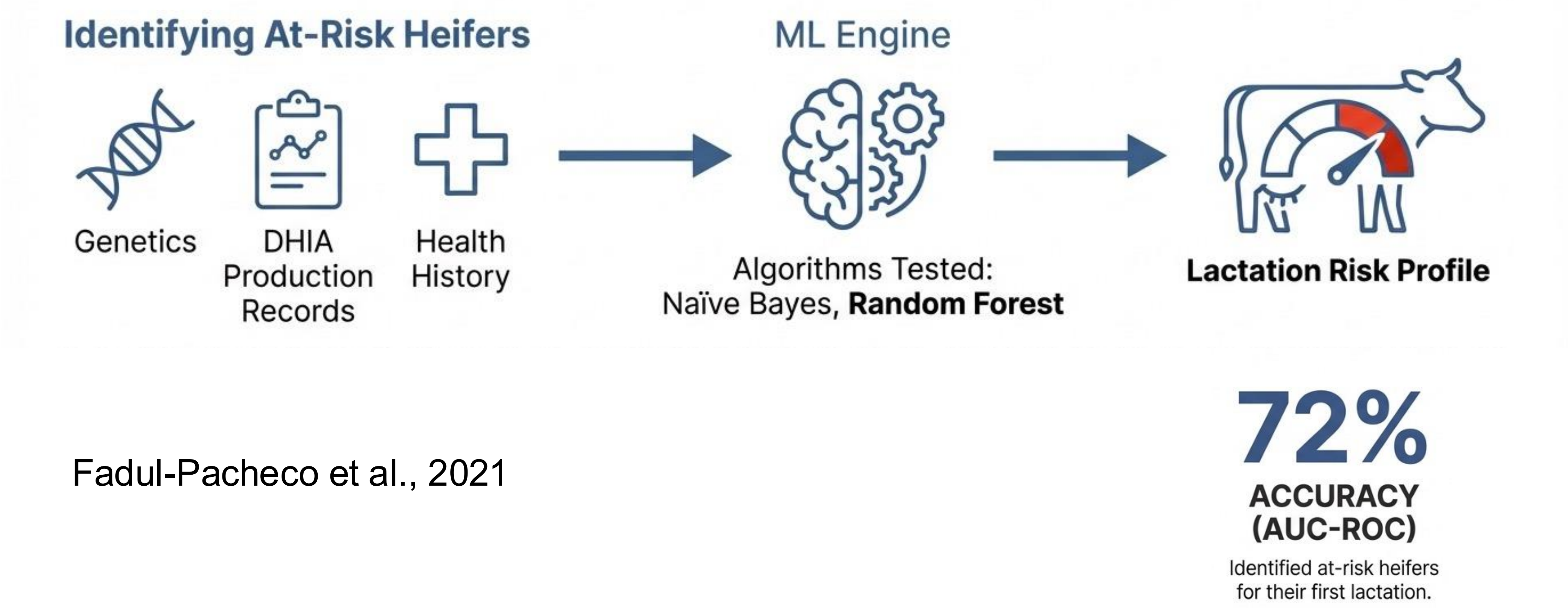

Dairy Performance & Pricing Strategy Analysis
Comparing Income Over Feed Cost (IOFC) Under Variable vs. Fixed Pricing | Mar - Nov 2025
Supporting Context: Feed Efficiency
Efficiency Ratio
2.000
1.500
1.000
Daily Income Over Feed Cost (IOFC) per Cow
$ per Cow
30
20
10
0
Published
Forecast
Mid-Year Market Dip
The fixed-price strategy provides a protective floor, mitigating risk during market volatility.
Mar 2025
May 2025
Jul 2025
Sep 2025
Nov 2025
Financial Outcomes
IOFC (Variable Price)
IOFC (Fixed Price)
Milk Price ($/cwt)
Operational Drivers
Milking Cows Feed Efficiency
Total Herd Feed Efficiency
Data Key
Published Data
Estimated Forecast



Freitas and Cabrera, 2025

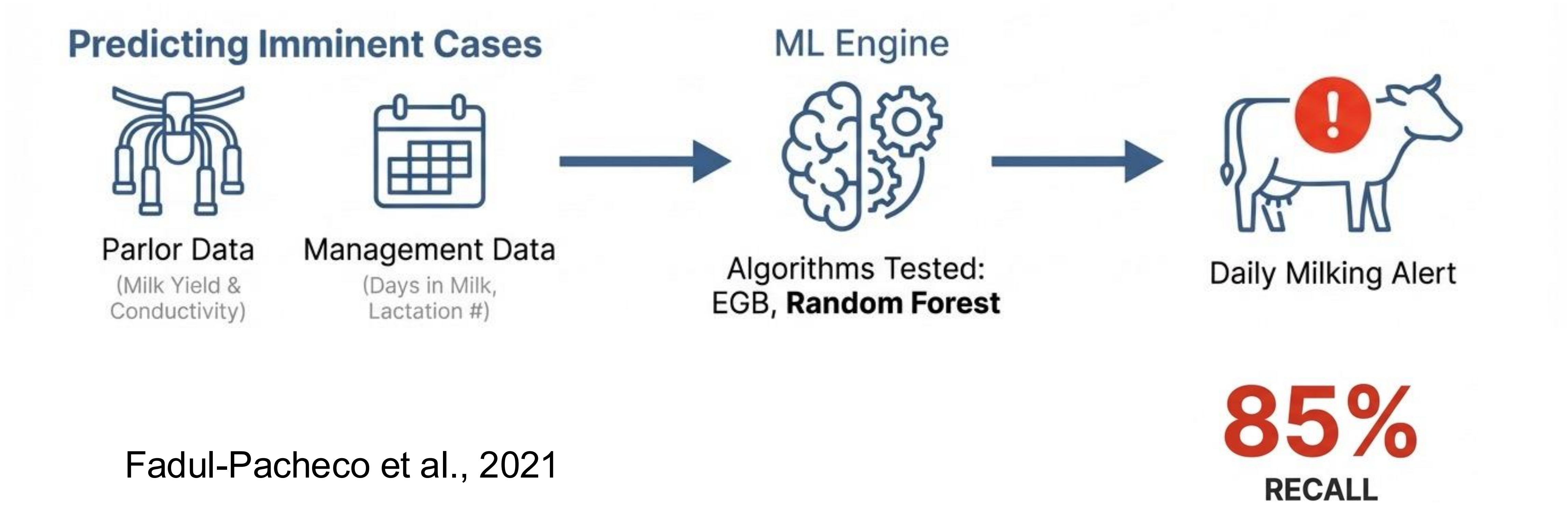

Progressive Goals
1. Basic
2. Moderate
3. Medium
4. Strong
4. Strong
3. Medium
2. Moderate
1. Basic
IOFC ($/cow/day)
18
16
14
12
10
8
6
60
70
80
90
100
110
120
Milk (lbs/cow/day)

Forecasting Mastitis Risk



Fadul-Pacheco et al., 2021

Having Early-Warnings of Mastitis

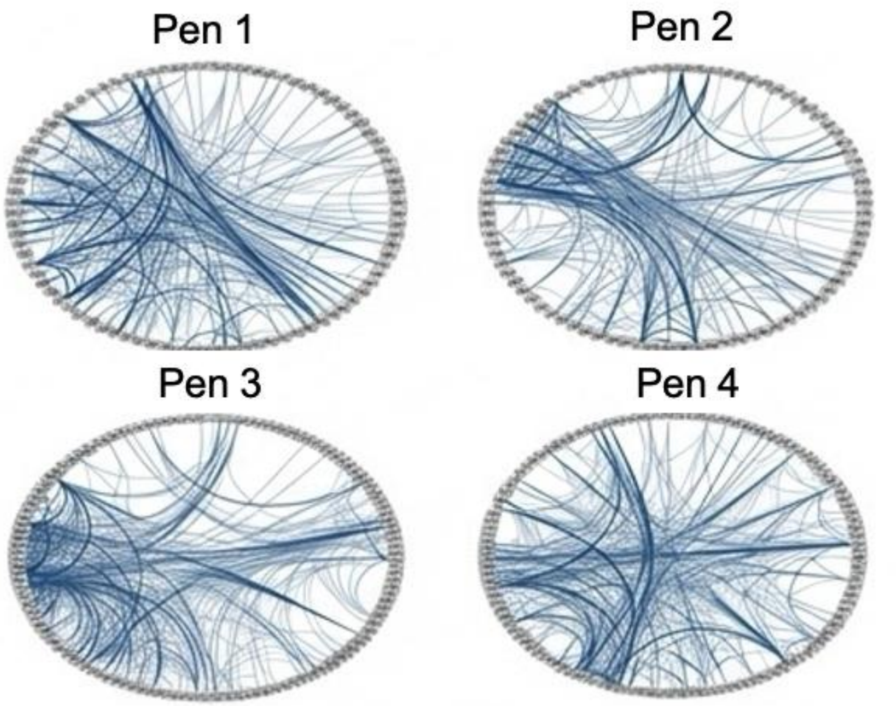


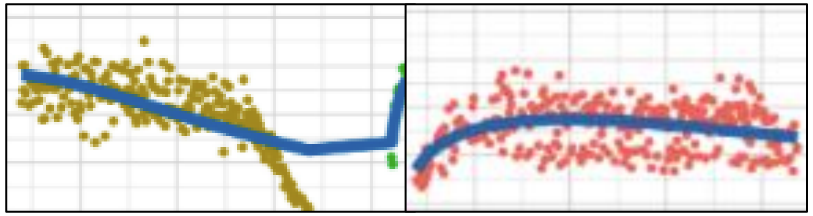
Fadul-Pacheco et al., 2021

Assessing Impact of Cows' Affinity

Data Capture

Network Analysis



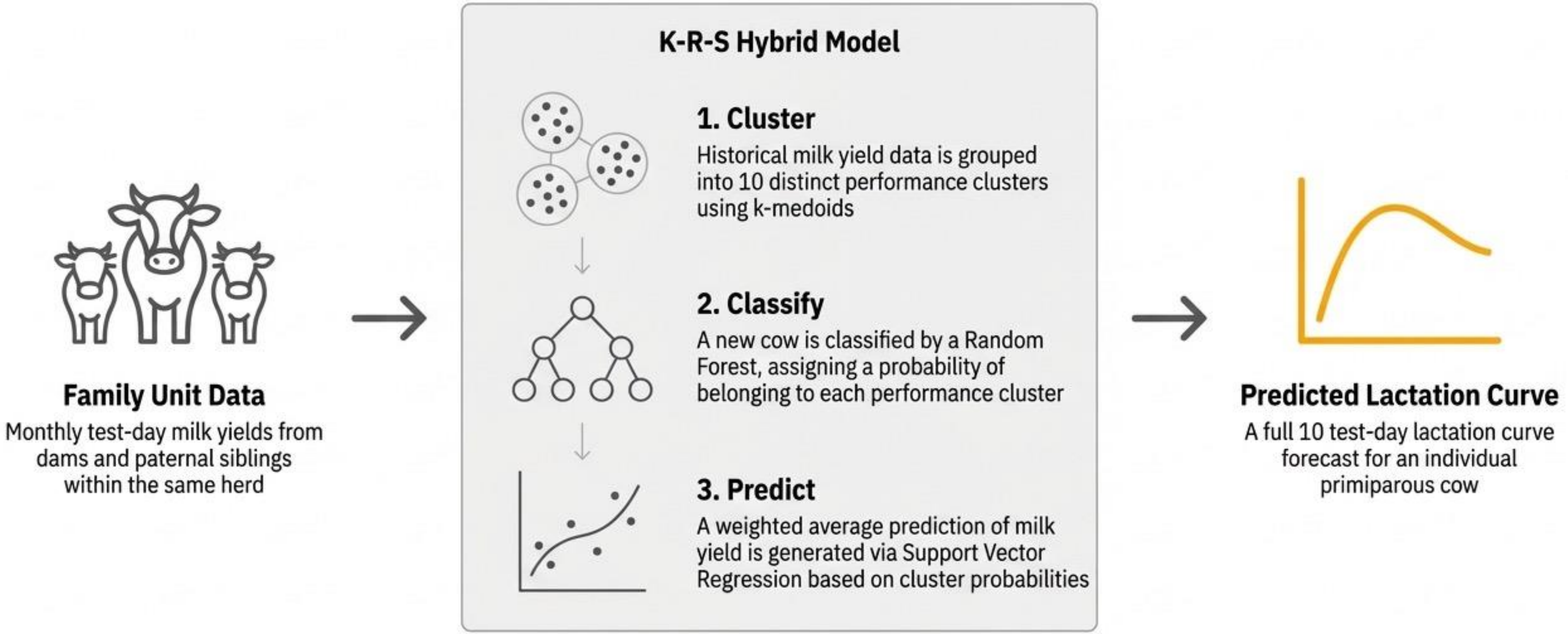


Fadul-Pacheco et al., 2022

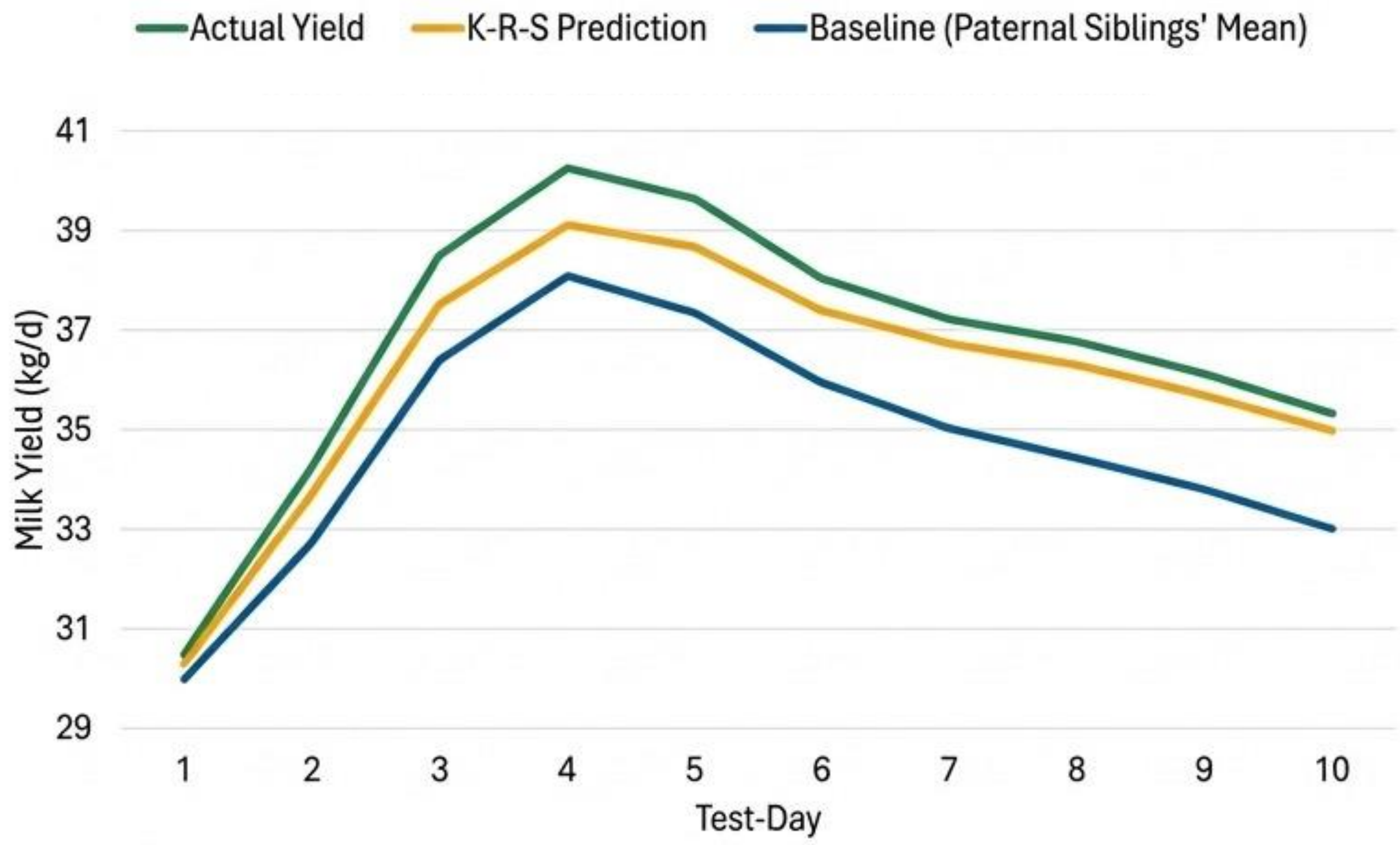
PRODUCTION VARIABILITY

3.3x HIGHER

Predicting Entire Lactation Curves



Zhang et al., 2022



-24.2%

Lower Prediction Error

Reduction in Mean Absolute Error (MAE) compared to the baseline prediction.

4.25x

Stronger Correlation

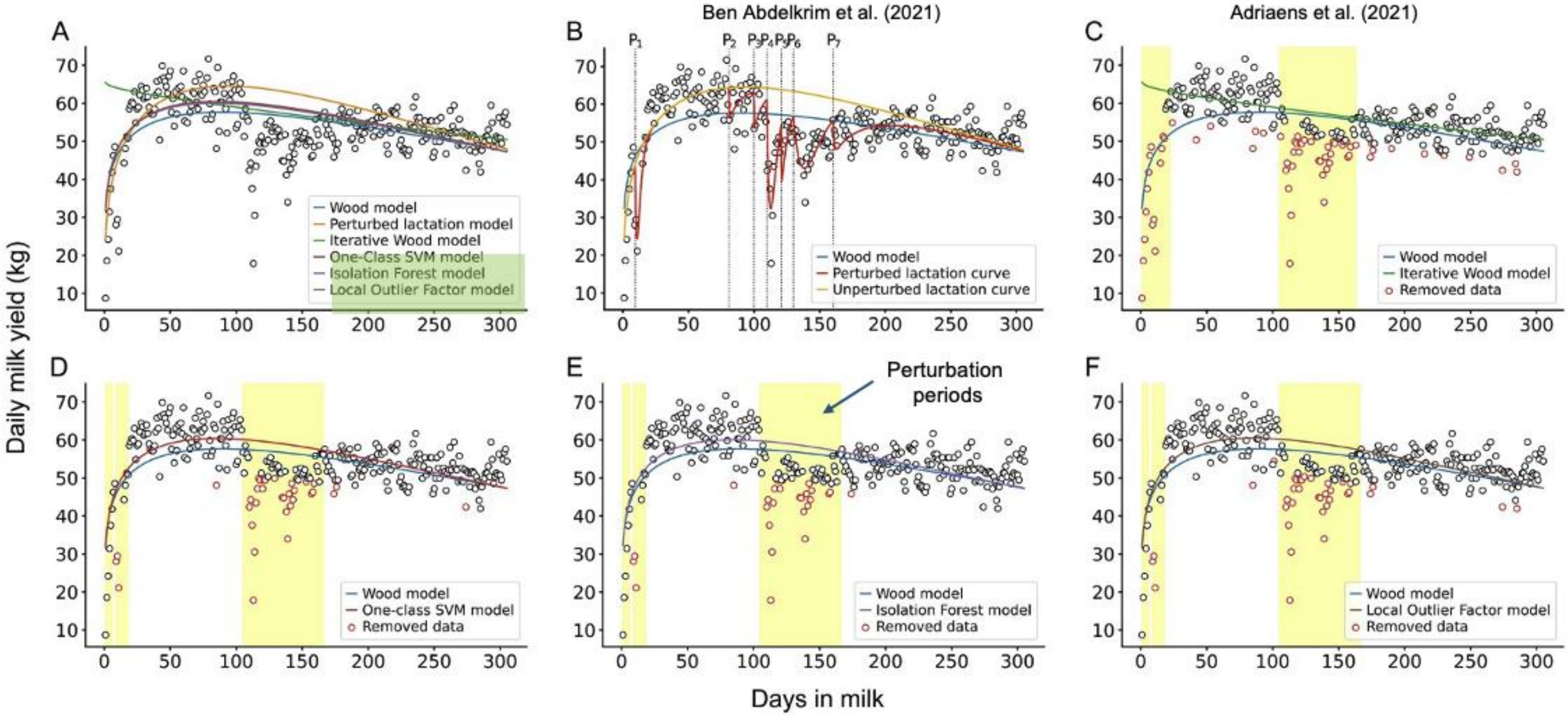
Correlation with actual yield (r = 0.34) versus the baseline (r = 0.08).

74.2%

More Frequently Correct

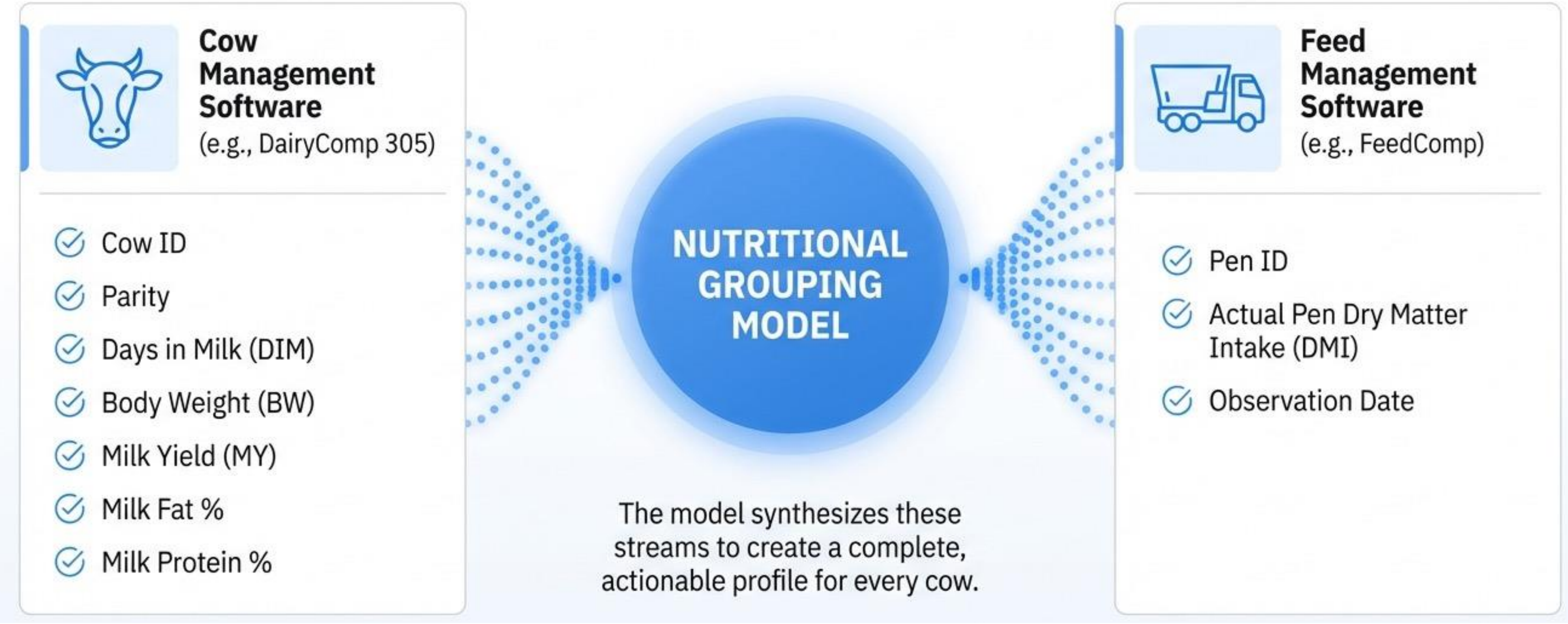
Percentage of cows for which the K-R-S prediction was closer to the actual yield than the baseline.

Finding perturbations in lactation curves

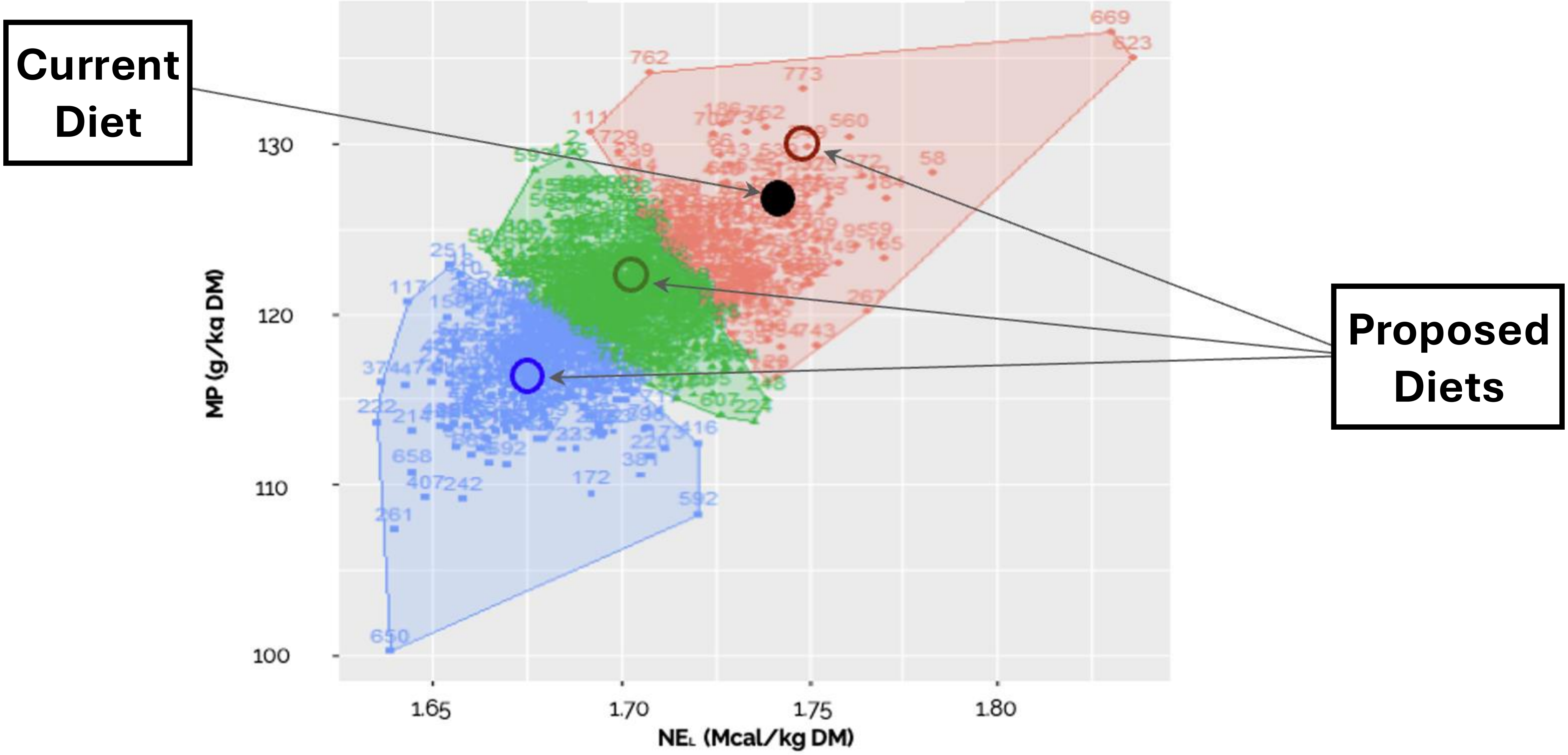


Higaki et al., 2025

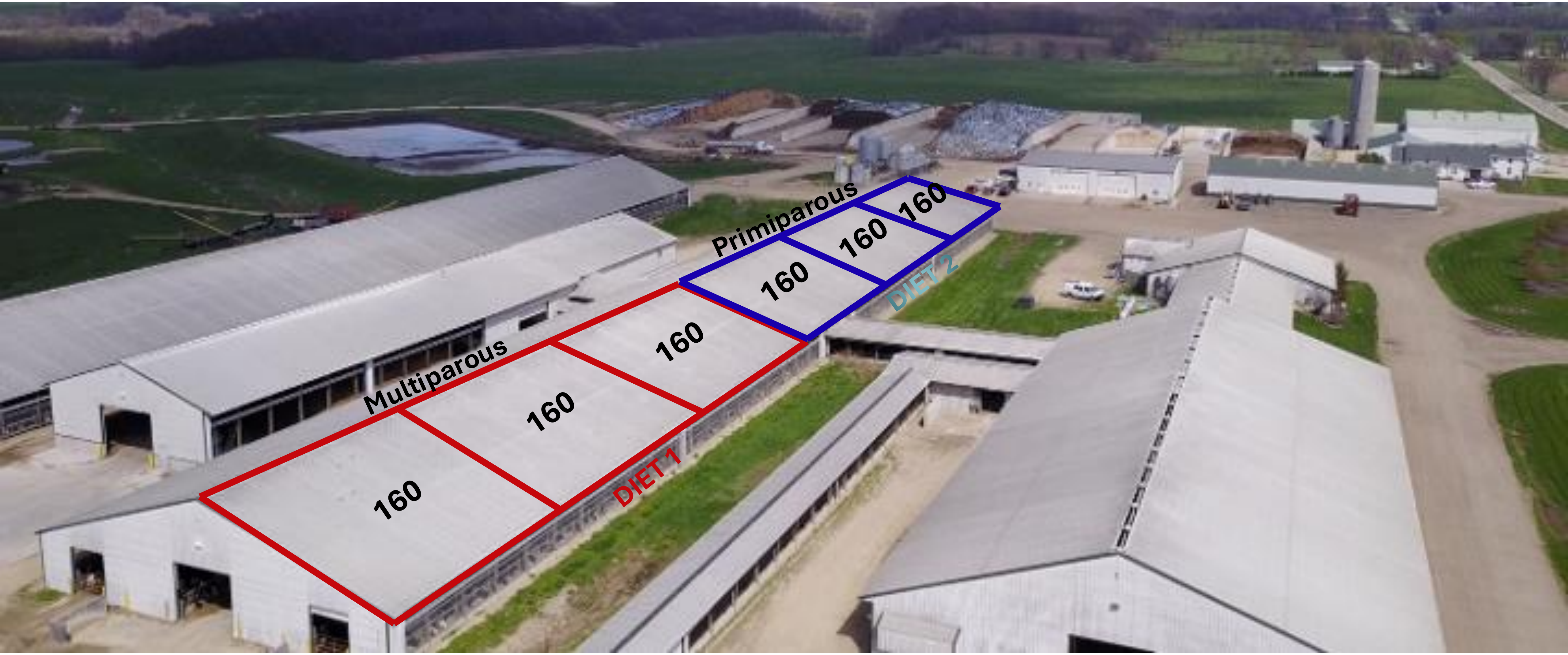
Improving Nutritional Accuracy



Barrientos et al., 2020



Current Diet
Proposed Diets
MP (g/kg DM)
NEL (Mcal/kg DM)
130
120
110
100
1.65
1.70
1.75
1.80


Primiparous
160
160
160
DIET 2
Multiparous
160
160
160
DIET 1

Precision in Practice: Reallocating Nutrients for Peak Lactation Cows

FARM GROUPING (FG): ONE-SIZE-FITS-ALL

One Diet for All Peak Cows

This method overfeeds lower producers and underfeeds higher producers within the same group.

NUTRITIONAL GROUPING (NG): THREE TAILORED DIETS

>$200/cow per yr

LOW Producers

-$0.60 / day Diet Cost Change

-89 g / day Nitrogen Change

A less expensive, lower-protein diet that meets their actual needs.

MEDIUM Producers

-$0.22 / day Diet Cost Change

-38 g / day Nitrogen Change

A slightly modified diet for significant savings.

HIGH Producers

+$0.25 / day Diet Cost Change

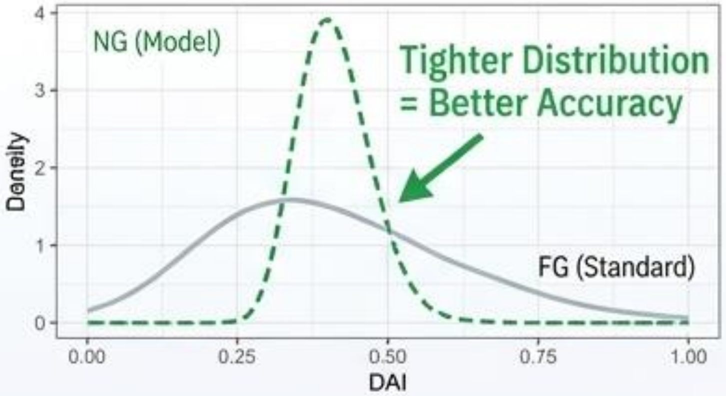
+36 g / day Nitrogen Change

A richer diet to support higher milk yield and prevent underfeeding.

Key Outcomes: Improved Accuracy, Economy, and Environmental Impact

The Nutritional Grouping (NG) model delivered significant, measurable benefits compared to the standard Farm Grouping (FG) strategy.

DIET ACCURACY



Lower Diet Accuracy Index (DAI)

Diets more closely matched individual cow requirements, reducing the nutrient gap between what is offered and what is needed.

ECONOMIC BENEFIT

$31

Savings

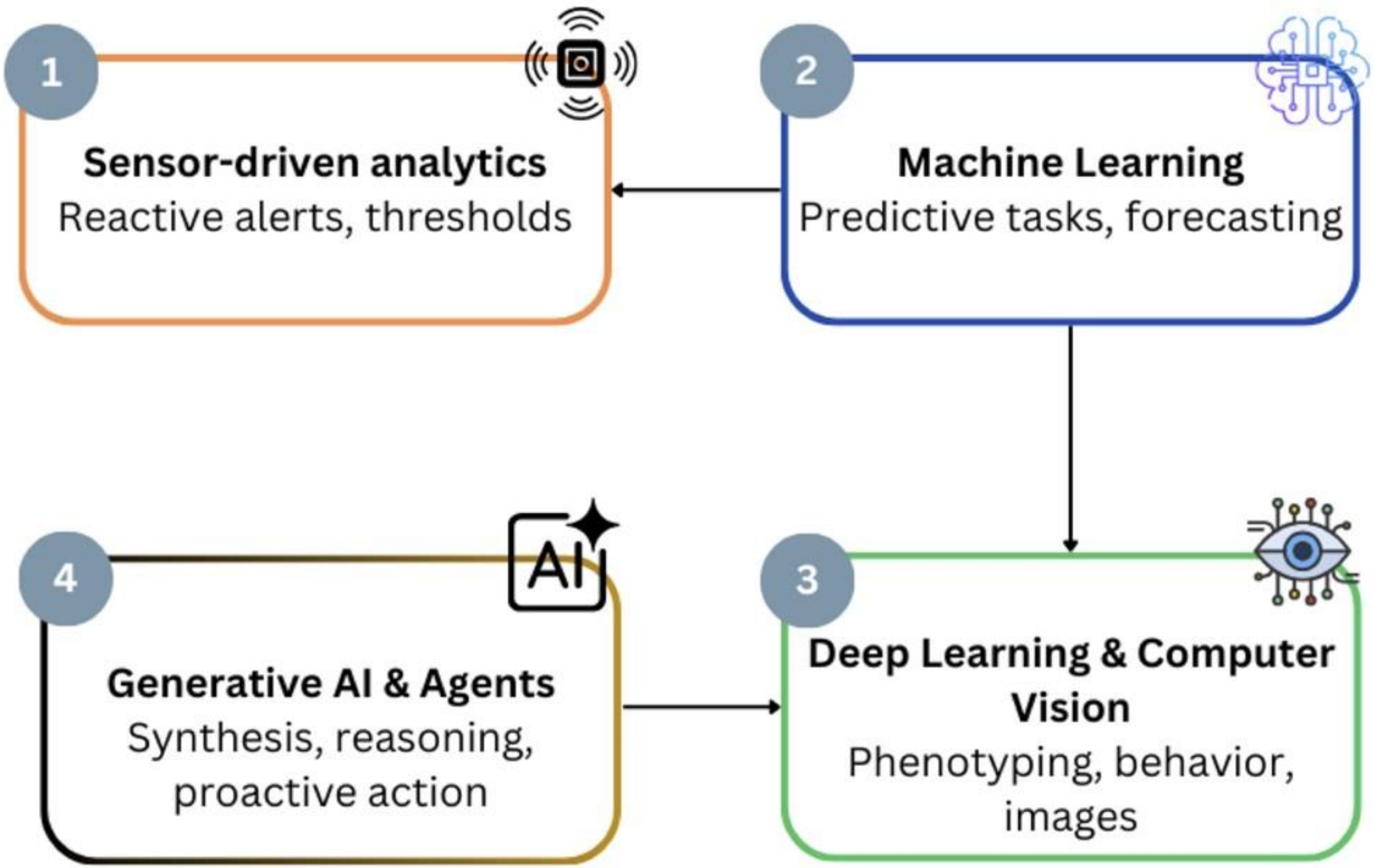
Per cow, per year in theoretical diet costs. ($3,219 for NG vs. $3,250 for FG). This excludes potential gains from increased milk yield.

ENVIRONMENTAL BENEFIT

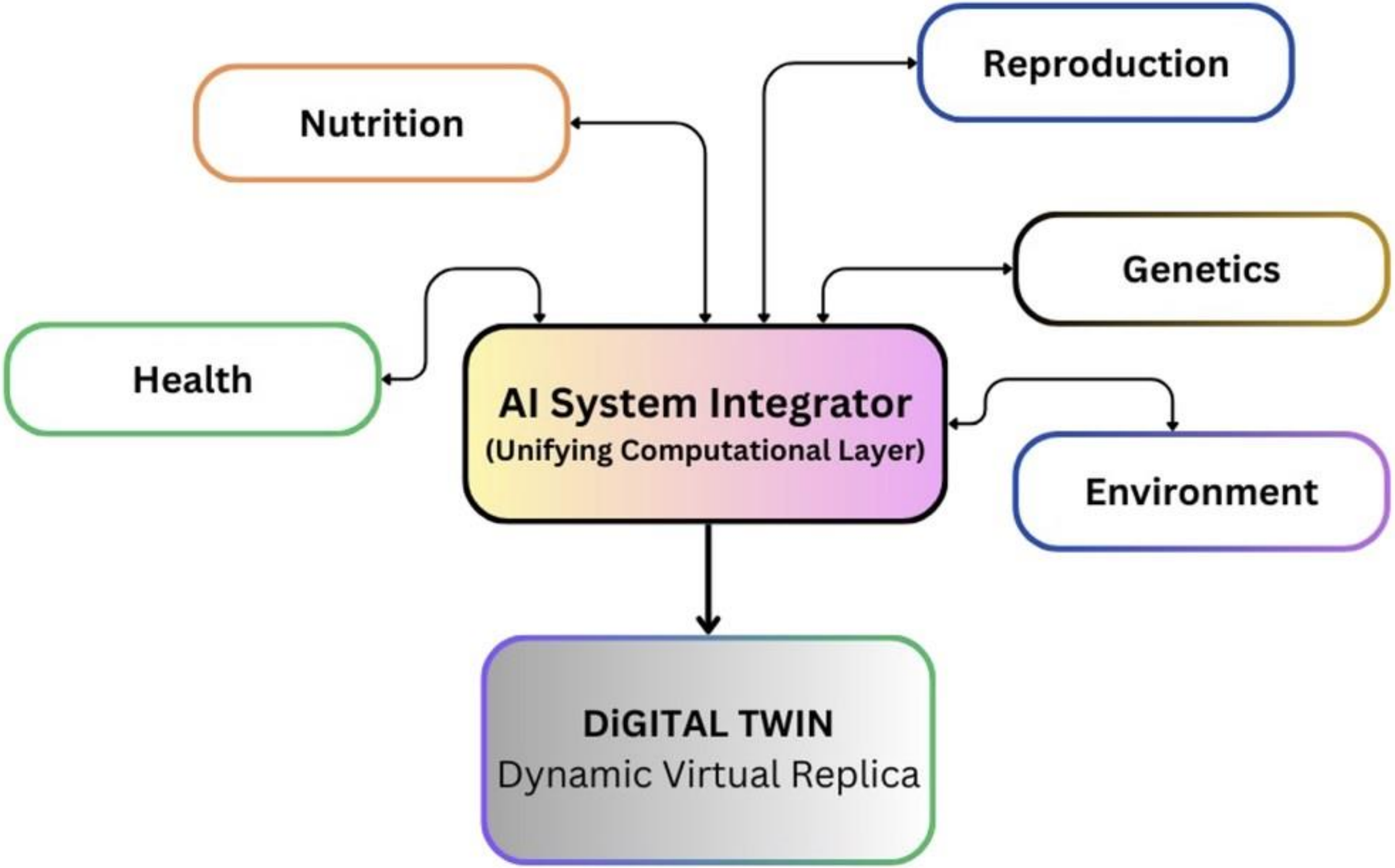
-15.14 g/day

Nitrogen Reduction

Reduction in predicted Nitrogen supply per cow. This totals over 13 tons of N annually for the 2,374-cow herd.

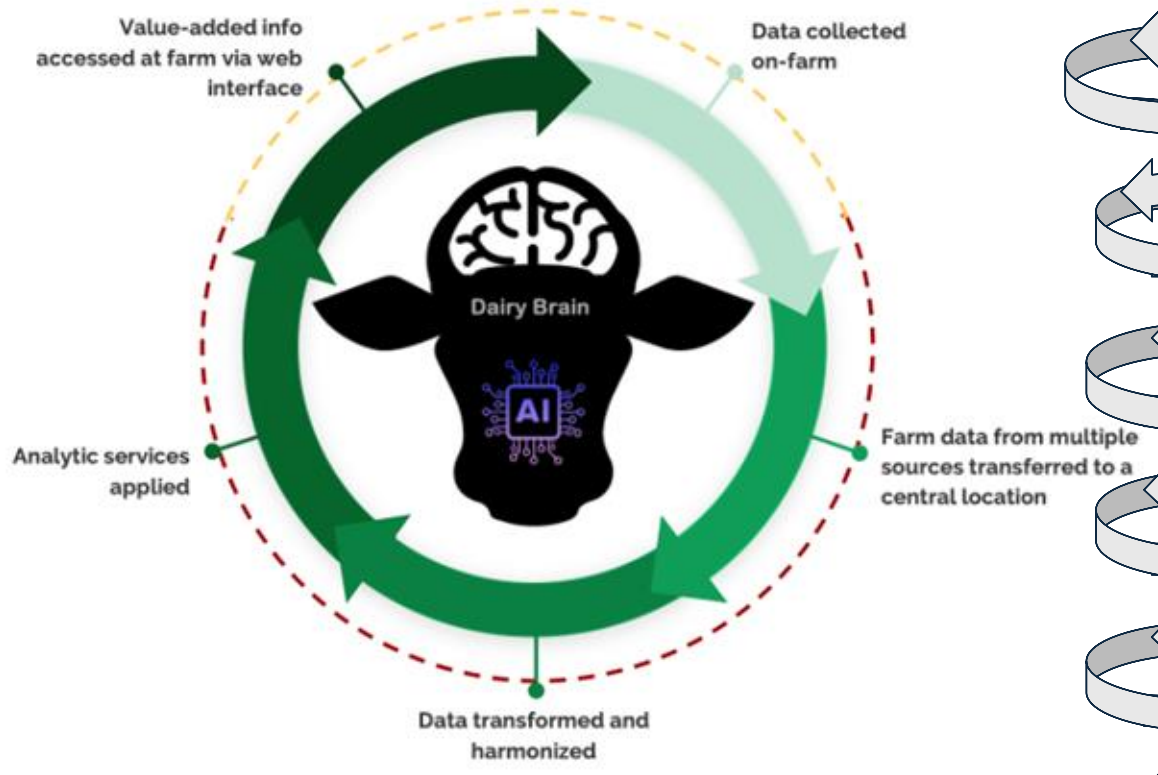


Niu et al., 2025

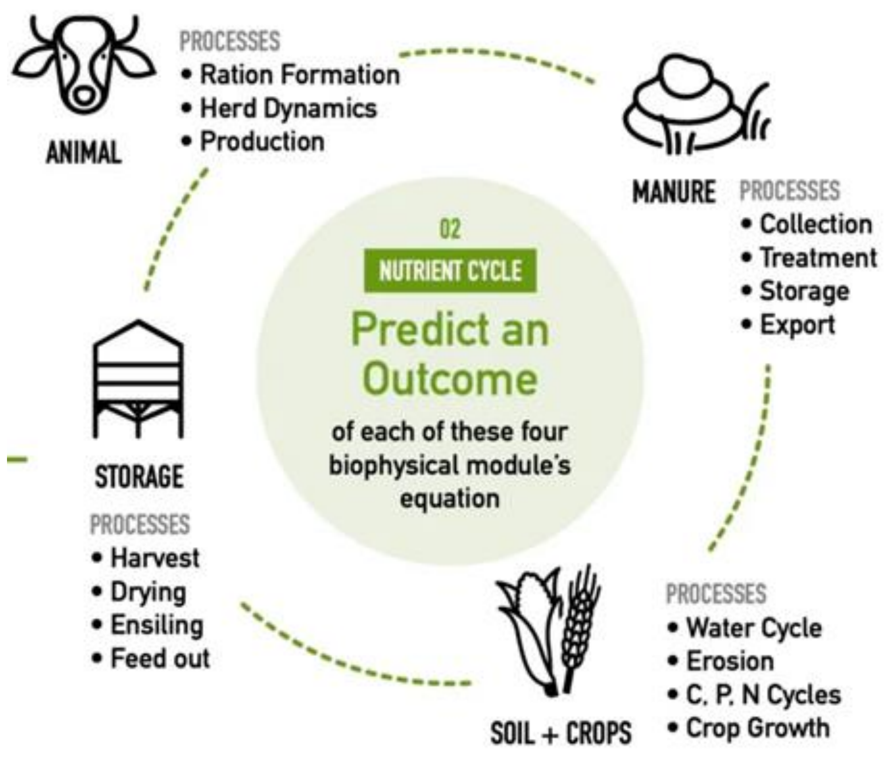

Reproduction
Nutrition
Genetics
Health
AI System Integrator
(Unifying Computational Layer)
Environment
DiGITAL TWIN
Dynamic Virtual Replica

Creating a Digital Twin

Dairy Brain



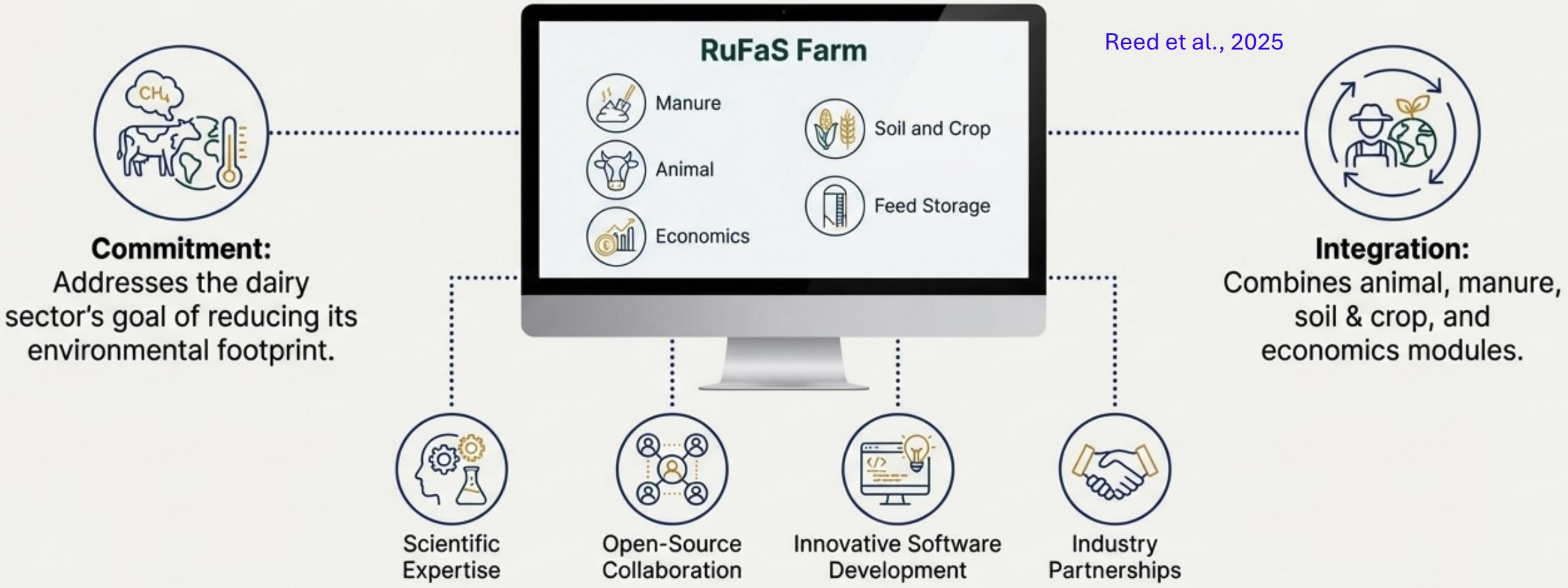
Ruminant Farm Systems



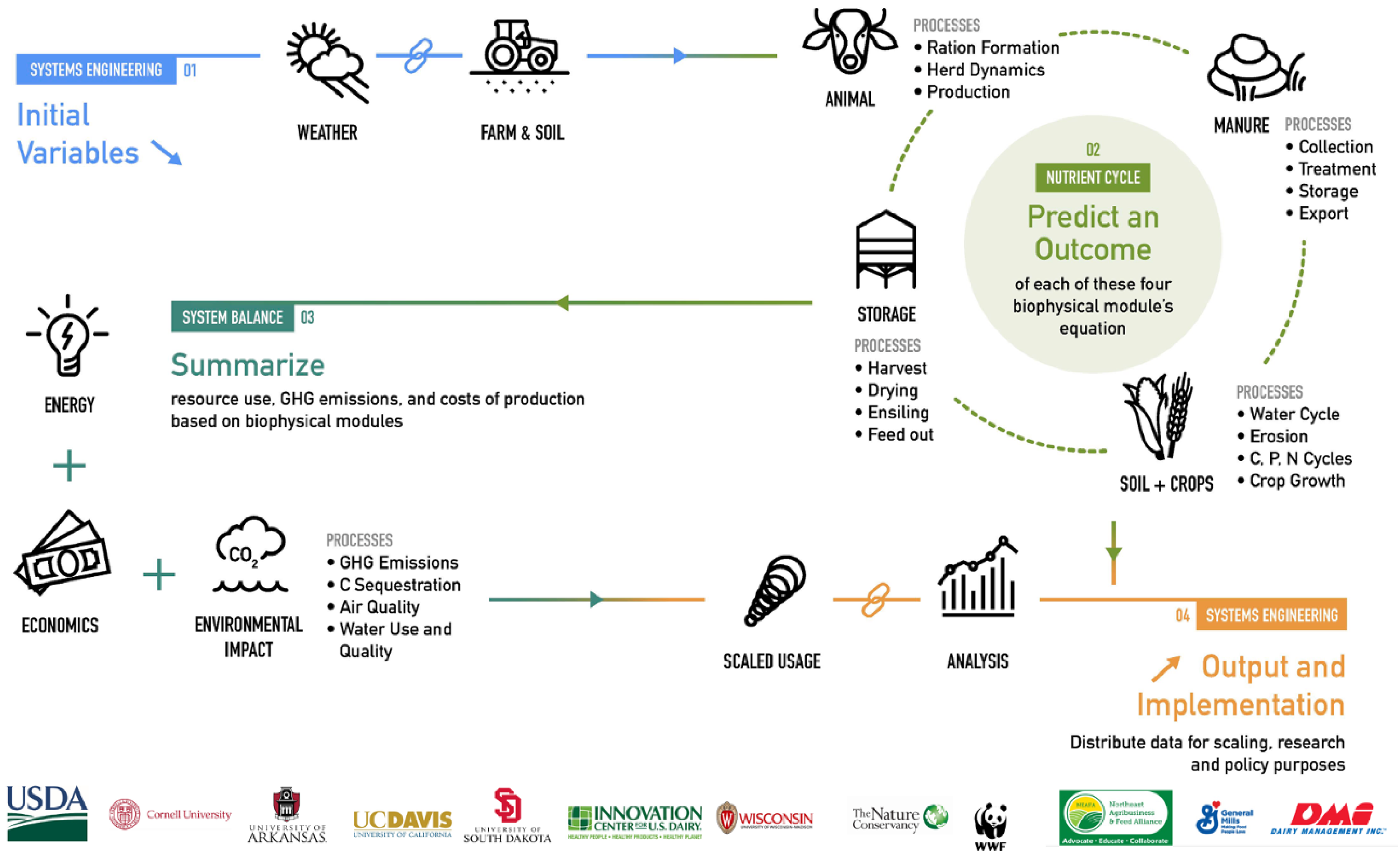
Reed et al., 2025

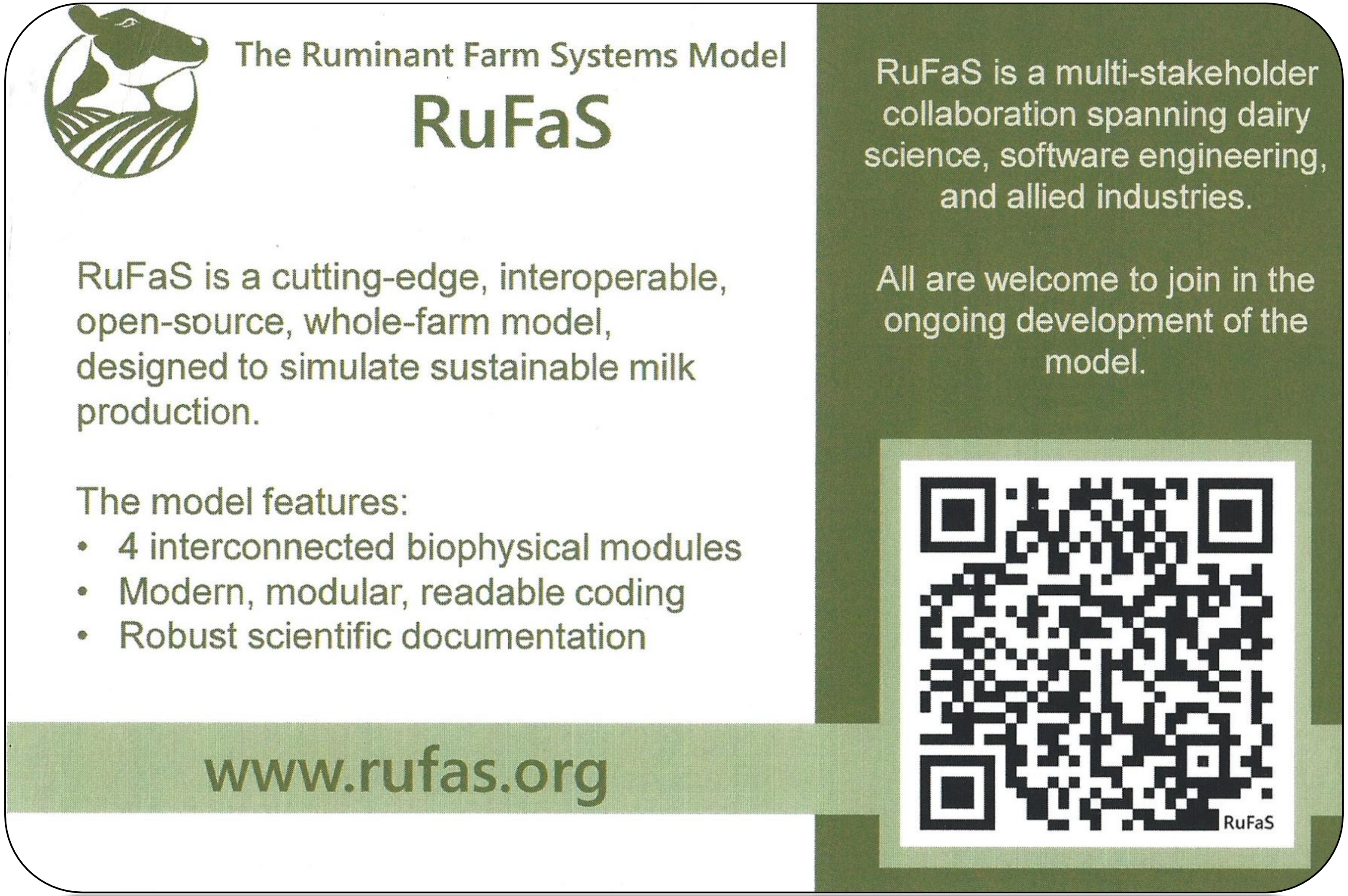
Introducing RuFaS: A Whole-Farm Simulation Platform

RuFaS is an open-source model that integrates the key functions of a dairy farm to simulate the real-world impact of management decisions.



Foundation: Built on scientific expertise, open-source collaboration, and innovative software.

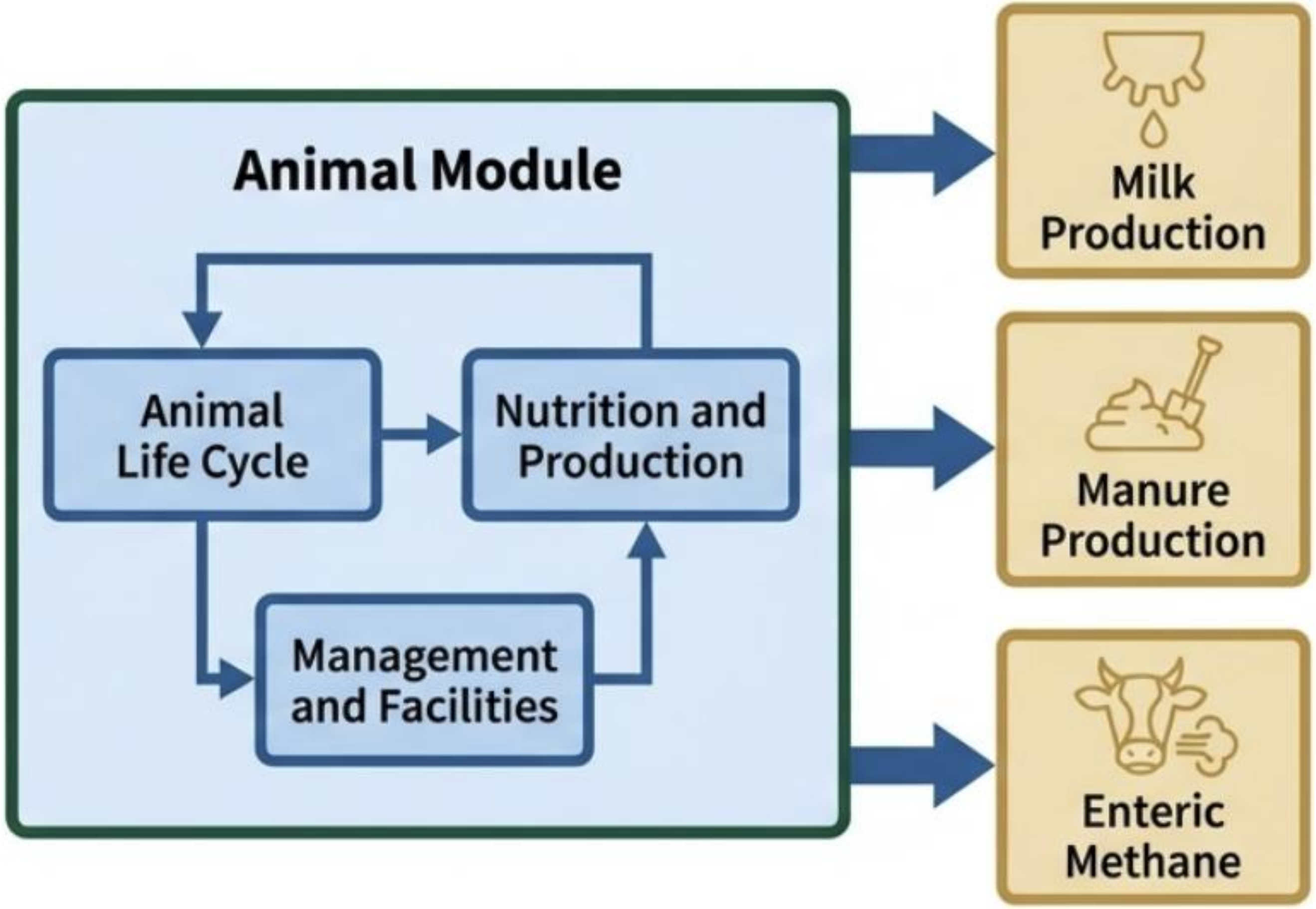

SYSTEMS ENGINEERING 01
Initial Variables
WEATHER
FARM & SOIL
ANIMAL
PROCESSES
• Ration Formation
• Herd Dynamics
• Production
MANURE
PROCESSES
• Collection
• Treatment
• Storage
• Export
02
NUTRIENT CYCLE
Predict an Outcome
of each of these four biophysical module's equation
STORAGE
PROCESSES
• Harvest
• Drying
• Ensiling
• Feed out
SOIL + CROPS
PROCESSES
• Water Cycle
• Erosion
• C, P, N Cycles
• Crop Growth
SYSTEM BALANCE 03
Summarize
resource use, GHG emissions, and costs of production based on biophysical modules
ENERGY
ECONOMICS
ENVIRONMENTAL IMPACT
PROCESSES
• GHG Emissions
• C Sequestration
• Air Quality
• Water Use and Quality
SCALED USAGE
ANALYSIS
04 SYSTEMS ENGINEERING
Output and Implementation
Distribute data for scaling, research and policy purposes
USDA
Cornell University
University of Arkansas
UC Davis University of California
University of South Dakota
Innovation Center for U.S. Dairy
Wisconsin
The Nature Conservancy
WWF
Northeast Agribusiness & Feed Alliance
General Mills
DMI Dairy Management Inc.


The Ruminant Farm Systems Model
RuFaS
RuFaS is a cutting-edge, interoperable, open-source, whole-farm model, designed to simulate sustainable milk production.
The model features:
• 4 interconnected biophysical modules
• Modern, modular, readable coding
• Robust scientific documentation
www.rufas.org
RuFaS is a multi-stakeholder collaboration spanning dairy science, software engineering, and allied industries.
All are welcome to join in the ongoing development of the model.
RuFaS

A Closer Look: The Animal Module

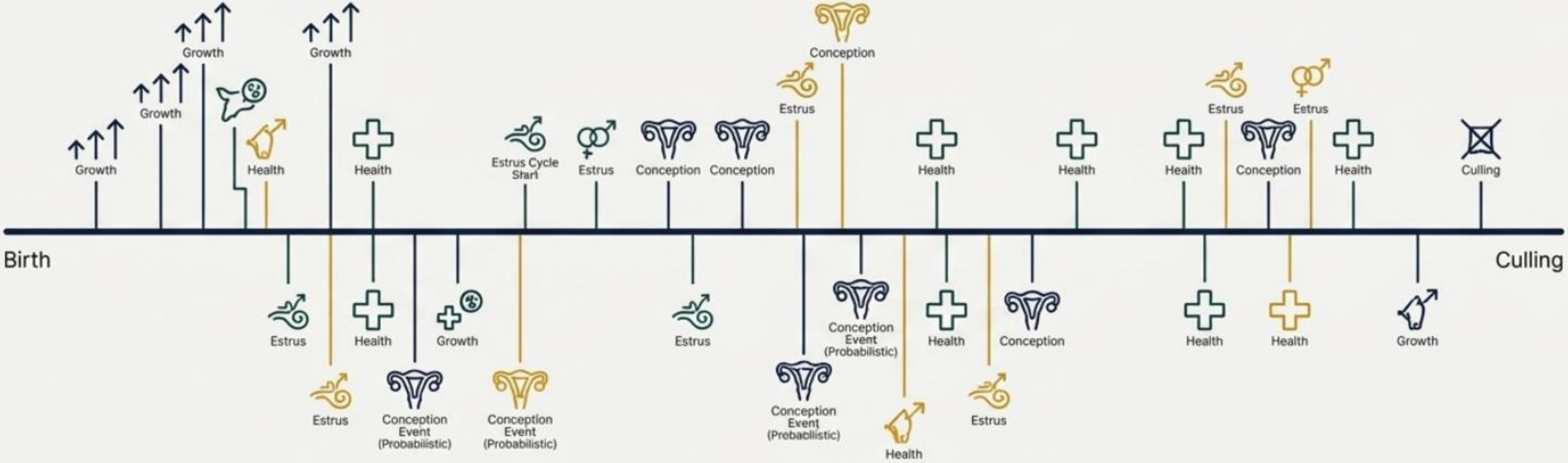
The Animal Module simulates the life cycle, health, and productivity of dairy cattle at both the individual and herd level. It operates on a daily time step, capturing key events:

- ✓ Growth and Reproduction
- ✓ Lactation and Production
- ✓ Health and Disease
- ✓ Culling and Replacement



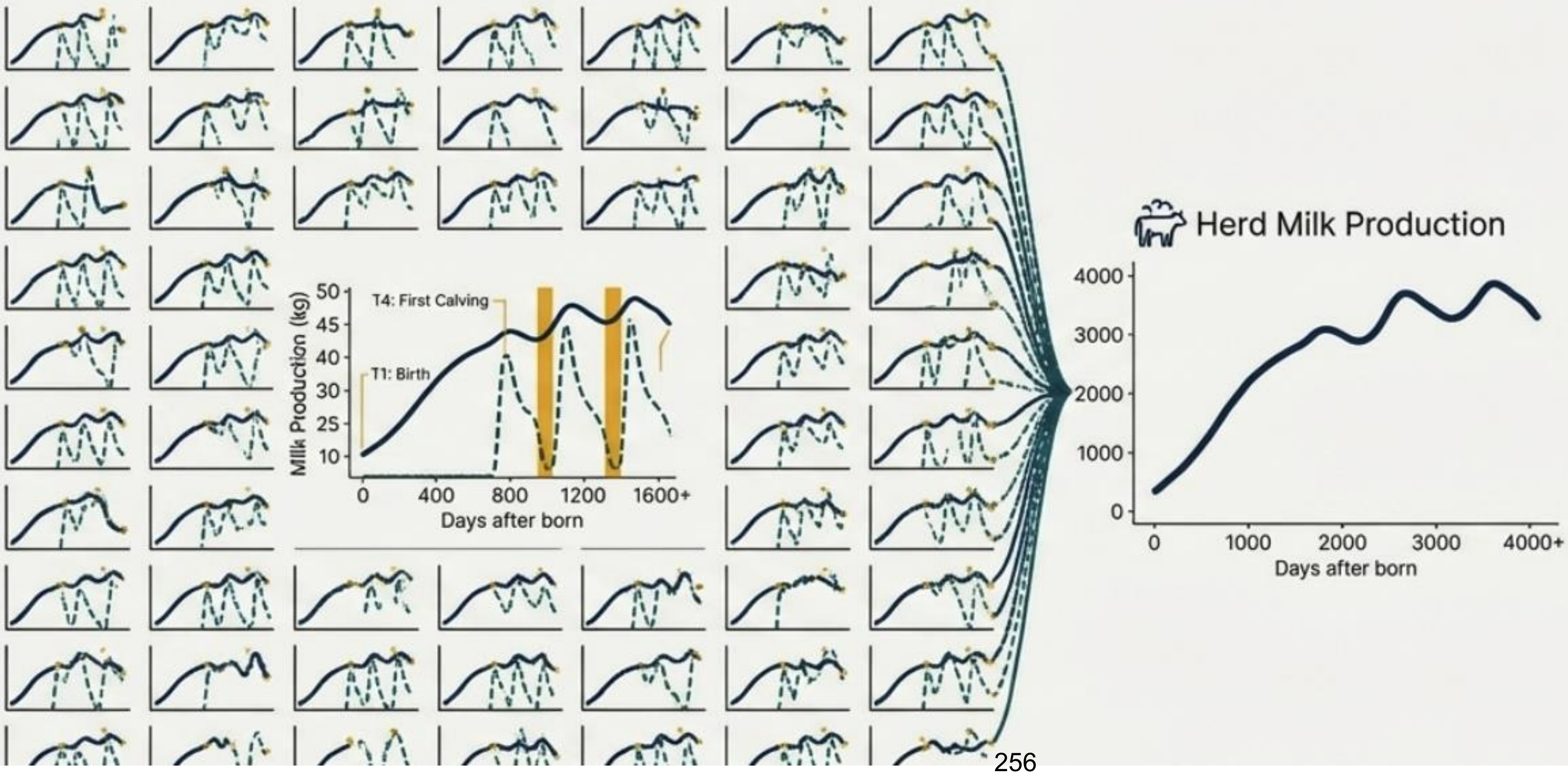
A Life Story Written by Science and Chance

Each animal's life is a unique sequence of daily events, each determined by a new roll of the dice.



From an Animal to a Herd

By simulating thousands of individual life stories simultaneously, RuFaS creates a dynamic and realistic model of the entire herd.



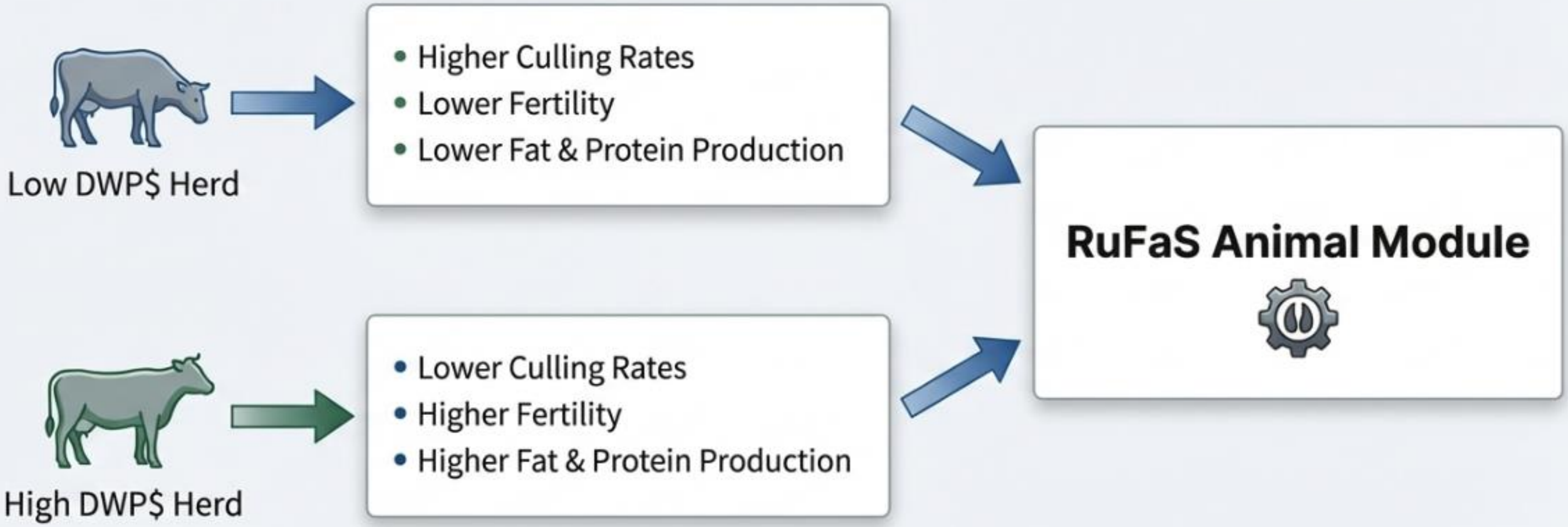
- Overall herd productivity
- Population dynamics (culling, replacement rates)
- Feed requirements and manure output for the entire farm

RuFaS is not just a research model; it underpins the environmental stewardship program for 80% of the U.S. milk supply.

Reed et al., 2025

Modeling the ‘Better’ Cow

The model was configured to reflect the distinct performance profiles of high- and low-ranking DWP$ animals.



Weigel et al., 2025

The Quantified Environmental Dividend

Selecting for higher DWP$ directly translates to a lower environmental footprint per unit of milk produced.

Lower Enteric Methane Intensity

THE EXTREMES: TOP 25% VS. BOTTOM 25% HERDS

-12.7%

Lower enteric methane per kg FPCM in the highest genetic merit herds.

Lower Nitrogen Excretion Intensity

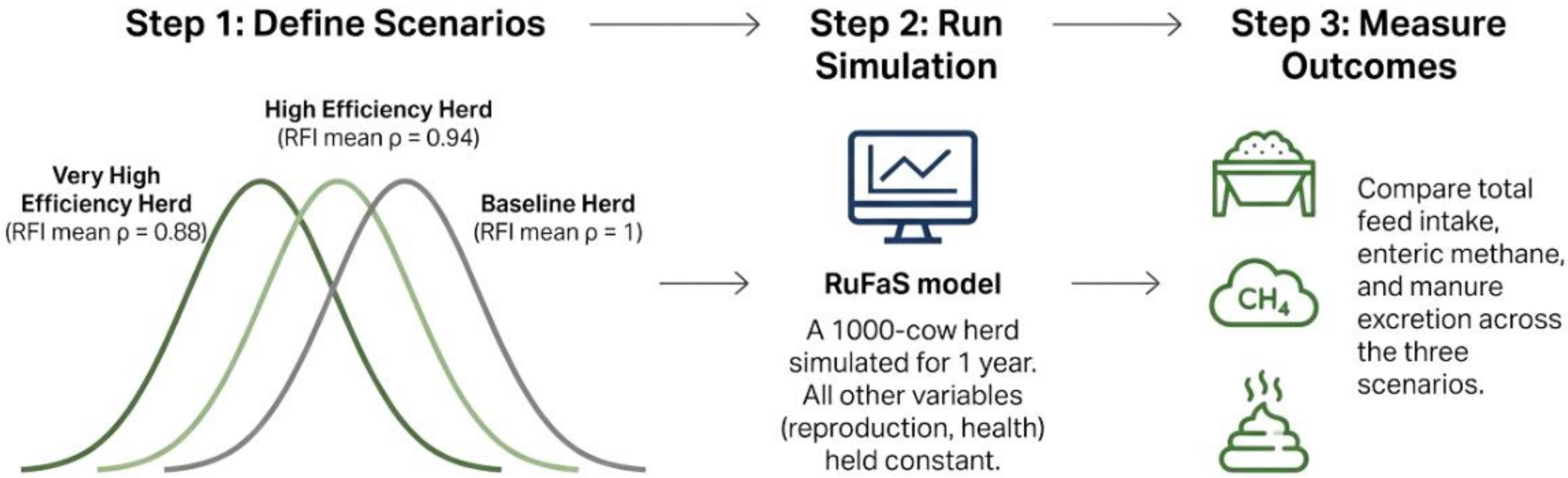
-9.5%

Lower manure nitrogen excretion per kg FPCM in the highest genetic merit herds.

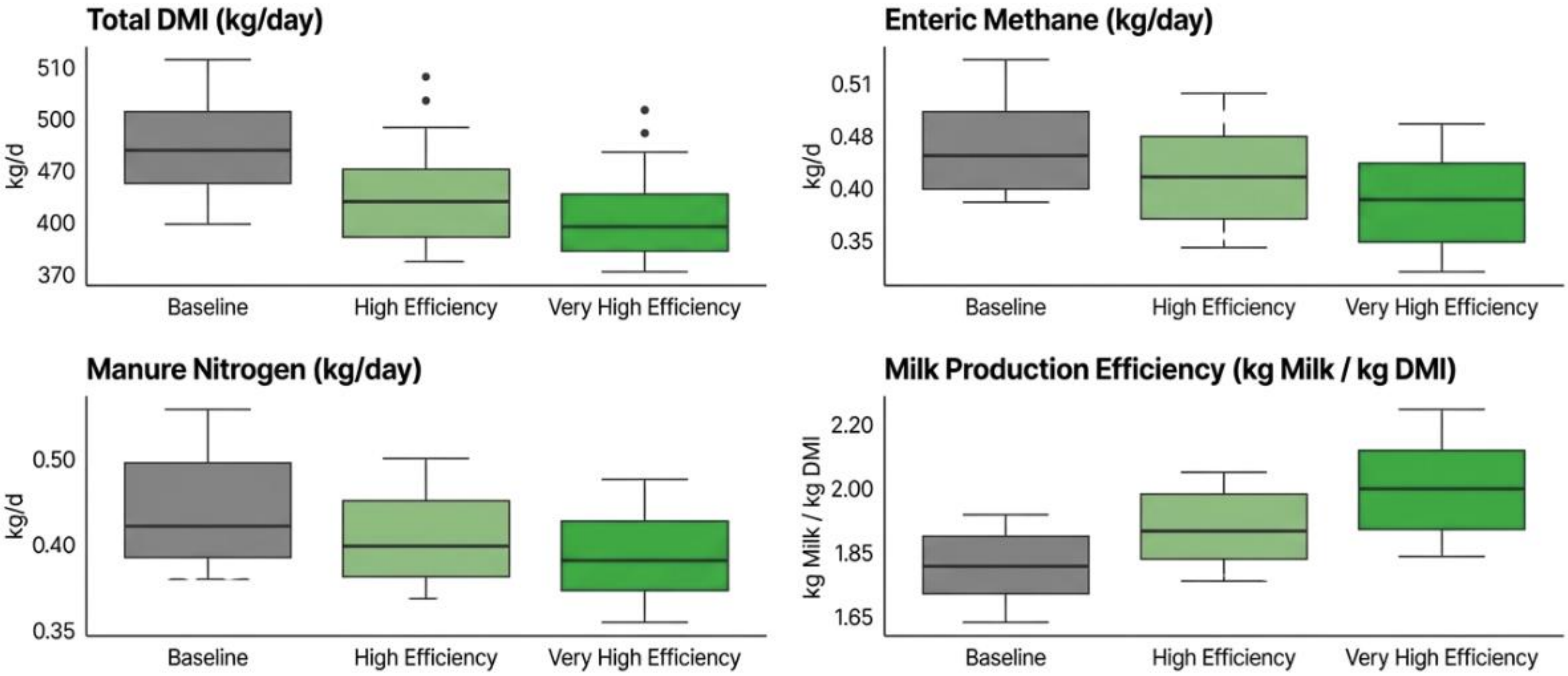
Genetic selection is a powerful environmental strategy. RuFaS provides the tool to quantify its impact and build it into sustainability planning.

Simulating a Shift in Herd Efficiency

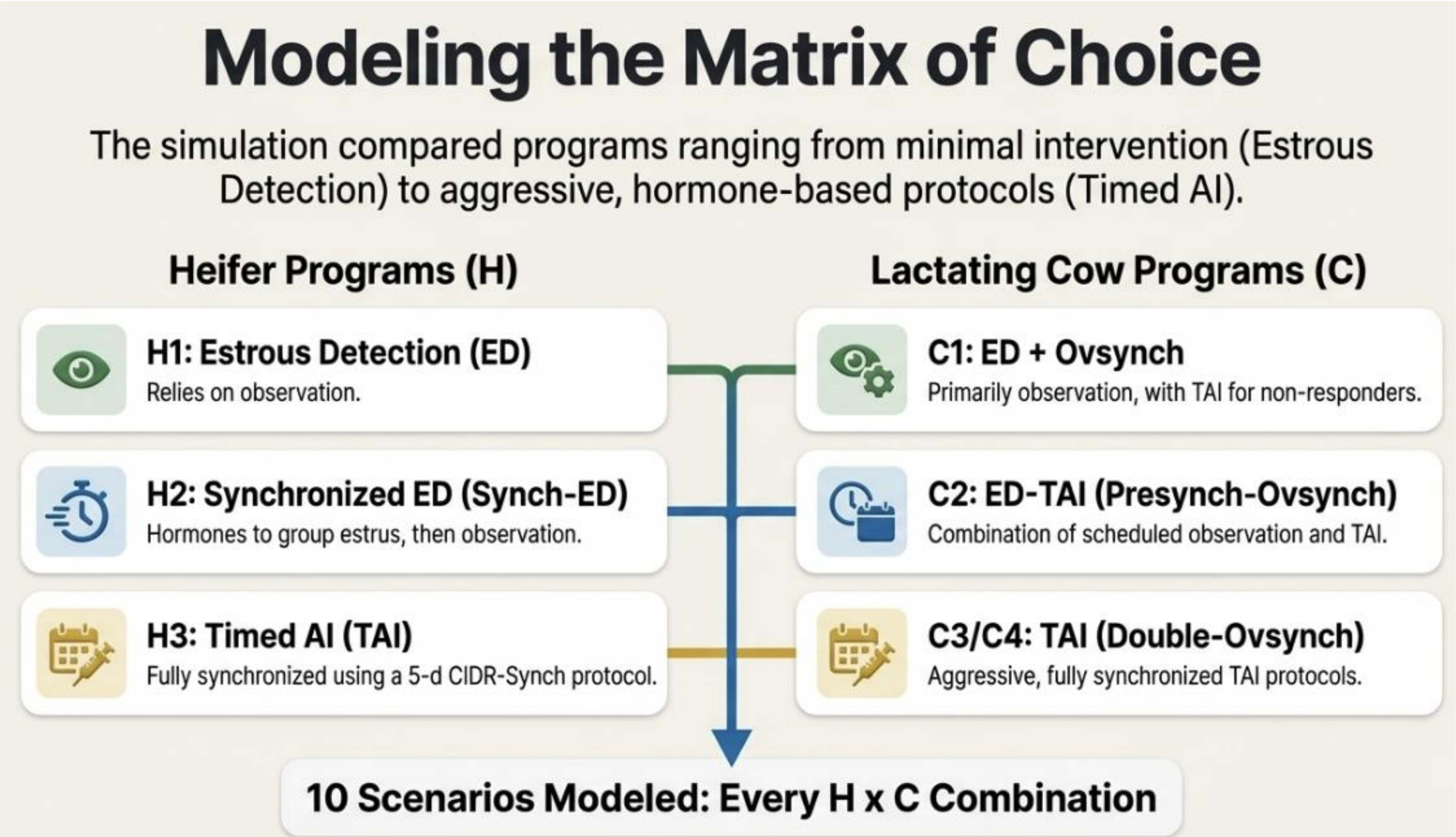
Modeling the Genetic Shift: Baseline vs. High-Efficiency Herds



Hansen et al., 2021

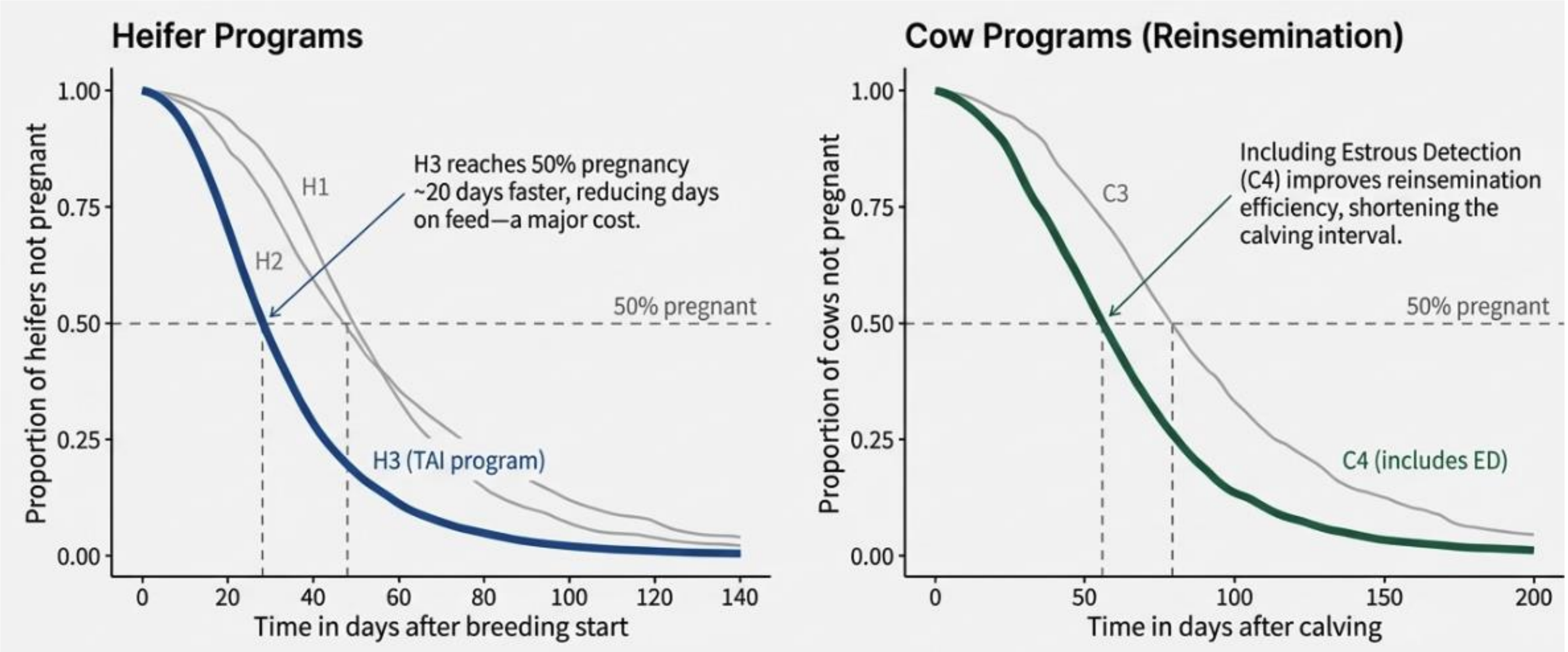


Total DMI (kg/day)
kg/d
510
500
470
400
370
Baseline
High Efficiency
Very High Efficiency
Enteric Methane (kg/day)
kg/d
0.51
0.48
0.40
0.35
Baseline
High Efficiency
Very High Efficiency
Manure Nitrogen (kg/day)
kg/d
0.50
0.40
0.35
Baseline
High Efficiency
Very High Efficiency
Milk Production Efficiency (kg Milk / kg DMI)
kg Milk / kg DMI
2.20
2.00
1.85
1.65
Baseline
High Efficiency
Very High Efficiency



Modeling the Matrix of Choice
The simulation compared programs ranging from minimal intervention (Estrous Detection) to aggressive, hormone-based protocols (Timed AI).
Heifer Programs (H)
Lactating Cow Programs (C)
H1: Estrous Detection (ED)
Relies on observation.
H2: Synchronized ED (Synch-ED)
Hormones to group estrus, then observation.
H3: Timed AI (TAI)
Fully synchronized using a 5-d CIDR-Synch protocol.
C1: ED + Ovsynch
Primarily observation, with TAI for non-responders.
C2: ED-TAI (Presynch-Ovsynch)
Combination of scheduled observation and TAI.
C3/C4: TAI (Double-Ovsynch)
Aggressive, fully synchronized TAI protocols.
10 Scenarios Modeled: Every H x C Combination

Li et al., 2023



+$39/cow per year between highest and lowest net return

Conclusions: From Data Streams to Decision Intelligence

Dairy Brain connects and interprets farm data; RuFaS turns that intelligence into whole-farm, testable decisions.

Connected Data Streams

Herd, milking, feed, sensors, weather, economics, crops, and genetics are brought into one data ecosystem.

→

Integrated Analytics

Dairy Brain harmonizes information and converts it into predictive and prescriptive insights.

→

Digital Twin Simulation

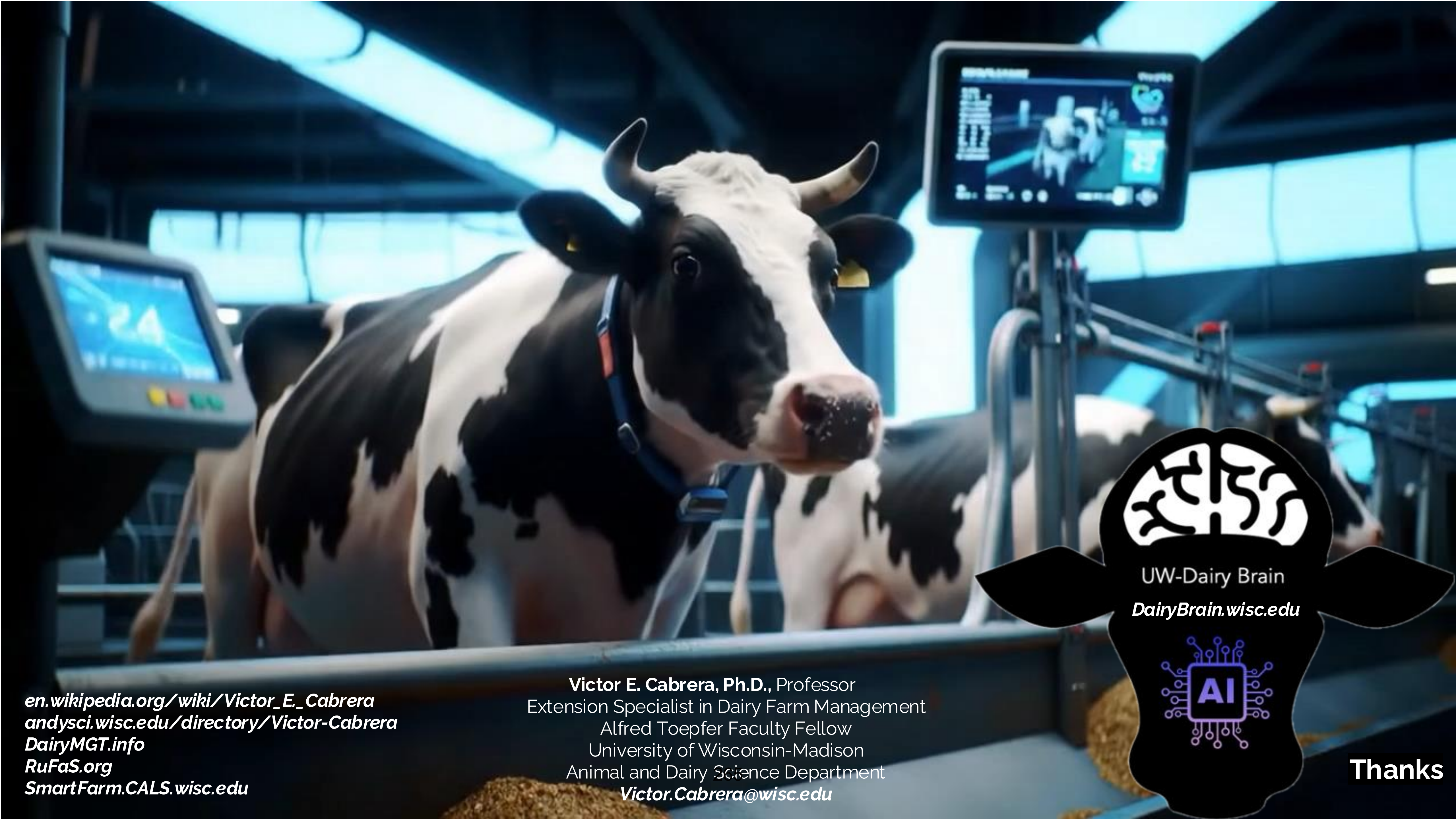
RuFaS provides a virtual farm where alternatives can be tested before implementation.

→

Actionable Dairy Decisions

The output is better management for health, efficiency, productivity, and environmental stewardship.

The future of dairy management is not data collection alone, but trusted integration, intelligence, and decision support at farm scale.



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Animal and Dairy Science Department
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en.wikipedia.org/wiki/Victor_E._Cabrera
andysci.wisc.edu/directory/Victor-Cabrera
DairyMGT.info
RuFaS.org
SmartFarm.CALS.wisc.edu

UW-Dairy Brain
DairyBrain.wisc.edu

AI

Thanks

From Suppression to Robustness: Reevaluating Immunity in the Periparturient Dairy Cow

Lance Baumgard PhD
Distinguished Professor
Iowa State University
Baumgard@iastate.edu

Department of Animal Science

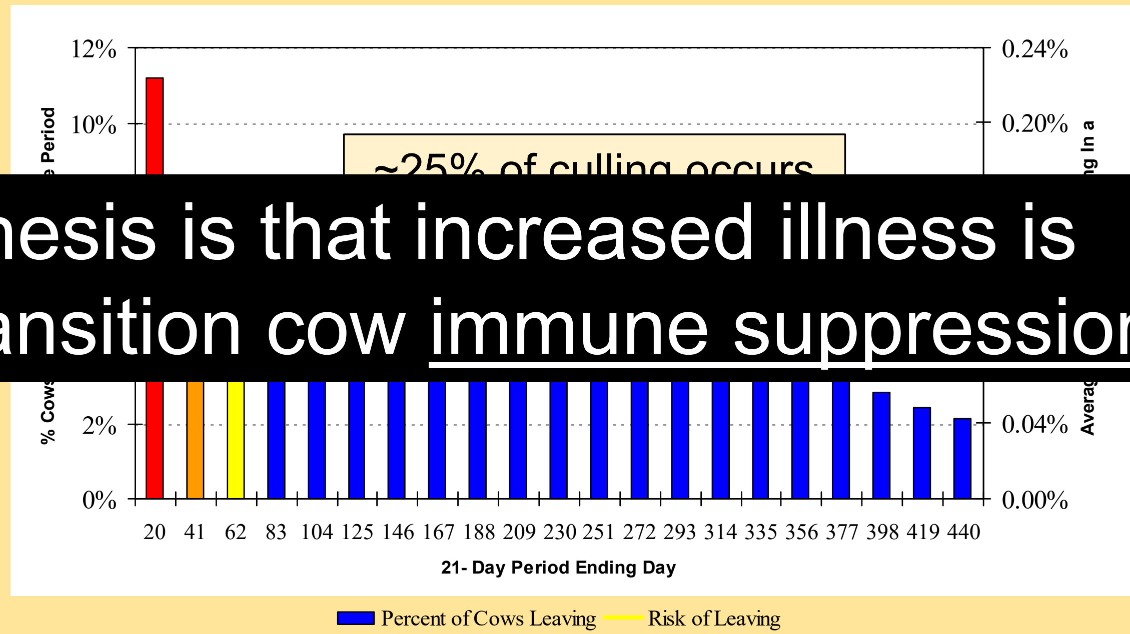
Transition Period Morbidity

Disorders affects 50%:

- Dystocia
- Milk fever
- Reta
- Metr
- Keto
- DA
- Fatty liver
- Lameness
- Death

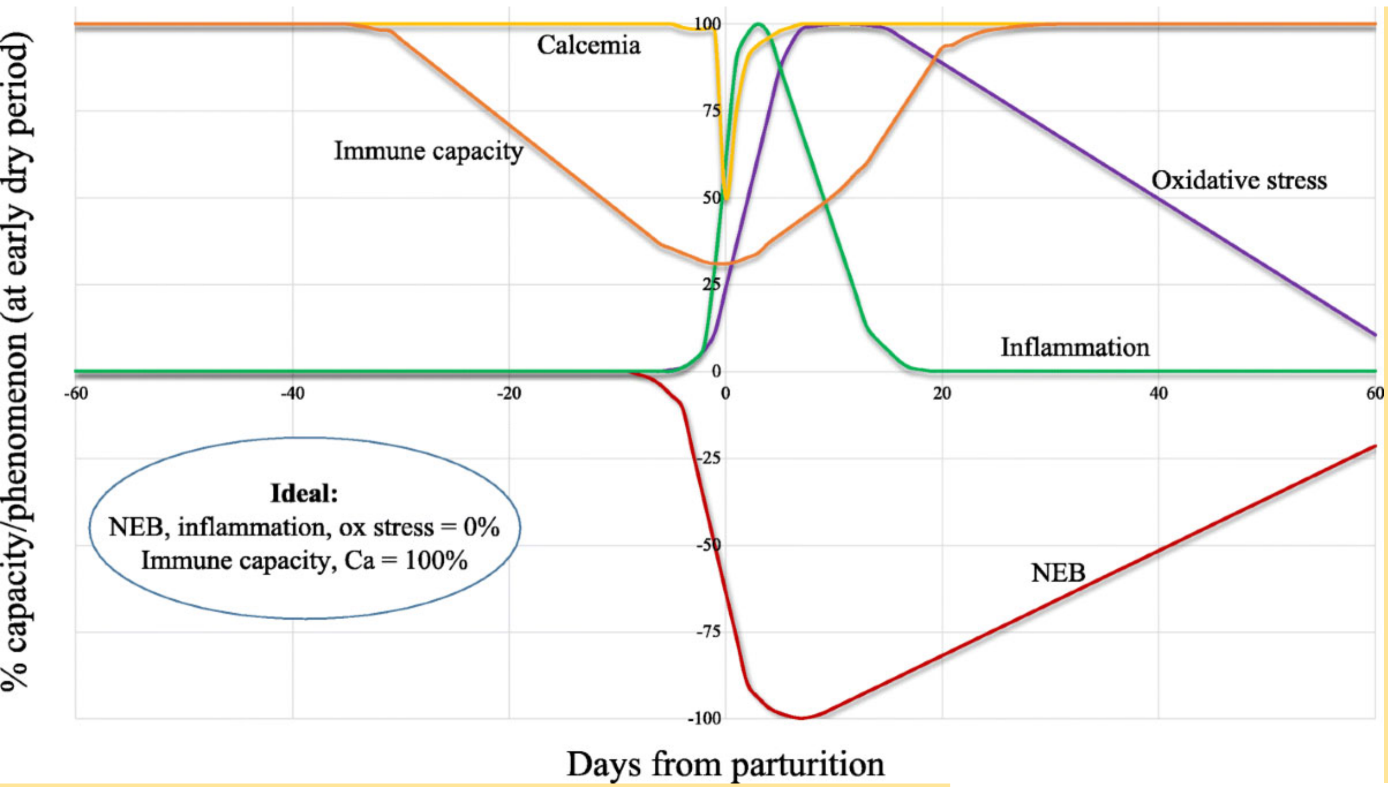
Drackley, 1999

When cows leave the herd



The hypothesis is that increased illness is caused by transition cow immune suppression

Source: 2002, Steve Stewart, DVM, Dipl.-ABVP, Univ. of Minnesota, College of Vet. Med.



Lopreiato *et al. Journal of Animal Science and Biotechnology* (2020) 11:96
https://doi.org/10.1186/s40104-020-00501-x

Journal of Animal Science and Biotechnology

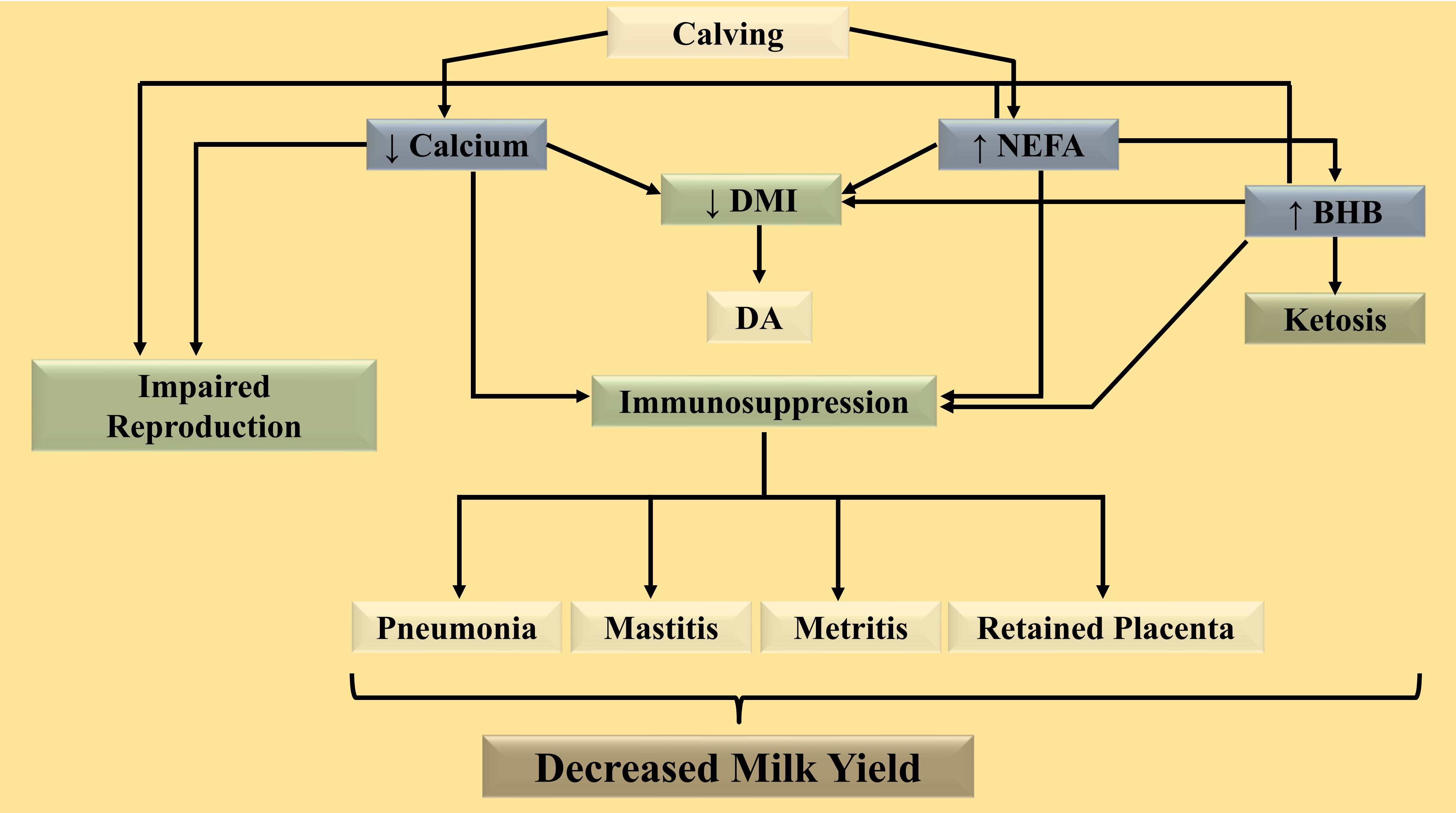
REVIEW **Open Access**

Role of nutraceuticals during the transition period of dairy cows: a review

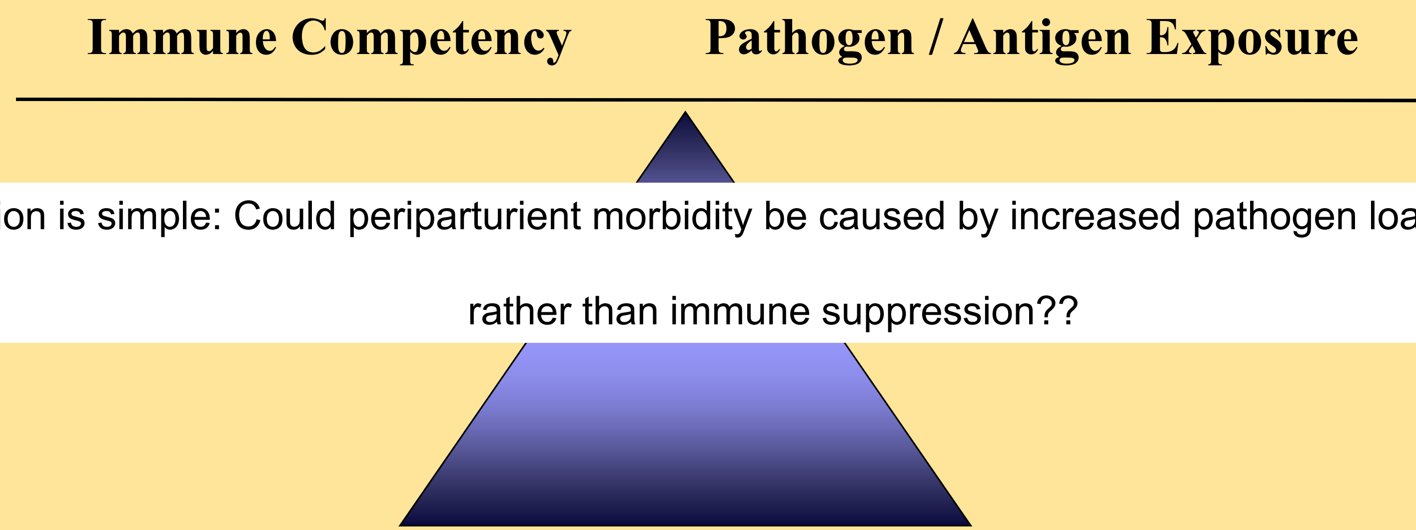
Vincenzo Lopreiato[1], Matteo Mezzetti[1], Luca Cattaneo[1], Giulia Ferronato[1], Andrea Minuti[1,2] and Erminio Trevisi[1,2*]

Transition Cow Dogma

Increased NEFA, Hyperketonemia, and Hypocalcemia…..**CAUSE** production and health problems


Calving
↓ Calcium
↑ NEFA
↓ DMI
↑ BHB
DA
Ketosis
Impaired Reproduction
Immunosuppression
Pneumonia
Mastitis
Metritis
Retained Placenta
Decreased Milk Yield

Immune Competency vs. Exposure

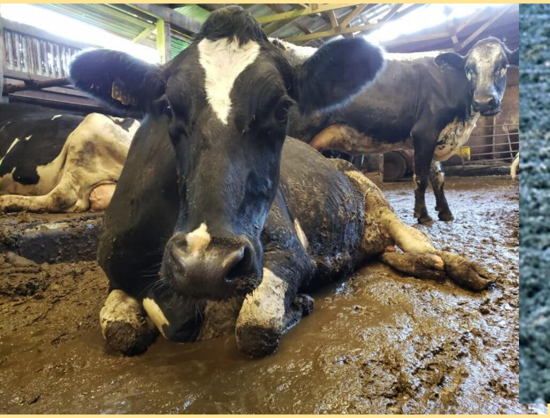


The question is simple: Could periparturient morbidity be caused by increased pathogen load at key epithelia,

rather than immune suppression??

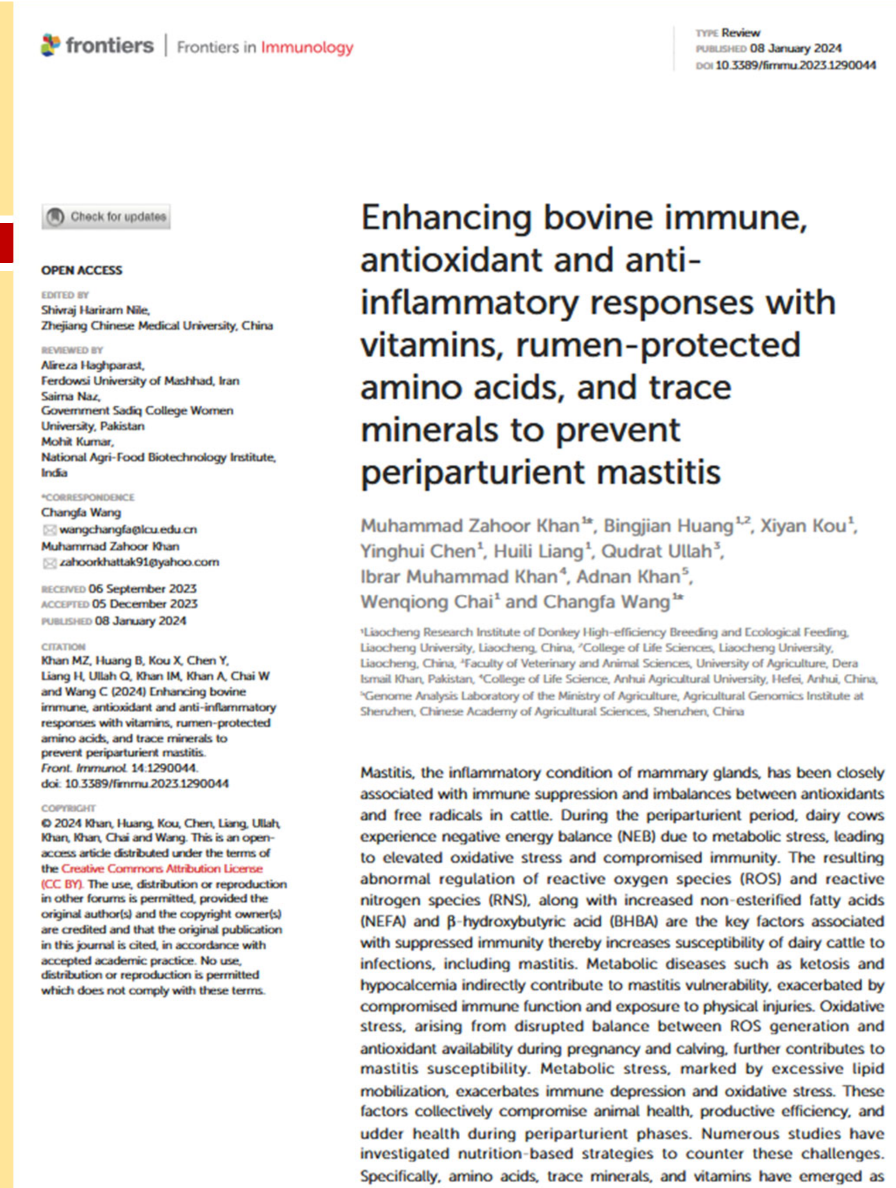
David Vetter, aka the “bubble boy”
Severe Combined Immunodeficiency (SCID)

Wellness:
Immune Competency vs. Pathogen Load



The concept of “immune suppression” is the foundation for a plethora of experiments and transition period nutritional strategies.

This paper is just one example



frontiers | Frontiers in Immunology

TYPE Review
PUBLISHED 08 January 2024
DOI 10.3389/fimmu.2023.1290044

Check for updates

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Front. Immunol. 14:1290044.
doi: 10.3389/fimmu.2023.1290044

Enhancing bovine immune, antioxidant and anti-inflammatory responses with vitamins, rumen-protected amino acids, and trace minerals to prevent periparturient mastitis

Muhammad Zahoor Khan[1*], Bingjian Huang[1,2], Xiyan Kou[1], Yinghui Chen[1], Huili Liang[1], Qudrat Ullah[3], Ibrar Muhammad Khan[4], Adnan Khan[5], Wenqiong Chai[1] and Changfa Wang[1*]

[1]Liaocheng Research Institute of Donkey High-efficiency Breeding and Ecological Feeding, Liaocheng University, Liaocheng, China, [2]College of Life Sciences, Liaocheng University, Liaocheng, China, [3]Faculty of Veterinary and Animal Sciences, University of Agriculture, Dera Ismail Khan, Pakistan, [4]College of Life Science, Anhui Agricultural University, Hefei, Anhui, China, [5]Genome Analysis Laboratory of the Ministry of Agriculture, Agricultural Genomics Institute at Shenzhen, Chinese Academy of Agricultural Sciences, Shenzhen, China

Mastitis, the inflammatory condition of mammary glands, has been closely associated with immune suppression and imbalances between antioxidants and free radicals in cattle. During the periparturient period, dairy cows experience negative energy balance (NEB) due to metabolic stress, leading to elevated oxidative stress and compromised immunity. The resulting abnormal regulation of reactive oxygen species (ROS) and reactive nitrogen species (RNS), along with increased non-esterified fatty acids (NEFA) and β-hydroxybutyric acid (BHBA) are the key factors associated with suppressed immunity thereby increases susceptibility of dairy cattle to infections, including mastitis. Metabolic diseases such as ketosis and hypocalcemia indirectly contribute to mastitis vulnerability, exacerbated by compromised immune function and exposure to physical injuries. Oxidative stress, arising from disrupted balance between ROS generation and antioxidant availability during pregnancy and calving, further contributes to mastitis susceptibility. Metabolic stress, marked by excessive lipid mobilization, exacerbates immune depression and oxidative stress. These factors collectively compromise animal health, productive efficiency, and udder health during periparturient phases. Numerous studies have investigated nutrition-based strategies to counter these challenges. Specifically, amino acids, trace minerals, and vitamins have emerged as

How (and why) do NEFA, Hyperketonemia and Hypocalcemia cause problems

- Biological plausibility?
  - Why would evolution favor a scenario where the mother endangers herself and compromises her ability to nourish her young?
- There remains little mechanistic evidence for how NEFA, ketones and Ca can directly have such a large influence on a variety of seemingly unconnected systems and diseases
- Best line of evidence is extrapolated from their purported role in immunosuppression.

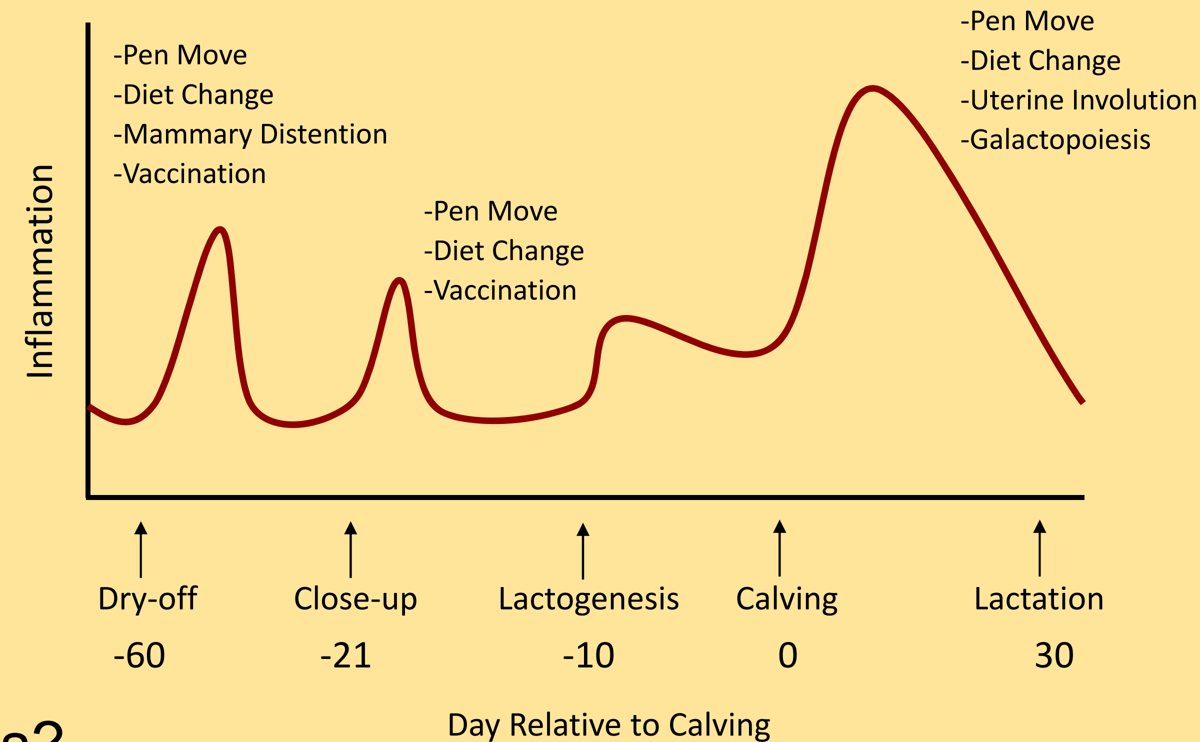
Inflammation in Transition Cows

- Observed in all cows

(Bertoni et al., 2008; Trevisi and Minuti, 2018)

- What is the source?
  - Mammary Gland
  - Uterus
  - Gastrointestinal tract

- What are the consequences?

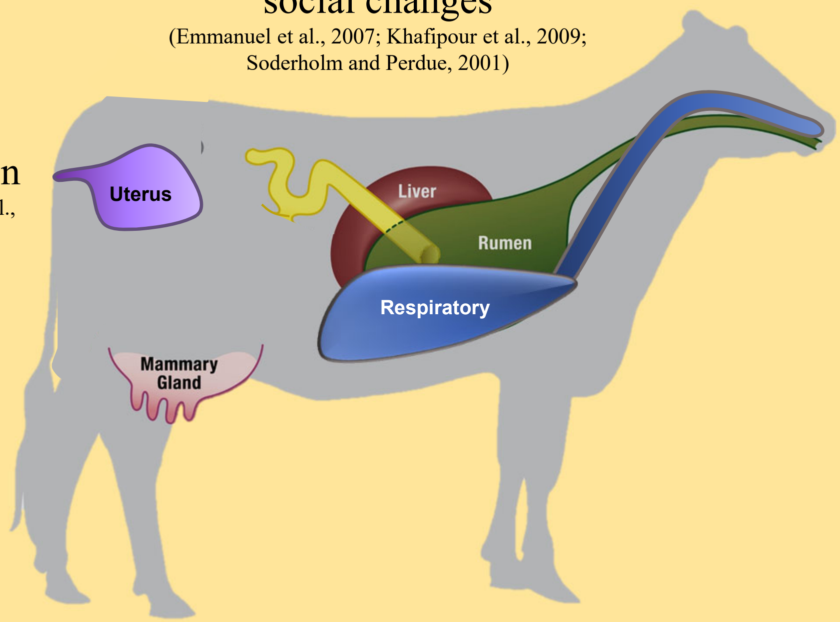


Dr. B. Goetz

Heightened risk of antigen insult in early lactation

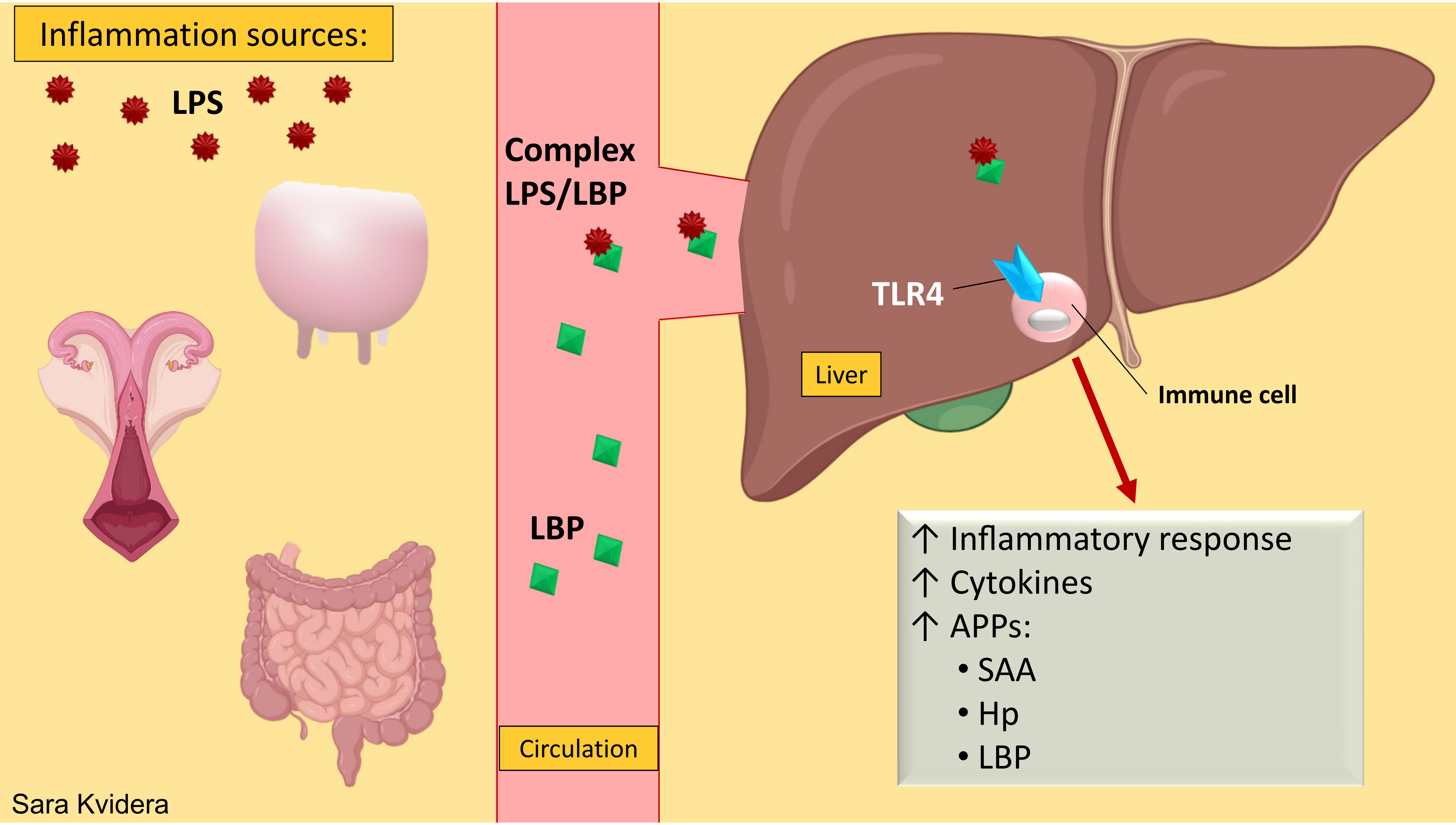
Increased gut permeability via diet and social changes
(Emmanuel et al., 2007; Khafipour et al., 2009; Soderholm and Perdue, 2001)

Uterine bacterial contamination post-parturition
(Paisley et al., 1986; Földi et al., 2006; Norman et al., 2007; Sheldon et al., 2008)

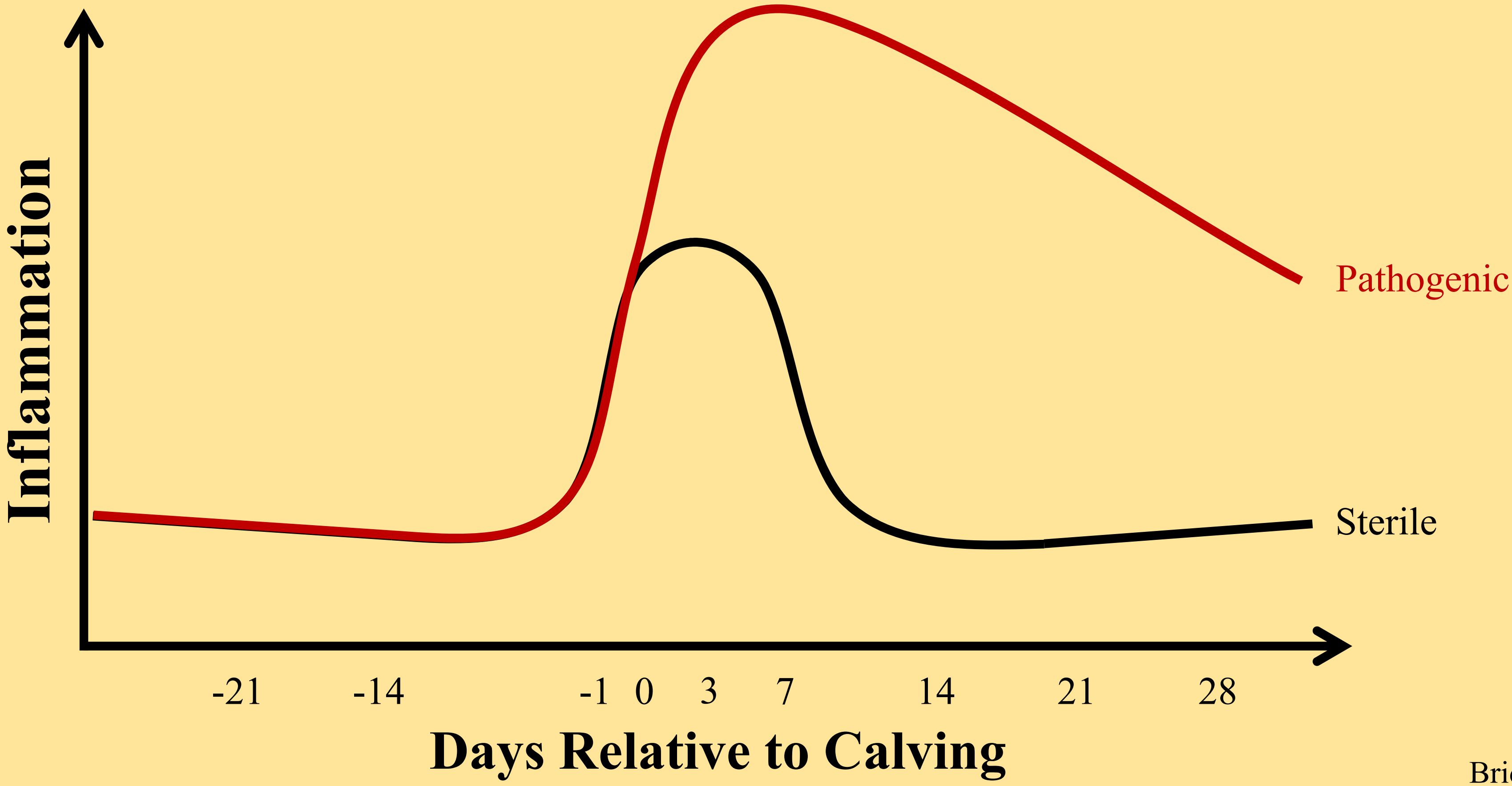


Lactogenesis and galactopoeisis
(Akers and Nickerson, 2011)

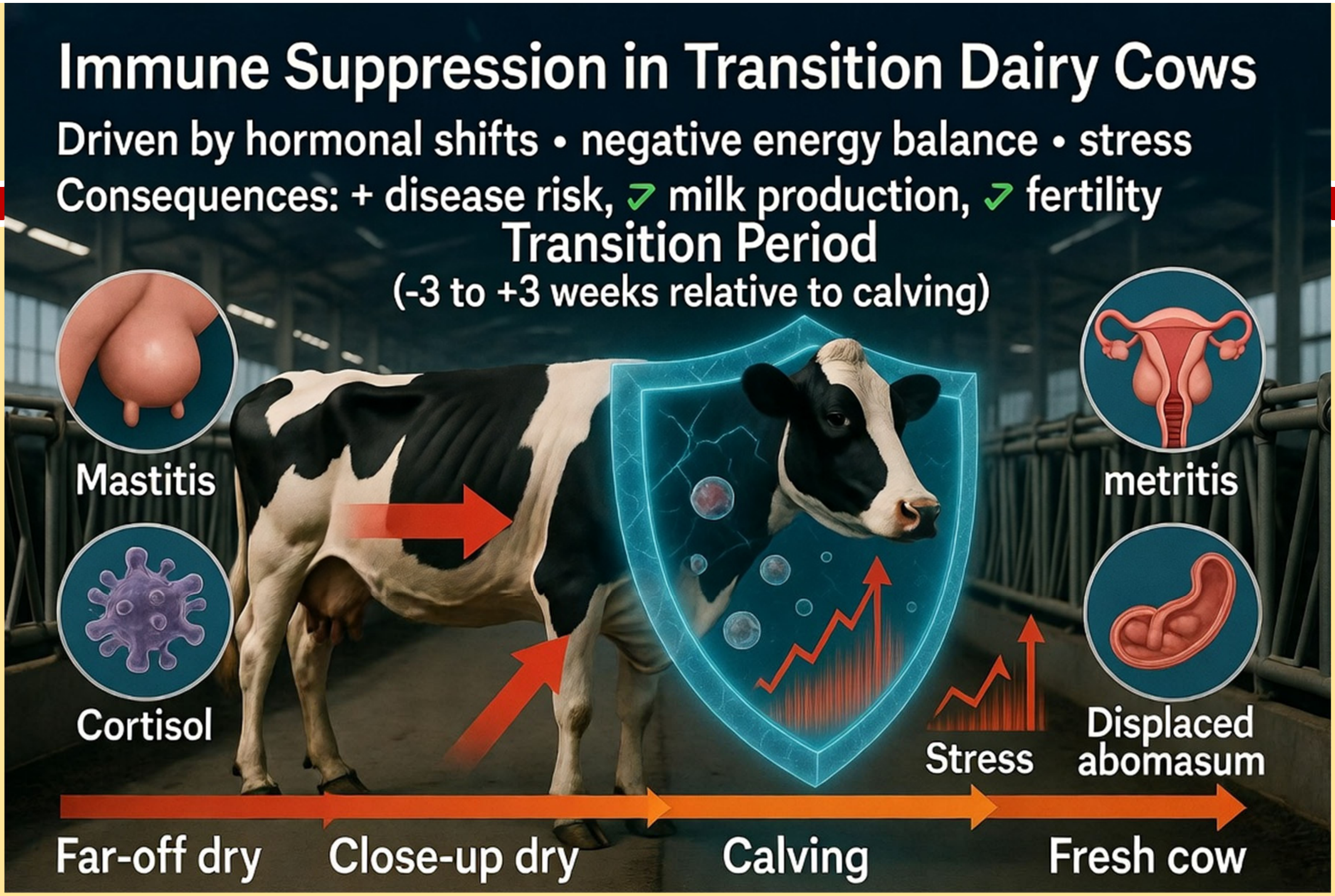
<u>Sterile Inflammation</u>
Parturition
Placenta Expulsion
Uterine Involution


Inflammation sources:
LPS
Complex
LPS/LBP
TLR4
Liver
Immune cell
LBP
Circulation
↑ Inflammatory response
↑ Cytokines
↑ APPs:
• SAA
• Hp
• LBP
Sara Kvidera

Transition Cow Inflammation



Bridget Buol


Immune Suppression in Transition Dairy Cows
Driven by hormonal shifts • negative energy balance • stress
Consequences: + disease risk, ↗ milk production, ↗ fertility
Transition Period
(-3 to +3 weeks relative to calving)
Mastitis
metritis
Cortisol
Stress
Displaced abomasum
Far-off dry
Close-up dry
Calving
Fresh cow

Grok.com

Historical Beginnings of "Immune Suppresion"

Research in Veterinary Science 1979, 26, 97–101

The pathogenesis of experimental *Escherichia coli* mastitis in newly calved dairy cows

A. W. Hill, A. L. Shears and K. G. Hibbitt

Agricultural Research Council, Institute for Research on Animal Diseases, Compton, Newbury, Berkshire

Slow diapedesis of neutrophils appears to be associated with the most severe cases of *E coli* mastitis. The animals appear to suffer from an impaired chemotaxis of cells which is associated with parturition or the stress of early lactation. This

Veterinary Immunology and Immunopathology, 4 (1983) 153–176 153
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

EFFECT OF PREGNANCY AND LACTATION UPON INFECTION

S. LLOYD
Department of Clinical Veterinary Medicine, University of Cambridge, Madingley Rd., Cambridge CB3 OES, England

More information is required as to the economic importance of infections arising as a result of periparturient immunosuppression in livestock. Also, information is required on the role periparturient immunosuppression may play in the epidemiology of a variety of infectious diseases of domesticated animals and man.

Immunosuppression: *"immunological unresponsiveness manifest as an increased susceptibility to infection and/or a recrudescence of infection during pregnancy and lactation"* (Lloyd, 1983)

ISU and USDA-NADC Immune Suppression Team

Dr. Mark Kehrli

Dr. Jim Roth

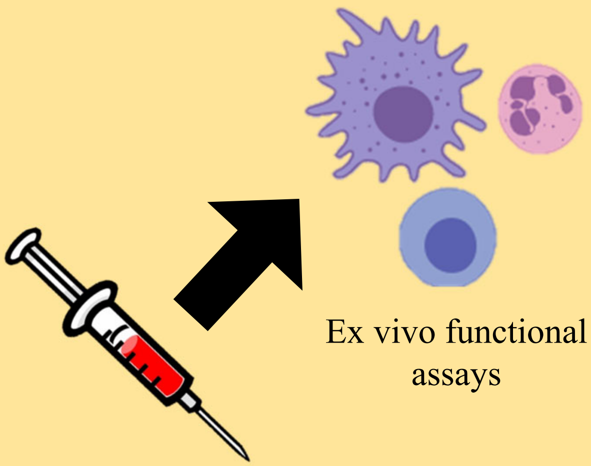
Dr. Ron Horst

Dr. Jesse Goff

Almost everything we know about periparturient immunology is because of these four guys that live(d) in Ames Iowa

Mechanistic Explanation for Immune Suppression

- Reduced leukocyte effector functions
  - e.g., oxidative burst, cytotoxicity
  - Kehrli et al., 1989; Cai et al., 1994; Detilleux et al., 1995; Shafer-Weaver et al., 1997
- Delayed leukocyte recruitment
  - e.g., adhesion, migration
  - Hill et al., 1979; Frost and Brooker, 1986; Lee and Kehrli, 1998



Impact on Leukocyte Function

↓ Calcium

↑ NEFA

↑ BHB

But too many inconsistencies (as reviewed by LeBlanc, 2020)

A solid foundation of any dogma should be a consistent pattern

↓ intracellular Ca stores
↓ neutrophil phagocytosis
(Ducusin et al., 2003; Kimura et al., 2006; Martinez et al., 2014))

↓ lymphocyte antibody secretion
↓ neutrophil chemotaxis, myeloperoxidase, and ROS production
(Hoeben et al., 1997; Suriyasathaporn et al., 1999 ; Lacetera et al., 2004; Hammon et al., 2006; Scalia et al., 2006; Grinberg et al., 2008; Ster et al., 2012)

No change in phagocytosis (Scalia et al., 2006)
No difference in mononuclear cell proliferation or cytokine production (Ster et al., 2012)
No impact on neutrophil killing ability (Hammon et al., 2006)

Periparturient Immune Suppression

Leukocyte Effectiveness

- < -14 DIM: highly functional
  - Kehrli e

But are these fair comparisons?

Is it apples to apples?

- 1-21 D
  - Guidry ... 93; Lee et al., 1998; M

- +21 DIM: return to highly functional
  - Gilbert et al., 1993; Meglia et al., 2001; Jahan et al., 2015

Neutrophils continue to mature while in circulation and this affects their ex vivo functionality properties

Trends in Immunology

CellPress

Series: Neutrophils in Action

Trends in Immunology, May 2016, Vol. 37, No. 5 http://dx.doi.org/10.1016/j.it.2016.03.005

Review

Aging: A Temporal Dimension for Neutrophils

José M. Adrover,[1] José A. Nicolás-Ávila,[1] and Andrés Hidalgo[1,*]

Neutrophils are first-responders, providing early protection against invading pathogens. Recent findings have revealed a temporal dimension to neutrophil function, associated with the clearance cycles for aging neutrophils, and also with a program that endows circulating neutrophils with distinct phenotypic and functional properties at different times of the day, before they are cleared from blood. We review here the process of neutrophil aging and its impact on homeostasis and inflammation. We outline the features of aged neutrophils, examine proposed mechanisms that drive aging, and discuss how these processes may contribute to tissue homeostasis and pathology. In this context we propose that neutrophil aging may optimize host defense by allowing neutrophils to anticipate infections while avoiding permanent activation and subsequent damage.

Introduction

Trends

Acute inflammatory syndromes, as well as other types of disease, show circadian patterns of manifestation that parallel changes in the number of circulating leukocytes.

Neutrophils are the most abundant myeloid cells in blood, and their numbers follow circadian patterns of release and clearance.

Neutrophils undergo phenotypic changes from the time they are released into blood (fresh neutrophils) to the time they disappear from the circulation (aged neutrophils). This phenotypic drift, which occurs within a single day, is referred to

frontiers in Physiology

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Check fo updates

Neutrophil: A Cell with Many Roles in Inflammation or Several Cell Types?

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OPEN ACCESS

Edited by:
Giovanni Li Volti,
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Neutrophils are the most abundant leukocytes in the circulation, and have been regarde as first line of defense in the innate arm of the immune system. They capture an destroy invading microorganisms, through phagocytosis and intracellular degradatior release of granules, and formation of neutrophil extracellular traps after detectin pathogens. Neutrophils also participate as mediators of inflammation. The classic view for these leukocytes is that neutrophils constitute a homogenous population c terminally differentiated cells with a unique function. However, evidence accumulate in recent years, has revealed that neutrophils present a large phenotypic heterogeneit and functional versatility, which place neutrophils as important modulators of bot inflammation and immune responses. Indeed, the roles played by neutrophils i homeostatic conditions as well as in pathological inflammation and immune processe are the focus of a renovated interest in neutrophil biology. In this review, I present th concept of neutrophil phenotypic and functional heterogeneity and describe sever neutrophil subpopulations reported to date. I also discuss the role these subpopulation seem to play in homeostasis and disease.

Inflammation causes the bone marrow to release immature and incompetent neutrophils

Leliefeld *et al. Critical Care* (2016) 20:73
DOI 10.1186/s13054-016-1250-4

Critical Care

REVIEW **Open Access**

CrossMark

The role of neutrophils in immune dysfunction during severe inflammation

Pieter H. C. Leliefeld[1,3*], Catharina M. Wessels[1], Luke P. H. Leenen[1], Leo Koenderman[2,3] and Janesh Pillay[3,4]

Abstract

Critically ill post-surgical, post-trauma and/or septic patients are characterised by severe inf
response consists of both a pro- and an anti-inflammatory component. The pro-inflam
contributes to (multiple) organ failure whereas occurrence of immune paralysis predisp
Strikingly, infectious complications arise in these patients despite the presence of a cle
propose that dysfunction of neutrophils potentially increases the susceptibility to infectior
inability to clear existing infections. Under homeostatic conditions these effector cells of t
system circulate in a quiescent state and serve as the first line of defence against invading
inflammation, however, neutrophils are rapidly activated, which affects their functional capaci
phagocytosis, intra-cellular killing, NETosis, and their capacity to modulate adaptive immunity.
overview of the current understanding of neutrophil dysfunction in severe inflammation. We
mechanisms of downregulation of anti-microbial function, suppression of adaptive immunity
contribution of neutrophil subsets to immune paralysis.

Zonneveld *et al. Critical Care* (2016) 20:235
DOI 10.1186/s13054-016-1391-5

Critical Care

LETTER **Open Access**

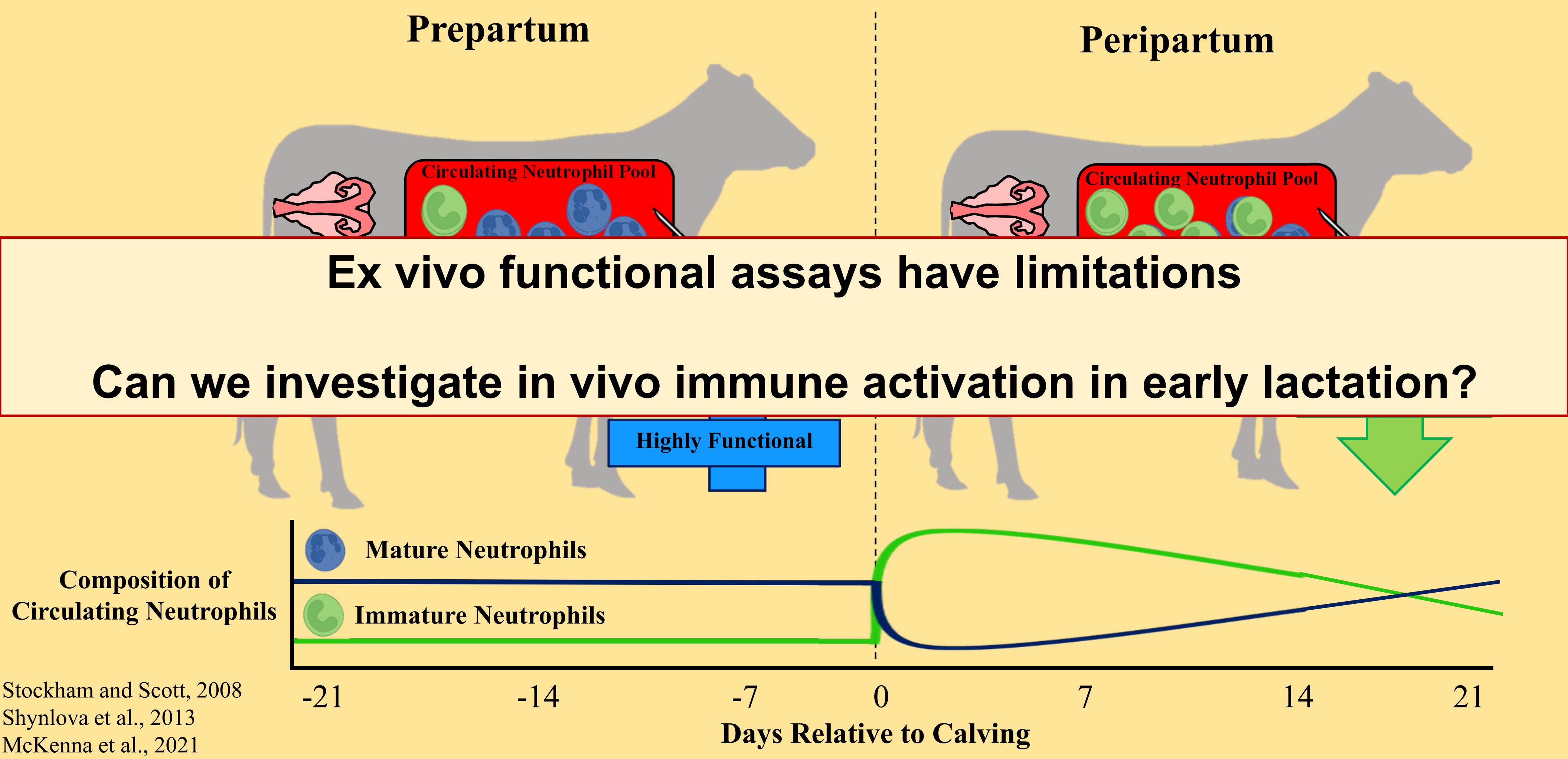
CrossMark

Measurement of functional and morphodynamic neutrophil phenotypes in systemic inflammation and sepsis

Rens Zonneveld[1,2,3*], G. Molema[2] and Frans B. Plötz[3]

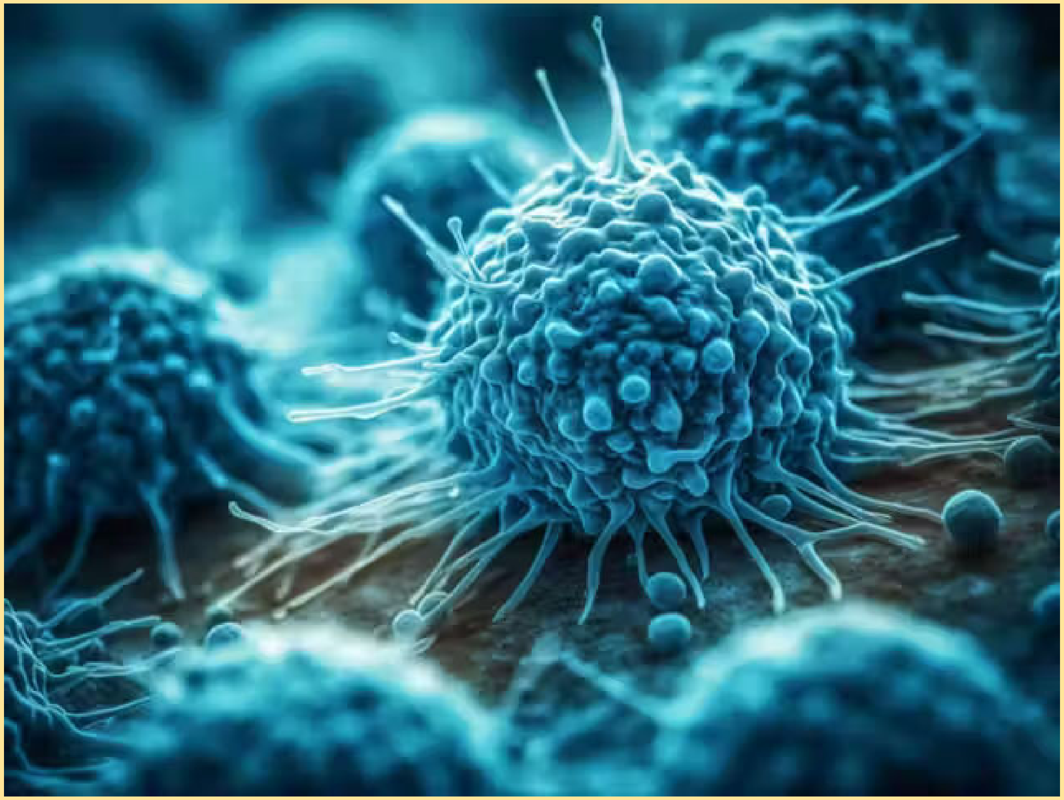
See related research by Leliefeld et al., http://ccforum.biomedcentral.com/articles/10.1186/s13054-016-1250-4.

Altered leukocyte dynamics



Stockham and Scott, 2008
Shynlova et al., 2013
McKenna et al., 2021

How To Study Periparturient Immune Competence?



https://theconversation.com/immune-cells-can-adapt-to-invading-pathogens-deciding-whether-to-fight-now-or-prepare-for-the-next-battle-223523

Modeling immune activation in transition cows

- Reasons to use mid-lactation cows:
  - Consistent milk yield and feed intake
  - Broader cow selection pool
  - Less variability in physiologic, metabolic, and inflammatory responses

- Obvious limitations exist:
  - The early lactation metabolic milieu is difficult to replicate
  - The periparturient immune status starkly contrasts with mid-lactation cows
  - The mammary gland's evolutionary drive to synthesize milk wanes over time

Modeling immune activation in transition cows

J. Dairy Sci. 97:330–339
http://dx.doi.org/10.3168/jds.2013-7222

Induced hyperketonemia affects the mammary immune response during lipopolysaccharide challenge in dairy cows

Connecting Metabolism to Mastitis: Hyperketonemia Impaired Mammary Gland Defenses During a *Streptococcus uberis* Challenge in

Immune activation models often attempt to characterize periparturient cow physiology… utilizing **mid-lactation cows**

Evaluating acute inflammation's effects on hepatic triglyceride content in experimentally induced hyperlipidemic dairy cows in late lactation

E. A. Horst,[1] L. M. van den Brink,[1] E. J. Mayorga,[1] M. Al-Qaisi,[1] S. Rodriguez-Jimenez,[1] B. M. Goetz,[1] M. A. Abeyta,[1] S. K. Kvidera,[1] L. S. Caixeta,[2] R. P. Rhoads,[3] and L. H. Baumgard[1]*
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[3]Department of Animal and Poultry Sciences, Virginia Tech University, Blacksburg 24061

J. Dairy Sci. 95
http://dx.doi.or

Local and systemic response to intramammary lipopolysaccharide challenge during long-term manipulated plasma glucose and insulin concentrations in dairy cows

M. C. M. B. Vernay, O. Wellnitz, L. Kreipe, H. A. van Dorland, and R. M. Bruckmaier[1]
Veterinary Physiology, Vetsuisse Faculty University of Bern, Bremgartenstrasse 109a, CH-3001 Bern, Switzerland

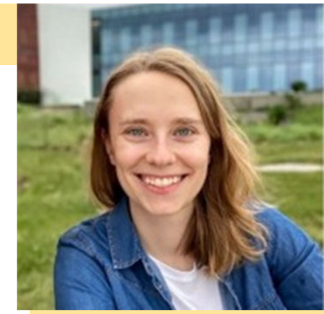
Effect of Lipopolysaccharide on Indices of Peripheral and Hepatic Metabolism in Lactating Cows[1]

M. R. Waldron,* T. Nishida,* B. J. Nonnecke,† and T. R. Overton*
*Department of Animal Science, Cornell University, Ithaca 14853 and
†National Animal Disease Center, USDA, ARS, Ames, IA 50010

J. Dairy Sci. 103
https://doi.org/10.3168/jds.2020-18268

Effects of maintaining eucalcemia following immunoactivation in lactating Holstein dairy cows

E. A. Horst, E. J. Mayorga, M. Al-Qaisi, M. A. Abeyta, S. L. Portner, C. S. McCarthy, B. M. Goetz, S. K. Kvidera, and L. H. Baumgard*
Department of Animal Science, Iowa State University, Ames 50011



J. Dairy Sci. 107:6225–6239
https://doi.org/10.3168/jds.2023-24350

Intravenous lipopolysaccharide challenge in early- versus mid-lactation dairy cattle. I: The immune and inflammatory responses

J. Opgenorth,[1] E. J. Mayorga,[1] M. A. Abeyta,[1] B. M. Goetz,[1] S. Rodriguez-Jimenez,[1] A. D. Freestone,[1] J. L. McGill,[2] and L. H. Baumgard[1]*
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Objecti

id-

lactation dairy cows

J. Dairy Sci. 107:6240–6251
https://doi.org/10.3168/jds.2023-24351

Intravenous lipopolysaccharide challenge in early- versus mid-lactation dairy cattle. II: The production and metabolic responses

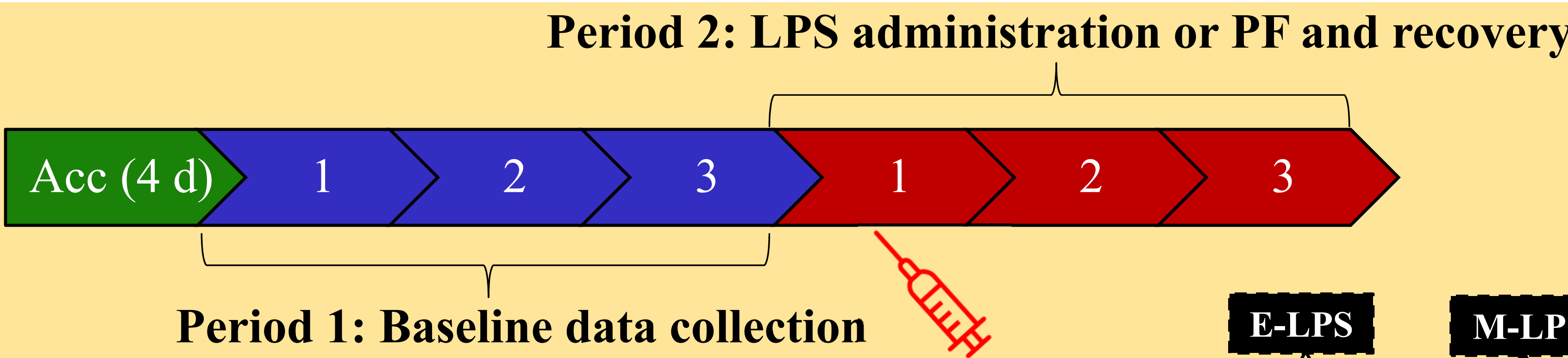
J. Opgenorth, E. J. Mayorga, M. A. Abeyta, S. Rodriguez-Jimenez, B. M. Goetz, A. D. Freestone, and L. H. Baumgard*
Department of Animal Science, Iowa State University, Ames, IA 50011

Hypoth

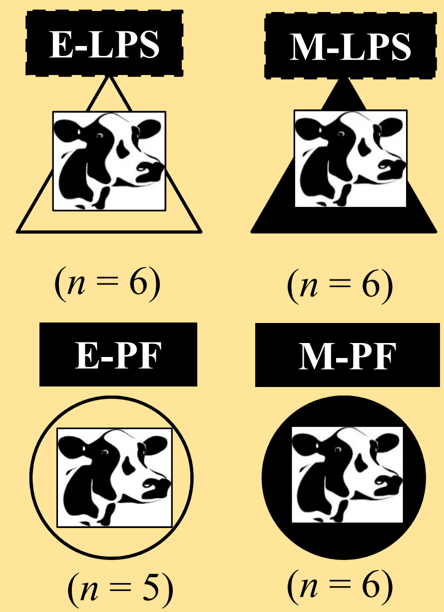
mmune

and inflammatory response towards LPS

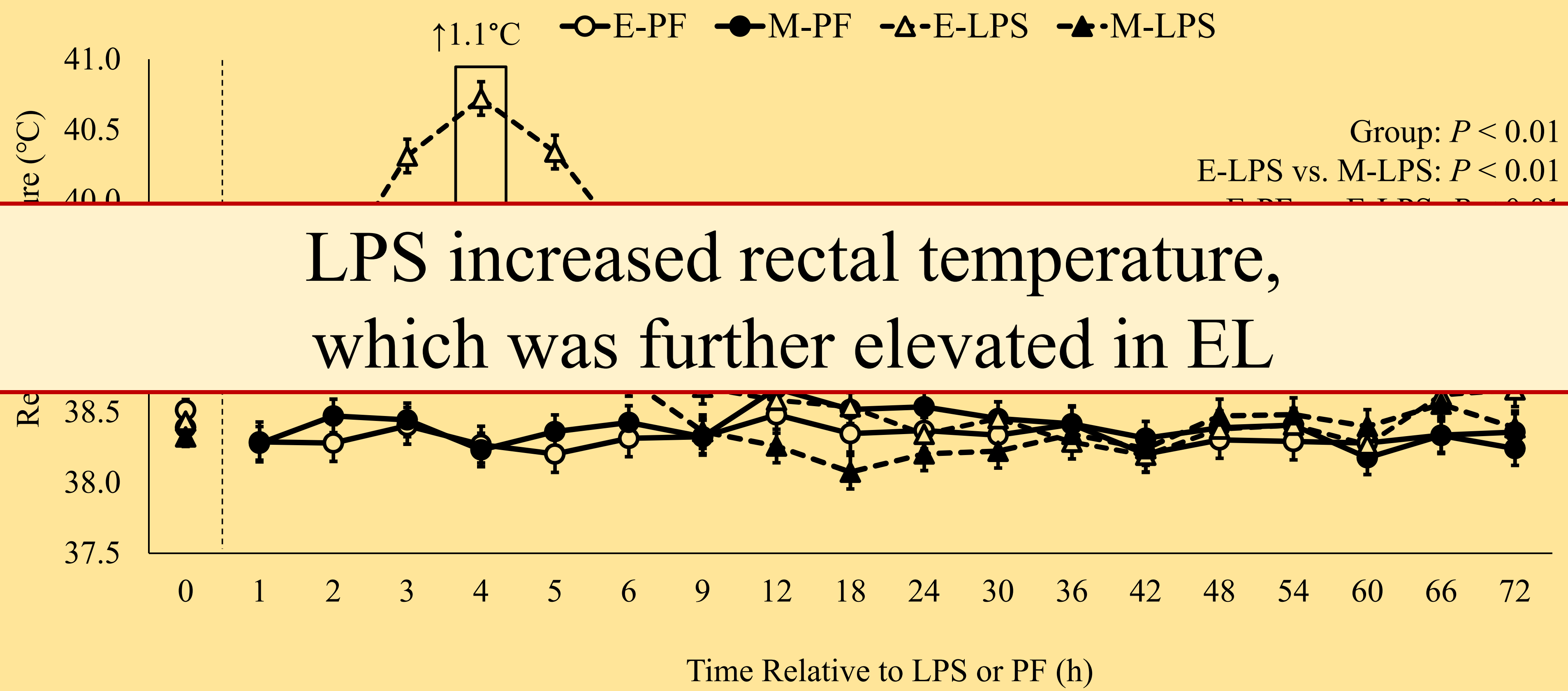
Experimental schematic



- 23 multiparous Holstein cows in 2 replicates
  - EL: 20 ± 2 DIM (n = 11)
  - ML: 131 ± 31 DIM (n = 12)
- Treatments administered at beginning of P2
  - LPS: lipopolysaccharide *Escherichia coli* O55:B5 (0.09 µg/kg BW)
  - PF: sterile saline and pair-fed relative to LPS counterparts
- 2 × 2 factorial
  - Group: LPS or PF
  - LS: EL or ML

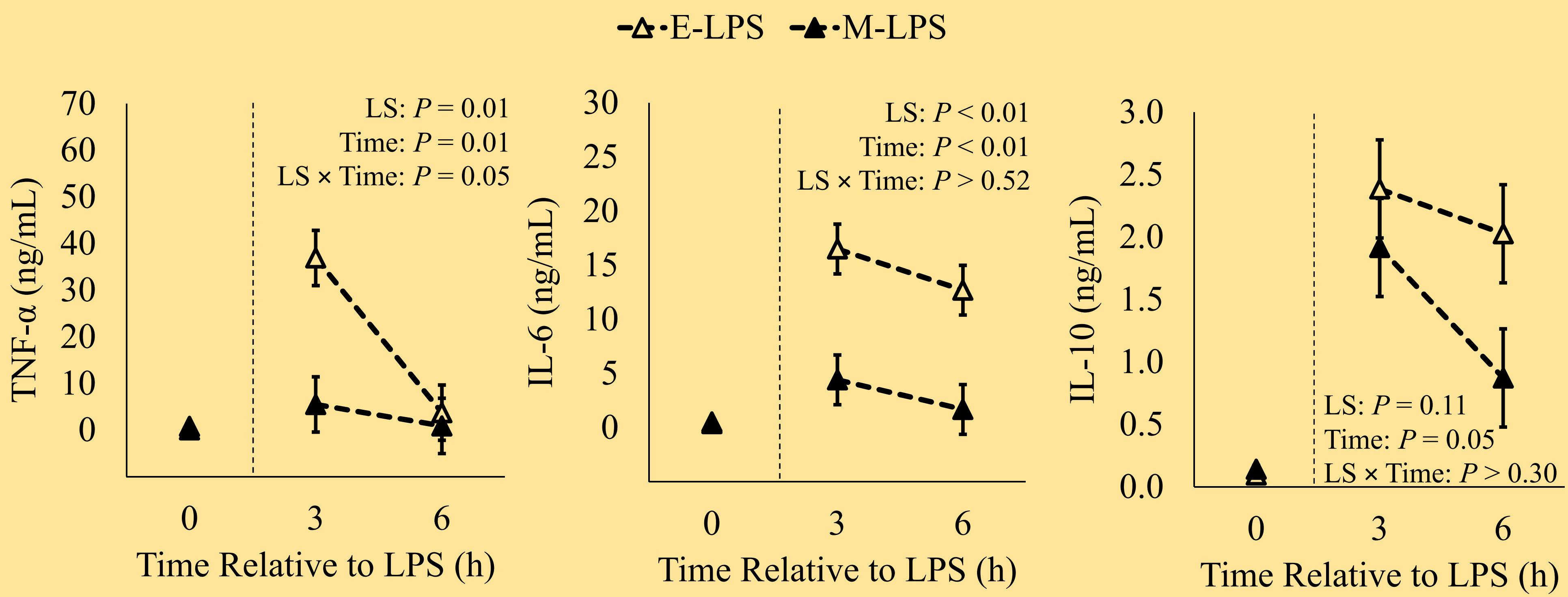


Febrile response



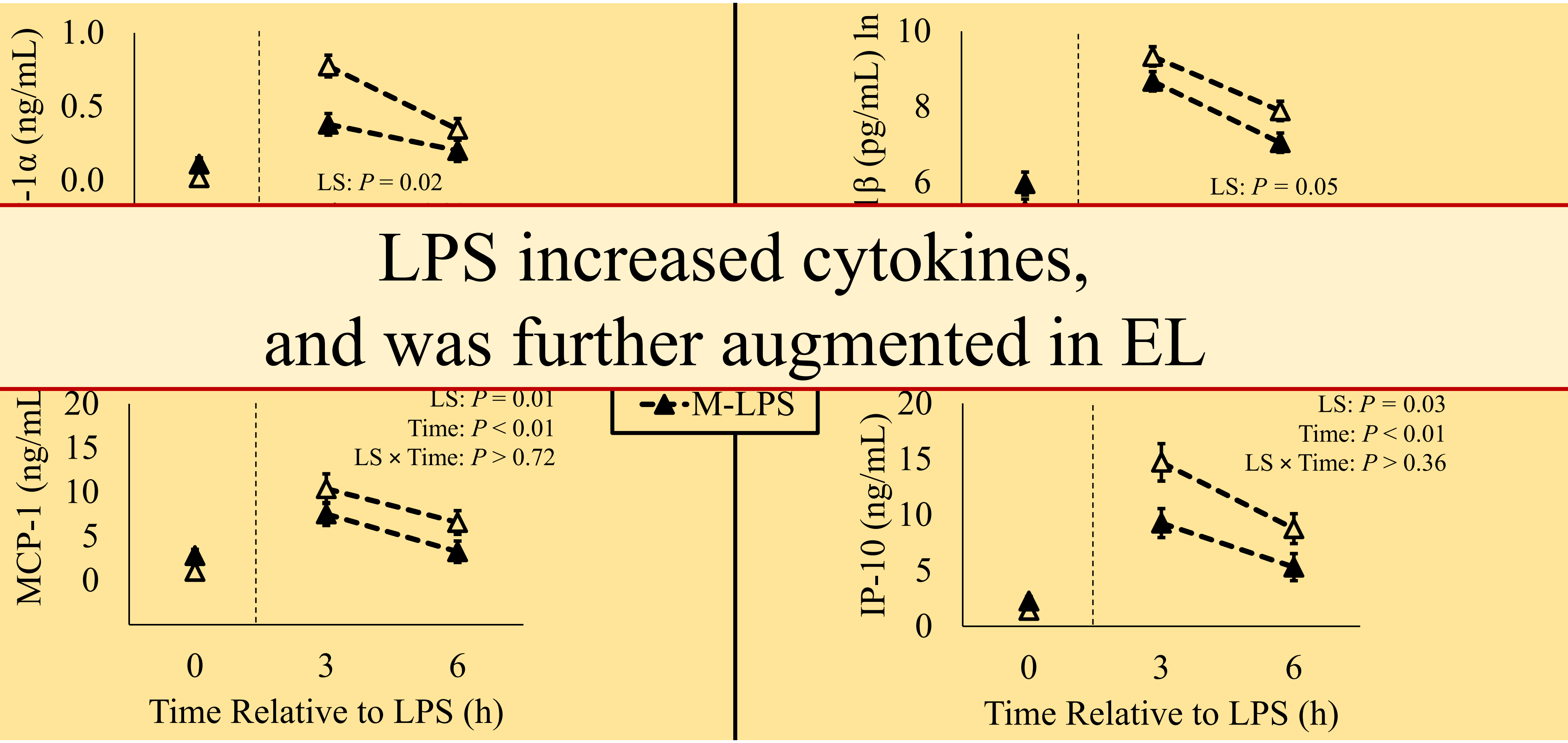
LPS increased rectal temperature, which was further elevated in EL

Cytokines



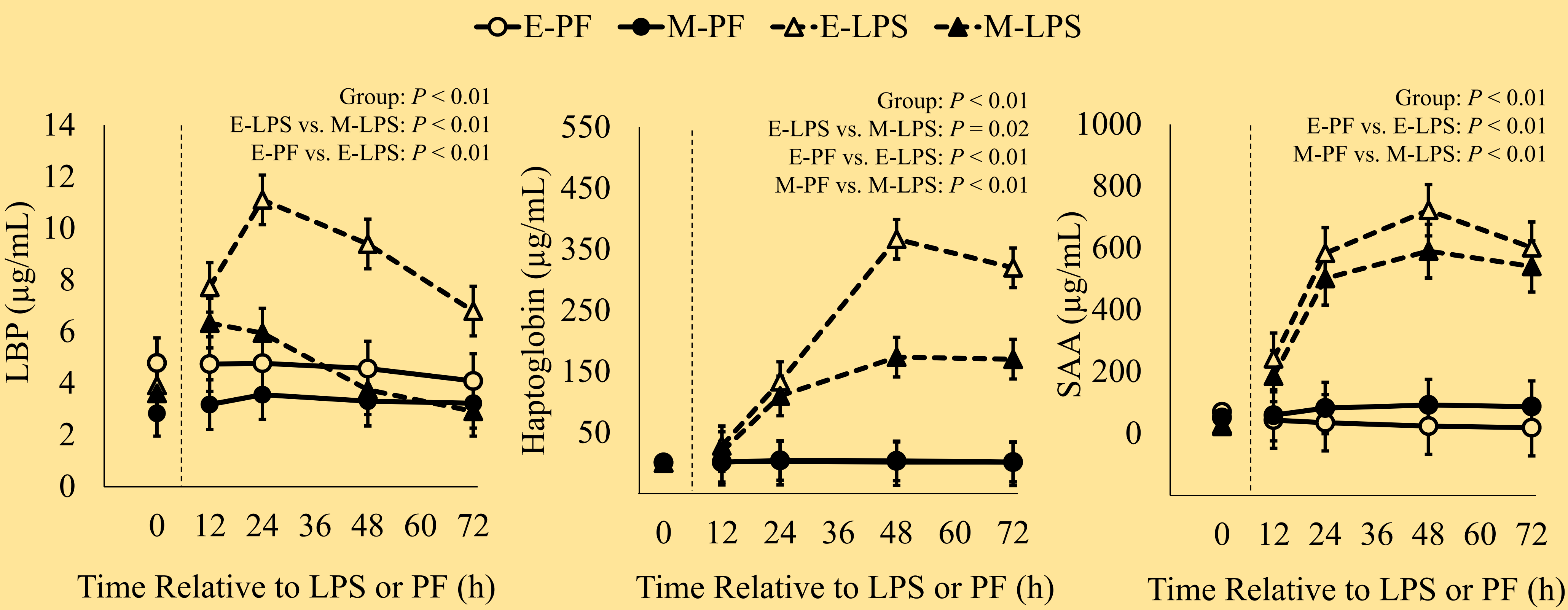
E-LPS
M-LPS
TNF-α (ng/mL)
70
60
50
40
30
20
10
0
LS: P = 0.01
Time: P = 0.01
LS × Time: P = 0.05
0
3
6
Time Relative to LPS (h)
IL-6 (ng/mL)
30
25
20
15
10
5
0
LS: P < 0.01
Time: P < 0.01
LS × Time: P > 0.52
0
3
6
Time Relative to LPS (h)
IL-10 (ng/mL)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
LS: P = 0.11
Time: P = 0.05
LS × Time: P > 0.30
0
3
6
Time Relative to LPS (h)

Chemotactic cytokines

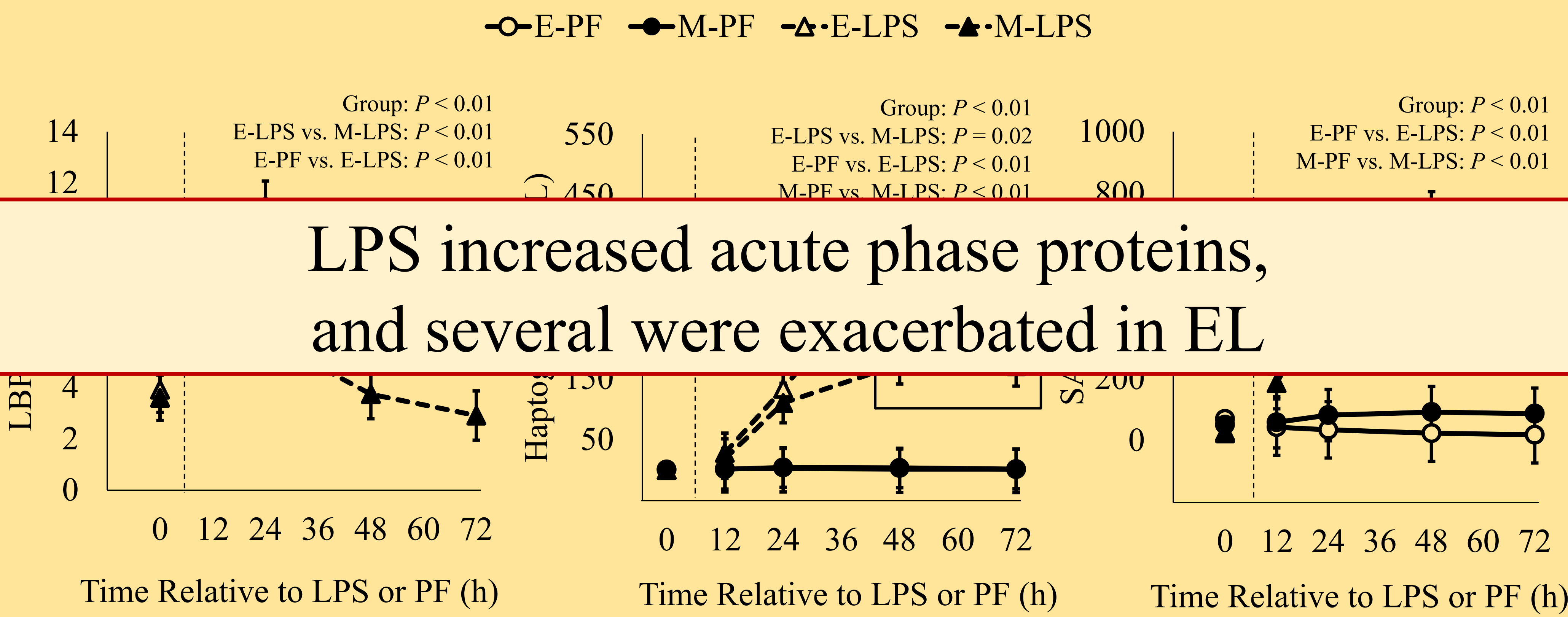


LPS increased cytokines,
and was further augmented in EL

Acute phase proteins

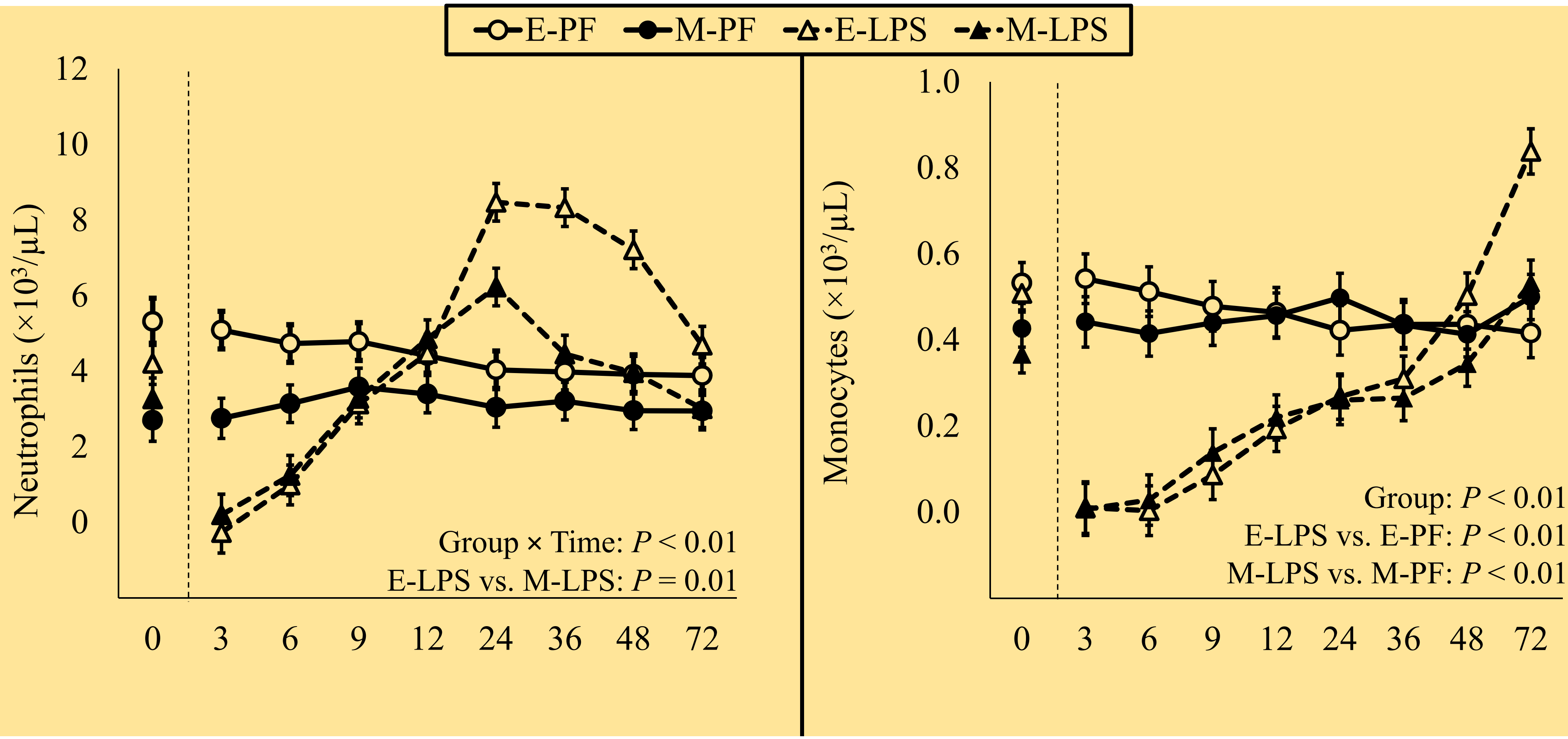


Acute phase proteins

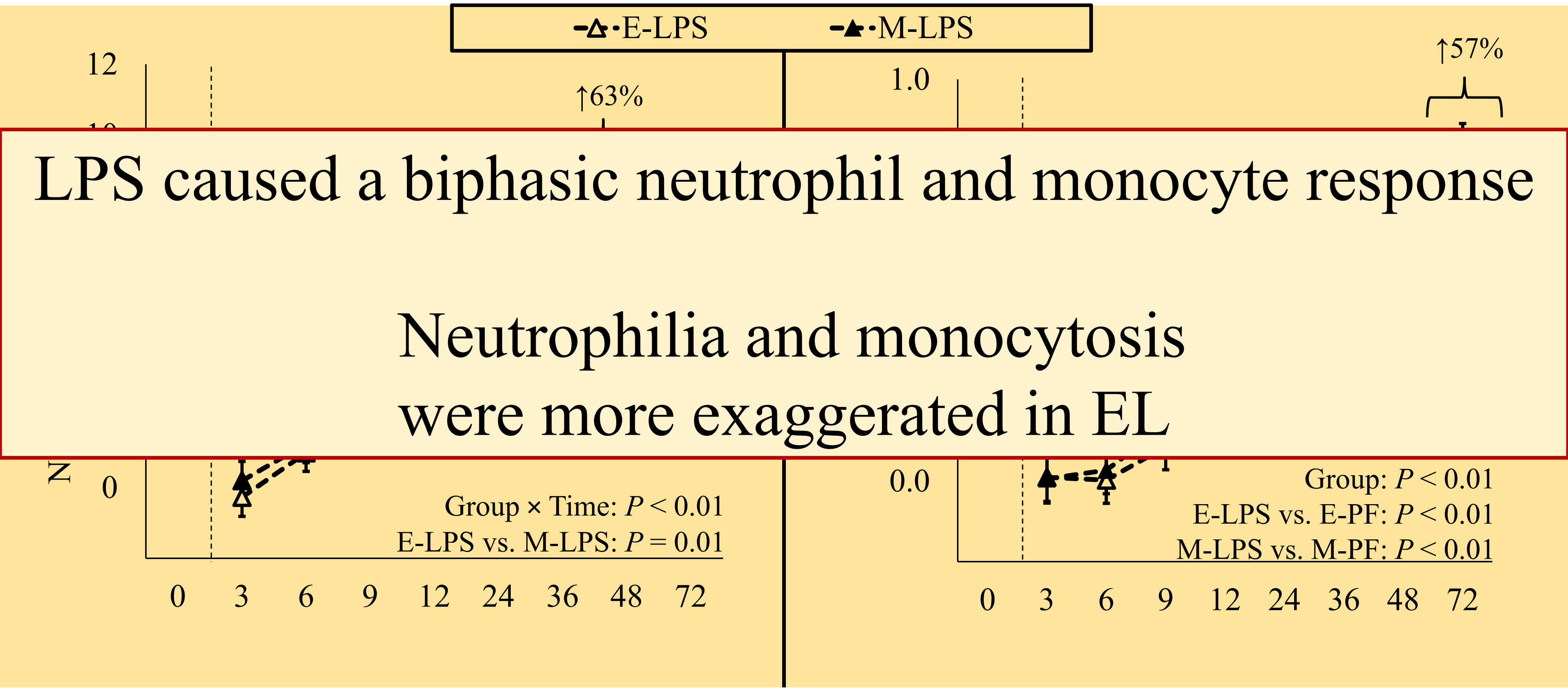


LPS increased acute phase proteins, and several were exacerbated in EL

Complete cell blood count



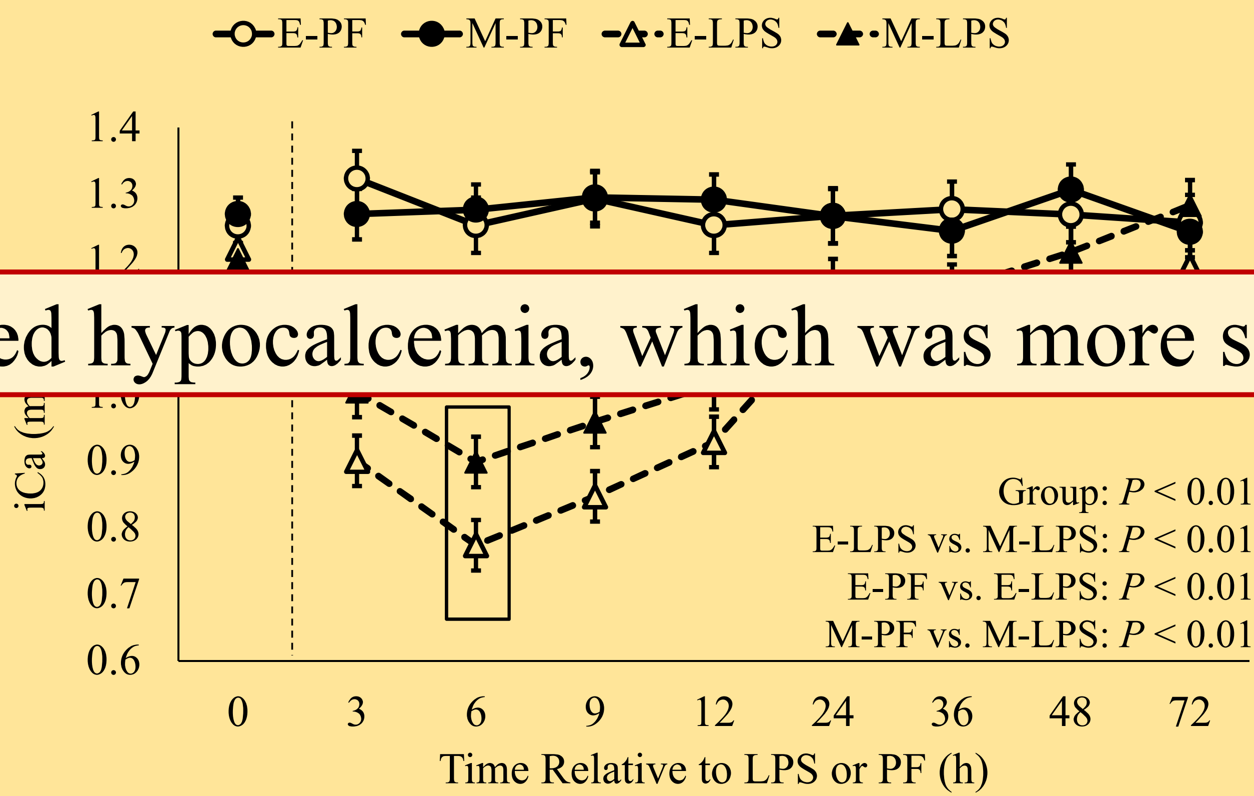
Complete cell blood count



LPS caused a biphasic neutrophil and monocyte response

Neutrophilia and monocytosis
were more exaggerated in EL

Ionized calcium



LPS caused hypocalcemia, which was more severe in EL

Immune Activation/Inflammation Summary

- LPS:
  - Increased fever, cytokines, and acute phase proteins
  - Caused neutrophilia and monocytosis
  - Decreased ionized Ca
- …which were further augmented in EL

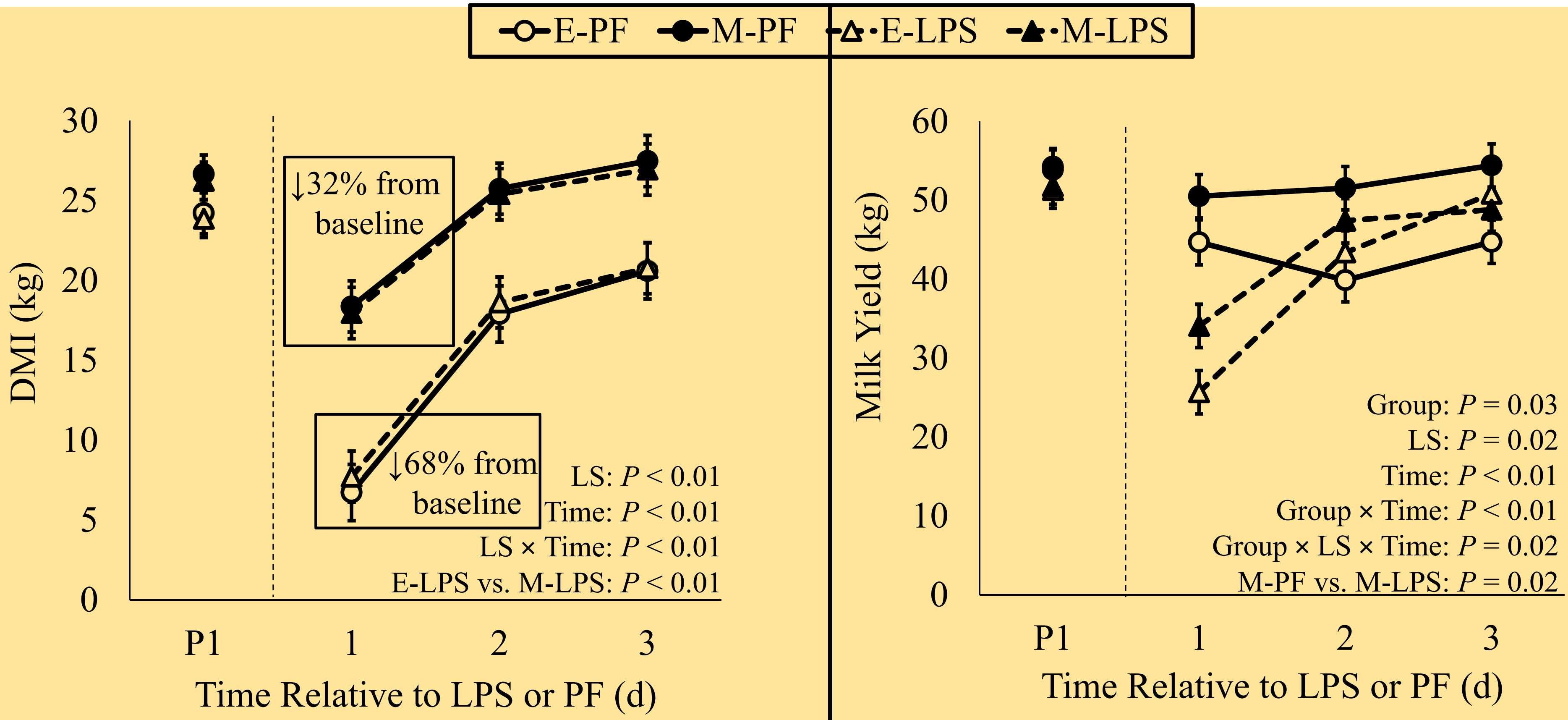
Our hypothesis could not have been more wrong

EL cows were *not* more LPS tolerant…

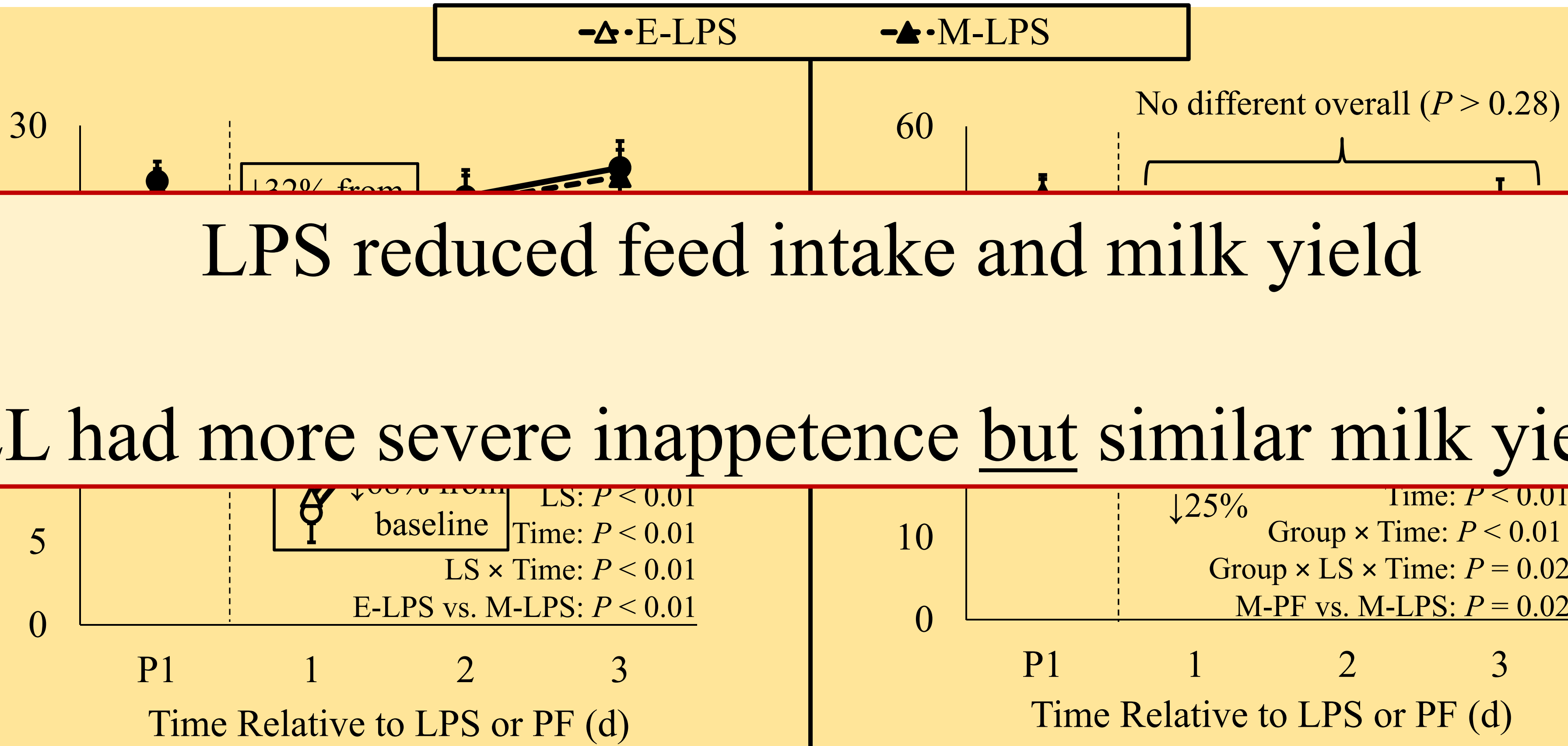
Some aspects of EL immunity are incredibly robust

Early vs. Late Lactation Production and Metabolism Responses to Immune Activation

Feed intake and production



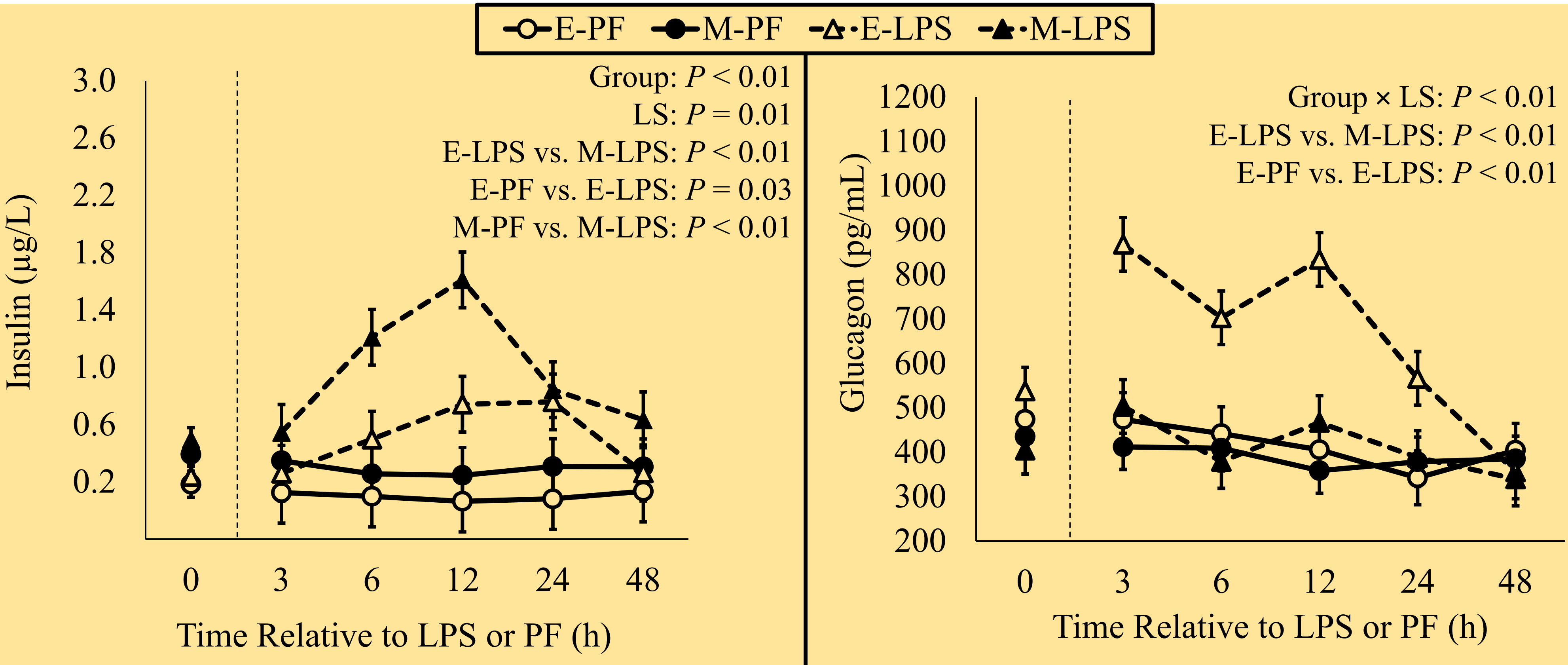
Feed intake and production



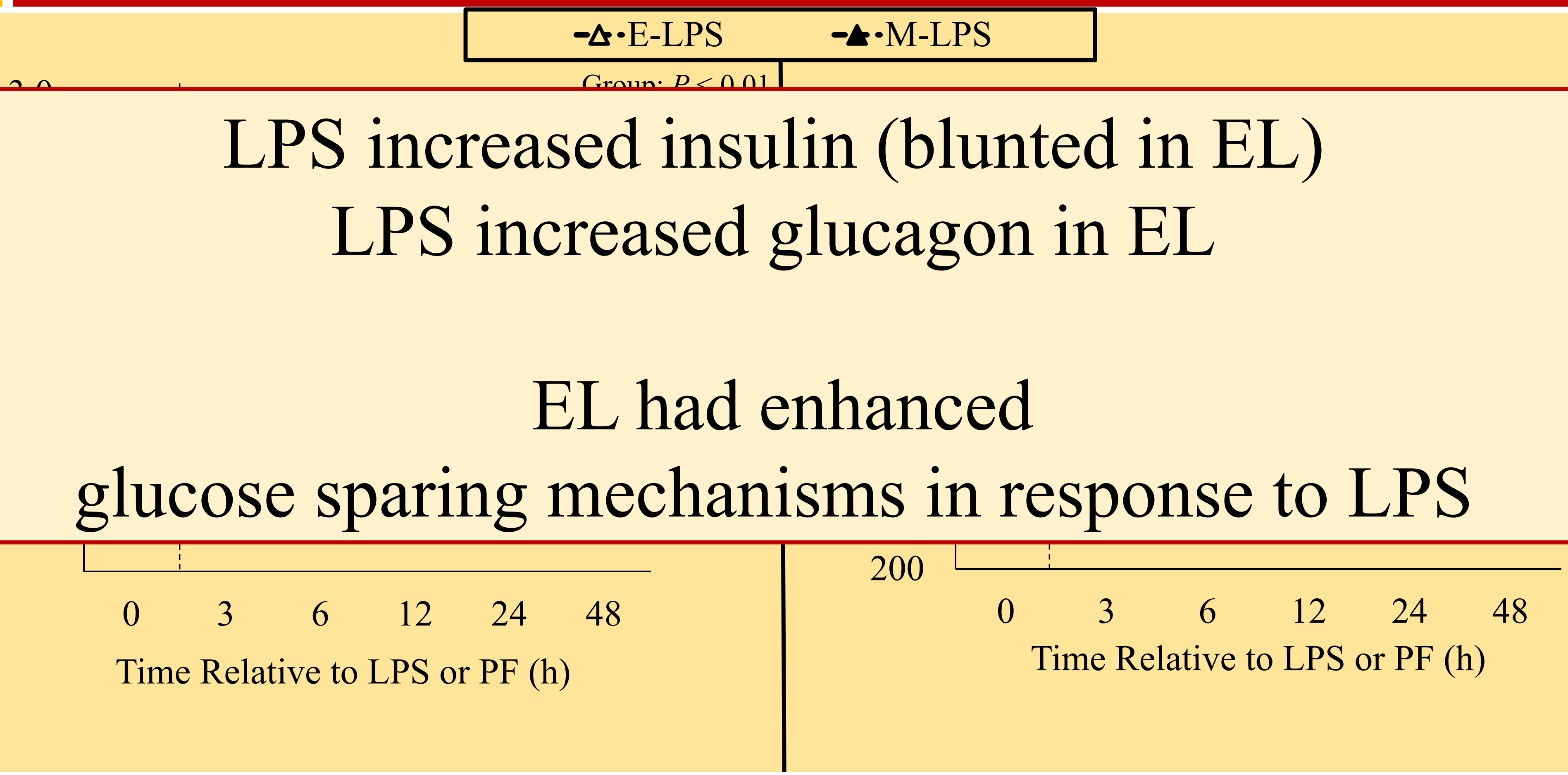
LPS reduced feed intake and milk yield

EL had more severe inappetence <u>but</u> similar milk yield

Metabolic hormones



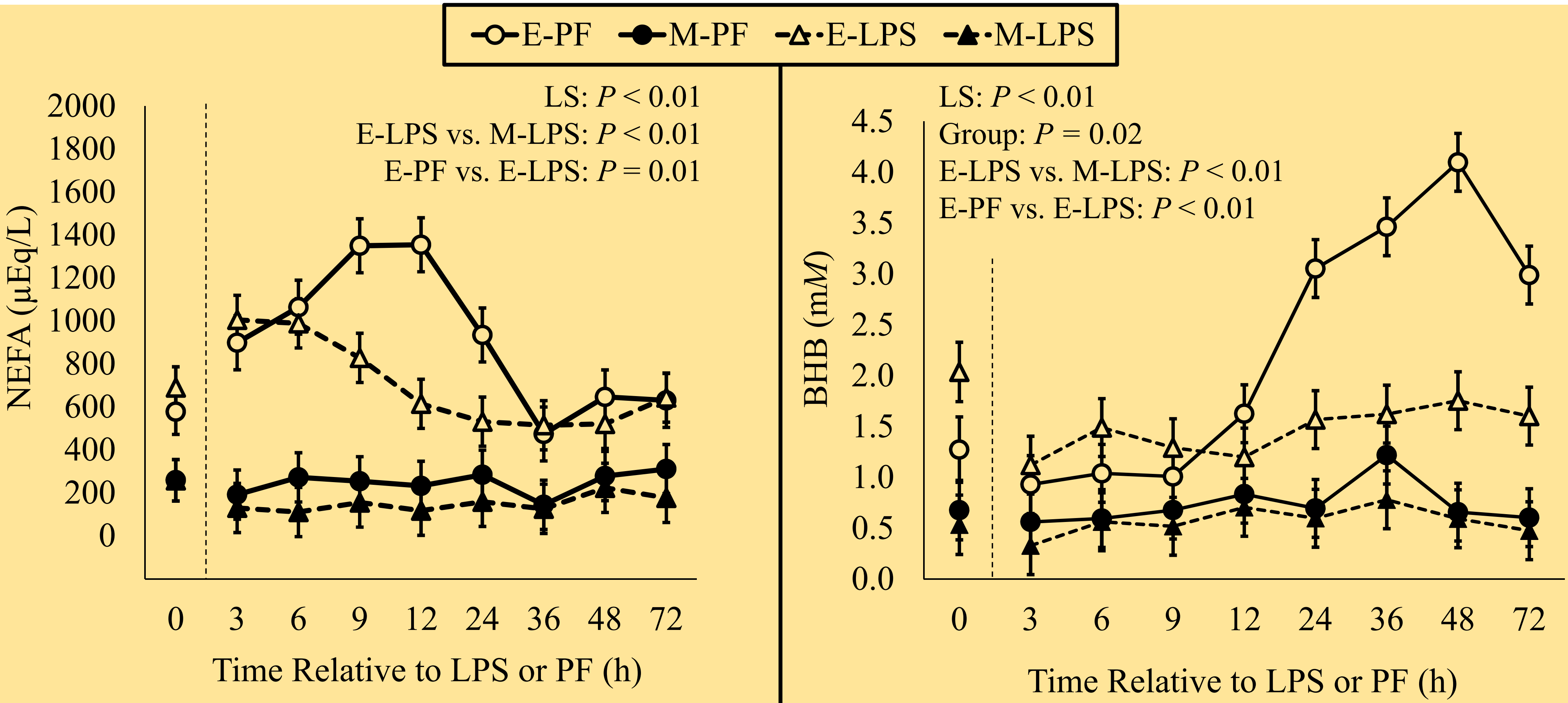
Metabolic hormones



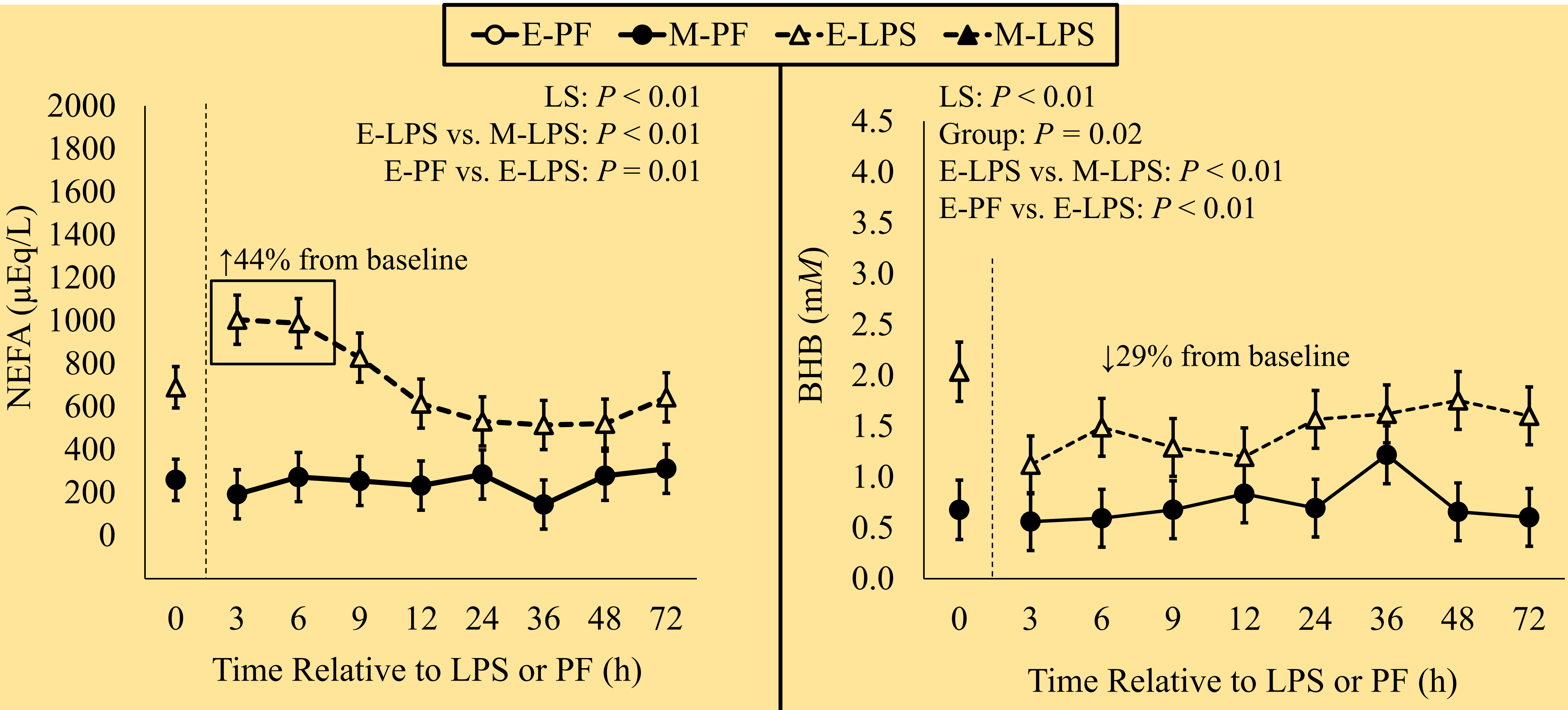
LPS increased insulin (blunted in EL)
LPS increased glucagon in EL

EL had enhanced
glucose sparing mechanisms in response to LPS

Auxiliary fuels



Auxiliary fuels



Metabolism Summary

- LPS:
  - Decreased feed intake and milk yield

Despite more severe hypophagia in EL, milk yield response did not differ from ML cows... Reflected by metabolic alterations favoring glucose sparing and catabolism

Does a mammary LPS challenge recapitulate the i.v. LPS challenge?

Obj

J. Dairy Sci. 107:6252–6267
https://doi.org/10.3168/jds.2023-24488

Every metric we evaluated in the mastitis model was almost identical to the I.V. LPS approach

Peripartурient Cows Do Not Appear Immune Suppressed

Hyp

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, but have similar milk yield; reflected by enhanced metabolic flexibility

Immune Activation: Early vs. Mid Lactation Cow

Parameter	Early-Lactation Cow	Mid-lactation Cow
Febrile Response	↑↑↑	↑
Inflammatory/Chemotactic Cytokines	↑↑↑	↑
Leukocytosis	↑↑↑	↑
Acute Phase Proteins	↑↑↑	↑
Ionized Calcium	↓↓↓	↓
Insulin	↑	↑↑↑
Glucagon	↑↑↑	↑
NEFA	↑↑↑	↓
BHB	↔	↓
BUN (muscle mobilization)	↑↑↑	↑
Dry Matter Intake	↓↓↓	↓
Milk Yield	↓	↓

Severe
Moderate
↔ No change

Is there anyone on the planet that agrees with us?

Veterinary Microbiology 298 (2024) 110201

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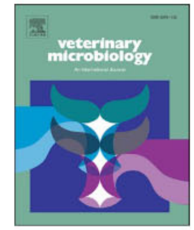

Mucosal immune responses in peri-parturient dairy cattle

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[c] *Department of Animal Sciences, Colorado State University, Fort Collins, CO 80523, USA*
[d] *Zoetis, Inc. Parsippany, NJ, USA*

“Contrary to previous reports of systemic immune-suppression, bovine mucosal responses appear to be intact during the peripartum period”

“The increases in local IFN-beta in the pre-partum period, and the IgA in the post-partum, despite published evidence of decreased systemic immune responsiveness during the same time frame (Heiser et al., 2015), provides support for further research to confirm whether there is an upregulation of mucosal immunity during the peripartum period.”

J. Dairy Sci. 109:856–868
https://doi.org/10.3168/jds
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Metabolic and functional c
during the periparturient p

T. Fernandez-Wallace,[1] U. Arshad,[1]
F. Sosa,[1] F. Peñagaricano,[1] R. E. S
[1]Department of Animal and Dairy Sciences, Unive
[2]Ruminant Diseases and Immunology Research U

ABSTRACT

The periparturient period in dairy cows is marked by major metabolic and physiological changes that increase disease susceptibility and challenge immune function. However, the function of T helper ($CD4^+$) cells across the periparturient period remains poorly understood. This study evaluated the in vitro metabolic function, proliferation capacity and phenotype of T helper cells across the periparturient period. Multiparous Holstein cows (n = 22) having mean ± SD lactation of 4.16 ± 1.34 were sampled at −28, +3, and +28 d relative to calving. Peripheral blood mononuclear cells were isolated and T helper cells were obtained using magnetic sorting. A Seahorse XF HS Mini analyzer was used to assess the metabolic function through a T cell metabolic persistence assay, measuring glycolysis and oxidative phosphorylation via extracellular acidification and oxygen consumption rates respectively. Cells were treated either with assay medium (nonactivated) or phorbol 12-myristate 13-acetate and ionomycin (activated) for metabolic measurements, as this combination induces rapid, receptor-independent activation. For proliferation capacity, isolated T helper cells were incubated with concanavalin A, as it provides sustained stimulation to assess clonal expansion, for 72h and tracked using cell trace in a flow cytometer. Cytokine production was measured in the cell culture supernatant using a MILLIPLEX Bovine Cytokine/Chemokine kit. RNA was extracted from isolated cells, and gene expression of immune-related and metabolic markers were evaluated by quantitative PCR. Data were analyzed using a linear mixed effect model in R 4.4.3 using day relative to calving, activation status and block as fixed effect and cow as a random effect. When properly, time of the assay and its interaction with day relative to calving was included as a fixed effect. Activated T helper cells showed greater glycolytic and oxidative metabolism at +3 and +28 d compared with −28. Expansion index was highest at +3 (2.65), followed by +28 (2.38) and −28 (1.91). Proinflammatory cytokine production, like IL-1 α, IL-1 β and IL-6 also increased during +3 and +28 compared with −28. However, no significant differences in gene expression were detected across time points. These findings suggest that T helper cell metabolism and proliferation capacity are upregulated after calving and that these cells express a more proinflammatory phenotype, indicating that after parturition, immune function on this subset of cells does not appear to be suppressed.

Key words: immune function, metabolism, T cells, transition cow

INTRODUCTION

The periparturient period in dairy cows spans approximately 3 wk before to 3 wk after calving and represents one of the most critical stages of lactation because of its profound impact on health and future performance (Drackley, 1999). At the onset of lactation, dairy cows face a steep rise in nutrient demands while feed intake lags behind, resulting in a marked nutrient deficit. The transition to lactation involves tightly coordinated metabolic, physiological, and hormonal adaptations that redirect resources toward milk synthesis and can restrict the availability of nutrients and circulating metabolites for other physiological processes (Bauman and Bruce Currie, 1980; Abuelo et al., 2023) and may affect the immune function. For instance, glucose is not only essential for milk lactose synthesis but also for sustaining the proliferation, survival, and function of immune cells (Sordillo and Raphael, 2013). Under periparturient conditions, immune cells may be forced to function in a resource-limited environment, influencing their functionality. Reflecting this metabolic strain, an estimated 30% to 50% of cows in a herd experience one or more pe-

Transition Cow "Immune Suppression"

- Almost every immune system variable we measured was more robust in early lactation compared to late lactation cows.
  - Albeit we did not measure the acquired immune system (U of WI did)
- Despite exaggerated immune response, early lactation cows prioritized milk synthesis
  - Energetic collision of priorities (immune system AND milk synthesis)
    - Hypoglycemia, high NEFA and Hyperketonemia
  - Late lactation cows just give up trying to make milk
- Maybe if it weren't for a super strong immune response morbidity would be even worse!
- If correct, what are the implications to dairy Vet-Med, nutrition and management?
- I am not suggesting that inflammation is innocuous
  - Efforts should be to limit the peak and hasten the resolution

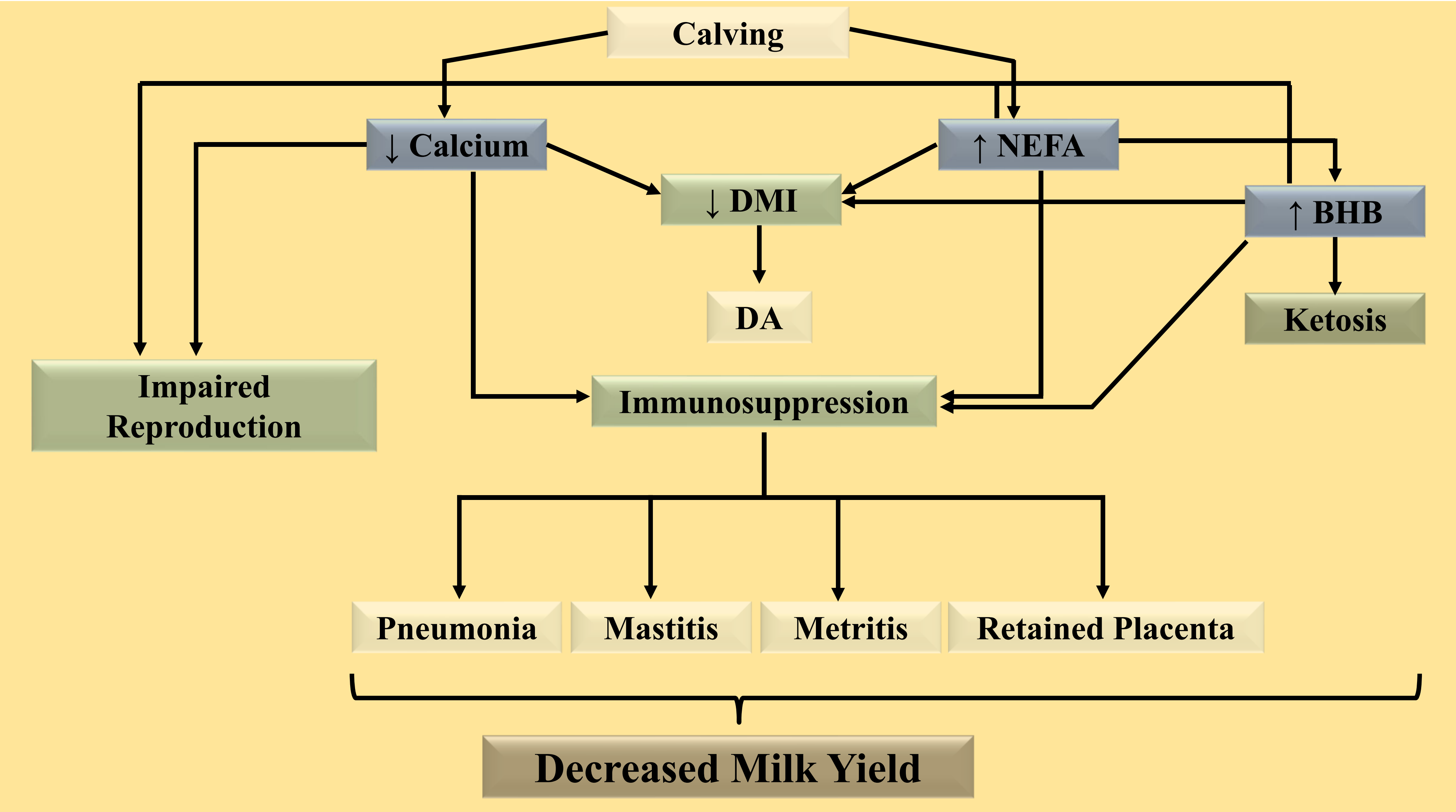
Practical on-farm Examples Which Supporting Our Thought Process

Done of these are supportive of immune suppression

- Imrestor™ (bovine granulocyte stimulating factor)
  - Increases circulating neutrophils
    - Should benefit an immune-suppressed transition cow
- Transition cows are less sensitive to high pathogenic avian bird flu
  - https://www.canr.msu.edu/news/hpai-dairy-herd-infection-case-report
  - https://www.cidrap.umn.edu/avian-influenza-bird-flu/avian-flu-detections-dairy-cows-raise-more-key-questions
  - https://wwwnc.cdc.gov/eid/article/30/7/24-0508_article
- Transition cows are less sensitive to heat stress (an immune activating event)
    - (Maust et al., 1972; Perera et al., 1986)
- Effects of anti-inflammatory (NSAIDs) administration to transition cows are highly inconsistent
    - (Horst et al., 2021)

Traditional Belief

Increased NEFA, Hyperketonemia, and Hypocalcemia…..**CAUSE** production and health problems



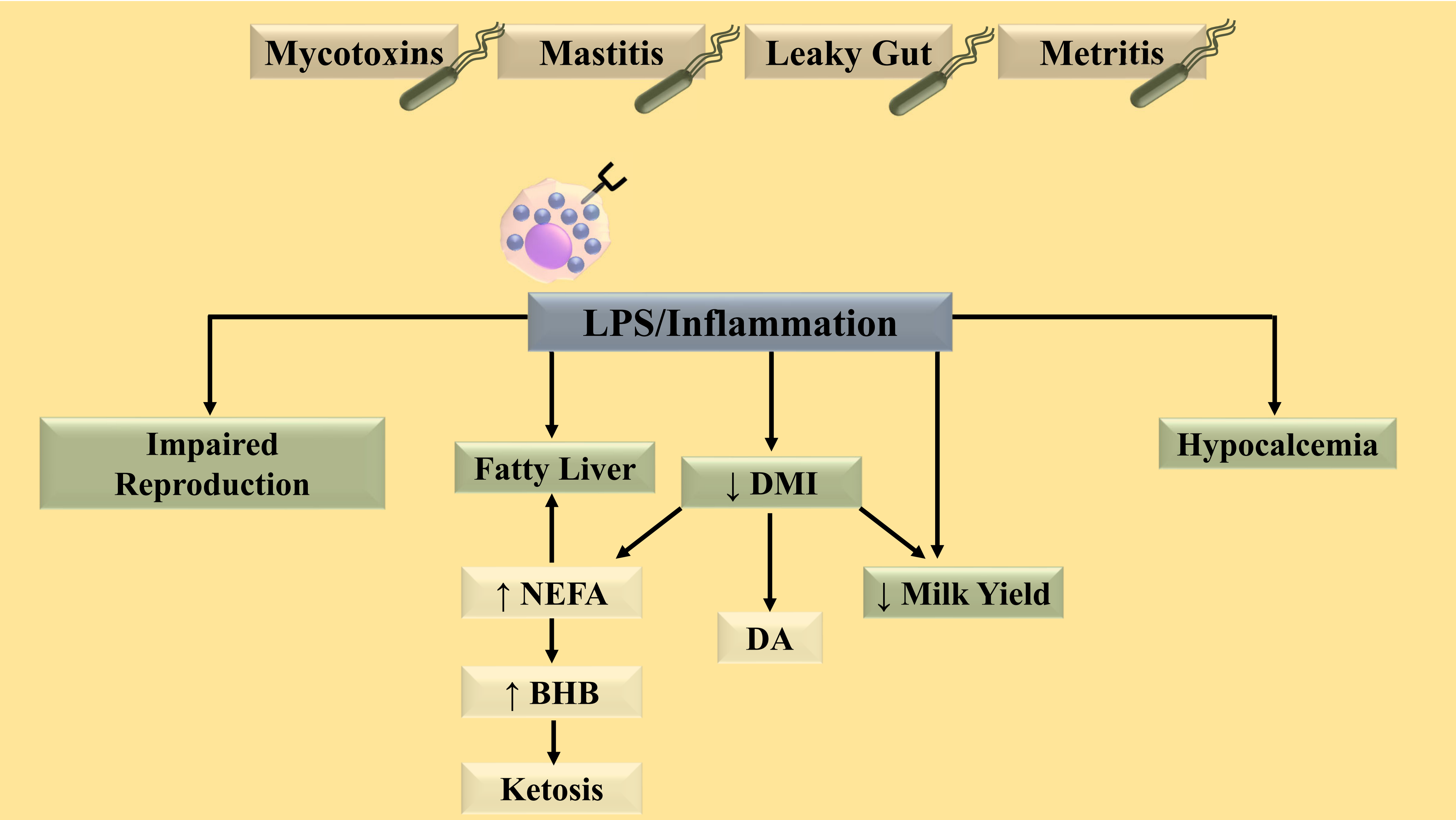
Calving
↓ Calcium
↑ NEFA
↓ DMI
↑ BHB
DA
Ketosis
Impaired Reproduction
Immunosuppression
Pneumonia
Mastitis
Metritis
Retained Placenta
Decreased Milk Yield

Paradigm Shifting Concept

Increased NEFA and Hyperketonemia are ca d

Low Feed Intake, high NEFA, Hyperketonemia and hypocalcemia are merely SYMPTOMS….a reflection of prior immune stimulation

Hypocalcemia is a consequence of immune activation


Mycotoxins
Mastitis
Leaky Gut
Metritis
LPS/Inflammation
Impaired Reproduction
Fatty Liver
↓ DMI
Hypocalcemia
↑ NEFA
DA
↓ Milk Yield
↑ BHB
Ketosis

Paradigm shift

- Immunosuppression is not evolutionarily advantageous

Periparturient "alterations" in the immune system are purposeful and reflect an animal that is in the midst of immune activation

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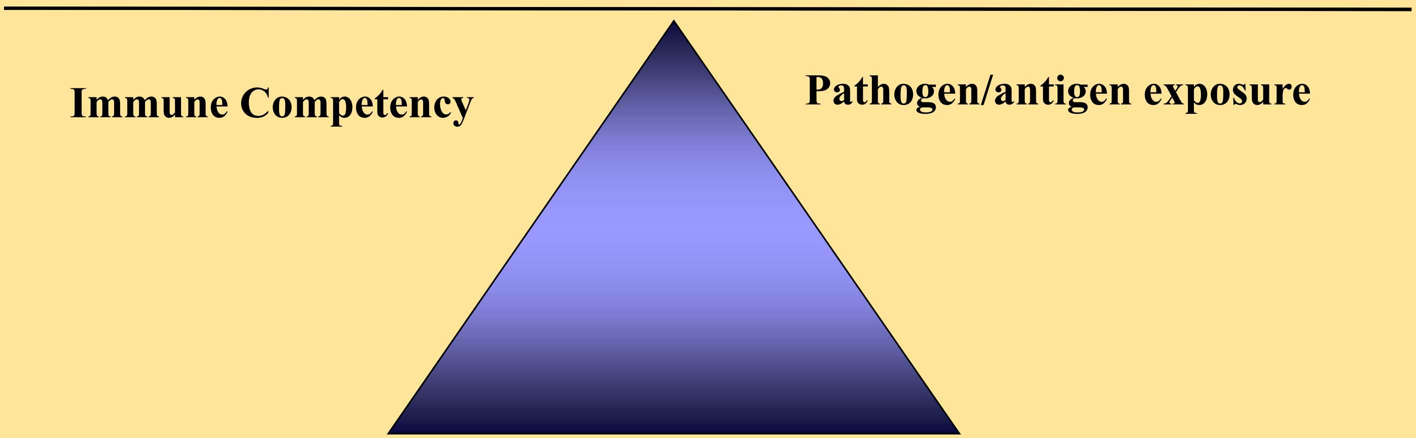
Take Home Message

- The periparturient cow does not appear immune suppressed, BUT she is at much greater risk of antigen exposure.

The increased epithelia pathogen exposure likely explains the morbidity

Immune Competency vs. Exposure



Dr. Bob Fry: Dairy Farmer, DVM and Practicing Nutritionist atlanticdairyconsulting.com

- Data from 3 herds
- 15 year's worth of data: >100,000 calvings
  - Metritis: 21.3% prior to management change

This does <u>not</u> support the immune suppression dogma.

It agrees with the idea that stress and pathogen load are responsible for increased periparturient morbidity

  - No change in nutrition strategy or immunization protocols

Presented with permission of Dr. Bob Fry
4-1-26

https://balchem.com/anh/podcasts-webinars/immunity-in-transition-cows/

Transition Cow NSAID Summary

↓ **Rumen Fermentation** [12]

[2]

The effects of anti-inflammatory agents are variable and sometimes negative

Mitigating Inflammation Strategies are in their Infancy, but are a promising approach

Aim should be to prevent immune activation in the first place
Management: hygiene, cleanliness, nutrition, etc.

meloxicam vs carpofen?

- **Dose**
- **Timing/frequency of administration?**

= [1,5,6,8,9,11,15,18,20]

et al., 2007
et al., 2017
[3]Shock et al., 2018
[4]Carpenter et al., 2016
[5]Meier et al., 2014
[6]Priest et al., 2013
[7]Bertoni et al., 2004
[10]Newby et al., 2014
[11]Carpenter et al., 2018
[12]Carpenter et al., 2017
[13]Montgomery et al., 2018
[14]Königsson et al., 2001
[17]Swartz et al., 2018
[18] Pascottini et al., 2019
[19]Barragan et al., 2020
[20]Pascottini et al., 2020

Acknowledgments

Funding Support

- USDA NRI/AFRI/NIFA
  - # 2005-35203-16041
  - # 2008-35206-18817
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  - # 2019- 07859
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  - # 2021- 09507

United States Department of Agriculture

National Institute of Food and Agriculture

•Industry Partners

- ADM
- ASCUS
- Biomin
- Celtic Sea Minerals
- Diamond V
- Elanco
- Idemitzu
- Micronutrients
- Novus
- Phileo Lesaffre
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- United Animal Health
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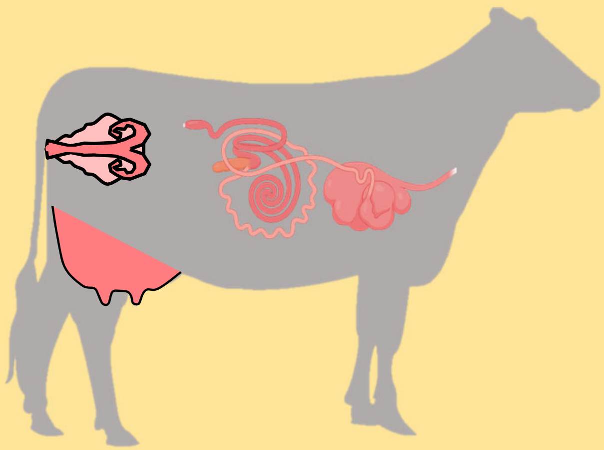
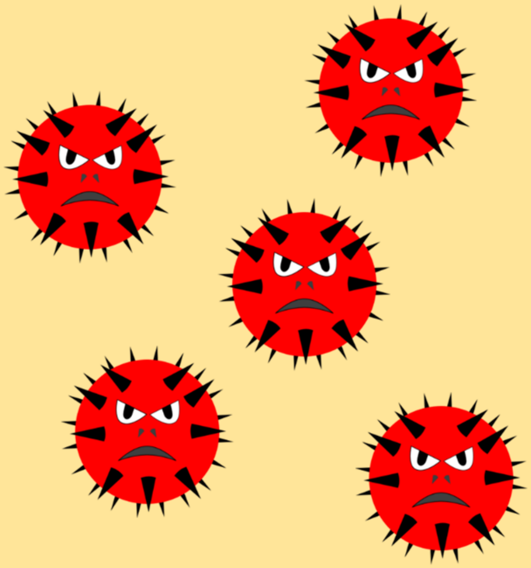
Immunosuppression Dogma

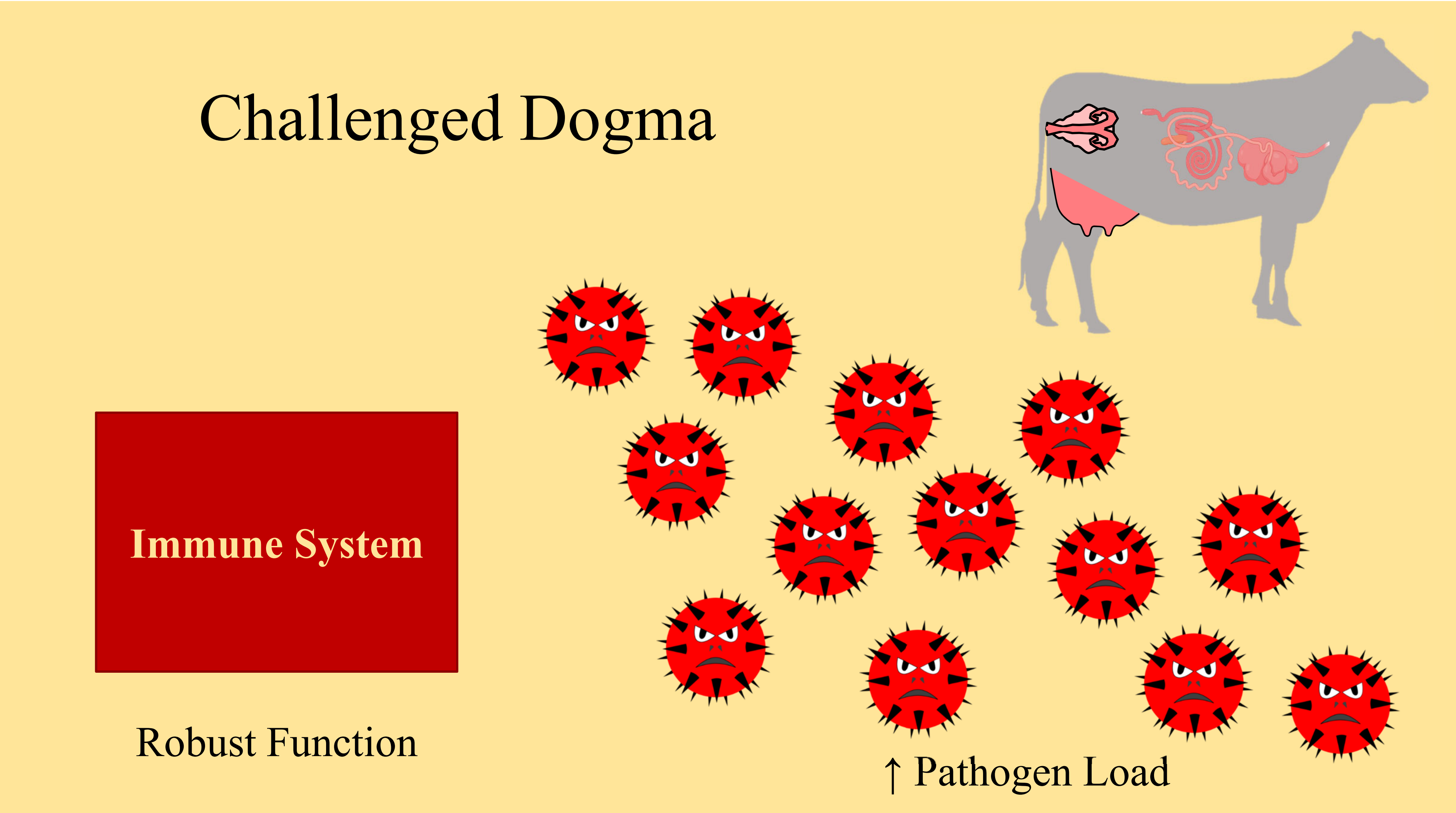


Immune System

↓ Function



≈ Pathogen Load


Challenged Dogma
Immune System
Robust Function
↑ Pathogen Load

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Impacts of Feeding Management On The Gastrointestinal Tract

G.B. Penner

Department of Animal and Poultry Science, University of Saskatchewan

California Animal Nutrition Conference

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Goals of feeding management

- Provide the right diet at the right amount to the right animal at the right time

Gastrointestinal tract functions

- Absorptive and secretory
  - Digesta movement
  - Digestion
  - Nutrient absorption
  - Urea recycling
  - Regulation of luminal pH
- Barrier function
  - Controlled luminal sensing and responses
  - Mucous secretion
  - Motility
  - Maintenance of paracellular permeability

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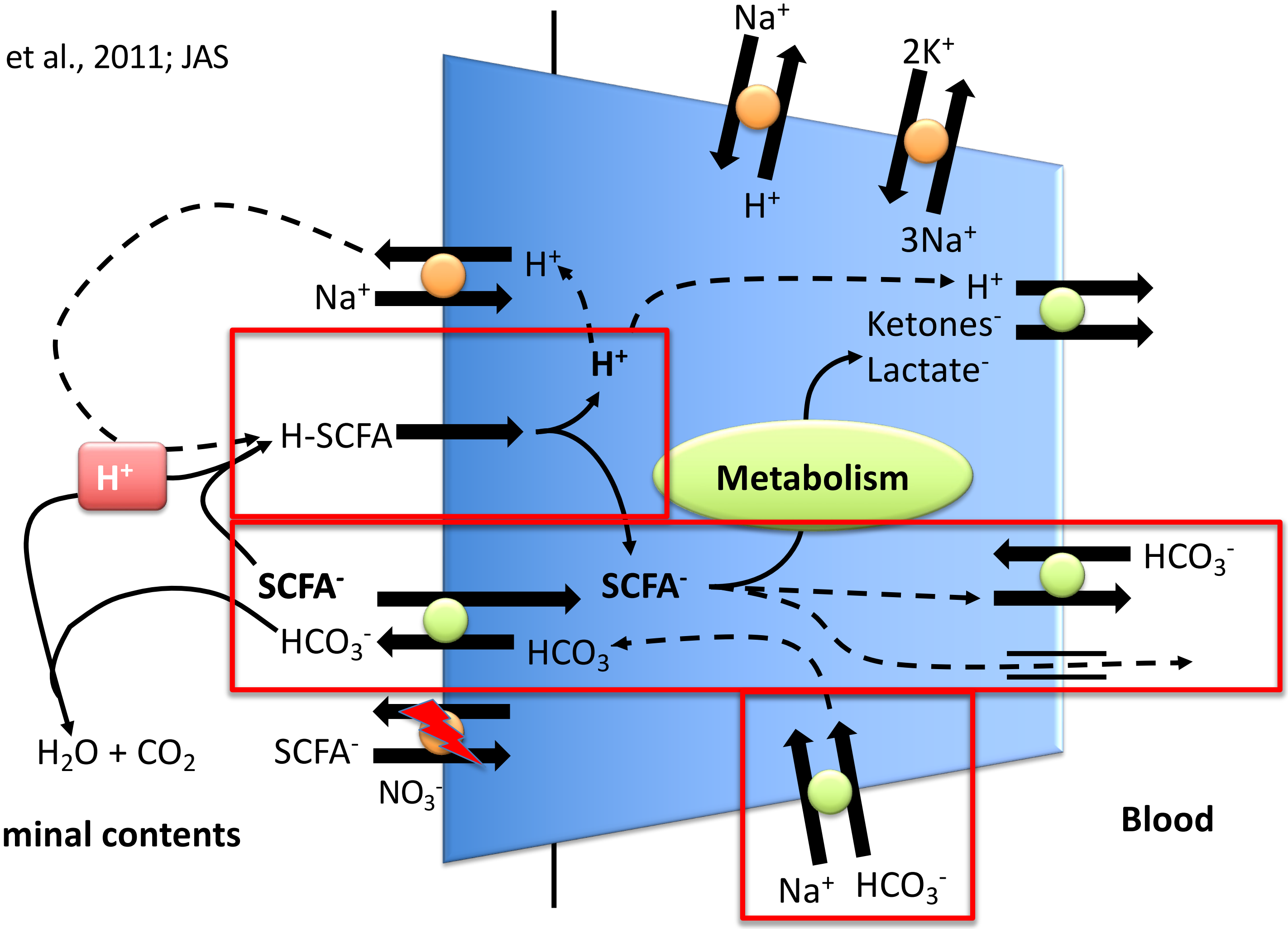
Absorption provides nutrients and buffers the rumen

Aschenbach et al., 2011; JAS



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Another look at ruminal epithelial buffering

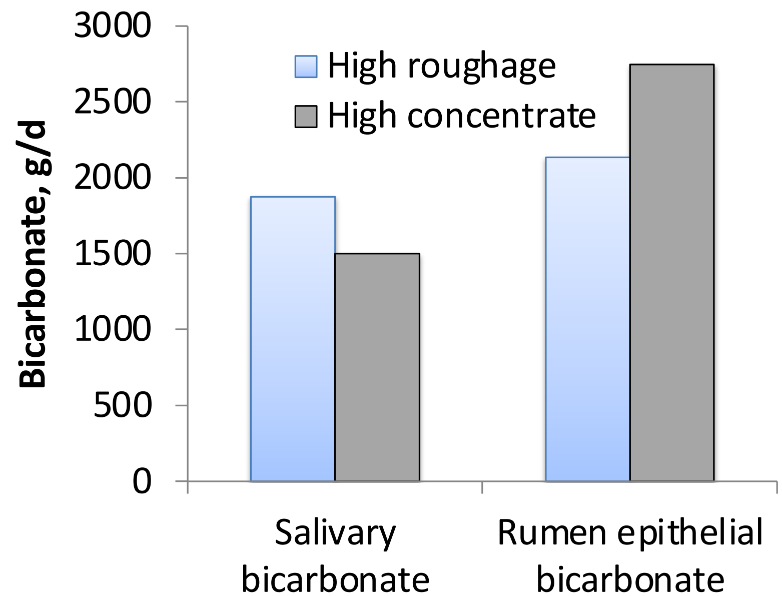
- >80 Mol/d
- C2:C3:C4 of 50:37:13
- 85% absorbed across the ruminal epithelium
- 50% bicarbonate dependent

Acetic acid
~2.40 L

Propionic acid
~2.18 L

Butyric acid
~0.93 L

Bicarbonate
~2.07 kg



Dijkstra et al., 2012; AFST

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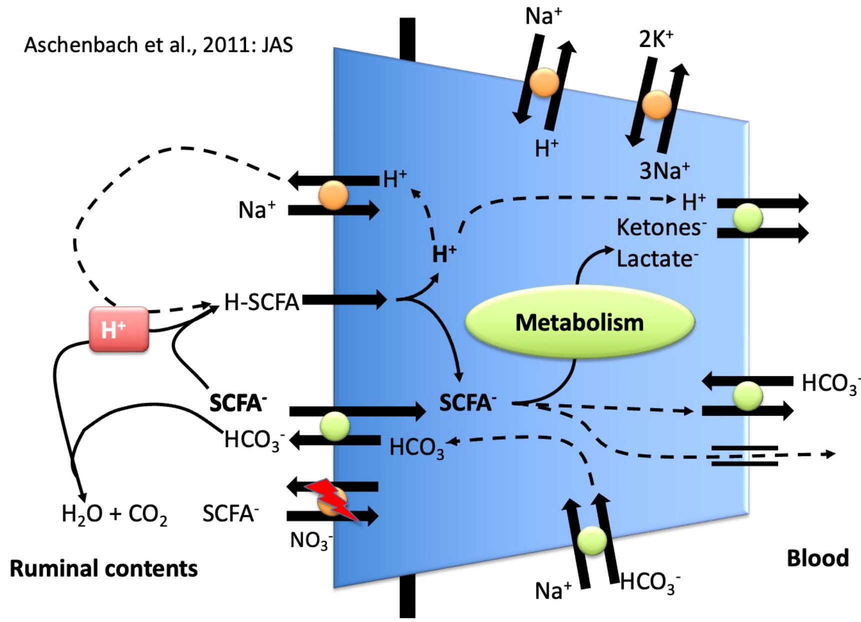
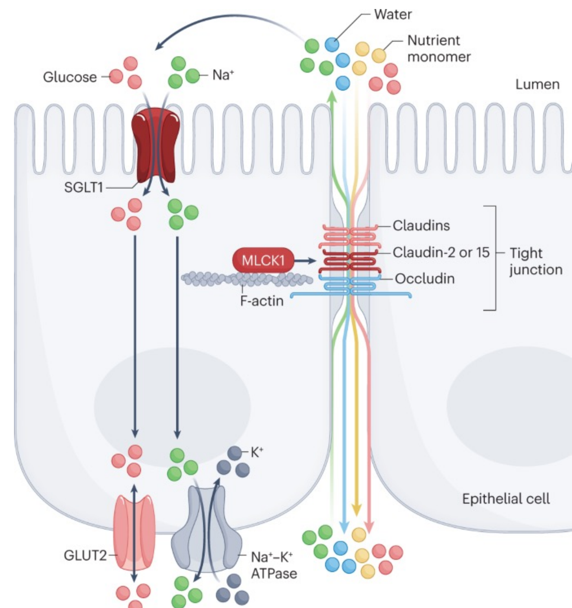
Horowitz et al., 2023; Nature Rev.

Permeability

- Epithelia separate cattle and the external environment in the GIT
- Permeability includes transcellular and paracellular movement

Aschenbach et al., 2011: JAS





Horowitz et al., 2023; Nature Rev.

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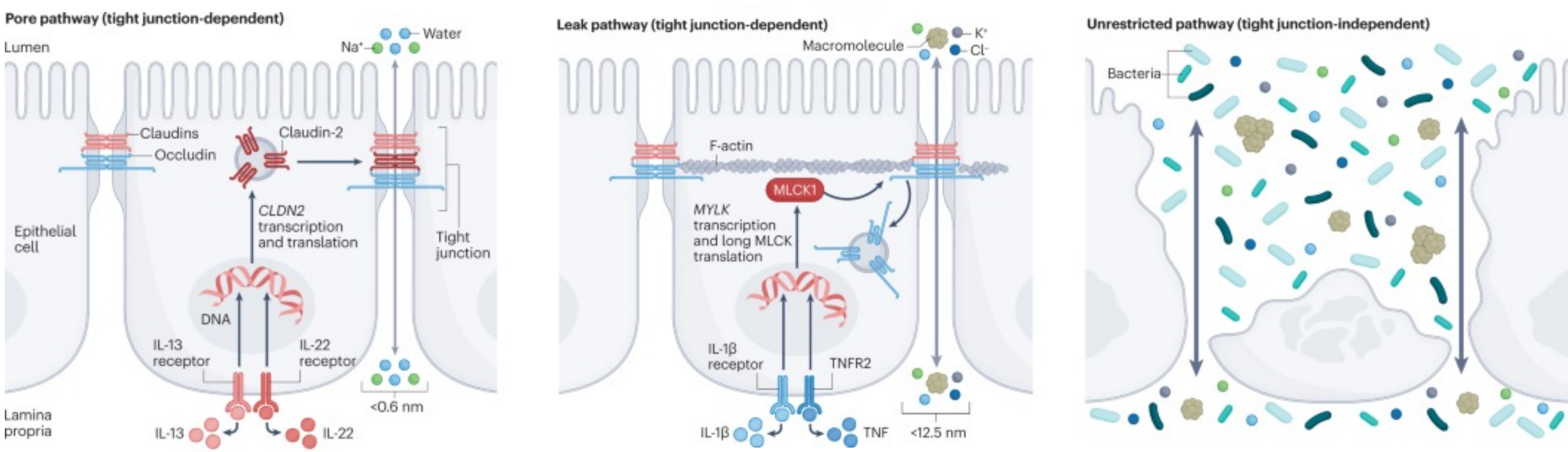
Paracellular permeability

- Paracellular movement includes pore, leak, and unregulated movement



Mannitol
Lactulose
4 kDa dextran

Horowitz et al., 2023; Nature Rev.

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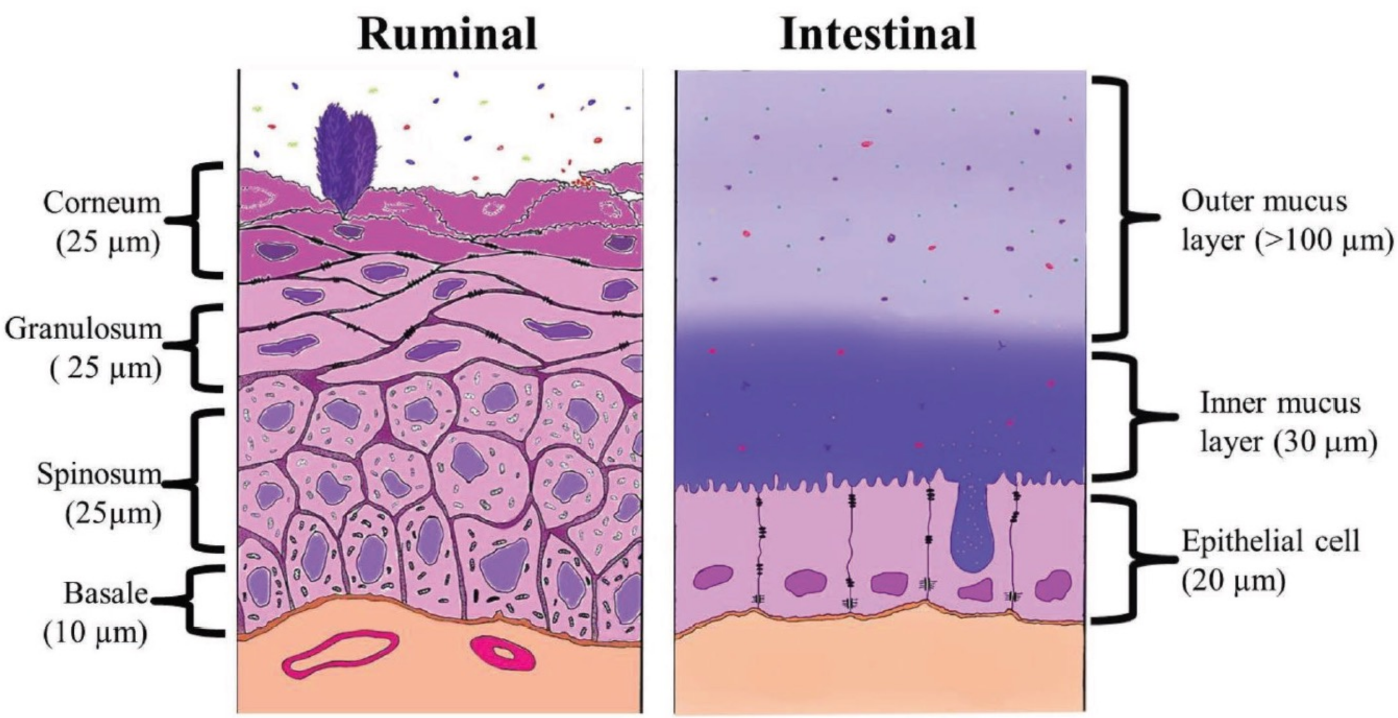
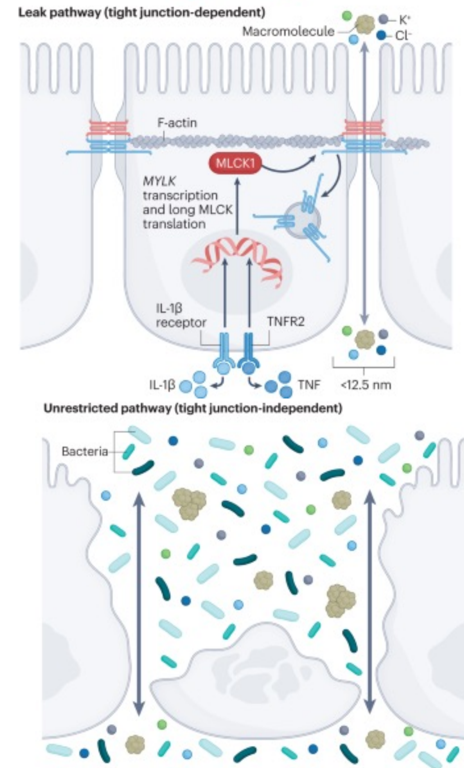
Regional differences: paracellular permeability



Steele et al., 2016; JDS



Horowitz et al., 2023; Nature Rev.

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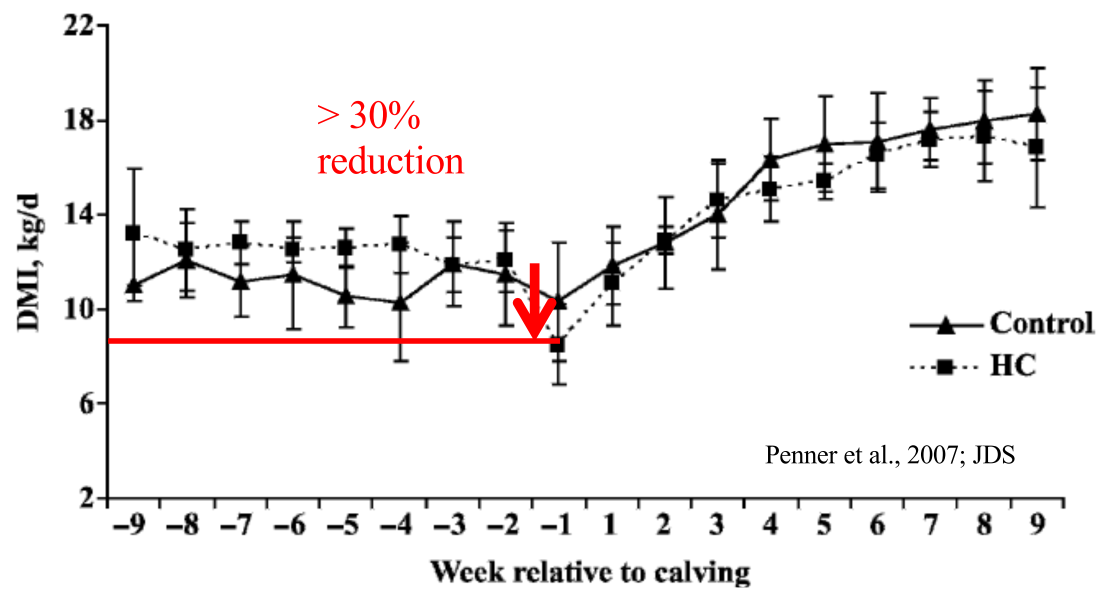
Complicating factors

- Management
  - Planned events
    - Transportation
    - Group and diet changes
    - Weaning
  - Unplanned events
    - Feed disruptions
- Physiological changes
- Environmental stress
- Disease?



- Average depression in DMI = 33%
- 88% of reduction in last week before calving

Hayirli et al., 2002; JDS

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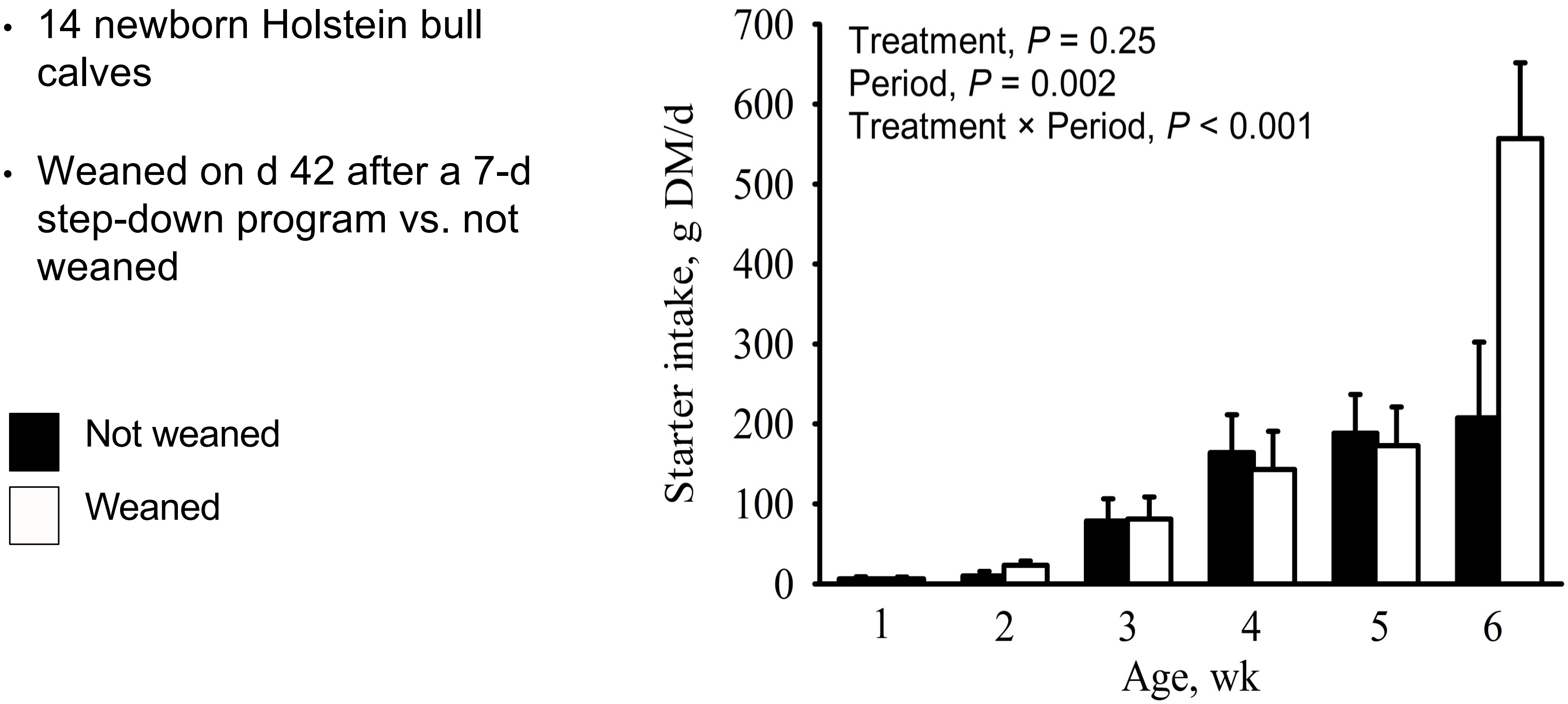
Wood et al., 2015: JDS

Rapid weaning: Impacts on the gastrointestinal tract

- 14 newborn Holstein bull calves
- Weaned on d 42 after a 7-d step-down program vs. not weaned



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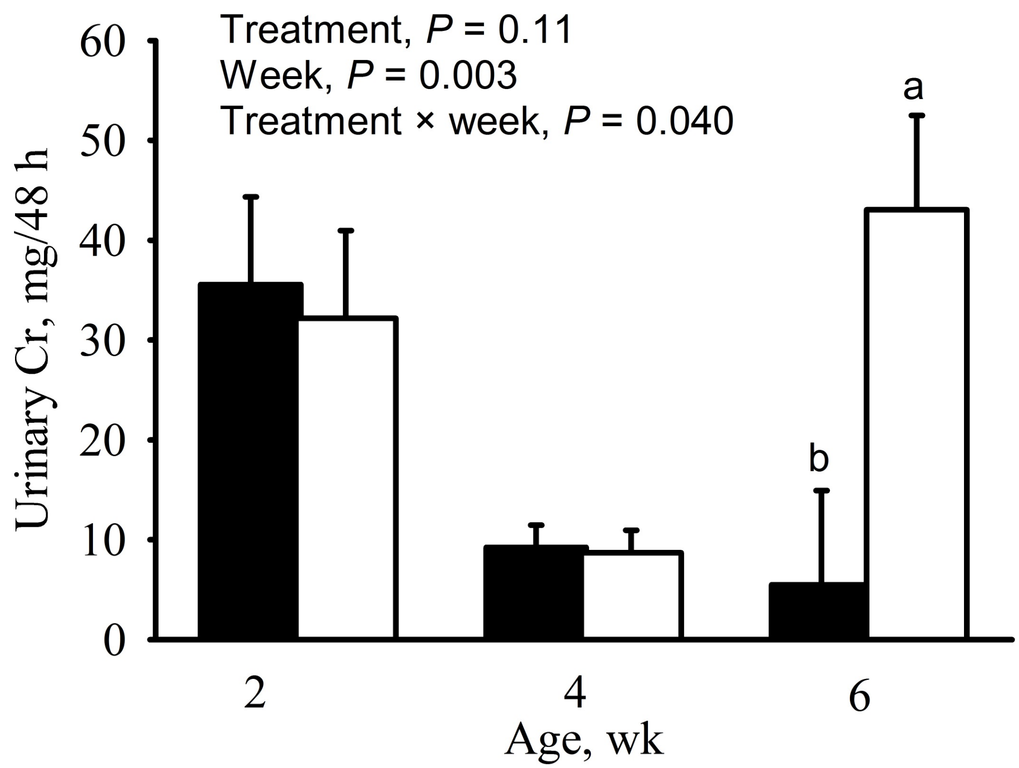
Wood et al., 2015: JDS

Rapid weaning: Impacts on the gastrointestinal tract

- 14 newborn Holstein bull calves
- Weaned on d 42 after a 7-d step-down program vs. not weaned

Not weaned

Weaned



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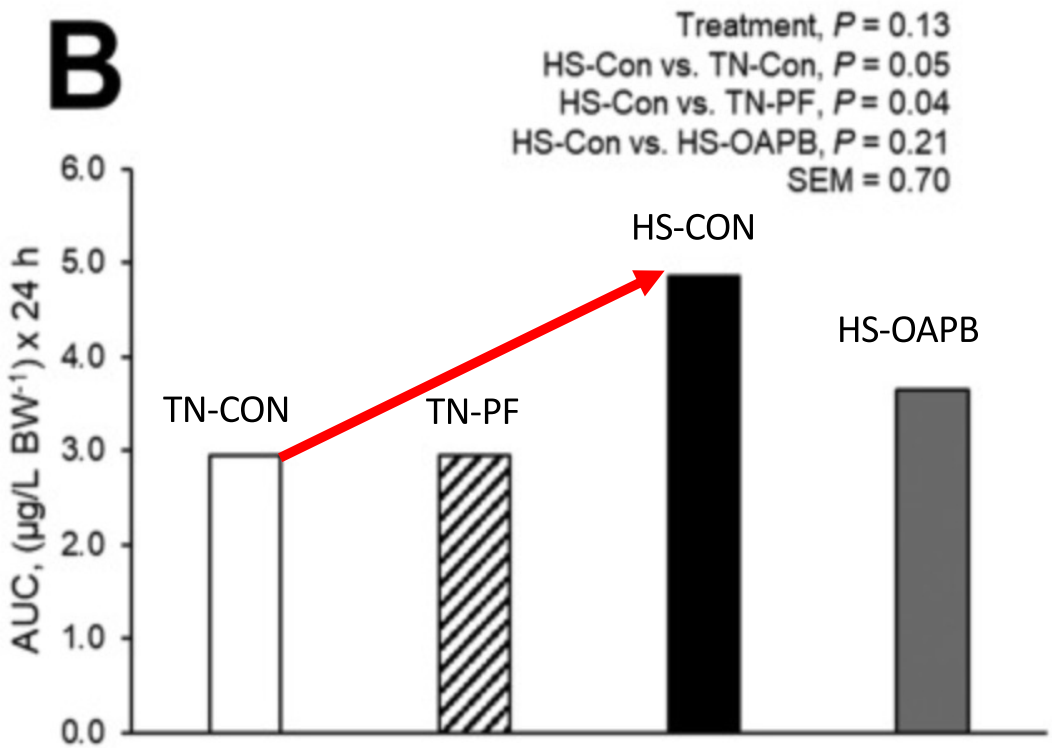
Heat-stress induced increases in paracellular permeability



Fontoura et al., 2022; JDS

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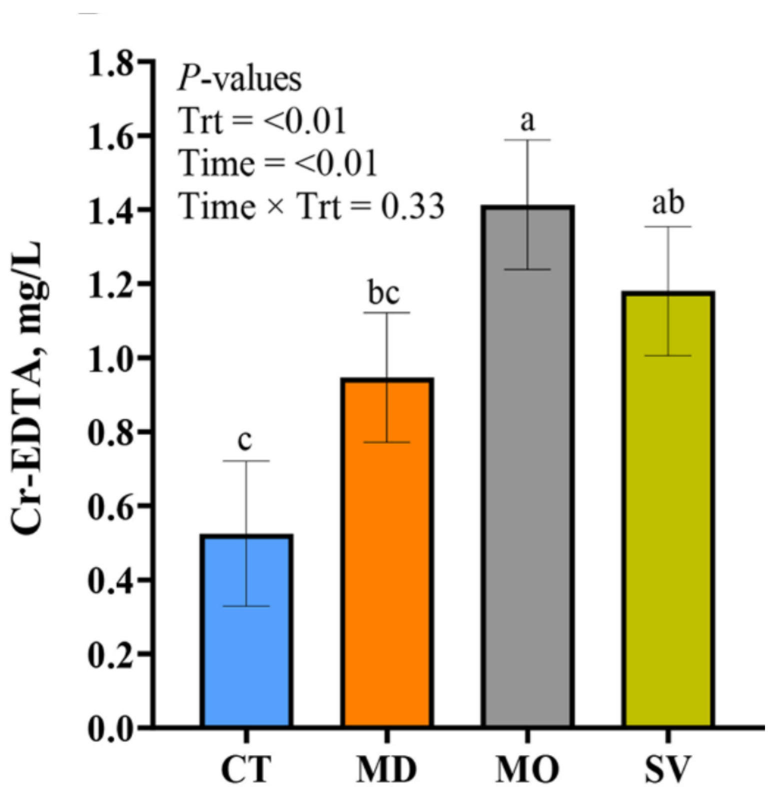
Pisoni et al., 2022; JDS

Withholding feed and transport increase paracellular permeability



- Young calves (~15 d) withheld from feed for differing duration/severity
- With transport

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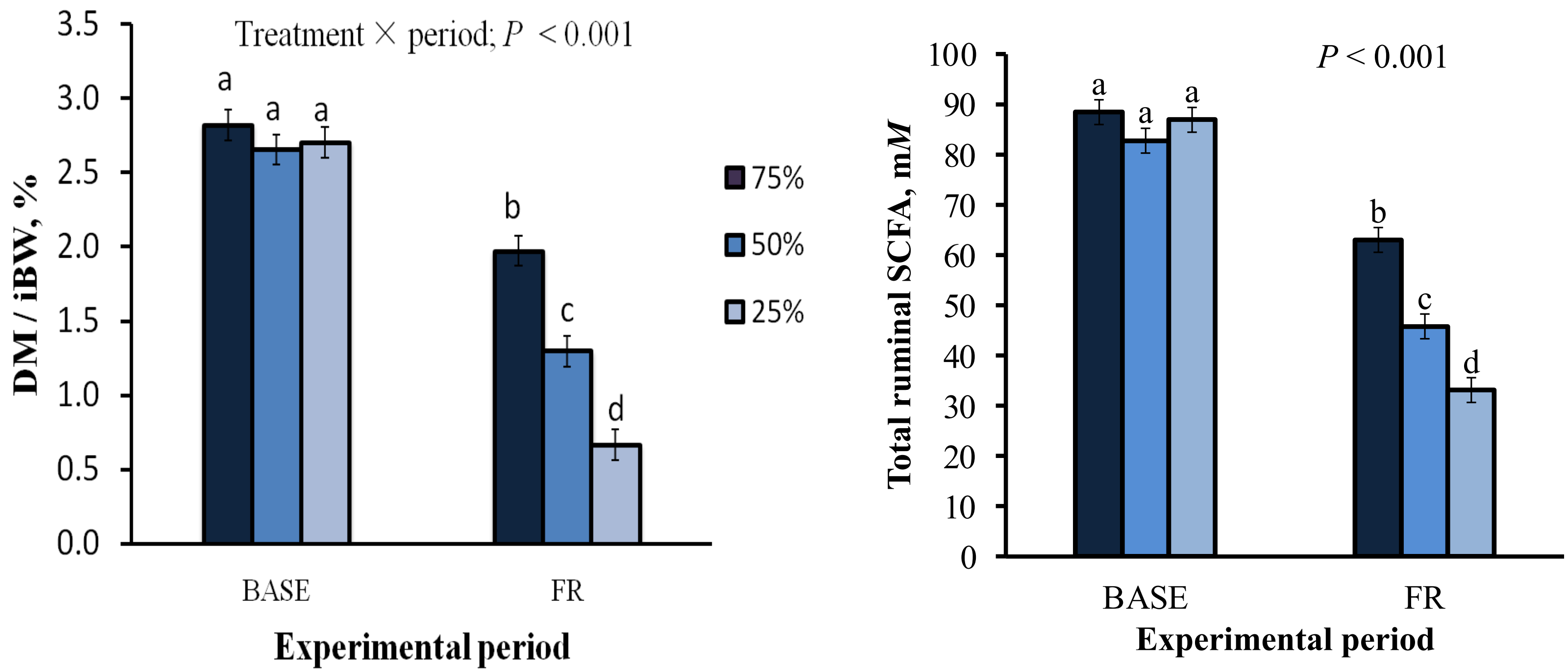
Zhang et al., 2013: JAS

Low feed intake as a model



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Pederzolli et al., 2018: JAS

Low feed intake: altered nutrient supply based on pH

	Treatment				*P* Value	
Region[1]	CON	RA	LFI	SEM	CON vs. RA	CON vs. LFI
Reticulo-rumen	6.14	5.33	6.61	0.14	**0.001**	**0.032**
Duodenum	5.28	4.99	5.18	0.35	0.71	0.82
Jejunum	7.03	6.98	7.31	0.16	0.82	0.22
Cecum	6.96	6.33	7.05	0.15	**0.012**	0.68
Proximal colon	6.94	6.52	7.30	0.10	**0.010**	**0.023**
Distal colon	6.90	6.52	7.13	0.14	0.06	0.26

[1]pH was measured using a ratio of 1:1 g/g of digesta and double distilled water

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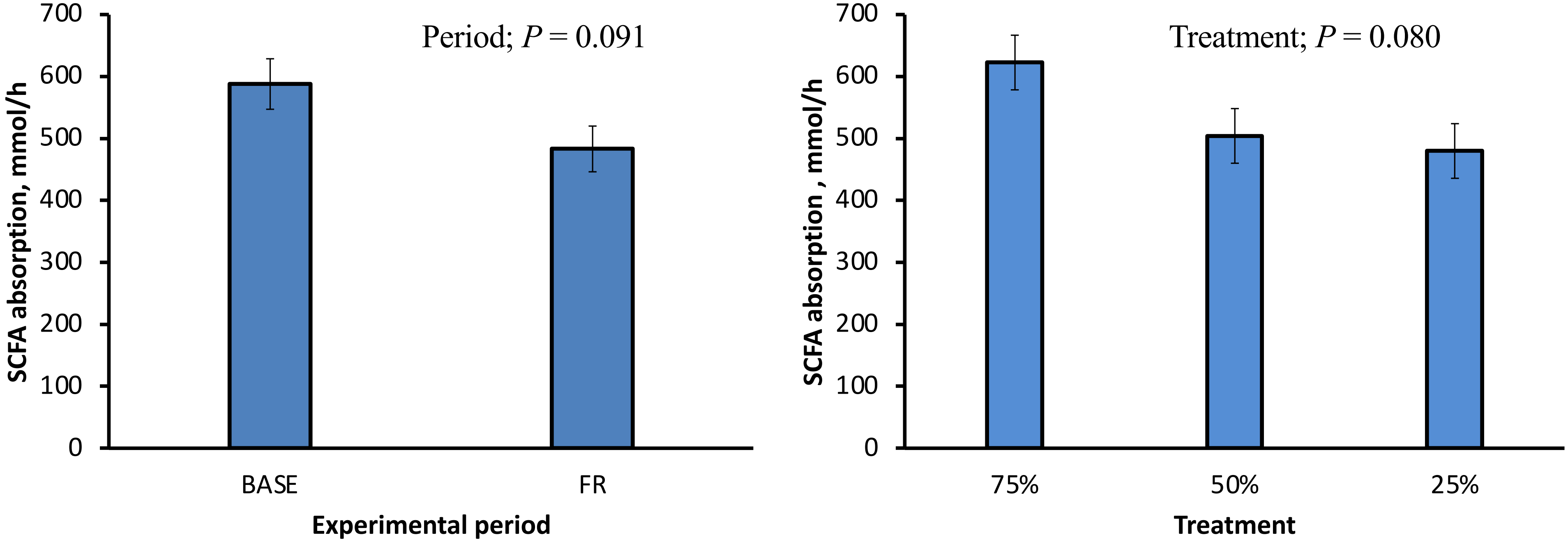
Zhang et al., 2013: JAS

SCFA absorption is reduced with low feed intake



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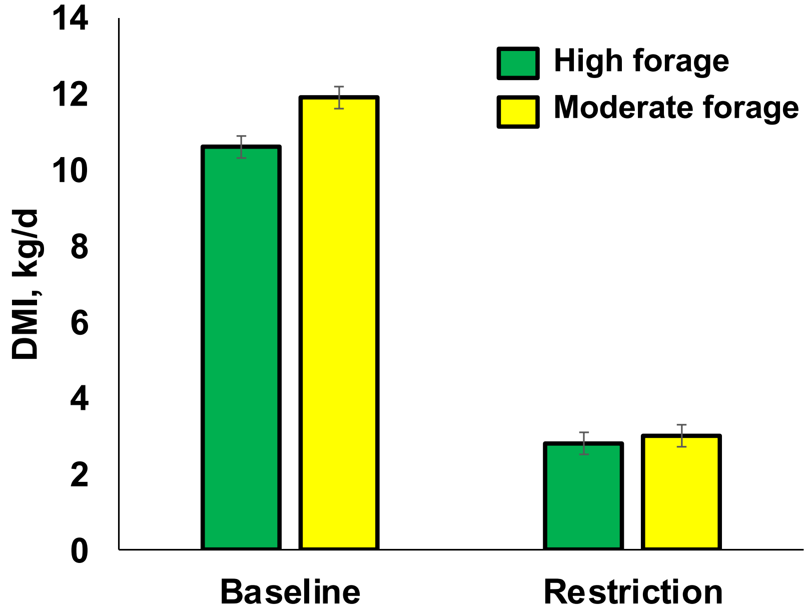
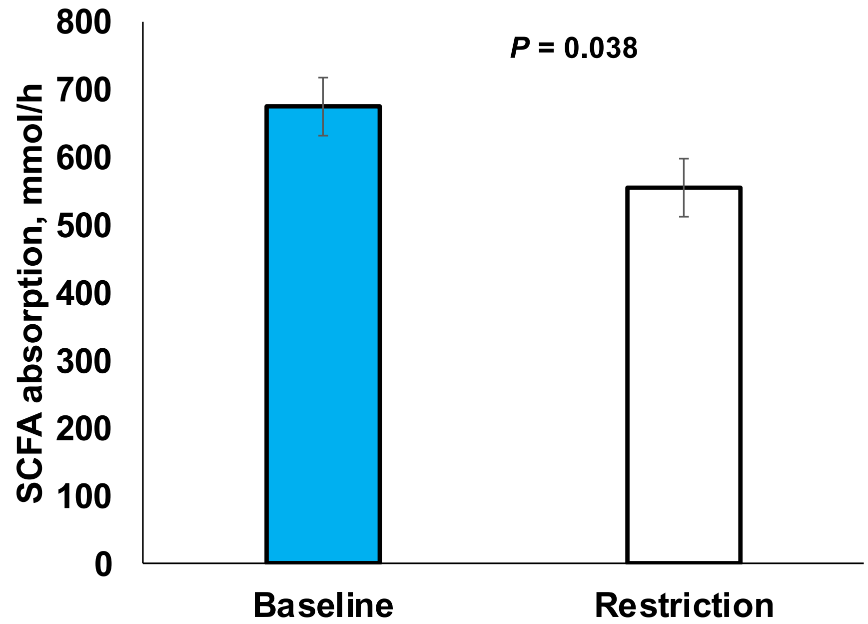
Albornoz et al., 2013; JAS

Low feed intake decreases SCFA absorption





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Pederzolli et al., 2018: J. Anim. Sci.

Low feed intake rapidly decreases absorptive surface area

5 d at 25% of voluntary intake

	Treatment				*P* value	
Item	CON	RA	LFI	SEM	CON vs. RA	CON vs. LFI
Length, mm	5.11	4.33	3.90	0.44	0.17	**0.043**
Width, mm	2.37	1.85	1.59	0.13	0.026	**0.002**
Perimeter, mm	13.81	11.43	9.97	0.98	0.09	**0.012**
Surface area[1], mm^2	18.71	13.18	7.72	1.86	0.08	**0.002**

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Pederzolli et al., 2018: J. Anim. Sci.

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Width, mm	2.37	1.85	1.59	0.13	0.026	**0.002**
Perimeter, mm	13.81	11.43	9.97	0.98	0.09	**0.012**
Surface area[1], mm^2	18.71	13.18	7.72	1.86	0.08	**0.002**

[1]Surface area was estimated as the surface area of one side of the papillae multiplied by 2

59% reduction in surface area

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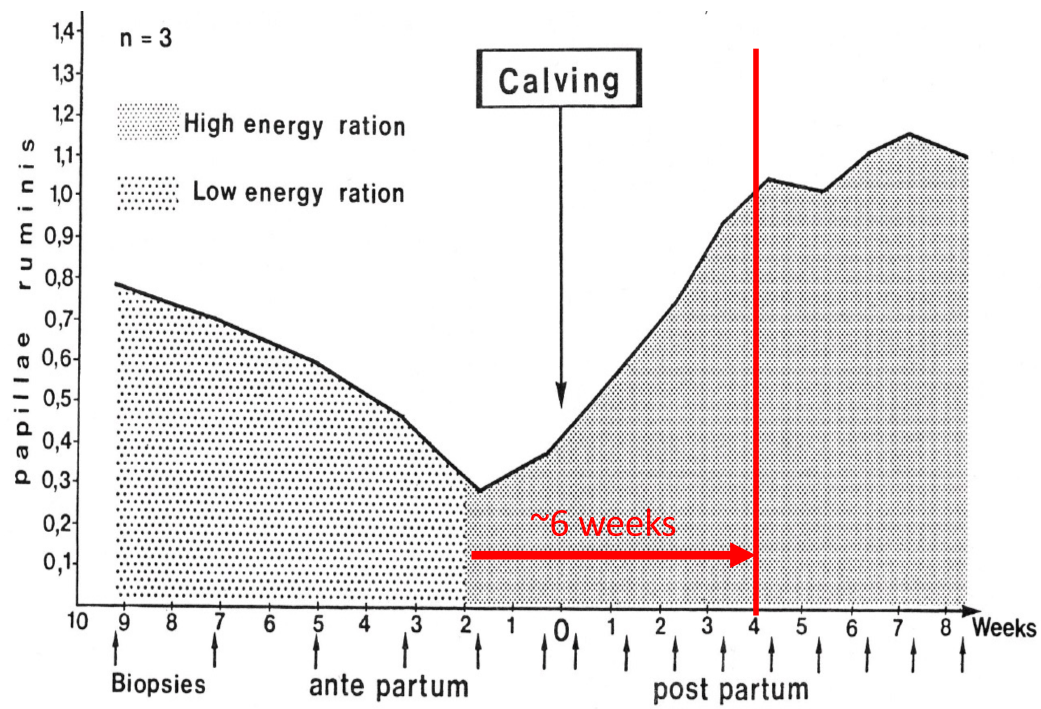
Dirksen et al., 1985; Bov. Pract.

Long-term adaptation



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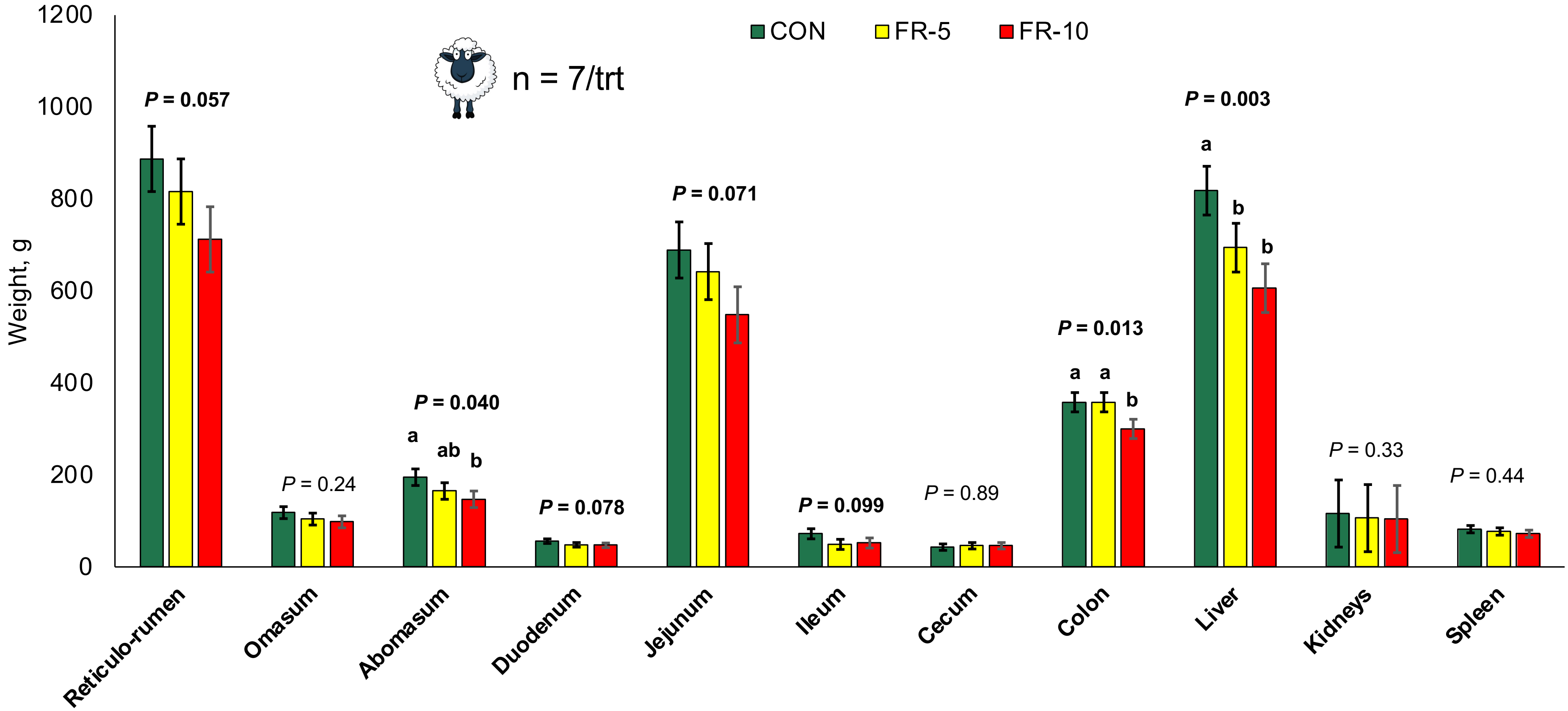
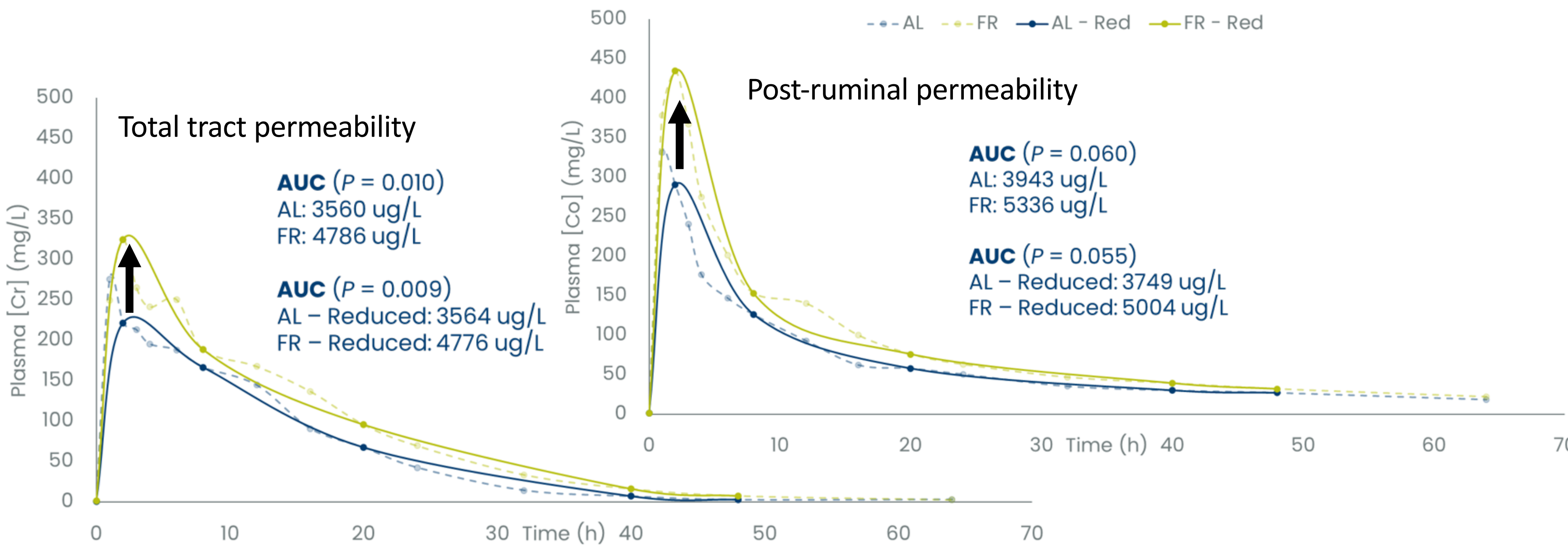
Lambert et al. (in review)

5 or 10 d of low feed intake (30%) reduces splanchnic tissue weights



Bertens et al. 2024; JDS

Low feed intake increases paracellular permeability of the GIT



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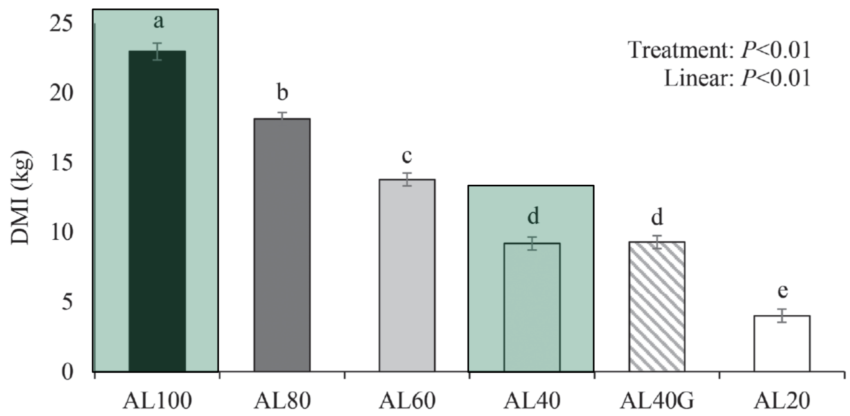
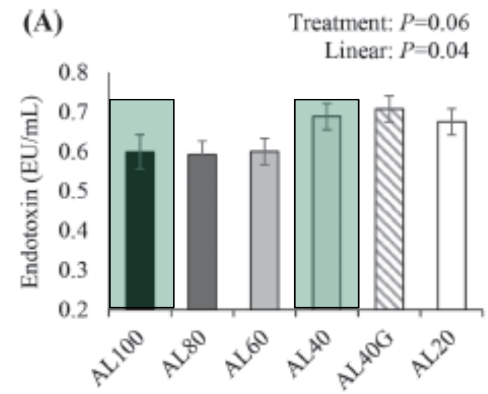
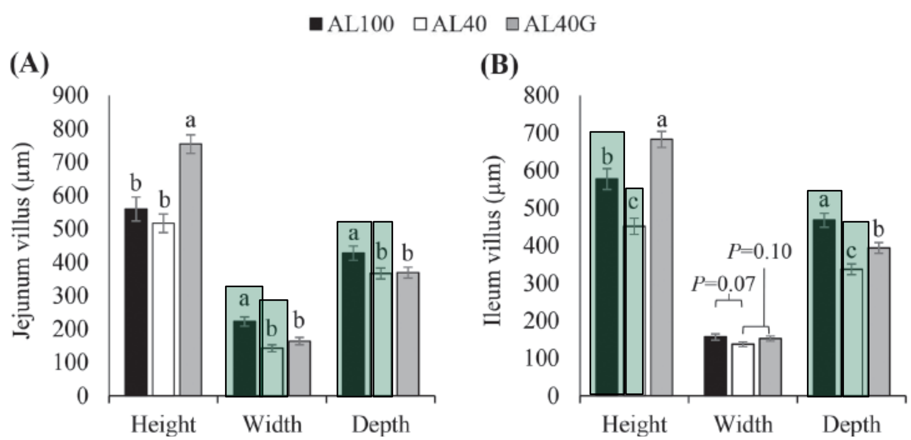
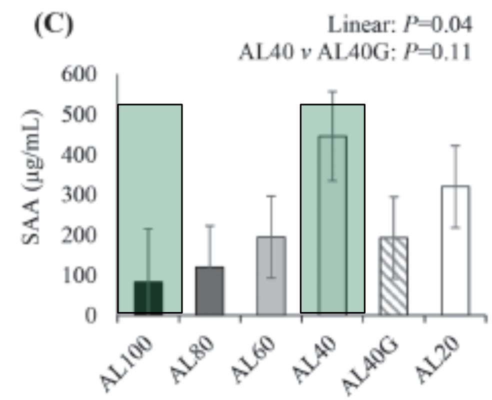
Kvidera et al., 2017; JDS

Low feed intake alters the GIT









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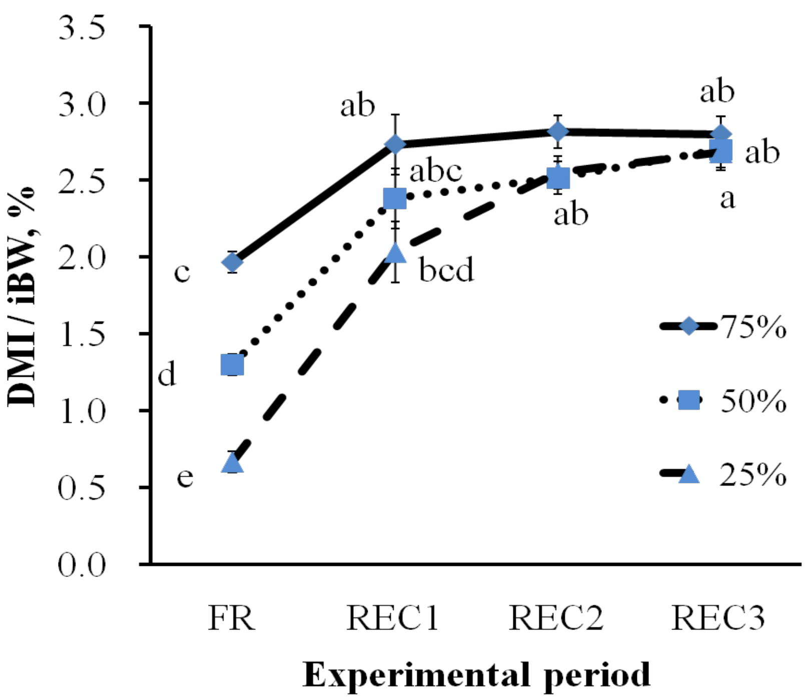
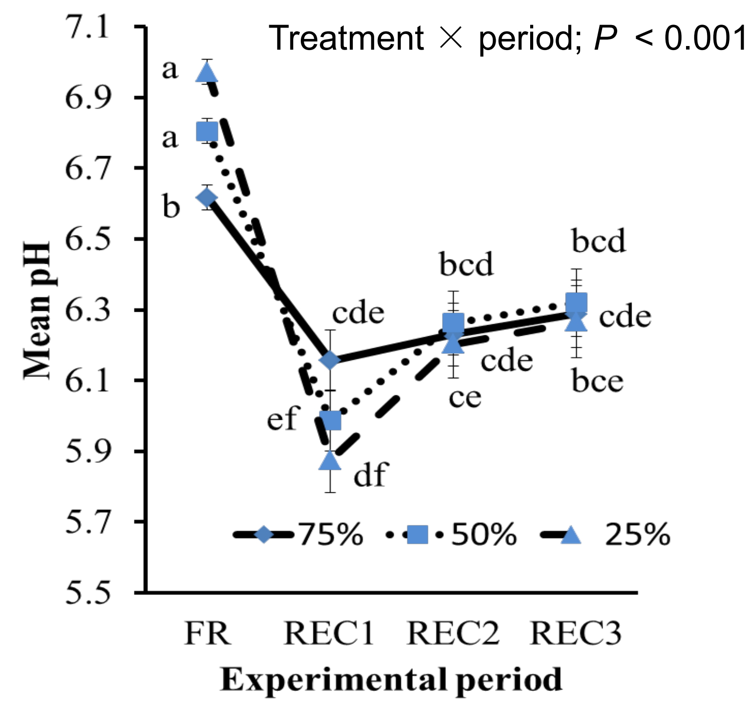
Zhang et al., 2013; JAS

High risk for ruminal acidosis as cows return to voluntary intake





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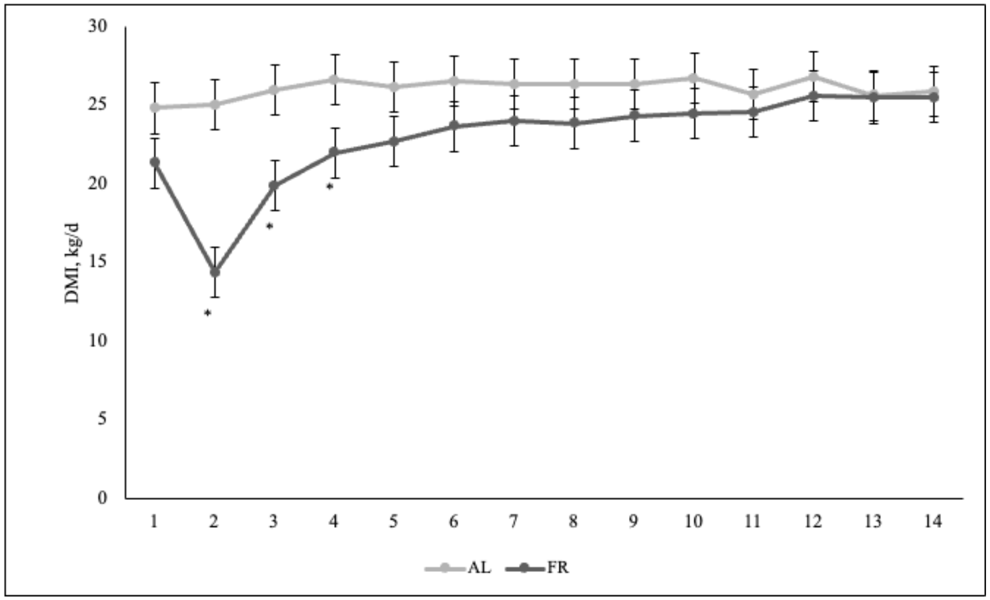
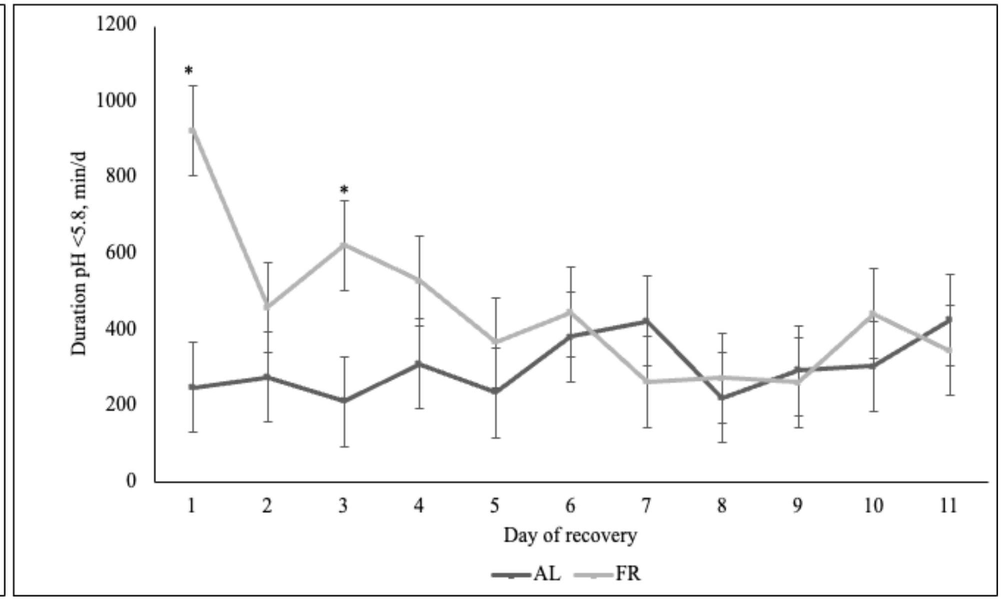
Bertens et al. 2024; JDS

Ad libitum feeding after low feed intake induces low ruminal pH





Responses for dairy cattle after being exposed to a 60% reduction in DMI for 5 d

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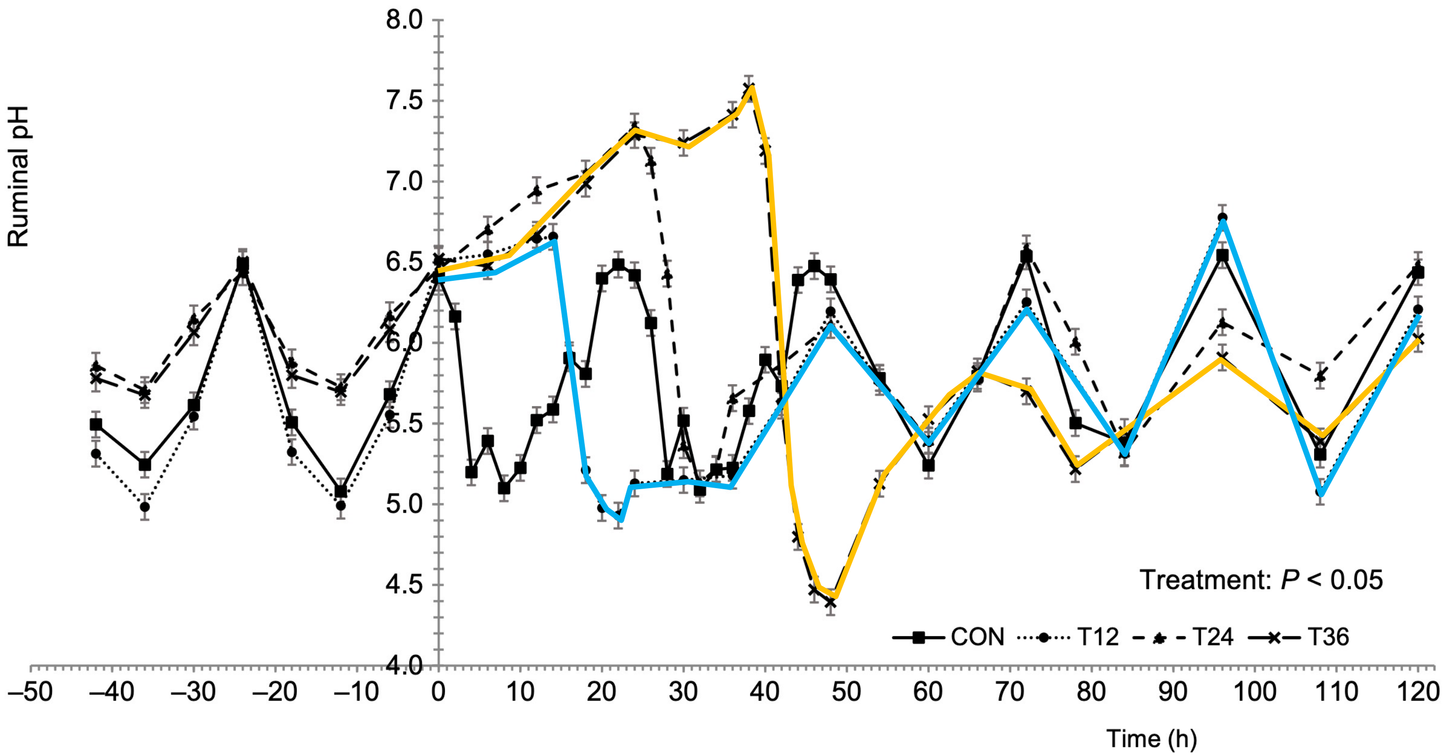
Rabaza et al., 2020; Animal

Delayed feeding may increase risk for ruminal acidosis



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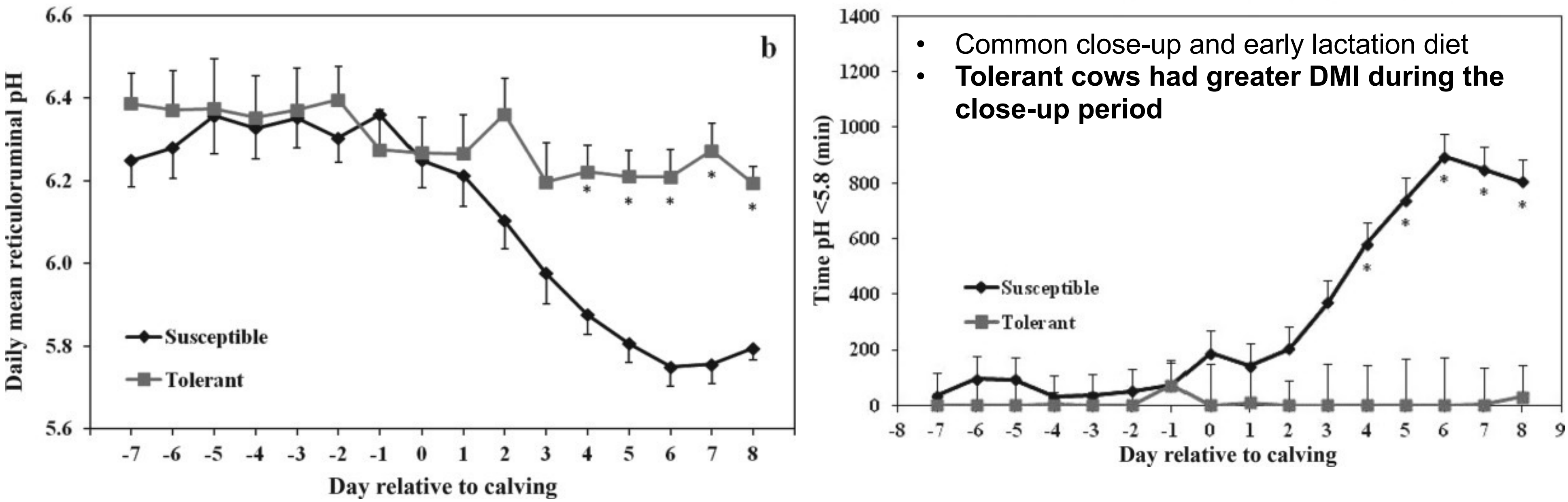
Cows with greater reduction in DMI pre-calving have lower reticulo-ruminal pH post-calving



- Common close-up and early lactation diet
- **Tolerant cows had greater DMI during the close-up period**

Humer et al., 2015; J. Dairy Sci.

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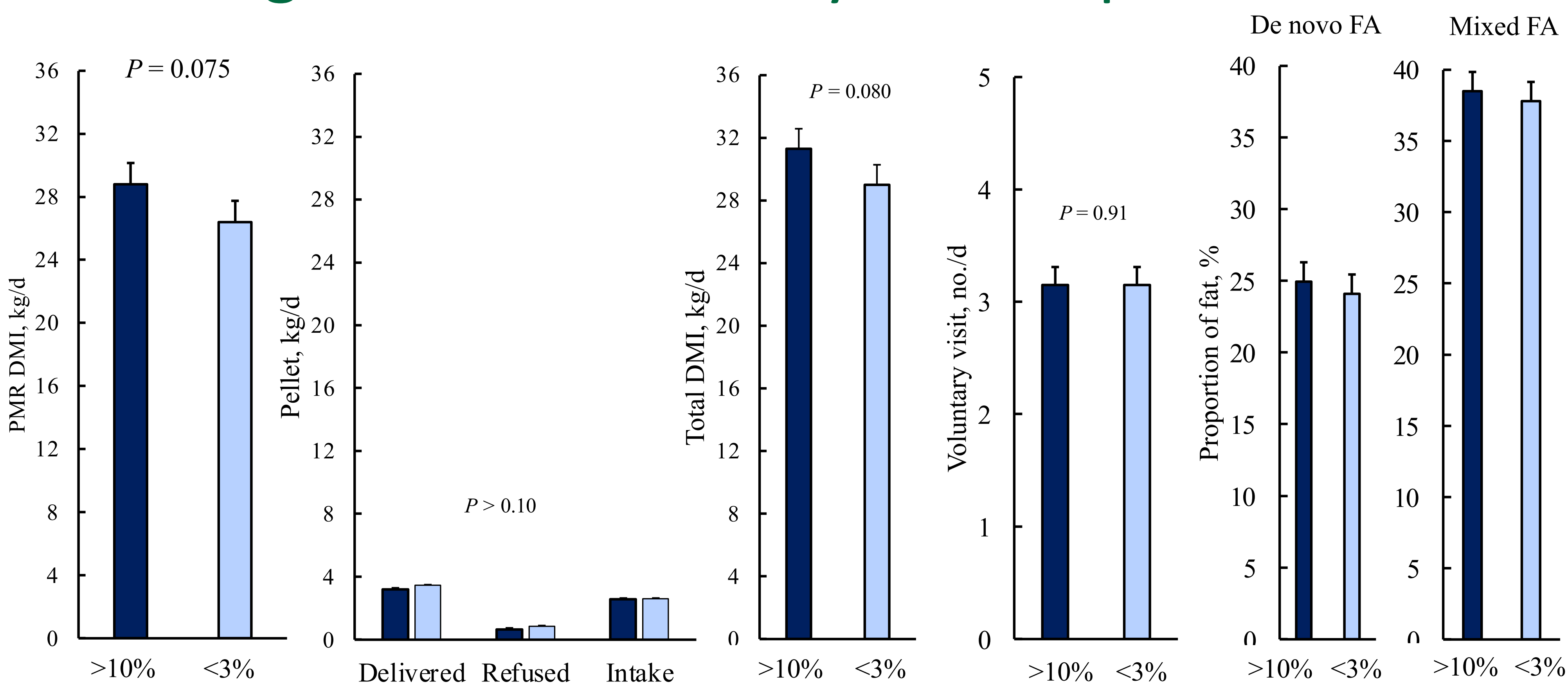
Dondé et al., unpublished

Limiting PMR refusals may reduce performance



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Take-home considerations

- Disruptions to feed intake (feed supply/access) can acutely alter functionality of the gastrointestinal tract
- Abrupt weaning and transportation events are known factors that may increase paracellular permeability
- High risk for ruminal acidosis after off-feed events
  - Short and medium duration events
  - Relevant for transition dairy cattle
  - Indicators when feed access is sub-optimal?

BE WHAT THE WORLD NEEDS

Managing Through Droughts and Floods by Optimizing Low-Forage Rations

Kirby Krogstad, PhD

Introduction

As recently as 2021, 72% of California was in an extreme or exceptional drought. By 2023, 39% of California was considered at least severely wet (drought.gov). These extreme swings will continue as extreme wet and dry conditions increase depending on time of year and geography (Dollan et al., 2022). Increasing incidence of droughts and floods can reduce forage production and quality and thus present a challenge to sustainable dairy production. In previous droughts, feed quality was affected, grain yields declined, and feed prices increased which had sustained effects on producer profitability and finished product prices for consumers (Kellner and Niyogi, 2014). Severe weather, such as droughts or floods, is a risk that livestock producers must acknowledge and be prepared to mitigate when, not if, they occur.

When reviewing the literature on climate change and crop production, it seems we are headed for a feast or famine situation. Some forecasts expect certain crop yields, like wheat, to increase, benefiting from increased temperature and CO_2 concentrations. Another caveat within these predictions is that projected increases in crop yields will rely on soil resources, especially moisture (reviewed by Izaurralde et al., 2011). For example, it is estimated that each 4 mm decrease in precipitation will reduce alfalfa yield by 1% (Izaurralde et al., 2011). At the same time, it's expected that severe, 'anomalous' events like droughts and floods will increase in their incidence, severity, and cost (Kellner and Niyogi, 2014, Fei et al., 2023). In particular, many parts of the United States should expect more frequent severely wet events and an increase in days under drought conditions which may challenge crop yields and quality (Singh et al., 2013, Dollan et al., 2022). In summation, intense variability in weather conditions will challenge forage quantity, quality, and as an artifact of those, the prices of high-quality forages.

All this adds up to the need for resilience and adaptability by the agricultural community; dairy farmers and their nutritionists are no exception. They too must be prepared for changes in nutritional strategies. One contingency to plan for is how your cows will be fed in a forage scarcity scenario. Whether you don't have forage because of quantity, quality, hygiene or economics, you need to be prepared to deal with it in as cost-effective manner as possible.

In order to maximize profitability, or reduce additional costs, by reducing dietary forage concentrations we must be prepared to manage their unique effects. Specifically, we will discuss how reducing forage in rations fed to dairy cattle alters DMI and feed digestibility. We will also discuss nutrient and ingredient substitution strategies as these decisions will affect digestibility of the diet and milk component production. By the end, we'll have outlined the consequences of reduced forage diets along with strategies for mitigating challenges which may arise.

Considerations for low-forage rations

Dry matter intake

One of, if not the most important, considerations when feeding dairy cattle is correct estimation of dry matter intake (DMI). Dry matter intake is influenced by both animal and dietary factors which ought to be considered when formulating rations (Allen et al., 2019, de Souza et al., 2019). Our discussion will focus on forage NDF (fNDF) concentrations as NASEM (2021)

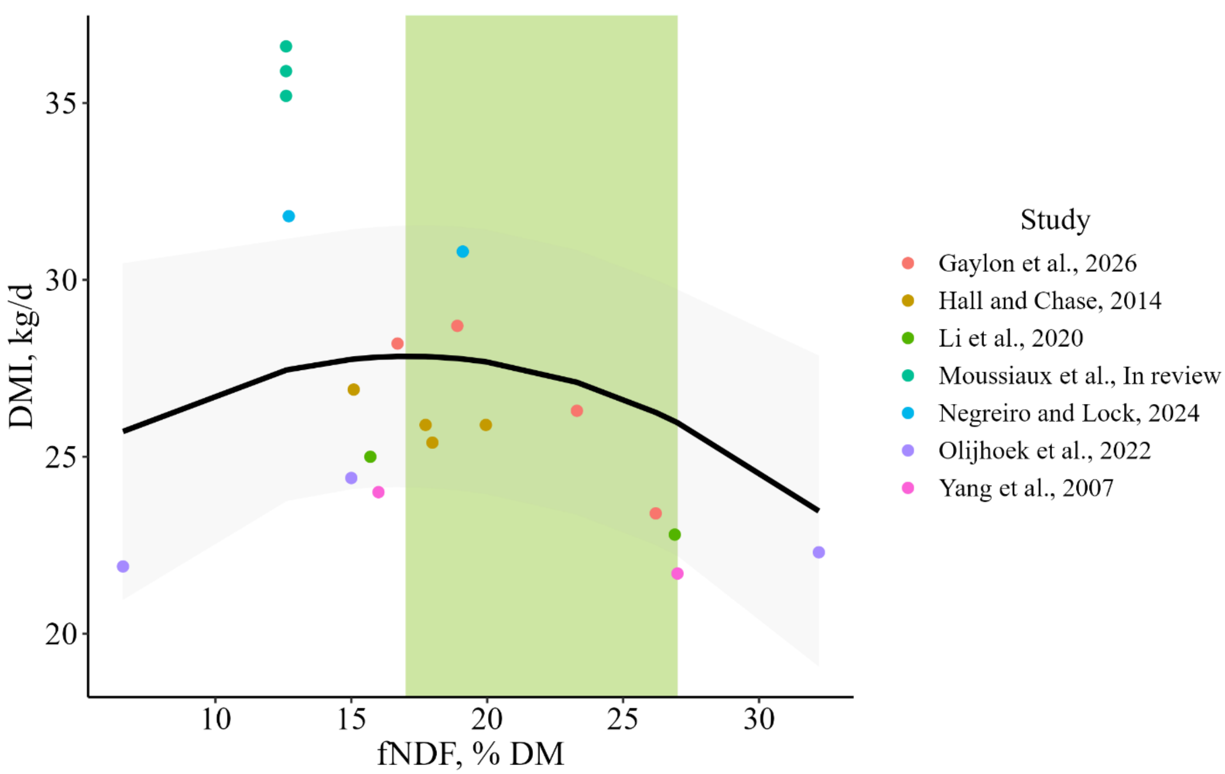

Figure 1. Association of forage NDF (fNDF) and DMI (% of BW) in lactating dairy cattle. Green shaded area indicates optimal fNDF range from NASEM (2021). 7 experiments and 20 treatment means included in simple analysis.

recommends it be a primary dietary consideration because of its relationship with DMI and rumen pH (Allen, 1997, Allen, 2000).

As outlined in NASEM (2021), the optimal fNDF ranges from 17-27% of diet DM. NASEM (2021) also described that the minimum fNDF is likely between 15 and 19% of diet DM and depends on other dietary constituents. Unfortunately, few experiments assess dietary fNDF below these boundaries. Through a limited literature review of papers published within the last 20 years, we can see that reducing forage NDF in rations fed to dairy cows increases feed intake, but only to a point (Figure 1). In a study feeding high producing mid-lactation dairy cattle, Negreiro and Lock (2024) increased DMI from 30.8 kg/d (4.4% of BW) to 31.8 kg/d (4.5% of BW) when reducing fNDF from 19.1 to 12.7. In this example they removed corn silage and alfalfa silage while increasing inclusion of beet pulp, ground corn, corn gluten feed, and cottonseed.

In our recent research at Ohio State, we fed diets that were 12.6% fNDF to early lactation dairy cows and observed DMI between 35 and 37 kg/d or about 5.2% of BW which was 8 kg/d greater than was estimated by NASEM (2021; Moussiaux et al., *In review*). Our data suggests that DMI estimates when feeding fNDF that is less than NASEM (2021) recommendations are less reliable and should be used cautiously. Reducing fNDF below 12.6% may begin reducing DMI. Olijhoek et al. (2022) reduced total forage from 30% to 9% of diet DM (estimated fNDF of 15% and 7%, respectively) and reduced DMI by 2.5 kg/d or from 3.9 to 3.4% of BW. When reducing fNDF, they removed grass silage and corn silage while providing additional barley straw. They also increased beet pulp, wheat, distillers' grains, canola, molasses, and palm fat. This formulation approach maintained consistent dietary gross energy and net energy estimates. The modest increase in dietary starch (19 to 22% of diet DM) or fat (3.9 to 4.2% of diet DM) may have contributed to the reduced DMI.

Understanding and estimating DMI when feeding less fNDF to high producing dairy cattle is critical as it may alter diet concentrations of critical and expensive nutrients like amino acids, fatty acids, vitamins, minerals, and some feed additives. In general, reducing fNDF increases DMI but if fNDF is reduced below 12.6% of diet DM, DMI may begin declining. Effects on DMI are also likely impacted by net change on dietary components like starch, fat, and total NDF. When feeding reduced fNDF, monitor DMI closely then you can adjust targeted nutrient concentrations being provided in the diet to ensure you're delivering adequate absolute supplies to meet the cow's nutrient requirements.

Digestibility

Nutrient digestibility is an important piece of applied nutrition. The only way a nutrient can be used for productive purposes is for it to first be digested. The digestibility of a ration is a function of the rate of digestion and the retention time within the gastrointestinal tract. These factors are influenced by DMI, physical feed characteristics, inherent degradability of individual ingredients, specific nutrients, and feeding management. In the context of reduced forage rations, the feed intake, physical feed characteristics, and degradability of specific feeds must be considered.

As we described previously, reducing forage in a diet usually increases DMI. Increased DMI is associated with reduced digestibility of DM, NDF, and starch (de Souza et al., 2018). With that in mind, it is no surprise that reducing forage in the ration results in reductions in total tract nutrient digestibility (Yang and Beauchemin, 2007b, Li et al., 2020, Olijhoek et al., 2022). At least part of the reduction in digestibility is due to increase rate of passage which reduces the time available for feed to digest within the rumen and intestine. Additionally, the substitution strategy must be taken into consideration. If you're replacing digestible nutrients or feeds, such as starch and corn, with less digestible nutrients or feeds, like NDF and byproducts, you're reducing the theoretical digestibility before the diet even gets to the cow.

The proportion of feed digested should not be the only concern; we should also be concerned with the mass of feed digested. The mass of feed digested is what determines the nutrients the cow may actually use, while the proportion of feed digested is an indication of efficiency. In most cases, the reduction in digestibility reduces total NDF digested while total DM and starch were maintained or slightly increased (Olijhoek et al., 2022, Galyon et al., 2026).

When reducing forage, the inherent feed digestibility should be evaluated closely. Galyon et al. (2026) fed diets that were approximately 17% fNDF or 25% fNDF with either boot stage or soft-dough stage triticale. Regardless of forage inclusion, feeding boot stage triticale increased total tract digestibility; even when reducing forage inclusion, improving forage quality still increased digestibility. Additionally, when reducing forage in a diet, the replacement non-forage feeds may increase or decrease digestibility depending on their digestibility in relation to the ingredients

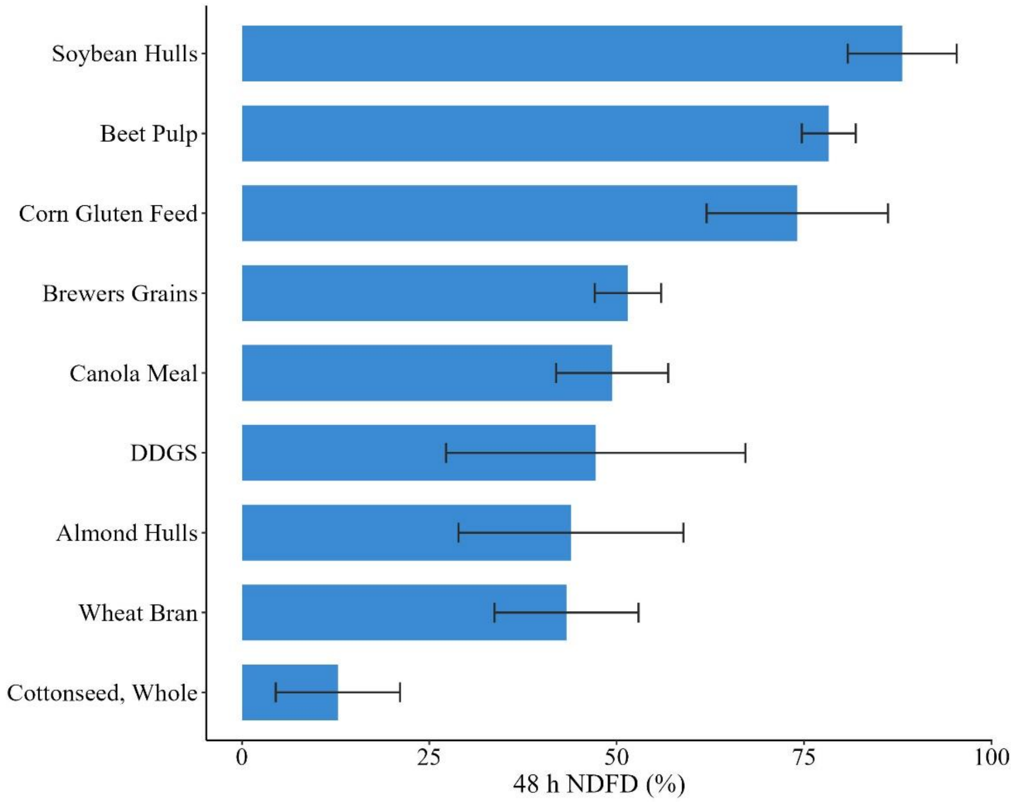

Figure 2. In vitro NDF digestibility of non-forage fiber sources that are fed to lactating dairy cattle. Adapted from NASEM, 2021.

being replaced. Highly degradable byproducts like beet pulp, soybean hulls, and corn gluten feed may aid in maintaining digestibility (Figure 2; NASEM, 2021).

One final note on digestibility, especially of NDF. Other nutrients like fatty acids and starch affect dietary NDF digestibility. For each unit increase in starch, we expect NDF digestibility to reduce by approximately 0.6 units, all else being equal (NASEM, 2021). When feeding reduced forage rations (12.6% fNDF) with dietary starch concentrations of 24, 28, and 32% of diet DM, we observed that NDF digestibility reduced 10 and 7 percentage units for each 4% DM increase in starch which was 1.5 to 2.5-fold greater reduction than what was estimated by NASEM (2021; Figure 3). The greater magnitude reduction is partially related to our substitution strategy; when increasing starch, we removed soybean hulls, which is a highly degradable NDF source. Perhaps some responses, like the response of NDF digestibility to dietary starch, are magnified as forage is reduced in lactating dairy cows' rations.

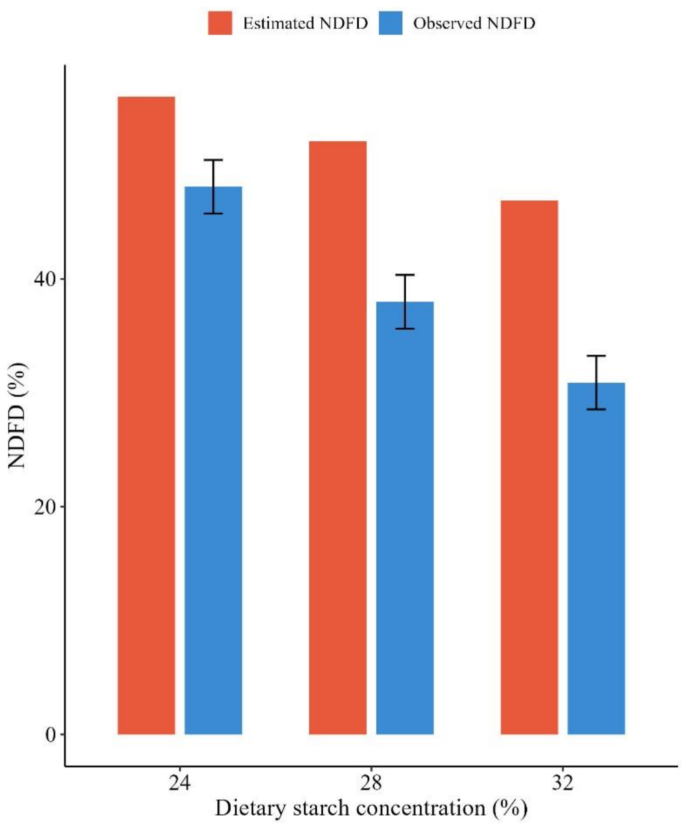

Figure 3. Observed NDFD in reduced forage rations with increasing dietary starch concentrations. Increasing starch in reduced forage rations dramatically reduced NDF digestibility ($P < 0.001$; Moussiaux et al., *In review*).

Rumen environment

One point of discussion whenever forages are reduced in rations is whether 'rumen health' is affected. Rumen health is a genuine concern but with poor definition. My working definition of a healthy rumen is one that possesses a microflora capable of efficiently degrading fiber while maintaining the gut barrier's integrity and functionality. Generally, we've used rumen pH to assess rumen health. Usually, decreasing forage inclusion in rations fed to dairy cattle reduces ruminal pH (Li et al., 2020, Krogstad et al., 2021). The reduction in rumen pH when reducing fNDF is likely a result of increasing intake or increasing the supply of degradable carbohydrates without concomitant increases in chewing and buffering activity. Continued investigation of the rumen's inflammatory tone, permeability, and immune profile will further enhance our understanding and definition of 'rumen health', especially when feeding challenging diets like those with less fNDF (Aschenbach et al., 2019, Vandevoorde and Krogstad, 2026).

The effects on rumen VFA are also compelling. Reducing fNDF from 27% to 16% reduced relative concentrations of acetate, increased propionate, increased butyrate, and reduced branched-chain VFA but these effects were confounded by increases in dietary starch concentration (Yang and Beauchemin, 2007a, Li et al., 2020). Similar results were also observed by Olijhoek et al. (2022) where reducing fNDF reduced relative concentrations of acetate, increased propionate, but reduced butyrate and branched chain VFA. The total VFA response in reduced forage rations of course depends on the dietary composition, but consistent reductions in acetate, increases in propionate, and reductions in branched chain VFA are worth further investigation. The reduction in branched chain VFA is especially intriguing as these metabolites are important for NDF digestibility (Firkins et al., 2025). Ruminal metabolism experiments where dietary forage was changed while maintaining similar dietary starch concentrations are scarce; such studies would help elucidate how VFA metabolism shifts under these circumstances independent of nutrition composition.

Upon interrogation, the literature does demonstrate that non-forage NDF sources may promote greater propionate production than expected. Feeding wet corn gluten feed in place of corn silage, alfalfa silage, and corn grain linearly increased ruminal propionate concentrations. Benchaar et al. (2013) observed similar results for distillers' grains; propionate increased as distillers' grains were increased in the diet. Continual improvement in understanding ruminal metabolism of fNDF and non-forage NDF will improve ration formulation, especially in reduced forage scenarios.

Milk and component production

All the above considerations result in milk and milk component production. Cows can produce high volumes of milk and milk components in reduced fNDF scenarios so long as they're receiving adequate nutrients and the rumen is properly functioning. Even when fNDF is below the NASEM (2021) recommended range, cows can produce as much as 50 kg/d of energy-corrected milk (Negreiro and Lock, 2024; Moussiaux et al. *In review*). The greatest challenge in feeding less fNDF is maintaining milk fat concentration and yield. Olijhoek et al. (

2022) reduced milk fat concentration from 3.82% to 2.49% when fNDF reduced from 15 to 7% of the diet DM. Yang and Beauchemin (2007b) and Li et al. (2020) also observed reduced milk fat concentration when reducing forage concentration but in both cases, the reduced forage diet was confounded by a greater dietary starch concentration. Much of the observed reduced milk fat concentration response is a dilution effect. Reducing fNDF also increases fluid milk yield (Yang and Beauchemin, 2007b, Li et al., 2020, Galyon et al., 2026) which maintains or can even increase milk fat yield (Redoy et al., 2025).

Reduced milk fat concentration is not a huge concern in most cases so long as milk fat yield is maintained. Reducing forage concentration is certainly a risk factor for diet-induced milk fat depression and reduced milk fat yield. Clearly in some cases, like Olijhoek et al. (2022), reducing fNDF led to diet-induced milk fat depression and reductions in milk fat yield. They also increased dietary fat, with palm fat distillate and distillers' grain, and dietary starch while reducing fNDF. Increasing unsaturated fat and dietary starch are additive risk factors for diet-induced milk fat depression (Ramirez Ramirez et al., 2015). Our research, Moussiaux et al., (*In review*), observed similar challenges when feeding 12.6% fNDF diets. We observed dramatic increases in *trans*-10 18:1 and *trans*-10, *cis*-12 18:2 in milk fat as dietary starch increased. Milk fat yield was dramatically reduced from 1.91 kg/d to 1.63 kg/d as dietary starch increased from 24% to 32% of diet DM.

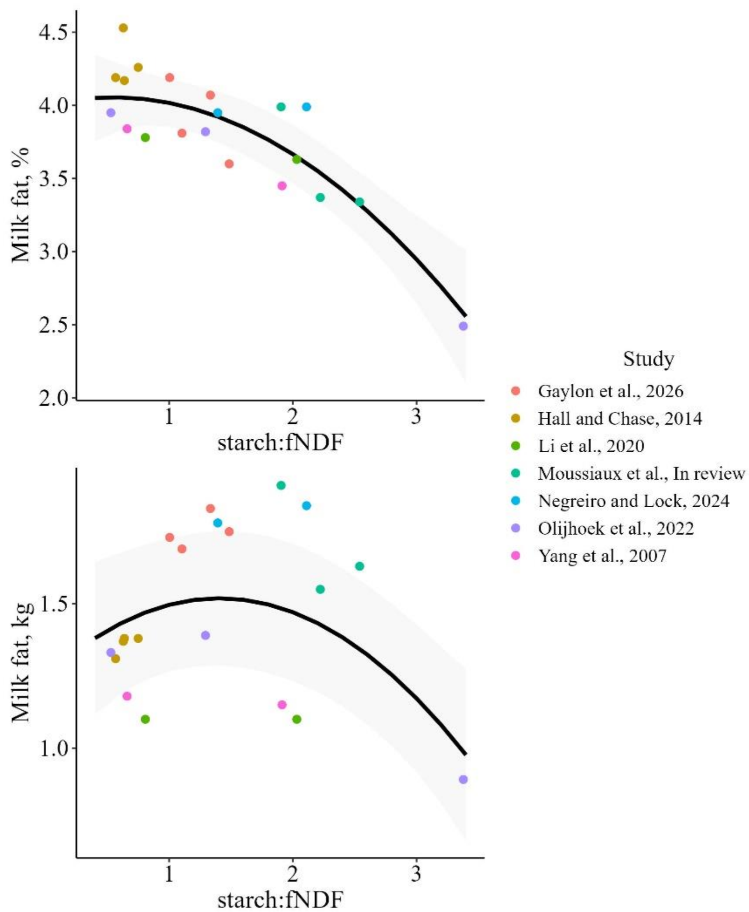

Figure 4. Milk fat concentration and yield respond quadratically to the starch:fNDF ratio ($P \leq 0.05$). Database includes 7 studies with 20 treatment means.

So what benchmarks should be considered when feeding reduced fNDF diets? Using our limited database, we investigated the starch:fNDF ratio in relation to milk fat concentration and yield. In both cases, milk fat concentration and yield responded quadratically to the starch:fNDF ratio ($P \leq 0.05$; Figure 4). Based on these results, maintaining a starch:fNDF ratio of 1.4 will maximize milk fat production.

Conclusions

In the future, being adaptable and prepared for extreme and anomalous weather, like droughts and floods, will be required for successful dairy production. These weather events will increase in incidence and severity which may challenge forage supplies. When these situations occur, here are the take-home points to remember:

1. Reducing fNDF increases DMI and models may not properly estimate DMI when this occurs.
2. Reducing fNDF may reduce digestibility but this depends on the ingredient replacement strategy and other nutrients in the diet (i.e. starch).
3. Reducing fNDF in the ration can reduce milk fat concentration but does not necessarily reduce milk fat yield. The risk of severe diet-induced MFD can be reduced by keeping the starch:fNDF ratio <2 and milk fat production was maximized when starch:fNDF was 1.4.

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IntelliBond

Smart Minerals
Smart Nutrition

California Animal Nutrition Conference

Carlyn Peterson, PhD, PAS

Dr. Jose Santos – Effects of Replacing Sulfate with IntelliBond Trace Minerals on Performance of Transition

- General Study Design:
  - Randomized Complete Block design
  - Two treatments:
    - Sulfate TM (**STM**) = $CuSO_4$, $MnSO_4$, $ZnSO_4$
    - IntelliBond TM (**IBTM**) = IntelliBond C, M, & Z
  - 141 cows (61 nulliparous and 80 parous)
    - **STM** = 30 nulliparous and 40 parous
    - **HTM** = 31 nulliparous and 40 parous
  - Treatments started at approximately 246 d of gestation (i.e., 28 d prepartum) and continued to 105 DIM
  - Diets formulated with NASEM (2021) software providing total concentrations:
    - 16 ppm Cu, 65 ppm Mn, 65 ppm Zn

Sarwar et al. (2026) JDS 109: accepted

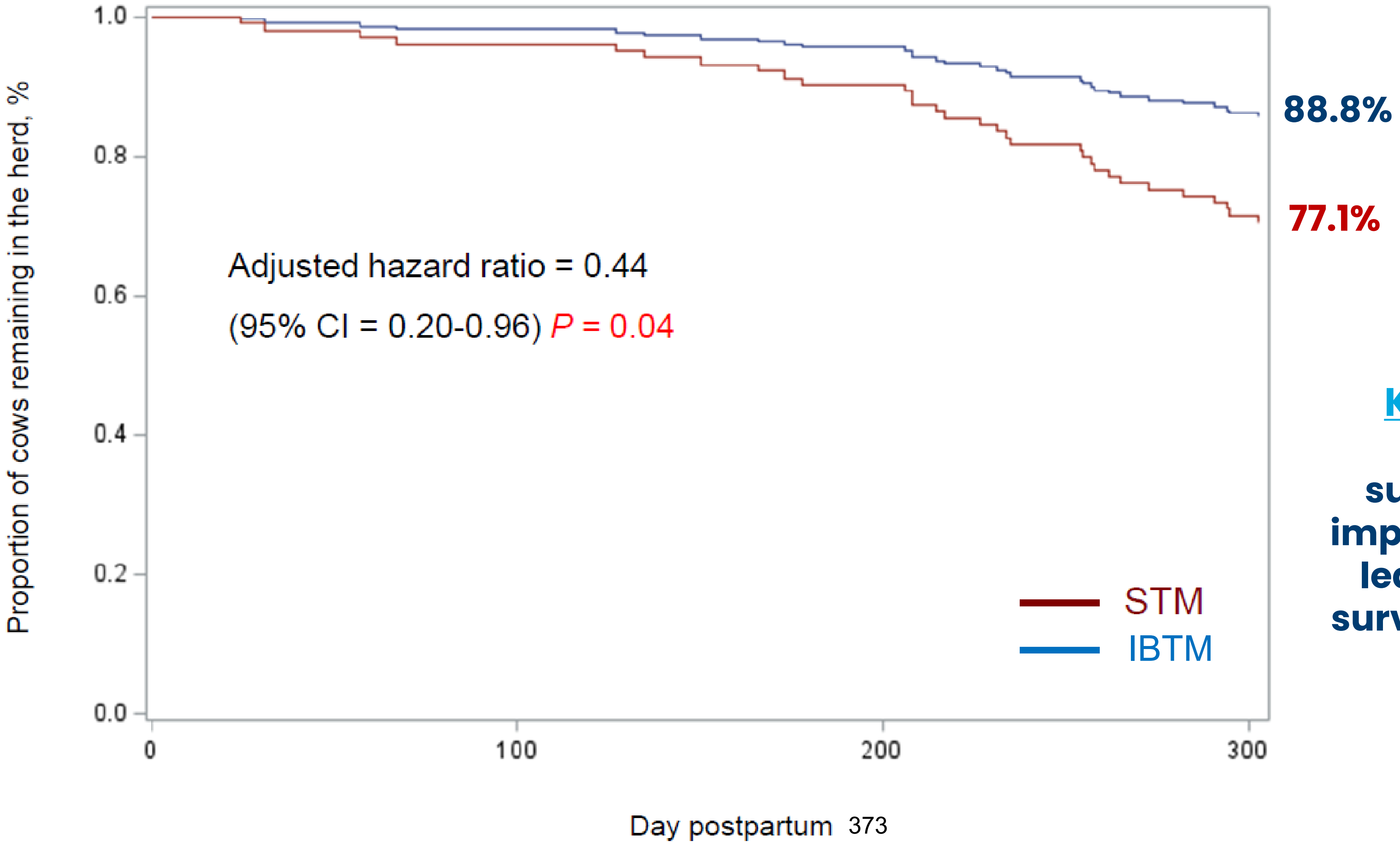
Effect of trace mineral source on colostrum and milk in dairy cows

	Item	Treatment					P-Value
		STM (n=70)		IBTM (n=71)			
		Null	Parous	Null	Parous	SEM	TRT
COLOSTRUM	Yield, kg	5.54	4.89	7.07	5.47	0.81	0.08
	Fat, kg	0.42	0.18	0.58	0.21	0.07	0.11
	True protein, kg	0.84	0.77	1.04	0.85	0.12	0.15
	Total solids, kg	1.53	1.19	1.97	1.53	0.22	0.08
MILK	Milk, kg/d	36.1	46.8	37.3	48	0.8	0.08
	ECM, kg/d	36.3	47.3	39.4	48.1	0.7	0.04
	Fat, kg/d	1.32	1.73	1.41	1.75	0.04	0.08
	True protein, kg/d	1.0	1.31	1.04	1.36	0.02	0.01
	Total solids, kg/d	4.42	5.71	4.62	5.86	0.1	0.04

Key Message: IntelliBond-supplemented cows produced more colostrum and energy-corrected milk

Sarwar et al. (2026) JDS 109: accepted

Effect of trace mineral source on survival curves of cows through 305 DIM



Key Message:
IntelliBond supplementation improved cow health leading to greater survivability through 305 DIM

Sarwar et al. (2026) JDS 109: accepted

Summary of UFL Trial Results:

Replacement of sulfate TM with IntelliBond TM from -28 days prepartum to 105 postpartum resulted in:

1) Increased colostrum yield by approximately 1 kg with no changes in colostrum quality
2) Increased daily milk yield by 1.2 kg, which resulted in:
    a) Increased energy-corrected milk (ECM) yield by 1.1 kg PER DAY
    b) Increased daily yields of true protein, total solids, fat, and lactose
3) Reduced incidence rate of retained placenta (3x ↓) and metritis
4) Improved uterine health through reduction in clinical and subclinical endometritis
5) Reduced plasma haptoglobin levels postpartum to 19 DIM
6) Reduced morbidity incidence by 34% and increased survival rate through 305 DIM
7) Increased proportion of cows pregnant at 305 DIM

Sarwar et al. (2026) JDS 109: accepted

Summary of benefits of IntelliBond TM:

IntelliBond TM have low solubility and low reactivity, which result in the following benefits:

1) Improved stability of feed components such as vitamins in premixes and feeds
2) Improved palatability of mineral premixes, fortified feeds, and cooked molasses tubs
3) Increased bioavailability
4) Improved fiber digestibility

These benefits result in improved health, performance, and sustainability:

1) Reduced morbidity, improved uterine health, and increased survivability (i.e., reduced culling)
2) Increased colostrum yield, increased milkfat yield and increased ECM yield
3) Validated LCA for a 2% reduction in a dairy cow's carbon footprint per kg of ECM

Dr. Lance Baumguard – Udderly Dependent: Dairy Cows and Their Glucose Economy

- Propionate is Essential for Liver Glucose Production
- Gluconeogenesis → “New Glucose”

- Cows have to make >5 lbs. of glucose every day to support milk production!

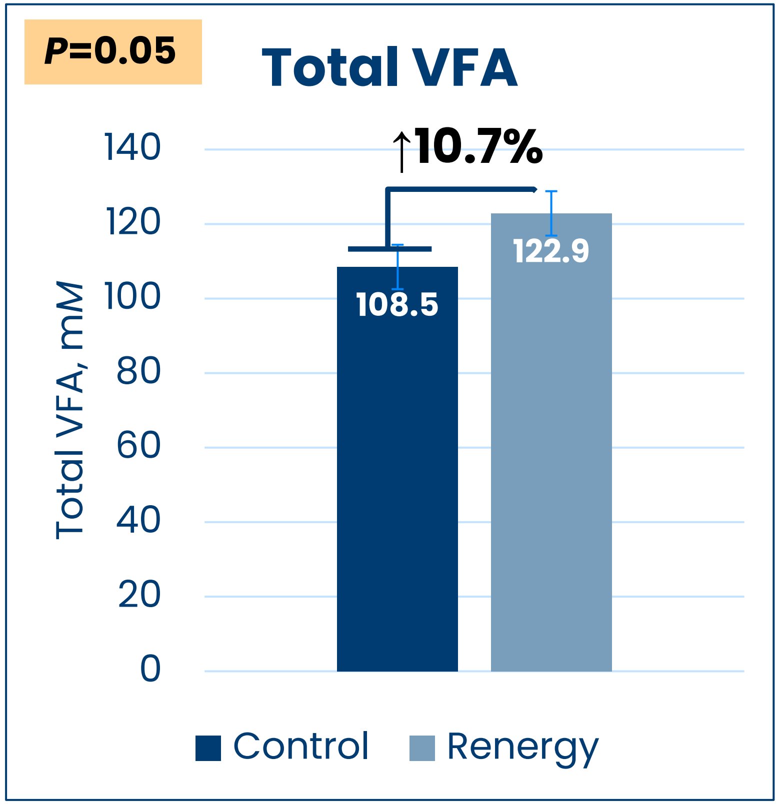
(That’s more than 1 bag of sugar every day!)

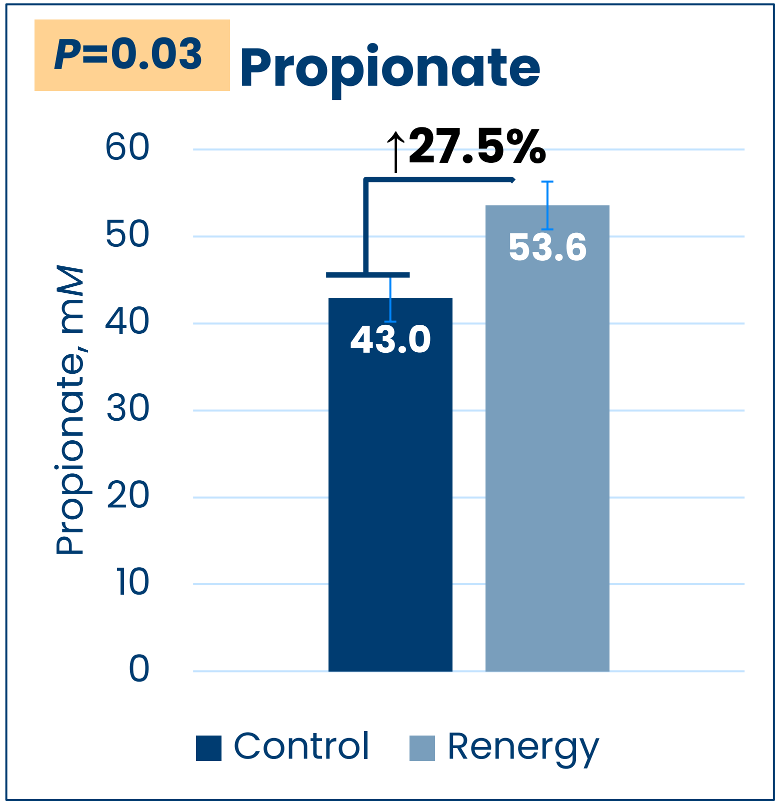
Gluconeogenic precursors:

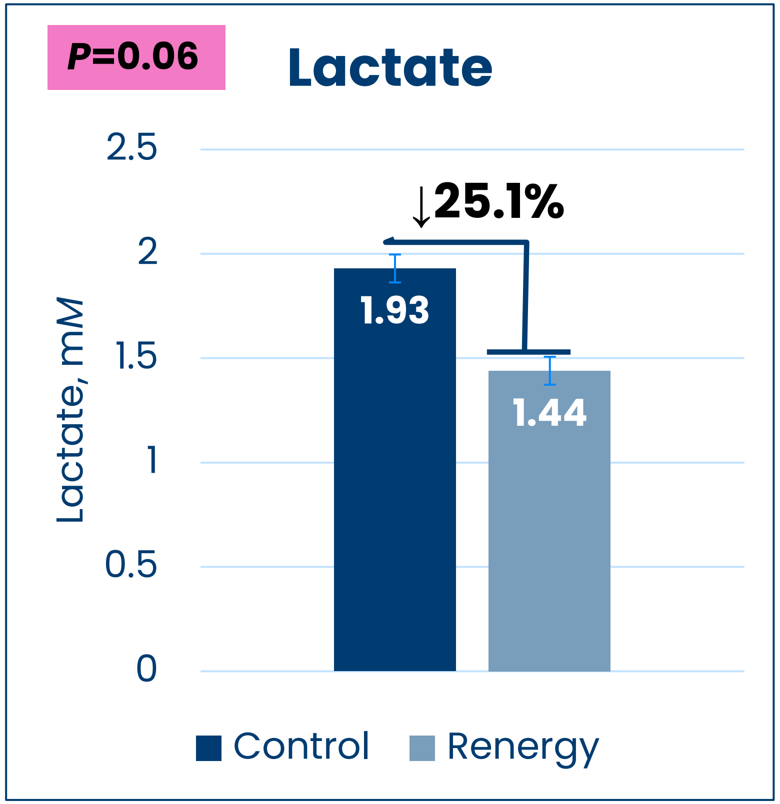
- Propionate (largest contributor to liver glucose)
- Lactate
- Glycerol
- Amino Acids

CSU Renergy Trial – Results

- No differences in pH or NH_3 concentrations







Renergy HC Summary

Renergy HC is a source of malic acid that increases propionate production in the rumen:

- CSU Mode of Action Trial: 27% ↑ in propionate with 25% ↓ in lactate on feedlot diet confirms the MOA from previous internal & external studies

Lactating Cow Trials

- Transition cows (-28 to 28 DIM): +11.8 ECM
- Early lactation cows (22 to 100 DIM): +4.6 lbs ECM
- Mid-lactation cows (153 to 237 DIM): +1.2 lbs ECM

Transition Cow trial (-28 to 28 DIM):

- Control (No Renergy) ≈ 80 lbs ECM
- Pre (Renergy Pre only) ≈ 84 lbs ECM
- Post (Renergy Post only) ≈ 86 lbs ECM
- Pre/Post (Renergy Pre/Post) ≈ 92 lbs ECM

Field Demonstration with Transition Cows (-21 to 21 DIM)

- Lower blood βHBA levels: Average blood βHBA level was numerically lower (0.59 vs. 0.71 mM) & was less variable (±0.20 vs. ±0.28 mM) compared to Pre-Renergy levels
- Greater 1st testday milk yield: 1st testday milk yield was numerically greater (≈93 ±27 vs. ≈ 82 ±33 lbs./day) compared to Pre-Renergy levels

Dr. Emma Wall - Discovery of Phytotechnologies for improving resilience of the modern dairy cow: a physiological perspective

Passive Immunity Summary

- Current benchmarks for passive transfer are outdated
- We need more refined approaches to improving passive immunity in calves
- We can directly impact passive immunity with Phytotechnologies during transition:
  - Increased Ig production by the dam
  - Increased Ig levels in calf serum
  - Improved health & growth performance (beef)
- Studies ongoing for dairy application with Fytera Lacteco

Dr. Emma Wall - Discovery of Phytotechnologies for improving resilience of the modern dairy cow: a physiological perspective (Fytera Lacteco)

Selko®

CHILLI

↓

Decreased Inflammation

TUMERIC

↓

improved adaptive & innate immunity

PEPPER

↓

increased bioavailability and efficacy of actives

Natural immune modulator

↑ Passive immunity

↓ Disease susceptibility

↑ Progeny health & performance

Selko
Thank you!
Contact us for more info!
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Navigating Dairy Data in a Big Data and AI World

Greg Bethard, Ph.D.
CEO and Managing Partner
High Plains Ponderosa Dairy
Plains, KS

High Plains Ponderosa Dairy

- We have a data-driven culture
- Decisions are data-driven when possible
- Data Visualization Tools that we use…
  - Excel
  - Power Point
  - Power Bi
- Spreadsheets are still best tool for many applications. Reports are Power Point or PDF
- Power Bi comes in when there is too much data for Excel
- We have fiber run to every building on our site

We make our own tools…

- Vendor software never seems to be good enough
  - Too detailed
  - Doesn't answer our questions
  - Not in a form that we can make decision

What is Big Data and how will AI impact us?

- AI is everywhere, it really isn't possible to avoid it
- Everybody wants to manage our data
- Most people don't know what we as dairy producers really need for decision making
- At HPPD we don't want to abandon *Critical Thinking*
- *Does it create the same value if you don't earn the knowledge?*
- The AI ship has left port

Locomotion Scoring – application of AI

- How do you find lame cows in your herd?
  - Harder with big pens
- How do you track trimmer performance?
- How do you know if your lameness is heading in the wrong direction?
- Can’t justify cost of Locomotion Scoring in labor savings….

Chat GPT and Claude

- Our team utilizes these tools to some extent
- Recent Teat End Hygiene Protocol evaluation from both tools was impressive.

Teat End Hygiene Protocol Evaluation — Overview *640 cows | 10 protocols | 4 contact times (15, 30, 45, 60 seconds) | Blood agar plate cultures graded 0–10*

Purpose
This study evaluated ten pre-milking teat end cleaning protocols to determine which method most effectively reduces bacterial load on teat skin prior to milking. Lab technicians cultured teat swabs on blood agar plates and graded growth on a 0–10 scale, with 0 representing no bacterial growth and 10 representing completely covered plates. Sixteen cows were sampled per protocol at each time point, producing 640 total observations. The goal was to identify the protocol that leaves the least viable bacteria on teat skin and to understand whether contact time meaningfully affects outcomes.

Methodology Note
Because growth scores are rated on an ordered scale rather than measured as a true continuous value, standard statistical tests like ANOVA are not appropriate. All analysis used non-parametric methods — specifically the Kruskal-Wallis test to assess whether any protocols differed from each other, and Mann-Whitney U tests for pairwise comparisons. These tests evaluate rank order rather than raw values, which makes them more appropriate for this type of data and more resistant to the influence of extreme scores.

Primary Finding
Chlorine/Soap applied with a brush is the most effective protocol across all contact times. It produced the lowest overall mean growth score of 2.00 out of 10, and this advantage over every other protocol was statistically significant ($p<0.05$ in all pairwise comparisons). The result held consistently whether cows were swabbed at 15, 30, 45, or 60 seconds after application.

Application Method Matters More Than Product
One of the clearest findings in the data is that the method of application — brush versus cup — has a larger and more consistent effect than which chemical product was used. Brush-applied protocols averaged a mean score of 2.38 compared to 3.03 for cup-applied protocols, a difference that was highly statistically significant ($p<0.0001$). This pattern held across all four time points and all five chemical products tested. The mechanical scrubbing action of the brush appears to physically dislodge bacteria from teat skin in a way that passive cup application does not replicate.

Contact Time
Contact time produced mixed results depending on the protocol. There is no universal "longer is better" conclusion. Chlorine/Soap Brush performed best at 15 seconds and showed only modest degradation through 60 seconds, suggesting that if speed is a priority in the parlor, 15–30 seconds is adequate for that protocol. Iodine Brush showed its best performance at 30 seconds and worsened noticeably at 60 seconds. DL 1200 Brush was the opposite — it actually improved with longer contact time and reached its lowest score at 60 seconds. These divergent patterns suggest that contact time recommendations should be protocol-specific rather than applied as a blanket rule across all products.

Outlier Analysis
Twenty-five scores of 10 were recorded across the dataset. To evaluate whether these extreme values represented genuinely dirty cows rather than protocol performance, each score of 10 was tested against the IQR fence (Q3 + 1.5×IQR) for its specific protocol and time group. Twenty-one of the 25 scores of 10 were identified as statistical outliers and removed in a cleaned scenario analysis. Four scores of 10 in the Iodine Cup at 45-second group were retained because that group's own variability was wide enough that a score of 10 did not qualify as extreme — correctly reflecting that protocol's genuine inconsistency.
Removing the outliers did not change the primary conclusion. Chlorine/Soap Brush remained the top-performing protocol, and its advantage over the field actually widened slightly with a cleaned mean of 1.61. The more important statistical finding from the cleaned analysis is that protocol differences at the 45-second time point, which were borderline in the original data ($p=0.052$), became clearly statistically significant after outlier removal ($p=0.038$). This tells us the extreme scores were masking real differences between protocols at that contact time, not amplifying them — which supports the decision to exclude them.

Bacteria Identified
All ten protocols showed the same spectrum of bacterial species recovered from culture: E. coli, Klebsiella, Staph, Pseudomonas aeruginosa, Bacillus, and Proteus, with occasional Strep. The consistent presence of these organisms across all protocols confirms that none of the ten methods achieved complete bacterial elimination — they differ in the degree of reduction, not whether reduction occurs.

Recommendations
Based on this analysis, Chlorine/Soap applied with a brush at 15–30 seconds of contact time is the recommended protocol for routine pre-milking teat preparation. It produced the lowest bacterial growth scores, was the most statistically distinguishable from all other protocols, and performed consistently across contact times — making it both the most effective and the most forgiving in terms of parlor timing variation.
If operational constraints require cup application, Oxisodium Chlorine Cup and Chlorine/Soap Cup were the better-performing cup methods, though both remained meaningfully inferior to the top brush protocols. DL 1200 Cup showed the highest scores overall and would be the least recommended option regardless of contact time.

Data Fundamentals

- *Ask the questions first*
- If you don't make decisions from data, stop wasting your time collecting it
- You need to know something about variation
  - How often is normality assumed?
- Understand the difference between observations and data
  - Most dairy data is actually observations
  - Data involves controls

Questions I have....

- Is cow health changing?
- Are cows experiencing heat stress?
- Is milk flow changing? Components? Money Corrected Milk?
- Are we generating the pregnancies we had planned for?
- Are cows being dried off at the proper DCC?
- Are we getting semen into heifers on time?
- Are we moving heifers or cows to Close-up on time?
- What bugs are causing mastitis?
- How much clinical mastitis do we have?
- How is milk quality? SCC, SPC, etc
- There are many more questions....

How do you justify the cost of data or AI?

- Subscriptions are commonplace
- Who owns the data?
- Are you held hostage to future fees or charges?
- Do you require improved performance or lower cost (labor savings) to justify?

Sources of Data for most dairy businesses..(HPPD)

- Herd Management Software (Dairy Comp)
- Meters in Parlor (SCR, DelPro)
- Activity Monitoring (SCR)
- Locomotion Scoring (NEDAP)
- Milk Plant Data: quantity, fat, protein, SCC, etc (DFA, Hilmar)
- Accounting (Quickbooks)
- Bill Paying (Stampli)
- Repairs and Maintenance (FIIX)
- Fuel systems (Clipboard)
- Spreadsheets – inventories, purchases, harvest, medicine, chemicals,etc.

We are big on Cost Centers…

- What does it cost per milking to run each parlor?
- What does it cost/hr to run various equipment lines?
  - Vacuum, Tractor, Wheel Loaders, Skid Loaders, etc.
- What does it cost to run a sample through milk lab?
- What does it cost to mix a load of TMR?
- What are Cow Costs/cwt?
- What are Facility Costs/cwt?
- *This still comes down to spreadsheets for us*….

Inventories

- Allow you to get *Accrual* costs…
- Feed
- Chemicals
- Medicine
- If you don't do Physical Counts you can't compute shrink
- *This still comes down to spreadsheets for us*….

How we at HPPD present data to managers…

- Spreadsheets, Power Point, Power Bi
- Some graphs, some tables
- If we don't *send* something the uptake is minimal…

How we at HPPD present data to managers…

- Some are daily…
  - Milk Sold
  - Parlor Reports
  - Heavy Breathing summary
- Some are weekly….
  - Fresh Cow report
  - Lame Report
  - Calf Cohort Report
  - Pregs Checked report
  - Breedings by semen type and projected calves born
  - Vet Check results (Dairy Comp Bredsum reports)
- Some are monthly…
  - Milk Sold Summary
  - Dead and Beef
  - Lame Summary
  - Calf Health Report

Financial Data

- Monthly Profit and Loss. Only shared with partners.
- Breakeven Milk Price is more important than anything.
- We don't try and match production and financial data. We don't think that is a good idea…
- *This still comes down to spreadsheets for us*….

How do you Look at Data?

- Dashboards?
- 100,000 foot report
  - Surveillance
- 30,000 foot report
- Ground Level

Data Warehouse

- You really need a Data warehouse to “push” all your “big” data to…
  - Herd Mgmt software
  - Parlor software
  - Etc
- The “Push” can be a CSV file or API
- Then you need a Data Visualization Tool (like Power Bi) to make charts and graphs

What is your model?

- Know your model
- Live your model
- Choose metrics and data that fit with your model

Our most important metrics

- *Breakeven milk price*
- *Static Variable Margin*
- Everything else is secondary
- These metrics reflect our model
- Individual cow metrics are less important

Income	
Milk Income	18.00
Other Income	3.00
Total Income	21.00
Expenses	
Feed	10.00
Other	9.00
Total Expense	19.00
Net Income	2.00
Class III	17.00
Basis	+1.00
Class III breakeven	15.00 (17.00 – 2.00)

What is cost of production?

$19.00

What is Breakeven Milk Price?

$16.00 (18.00 – 2.00)

What is Class III Breakeven?

$15.00 (17.00 – 2.00)

Other Income is a Big Deal! $1.00 of Other income lowers Breakeven $1.00

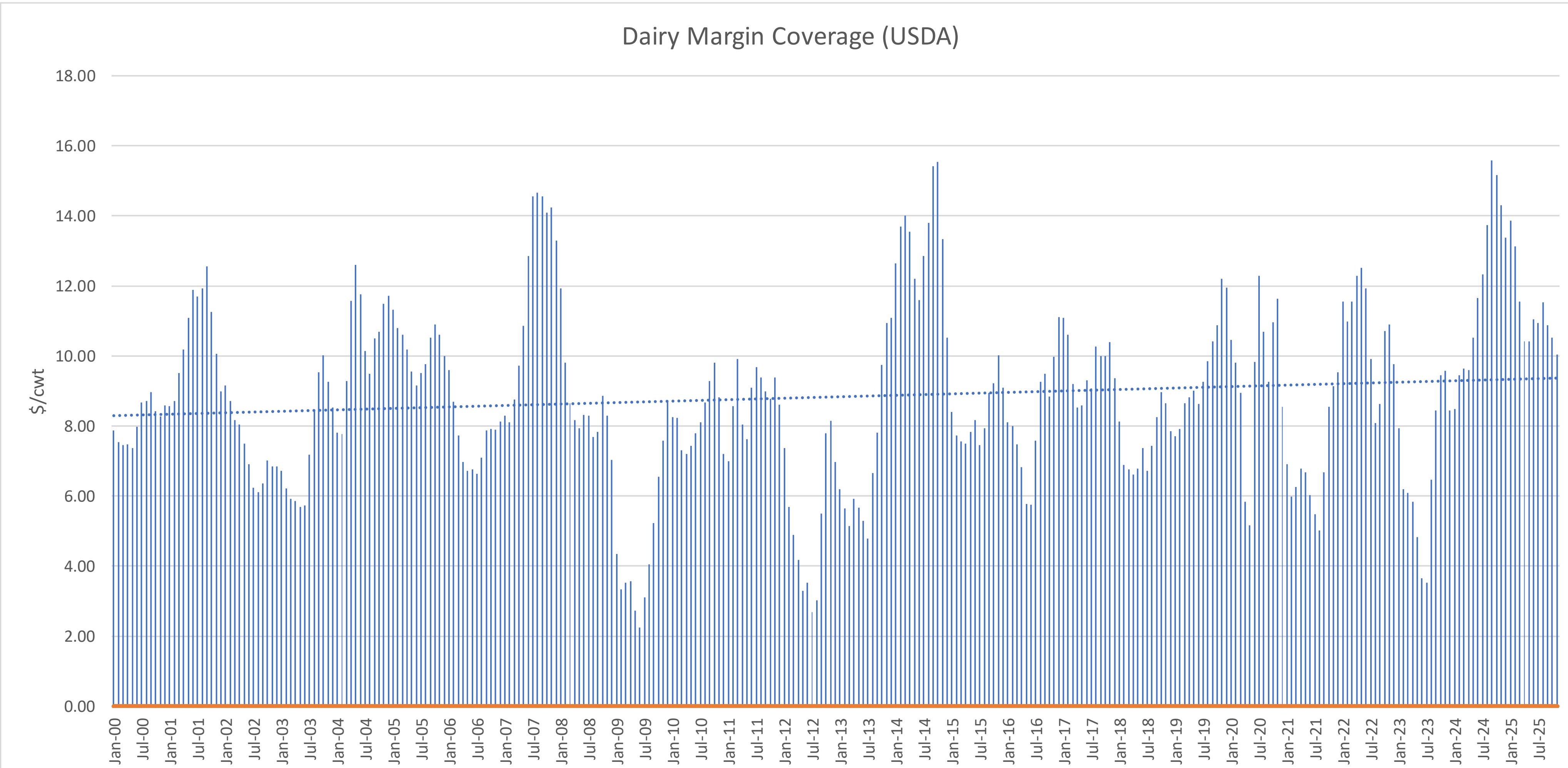
Income	
Milk Income	18.00
Other Income	3.00
Total Income	21.00
Expenses	
Feed	10.00
Other	9.00
Total Expense	19.00
Net Income	2.00
Class III	17.00
Basis	+1.00
Class III breakeven	15.00 (17.00 – 2.00)

Income	
Milk Income	18.00
Other Income	4.00
Total Income	22.00
Expenses	
Feed Cost	10.00
Other	9.00
Total Expenses	19.00
Net Income	3.00
Class III	17.00
Basis	1.00
Class III Breakeven	14.00

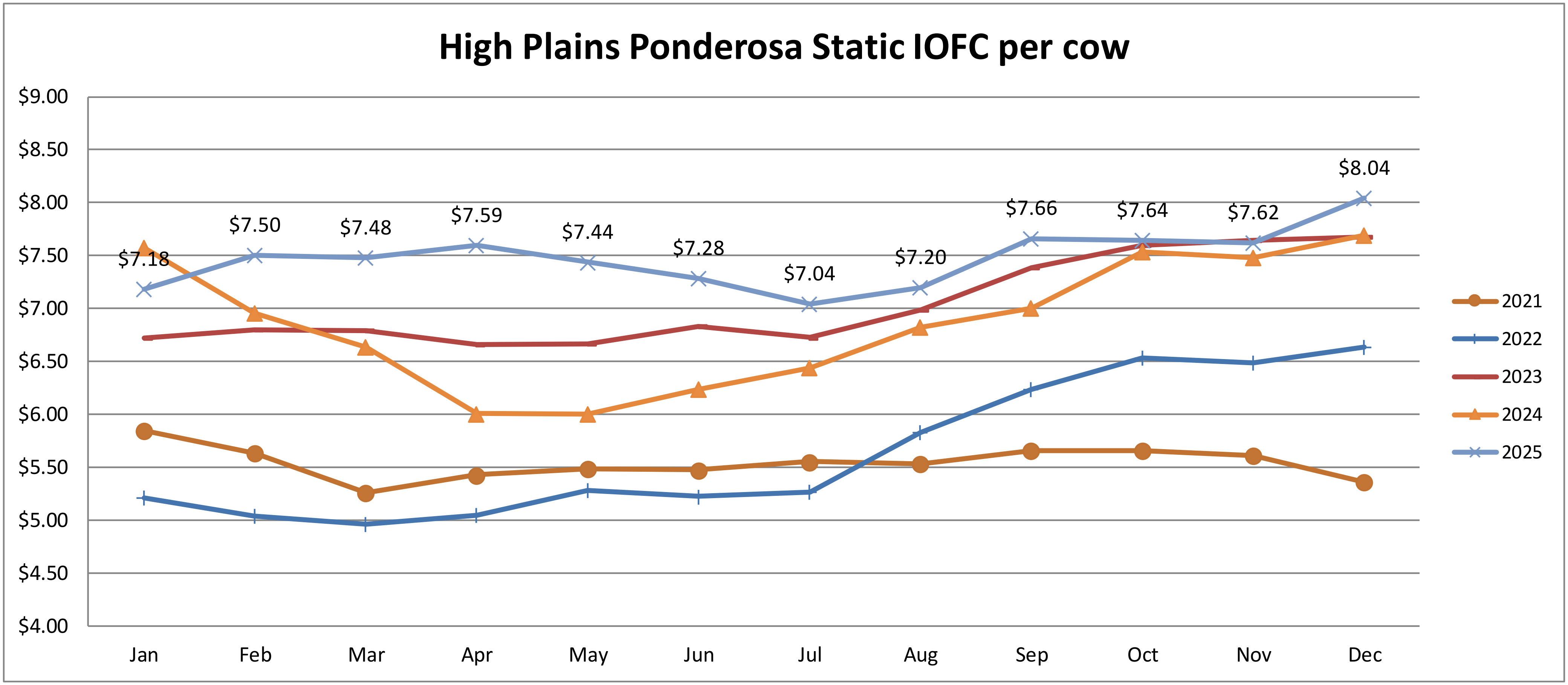
Income Over Feed Cost

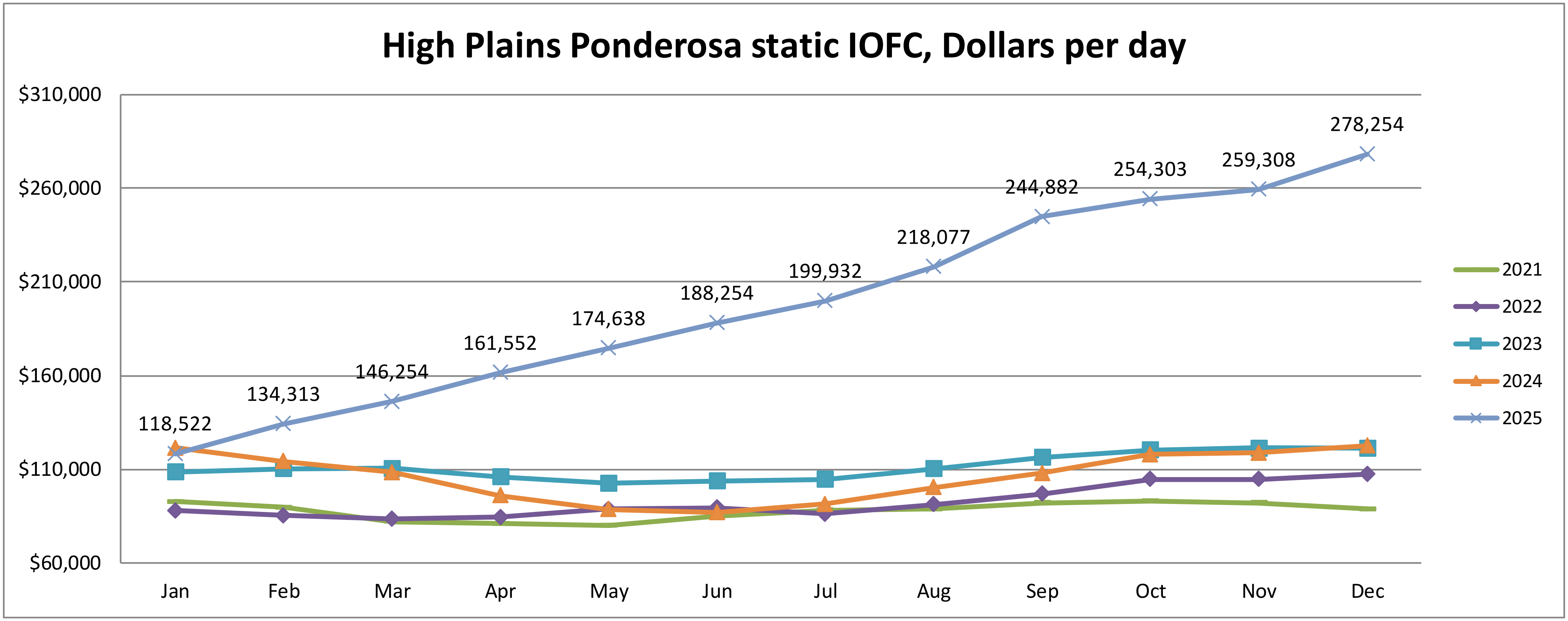
- The margin you must track
- Three ways to compute
  - Actual IOFC
  - Static IOFC with *Market Factors* fixed
  - Static IOFC with *Cow Factors* fixed
- Total IOFC per day more important than per cow

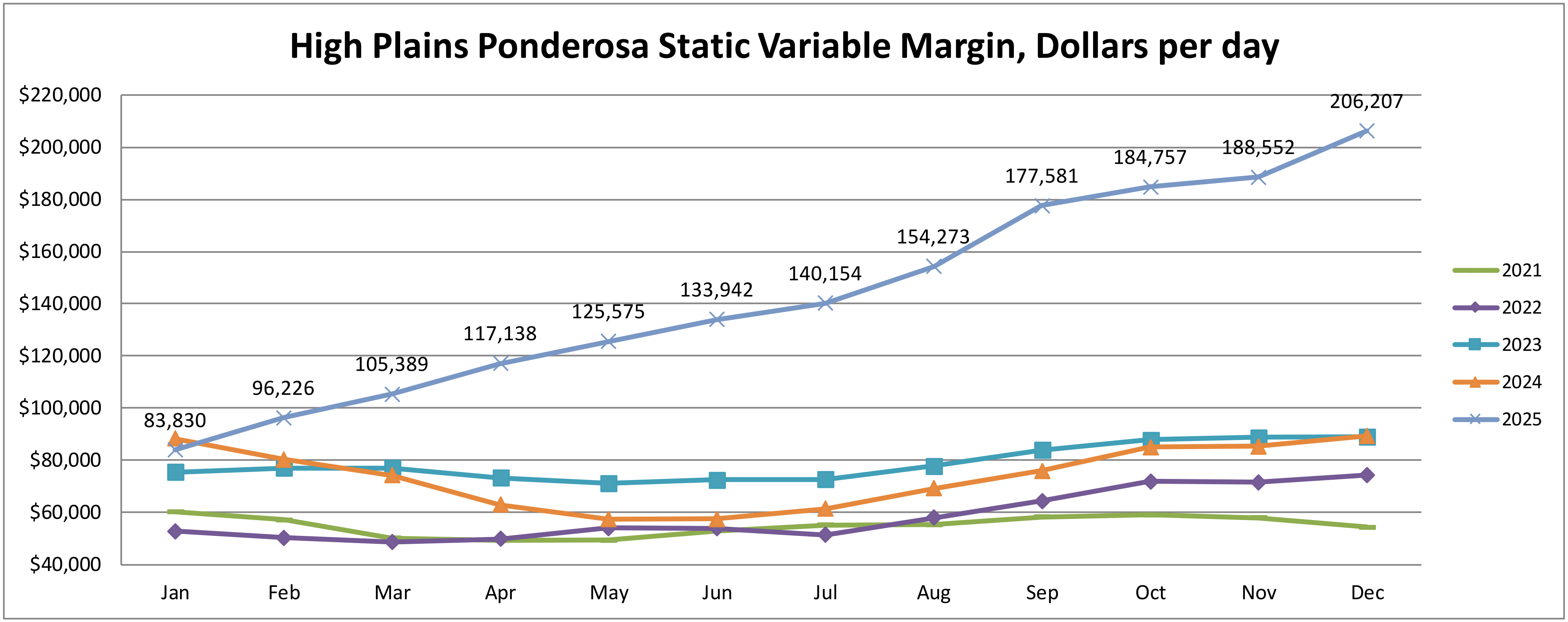
Cow fixed, market varies



Market fixed, cow varies




High Plains Ponderosa static IOFC, Dollars per day
$310,000
$260,000
$210,000
$160,000
$110,000
$60,000
118,522
134,313
146,254
161,552
174,638
188,254
199,932
218,077
244,882
254,303
259,308
278,254
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2021
2022
2023
2024
2025

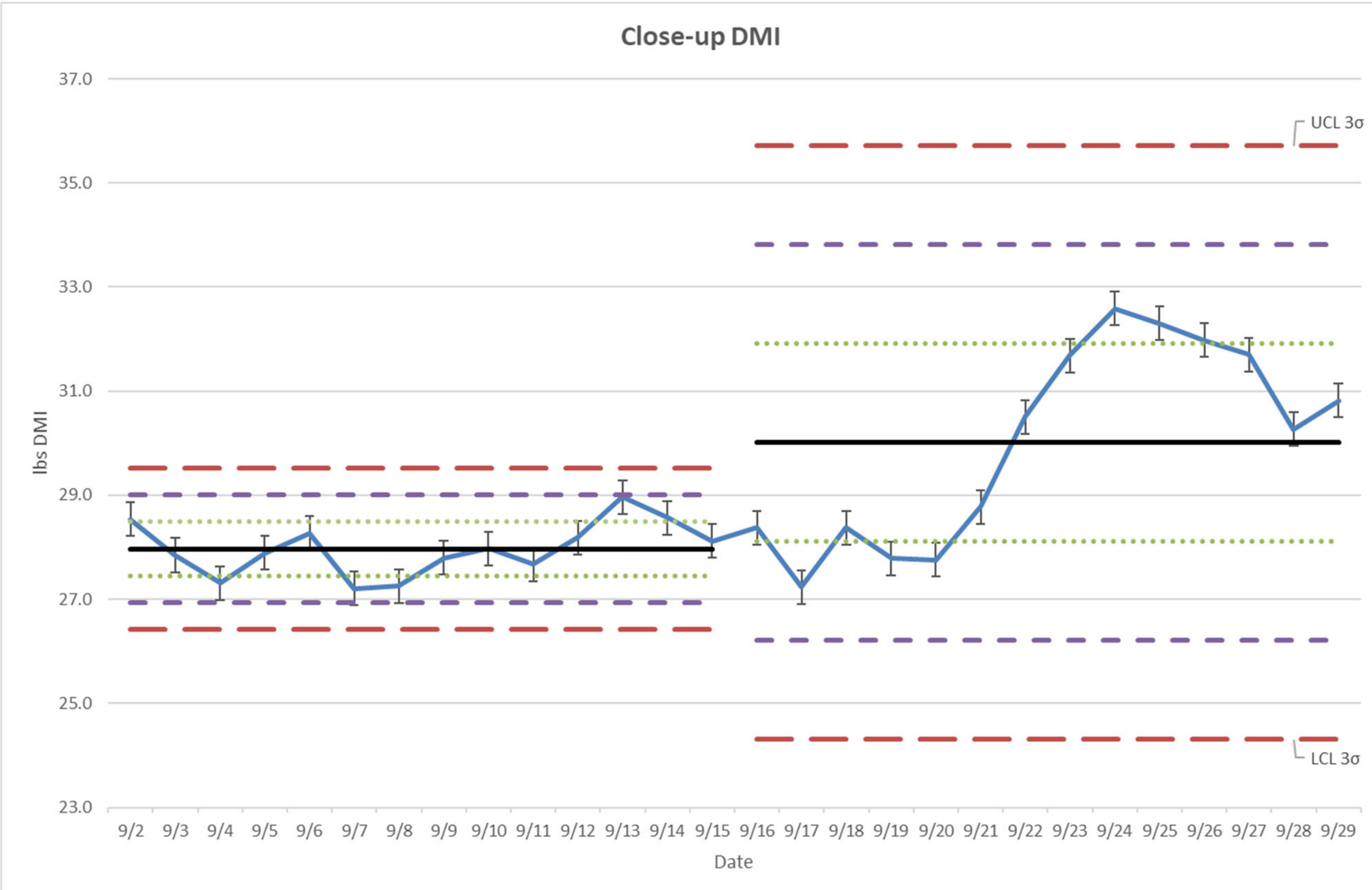


Static Margin = IOFC/d – $2.05/d

$2.05/d = Dry Cow Feed ($0.30/d) + Replacement ($1.25/d) + supplies ($0.50/d)

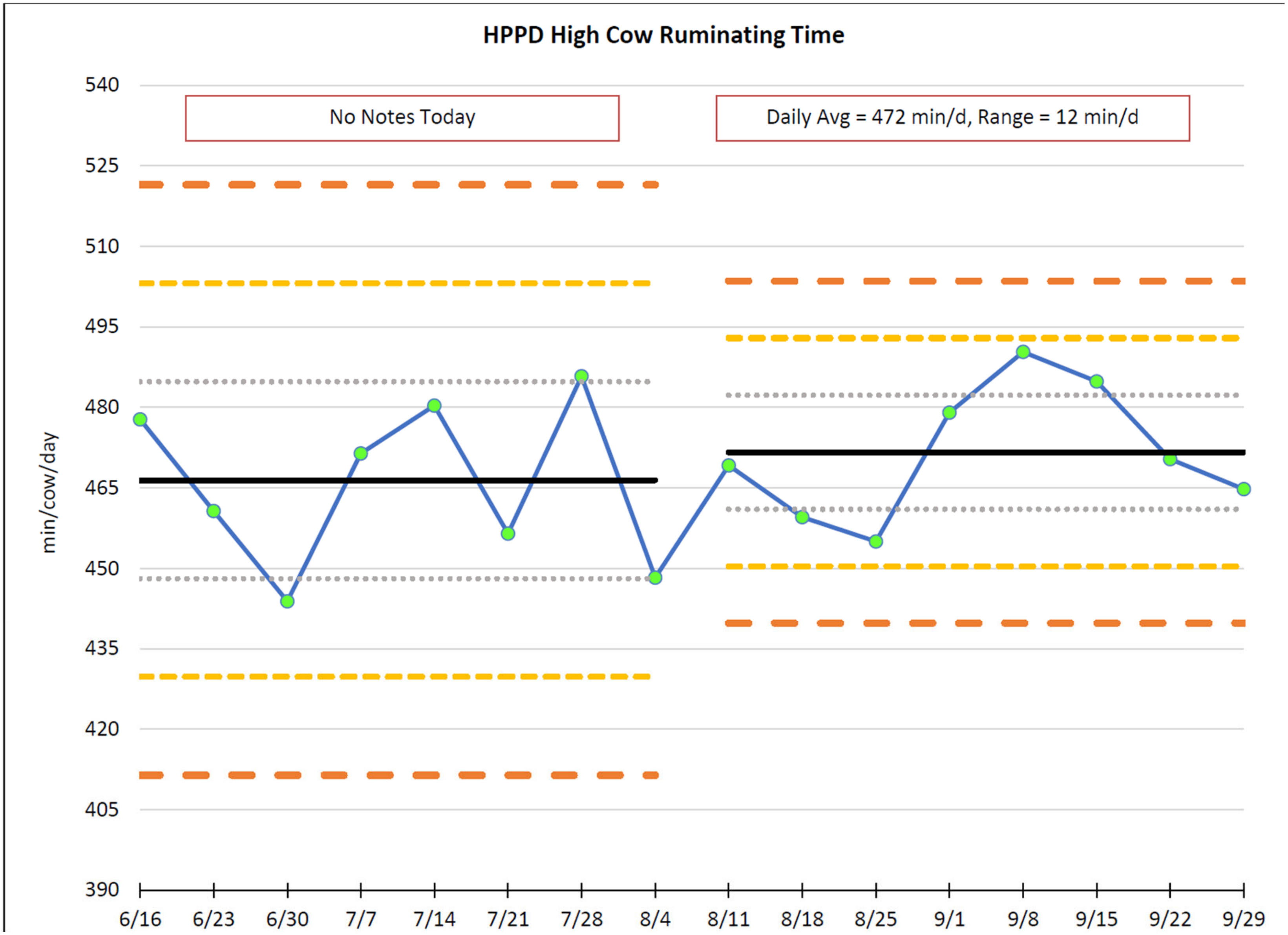
Understanding Variation

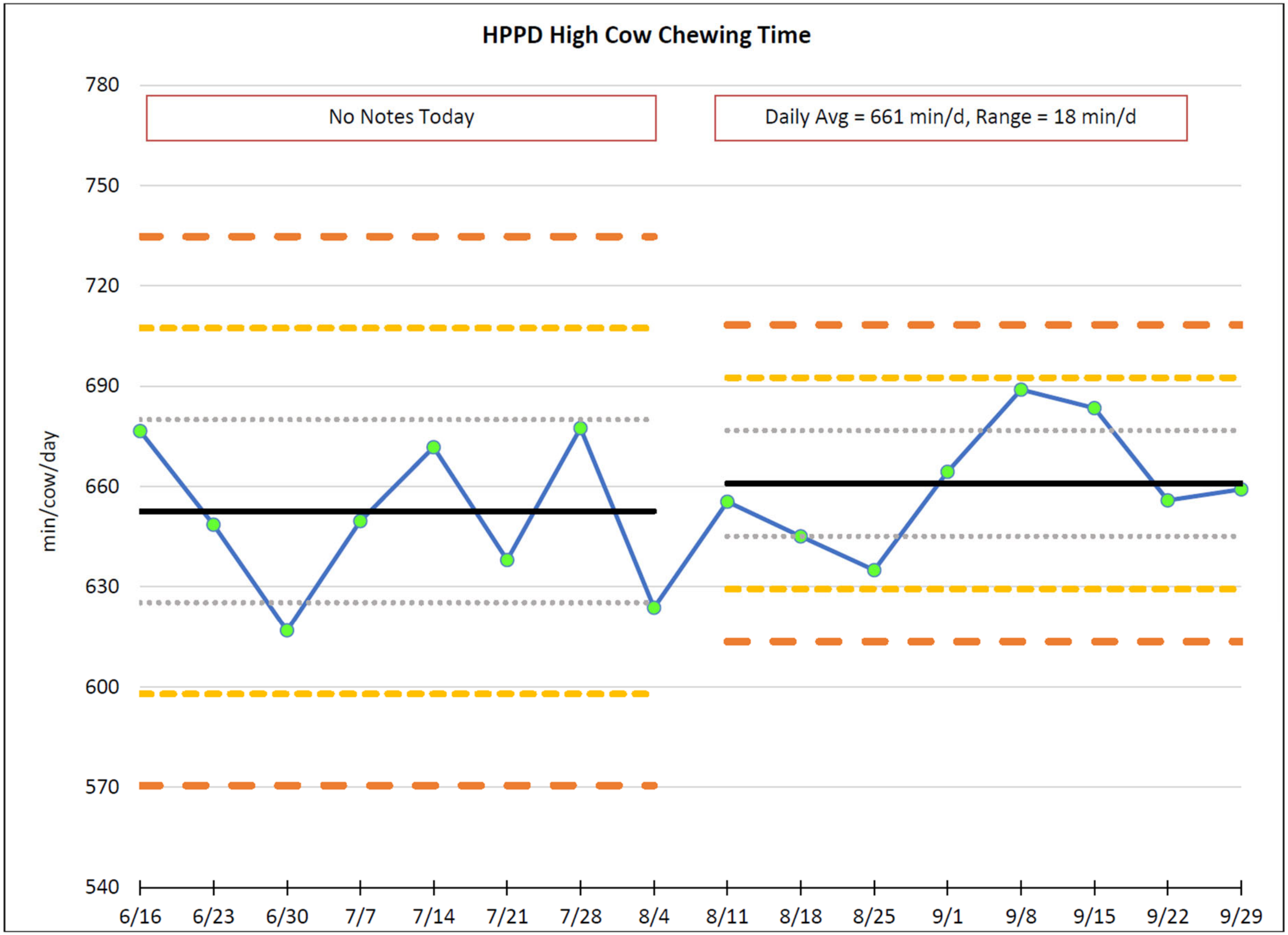
- SPC Charts
- Is it normally distributed?
- What triggers action?


Close-up DMI
37.0
35.0
33.0
31.0
29.0
27.0
25.0
23.0
lbs DMI
UCL 3σ
LCL 3σ
9/2 9/3 9/4 9/5 9/6 9/7 9/8 9/9 9/10 9/11 9/12 9/13 9/14 9/15 9/16 9/17 9/18 9/19 9/20 9/21 9/22 9/23 9/24 9/25 9/26 9/27 9/28 9/29
Date

Collars

- Rumination Time
- Eating Time
- Chewing Time
- Eating Pace (computed)
- Heavy Breathing

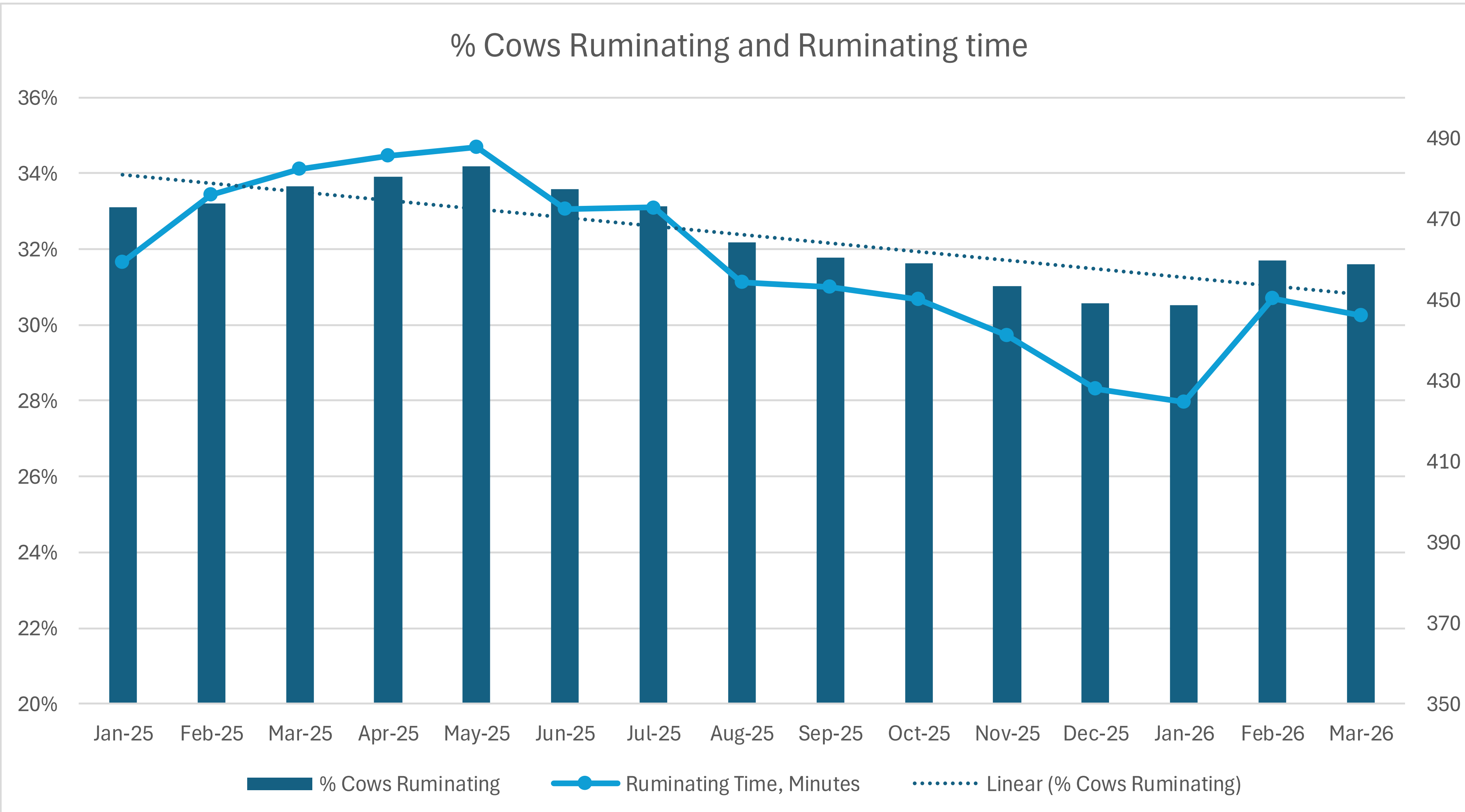

HPPD High Cow Ruminating Time
No Notes Today
Daily Avg = 472 min/d, Range = 12 min/d
min/cow/day
540
525
510
495
480
465
450
435
420
405
390
6/16
6/23
6/30
7/7
7/14
7/21
7/28
8/4
8/11
8/18
8/25
9/1
9/8
9/15
9/22
9/29


HPPD High Cow Chewing Time
No Notes Today
Daily Avg = 661 min/d, Range = 18 min/d
780
750
720
690
660
630
600
570
540
min/cow/day
6/16
6/23
6/30
7/7
7/14
7/21
7/28
8/4
8/11
8/18
8/25
9/1
9/8
9/15
9/22
9/29

Heavy Breathing (Last Two Weeks)

Last 2 weeks	10-Aug	11-Aug	12-Aug	13-Aug	14-Aug	15-Aug	16-Aug	17-Aug	18-Aug	19-Aug	20-Aug	21-Aug	22-Aug	23-Aug
Temp														
Max	90	83	86	93	99	101	95	98	98	92	91	90	90	80
Min	58	60	65	65	69	71	75	72	67	68	64	70	62	67
Humidity														
Avg	60	77	68	63	58	52	55	59	60	62	67	65	55	67
THI														
Using avg Temp and Hum	74	70	73	74	77	79	78	78	77	75	73	74	73	71
Heavy Breathing, Minutes														
Fresh Cow Barn	20	12	10	11	0	12	13	14	10	0	8	10	13	11
Crossvent #2	183	87	46	57	61	97	131	126	159	142	103	58	67	46
Crossvent #3	150	53	32	41	45	71	99	97	114	99	60	40	51	40
Crossvent #4	129	52	26	33	38	58	80	77	89	83	54	34	45	33
Dry Cow Barn	17	13	11	12	0	14	14	13	12	0	9	12	12	11
Severe Heat Stress: (> 30%)	% time	% time	% time	% time	% time	% time	% time	% time	% time	% time	% time	% time	% time	% time
Fresh Cow Barn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Crossvent #2	0%	0%	0%	0%	0%	2%	0%	3%	4%	0%	0%	0%	0%	0%
Crossvent #3	0%	0%	0%	0%	0%	2%	1%	2%	1%	0%	0%	0%	0%	0%
Crossvent #4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dry Cow Barn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mod/Sev Heat Stress: (> 20%)														
Fresh Cow Barn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Crossvent #2	2%	3%	0%	0%	5%	8%	7%	15%	11%	6%	0%	0%	0%	0%
Crossvent #3	0%	0%	0%	0%	2%	4%	3%	4%	3%	1%	0%	0%	0%	0%
Crossvent #4	0%	0%	0%	0%	0%	2%	1%	2%	1%	0%	0%	0%	0%	0%
Dry Cow Barn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mild Heat Stress: (> 10%)														
Fresh Cow Barn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Crossvent #2	18%	9%	6%	7%	22%	35%	33%	46%	41%	23%	5%	7%	1%	1%
Crossvent #3	5%	0%	3%	3%	7%	19%	13%	27%	22%	4%	2%	3%	2%	1%
Crossvent #4	4%	0%	1%	2%	5%	13%	9%	21%	17%	5%	1%	2%	1%	0%
Dry Cow Barn	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

*% of 5-minute increments when (30%, 20%, or 10%) of the cows were breathing heavy


% Cows Ruminating and Ruminating time
36%
34%
32%
30%
28%
26%
24%
22%
20%
490
470
450
430
410
390
370
350
Jan-25
Feb-25
Mar-25
Apr-25
May-25
Jun-25
Jul-25
Aug-25
Sep-25
Oct-25
Nov-25
Dec-25
Jan-26
Feb-26
Mar-26
% Cows Ruminating
Ruminating Time, Minutes
Linear (% Cows Ruminating)

What I look at with collars

- Number of Sick cows every day
- % of Fresh cows that are sick
- Heavy Breathing Minutes
- I find the Health Index very useful
- I don't find ruminating or eating data very useful by itself but it can signify changes

How do collars pay?

- Labor cost savings are necessary to make it pay
- Cow health? Depends on cow docs
- Repro success? Depends on service rate
- Performance improvement? Depends on current situation.

HPPD installed collars in 2020

- Cost of collars was $15K per month
- Saved almost $25K/mo in labor
- Letting a cow be a cow has to have some benefits

Parlor meters

- Milk weight by itself is not very useful
- Data allows us to optimize our rotaries

% Undermilked Cows (> 5 lbs flow rate at detach, by Pen).

	29-Mar	30-Mar	31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	**2 WK Avg**	Current Wheel Speed	**7-d Avg** Milk Flow	Machine On Time
% Undermilked				**Alarm** ----> greater than		10%			**Goal** ----> less than	7%								
Pen 30	7%	13%	12%	8%	20%	16%	16%	13%	11%	16%	20%	12%	8%	8%	**13%**	3.0	69.7	04:11
Pen 31	8%	11%	11%	9%	20%	14%	15%	12%	13%	14%	18%	11%	7%	8%	**12%**	3.0	69.1	04:20
Pen 32	5%	9%	12%	7%	18%	12%	10%	10%	12%	13%	6%	8%	5%	5%	**9%**	3.1	71.9	04:19
Pen 33	6%	9%	11%	9%	11%	10%	13%	12%	12%	12%	7%	10%	6%	4%	**9%**	3.5	93.5	04:40
Pen 34	4%	7%	9%	7%	9%	8%	10%	9%	9%	11%	12%	11%	6%	5%	**8%**	3.5	90.7	04:34
Pen 35	7%	8%	10%	7%	11%	11%	12%	11%	11%	14%	15%	6%	9%	5%	**10%**	3.1	70.9	04:19
Pen 36	14%	19%	18%	12%	14%	18%	16%	16%	15%	14%	16%	6%	11%	9%	**14%**	2.9	70.0	04:11
Pen 37	13%	17%	20%	11%	17%	21%	21%	18%	15%	17%	23%	9%	14%	10%	**16%**	2.9	70.3	04:17
Pen 38	4%	6%	8%	8%	6%	7%	6%	6%	5%	9%	9%	5%	8%	5%	**7%**	3.7	85.6	04:26
Pen 39	6%	12%	14%	12%	13%	15%	14%	14%	12%	17%	19%	10%	14%	9%	**13%**	3.2	73.9	04:22
NoGroup	9%	12%	11%	9%	14%	14%	14%	11%	12%	12%	11%	10%	8%	7%	**11%**			
AM Shift	6%	11%	13%	9%	14%	14%	13%	12%	12%	14%	15%	10%	10%	6%	11%			
PM Shift	9%	11%	11%	9%	14%	13%	13%	12%	11%	13%	16%	12%	8%	7%	11%			
Total	7%	11%	12%	9%	14%	13%	13%	12%	11%	14%	16%	11%	9%	7%	11%	3.2	76.6	04:21

2-minute milk (by Pen)

	29-Mar	30-Mar	31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	**2 WK Avg**
2 minute Milk, lbs				**Alarm** ----> less than		19.0		**Goal ----> greater** than		20.0					
Pen 30	17.3	16.4	17.1	17.1	16.8	16.3	16.4	16.9	17.4	16.2	16.5	17.7	17.6	17.9	**17.0**
Pen 31	17.0	16.2	16.6	16.6	16.3	15.8	16.1	16.6	16.4	16.1	16.0	17.1	17.0	17.1	**16.5**
Pen 32	17.1	16.0	17.0	17.0	16.6	16.2	16.1	16.6	16.6	16.5	16.6	17.3	17.7	17.9	**16.8**
Pen 33	22.1	21.1	21.6	21.4	21.0	20.8	20.1	21.1	21.2	20.9	21.6	21.6	22.3	22.0	**21.3**
Pen 34	21.9	20.8	21.5	20.9	20.6	20.5	20.4	21.1	20.9	20.6	20.6	21.5	21.7	21.8	**21.1**
Pen 35	17.2	16.6	17.3	17.4	16.6	16.7	16.3	17.1	17.0	16.5	16.9	16.4	17.2	17.9	**16.9**
Pen 36	16.9	16.5	17.1	17.1	17.0	16.4	16.3	17.1	17.3	17.1	17.3	16.0	17.5	17.8	**17.0**
Pen 37	16.3	16.0	16.7	17.1	16.4	15.6	15.8	16.3	16.6	16.6	17.0	15.6	17.2	17.6	**16.5**
Pen 38	20.6	20.4	20.7	21.3	20.9	19.6	20.0	20.4	20.5	20.2	20.8	19.1	20.4	21.1	**20.4**
Pen 39	17.8	17.7	17.6	18.2	17.9	17.2	17.2	17.6	17.7	17.2	17.5	17.5	17.6	18.1	**17.6**
NoGroup	16.8	16.3	17.3	16.9	16.8	16.2	15.6	16.7	17.1	16.3	16.8	16.7	17.3	16.5	**16.7**
AM Shift	18.7	17.8	17.8	18.5	18.3	17.5	17.6	18.2	18.2	17.9	17.9	18.3	18.4	19.0	**18.1**
PM Shift	18.1	17.6	18.8	18.4	17.7	17.5	17.3	18.0	18.0	17.7	17.9	18.6	19.0	18.7	**18.1**
Total	18.4	17.7	18.3	18.5	18.0	17.5	17.4	18.1	18.1	17.8	17.9	18.5	18.7	18.9	**18.1**

First Shift (AM)

		29-Mar	30-Mar	31-Mar	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr
		AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift	AM shift
Cows		11,994	11,899	11,338	11,570	12,094	12,457	12,442	12,383	12,349	11,548	11,272	7,069	12,103	12,185
Shift Yield		38.0	38.8	39.1	39.2	38.5	37.4	37.5	37.8	38.3	38.9	38.9	39.1	37.7	37.7
Avg Flow		9.1	8.9	8.8	9.0	9.0	8.7	8.7	8.9	9.0	8.8	8.9	9.3	8.9	9.1
SD		4.2	4.2	4.2	4.3	4.2	4.1	4.1	4.2	4.2	4.2	4.2	4.6	4.2	4.3
ID to Attach		00:42	00:45	00:49	00:43	00:50	00:41	00:42	00:41	00:41	00:43	00:43	00:44	00:42	00:42
FLOW: 15-30 < 0-15		1.6%	1.6%	1.5%	2.0%	1.5%	1.8%	2.1%	2.3%	2.2%	1.9%	2.2%	2.1%	2.7%	1.9%
FLOW: 30-60 < (15-30 or 0-15)		4.8%	3.9%	3.9%	4.6%	4.1%	4.6%	5.3%	5.4%	4.9%	5.1%	4.8%	4.6%	5.6%	4.2%
% Biomdal (either condition YES)		5.5%	4.7%	4.8%	5.6%	4.9%	5.4%	6.3%	6.4%	6.0%	5.8%	5.8%	5.4%	6.9%	5.4%
Flow Rate at 15 sec		2.2	1.9	1.9	2.1	2.0	1.8	1.8	2.0	2.0	2.0	2.0	2.3	2.1	2.1
Flow Rate at 30 sec		7.2	6.7	6.8	7.1	7.0	6.4	6.6	6.9	6.9	6.8	6.8	7.0	7.1	7.4
Flow Rate at 60 sec		10.1	9.5	9.6	10.0	9.9	9.3	9.4	9.8	9.8	9.6	9.7	9.9	10.0	10.3
Flow Rate at 120 sec		11.6	11.0	10.9	11.4	11.3	10.9	10.9	11.2	11.3	11.1	11.1	11.3	11.3	11.6
Peak flow (lbs)		22.1	21.6	21.4	21.7	21.5	21.0	20.8	21.0	21.2	21.1	21.2	21.8	21.6	21.9
Machine on-time	Setting	04:14	04:27	04:32	04:25	04:21	04:23	04:24	04:19	04:20	04:28	04:27	04:24	04:18	04:12
SD		19:47	19:43	19:50	19:46	19:43	19:41	19:40	19:42	19:43	19:46	20:07	20:10	19:49	19:49
% over	05:00	20%	29%	32%	28%	21%	24%	25%	22%	22%	30%	29%	27%	23%	18%
% under	03:00	9%	6%	6%	7%	7%	7%	6%	7%	7%	6%	7%	10%	7%	9%
2 minute Milk, lbs	`	18.7	17.8	17.8	18.5	18.3	17.5	17.6	18.2	18.2	17.9	17.9	18.3	18.4	19.0
SD		9.80	9.56	9.77	9.92	9.69	9.52	9.51	9.77	9.79	9.66	9.75	9.88	9.93	10.01
% over	20.0	41%	35%	35%	39%	38%	34%	34%	37%	38%	36%	36%	38%	39%	42%
% under	10.0	11%	13%	12%	11%	11%	13%	13%	11%	11%	13%	13%	11%	11%	9%
% milk at 2 minutes		50.3	46.8	46.4	48.4	48.7	47.5	47.7	49.0	48.6	46.9	47.2	48.6	49.7	51.5
SD		62.91	63.35	63.33	62.74	62.62	62.79	62.43	62.32	62.52	62.98	64.54	64.58	62.02	61.74
% over	60.0	23%	17%	16%	19%	18%	17%	18%	20%	19%	16%	17%	19%	21%	25%
% under	40.0	26%	36%	37%	31%	30%	33%	32%	29%	30%	35%	35%	32%	27%	22%
Flow Rate at Removal		3.4	3.7	3.8	3.5	3.7	3.7	3.7	3.6	3.6	3.7	3.8	3.6	3.6	3.4
% undermilked	5.0	6%	11%	13%	9%	14%	14%	13%	12%	12%	14%	15%	10%	10%	6%
FORCED DETACHES		12%	20%	22%	16%	24%	24%	24%	21%	20%	24%	27%	17%	18%	14%

Summary

- HPPD has a data driven culture
- We seek to make decisions with data when possible
- Takes a strong team with interest in numbers
- Goal is to lower our breakeven milk price. Period.

Questions?

Strategies to Reduce Hypocalcemia in the First Days of Lactation
+
S. glaucophyllum boluses

Jesse Goff
Emeritus Professor of Veterinary Medicine
Iowa State University
Ames, IA 50011 USA

Jesse Goff Conflict of Interest

Invented Soychlor anionic supplement – work as advisor for the Landus Farmer's Cooperative on issues related to formulating diets with Soychlor.

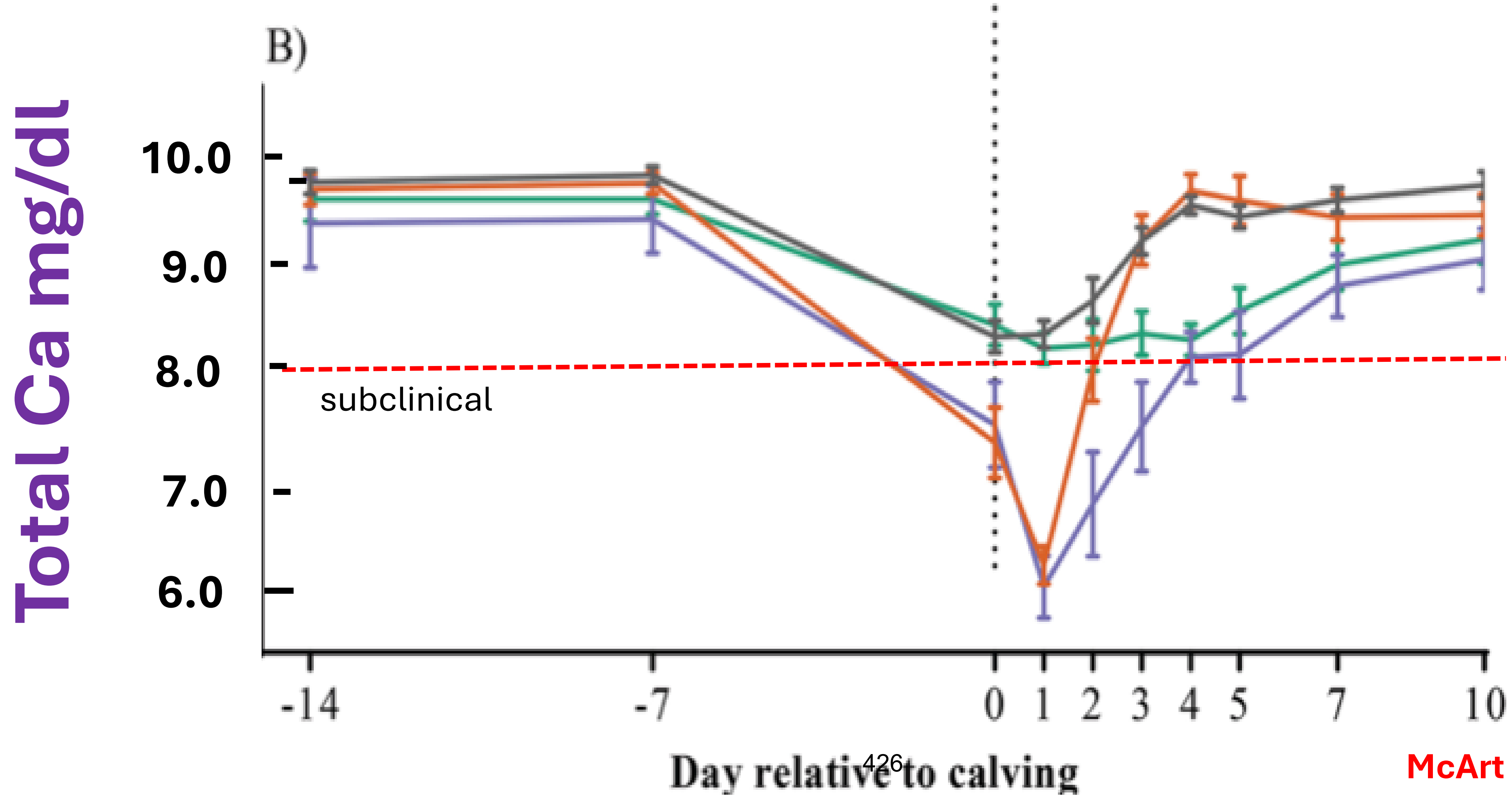
Invented calcium propionate drench formulations.

Designed, Tested, and Plan to help market Solanum glaucophyllum bolus with Silberhorn Animal Health called Goff-Bol.

Owner of GlycoMyr- a company that makes vitamin drench for neonatal pigs. Holds patent on use of glycosides of vitamin D for colon health uses

Have been a paid speaker at conferences put on by Elanco, Pfizer, GLC Minerals, Costa Rica Veterinary Congress, Ca Animal Nutr Conference, Independent Dairy Vet Consultants meeting, Northeast Dairy production Medicine conf, Turkish Veterinary Congress, Balchem pre-conference symposia.

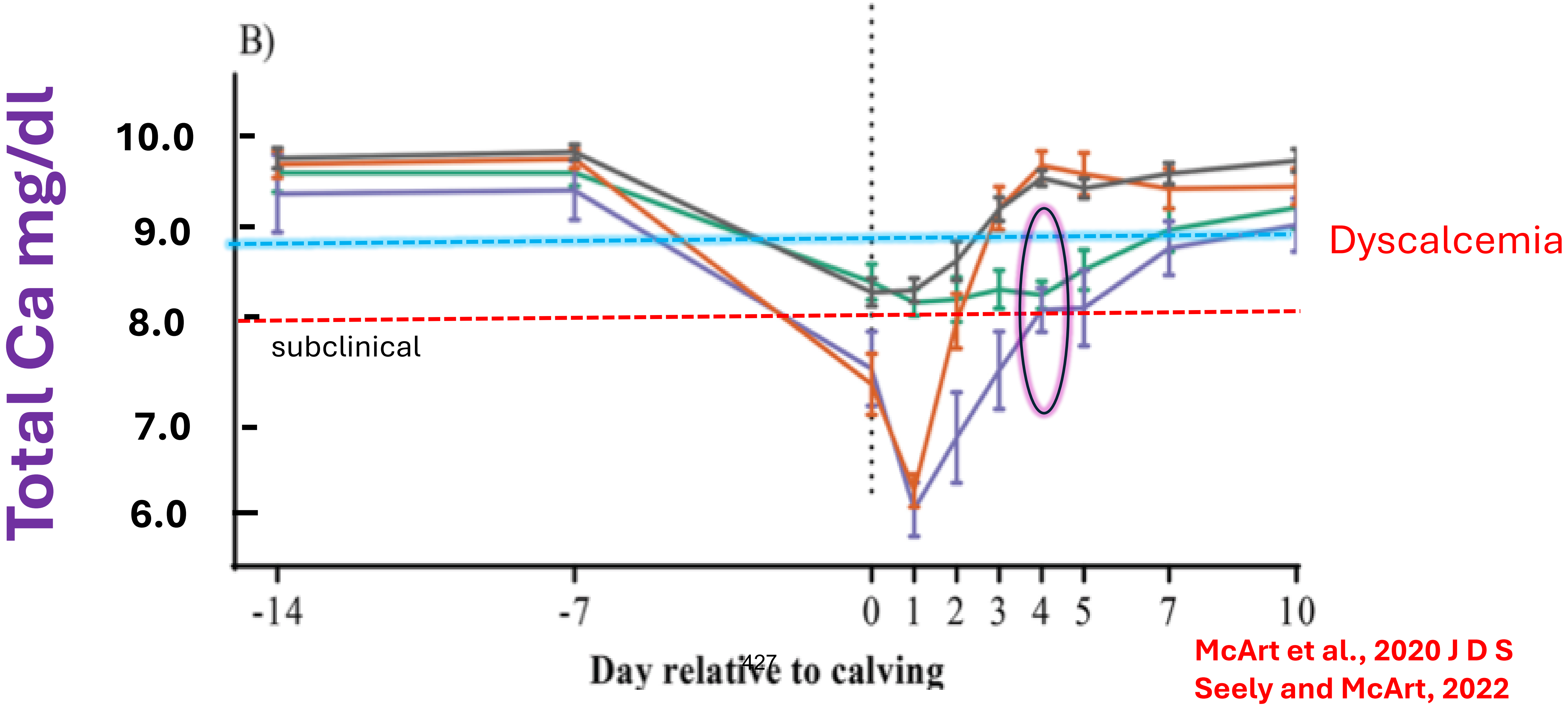
Some cows do not develop any subclinical hypocalcemia (black).
Transient hypocalcemia (red) associated with higher milk production.
Persistent hypocalcemia (purple) associated with higher cull rate.
Delayed -A few cows develop hypocalcemia after day 2 of lactation (green).



McArt et al., 2020 J D S

Dyscalcemia = cows with blood Ca below 8.8 mg/dl (2.2 mM) on day 4.

- **reduced DM intake, rumination, fertility**
- **1.7 to 5.3 times more likely to be culled or dead**
- **reduced milk production**



McArt et al., 2020 J D S
Seely and McArt, 2022

Parity	Ca nadir	% cows with Ca nadir < 8.0	% SCH at 2 DIM	% Dyscalcemia Ca < 8.8 4 DIM
2	7.96 ± 0.12 [a]	41 ± 6[c] (122/298)	20 ± 3 [b] (54/272)	**27 ± 5 [b] (61/227)**
3	7.48 ± 0.16 [b]	63± 6 [b] (123/195)	27 ± 4 [b] (48/176)	41 ± 6 [a] (68/165)
≥ 4	6.80 ± 0.16 [c]	87 ± 4 [a] (145/167)	45 ± 0.4 [a] (60/134)	41 ± 6 [a] (58/142)

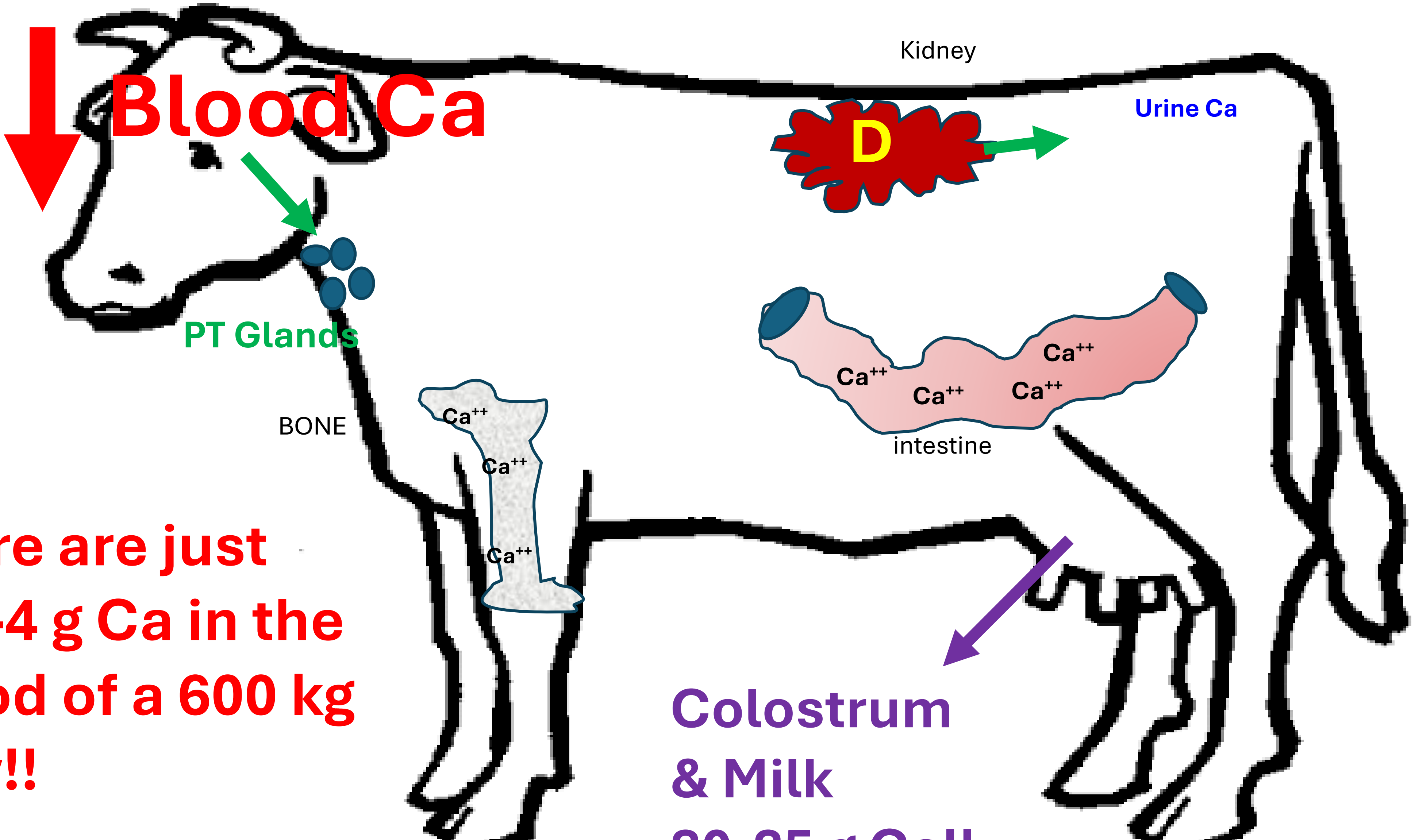
Old Cows have more subclinical hypocalcemia (Ca below 8 mg/dl)

and

More Dyscalcemia (Ca below 8.8 on day 4)

Goff et al, Front Vet Science 2025

Why does blood Ca fall in almost every cow??

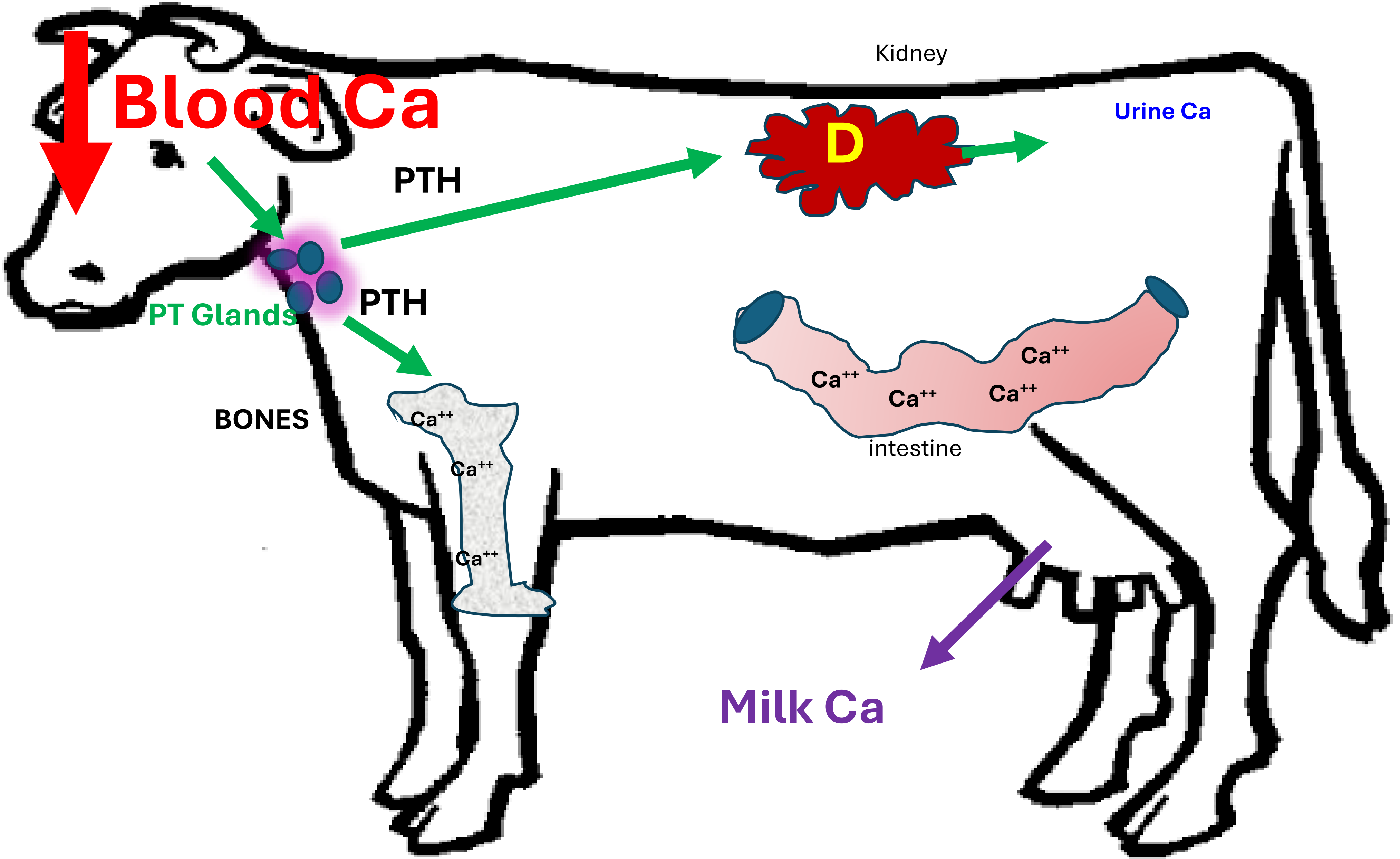


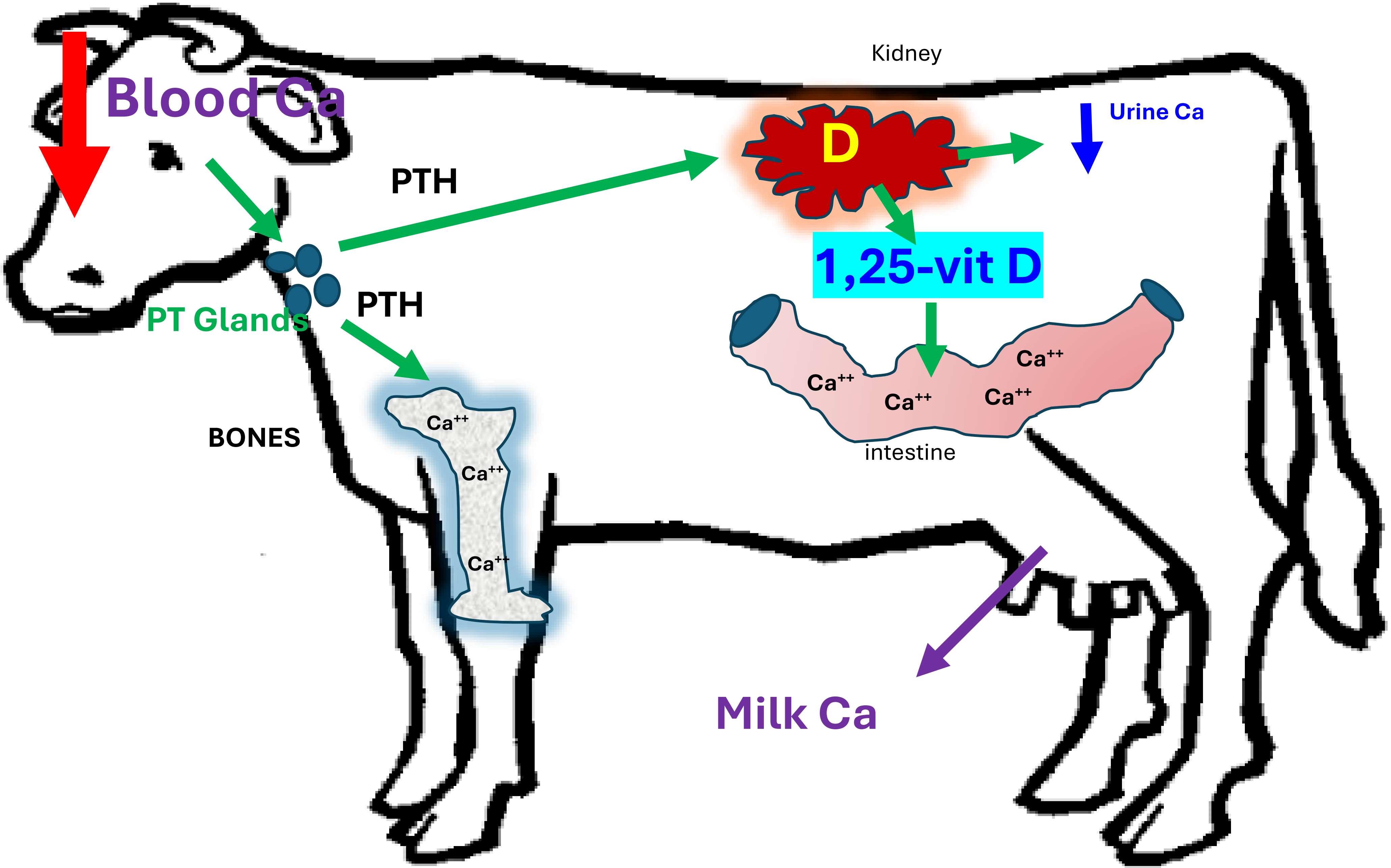
There are just 3.5 -4 g Ca in the blood of a 600 kg cow!!

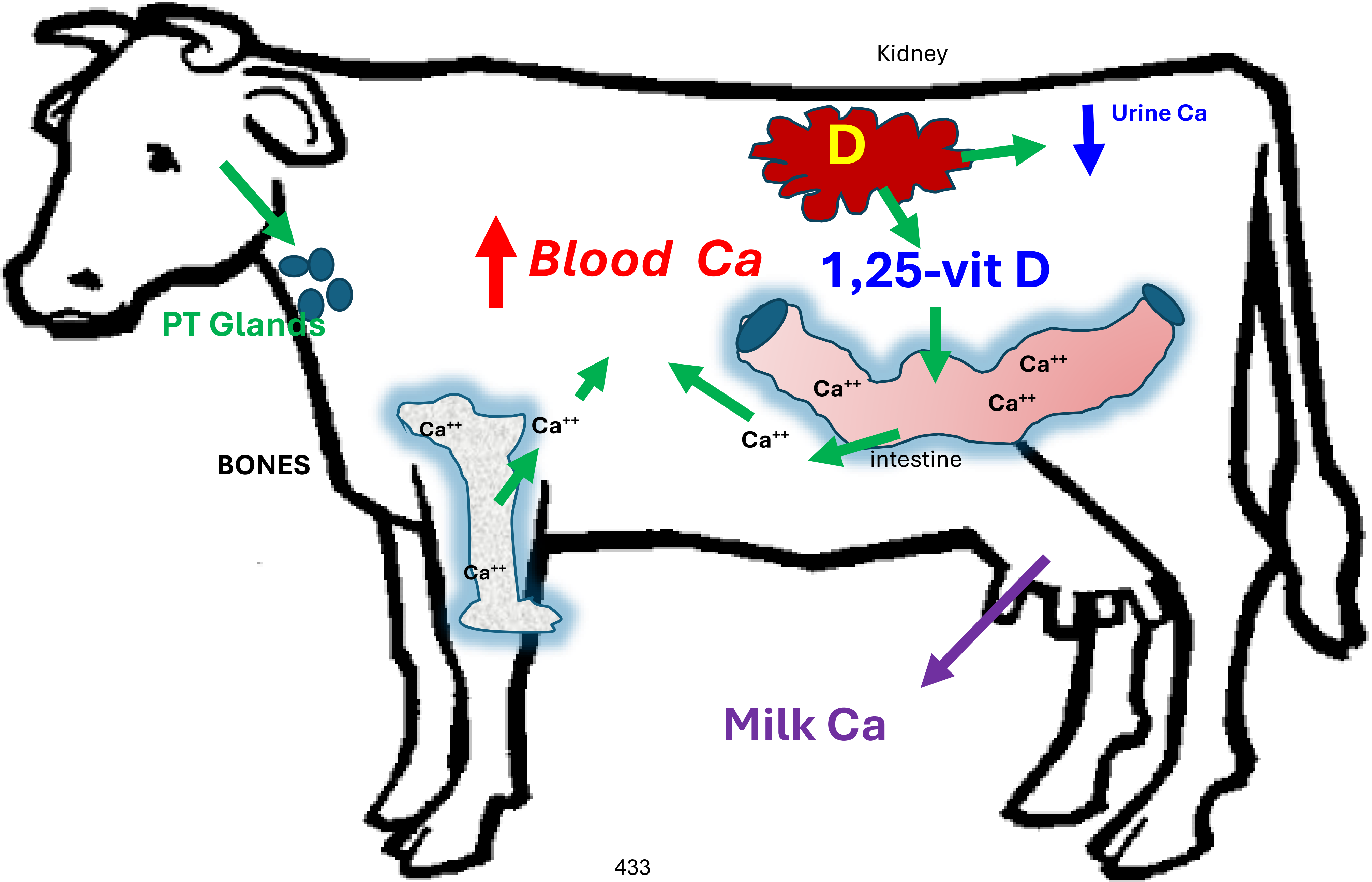
Colostrum & Milk 30-35 g Ca!!

Why don’t all cows get milk fever????

Calcium Homeostasis!


Blood Ca
PTH
PT Glands
PTH
BONES
Ca++
Ca++
Ca++
Kidney
D
Urine Ca
Ca++
Ca++
Ca++
Ca++
intestine
Milk Ca


Blood Ca
PTH
PT Glands
PTH
BONES
Ca++
Ca++
Ca++
Kidney
D
Urine Ca
1,25-vit D
Ca++
Ca++
Ca++
Ca++
intestine
Milk Ca



Kidney
D
Urine Ca
Blood Ca
1,25-vit D
PT Glands
Ca++
Ca++
Ca++
Ca++
Ca++
Ca++
Ca++
BONES
intestine
Milk Ca

Milk Fever & Downer cows

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

OLD AGE!!!

Cow stops growing by end of 2^{nd} lactation!

OLD Bones are slow to release Ca, heifers don't get milk fever!

Renal production of 1,25-dihydroxyvitamin D delayed.

- **+ lower # of receptors for 1,25-dihydroxyvitamin D in intestine of older cows**

ALL CLOSE-UP DIETS SHOULD FOLLOW THESE 3 PRINCIPLES

Keep Diet Potassium as low as possible

a. Limit alfalfa and rye/ brome type grass hays or haylages (2.2-4% K)
b. Use Prairie hays and clean wheat straw (0.8 – 1.4% K)
c. Use some corn silage (0.9-1.3% K)

Keep Diet Phosphorus as low as possible

a. **Avoid Canola meal (1.05% P), DDG (0.8% P) and Brewers grains (0.65% P)**

Provide Adequate Magnesium

a. **> 0.4% Mg for prepartum and early postpartum diets**
b. **Use Readily soluble Mg source**

1. Diets High in potassium cause alkalosis of blood and urine → bone & kidney PTH resistance

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Anionic diets ↓ alkalinity of blood allowing parathyroid hormone to work!

1. Diets High in **potassium** cause alkalosis→ bone & kidney PTH resistance

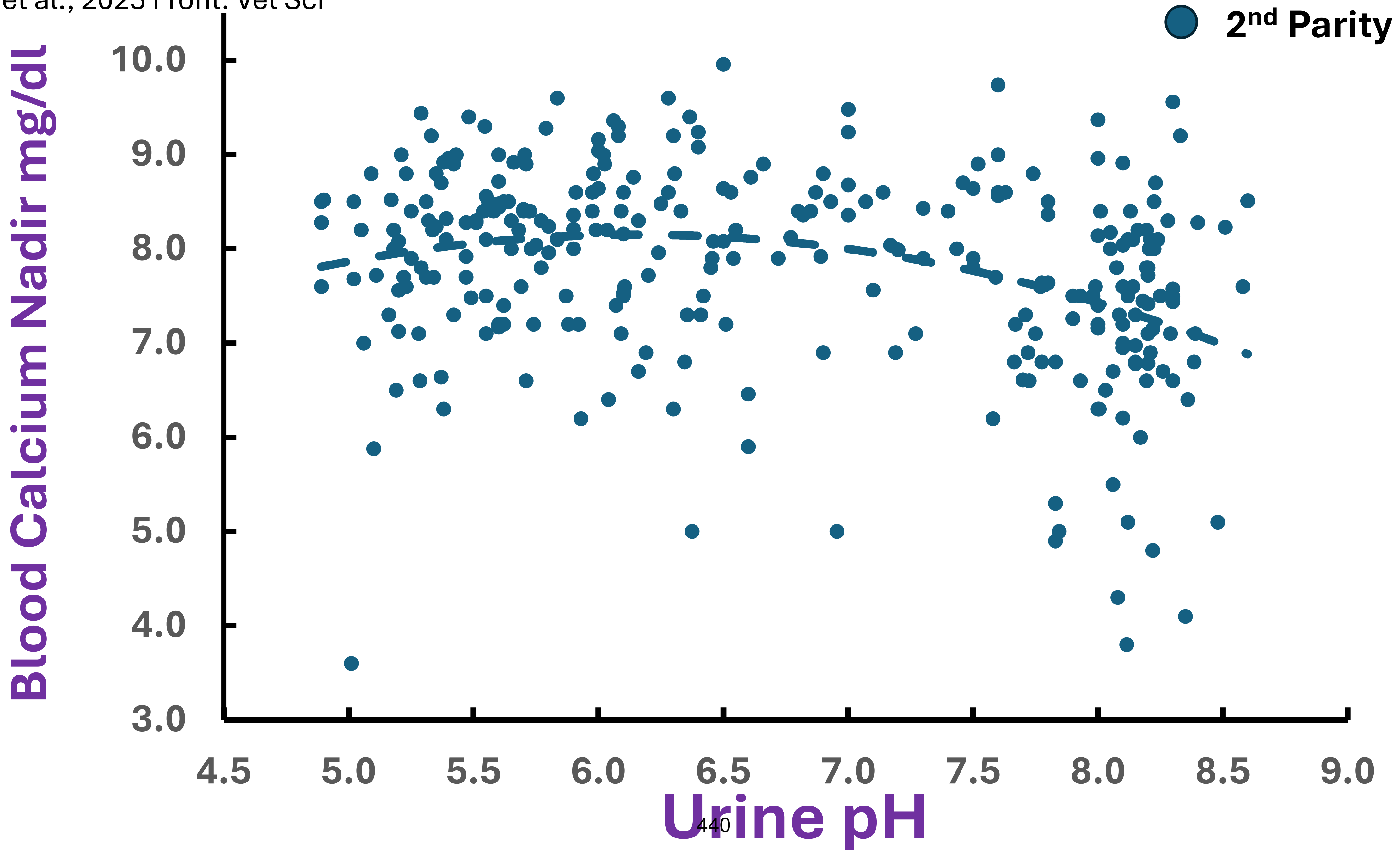
Anionic diets ↓ alkalinity of blood allowing parathyroid hormone to work!

Debate

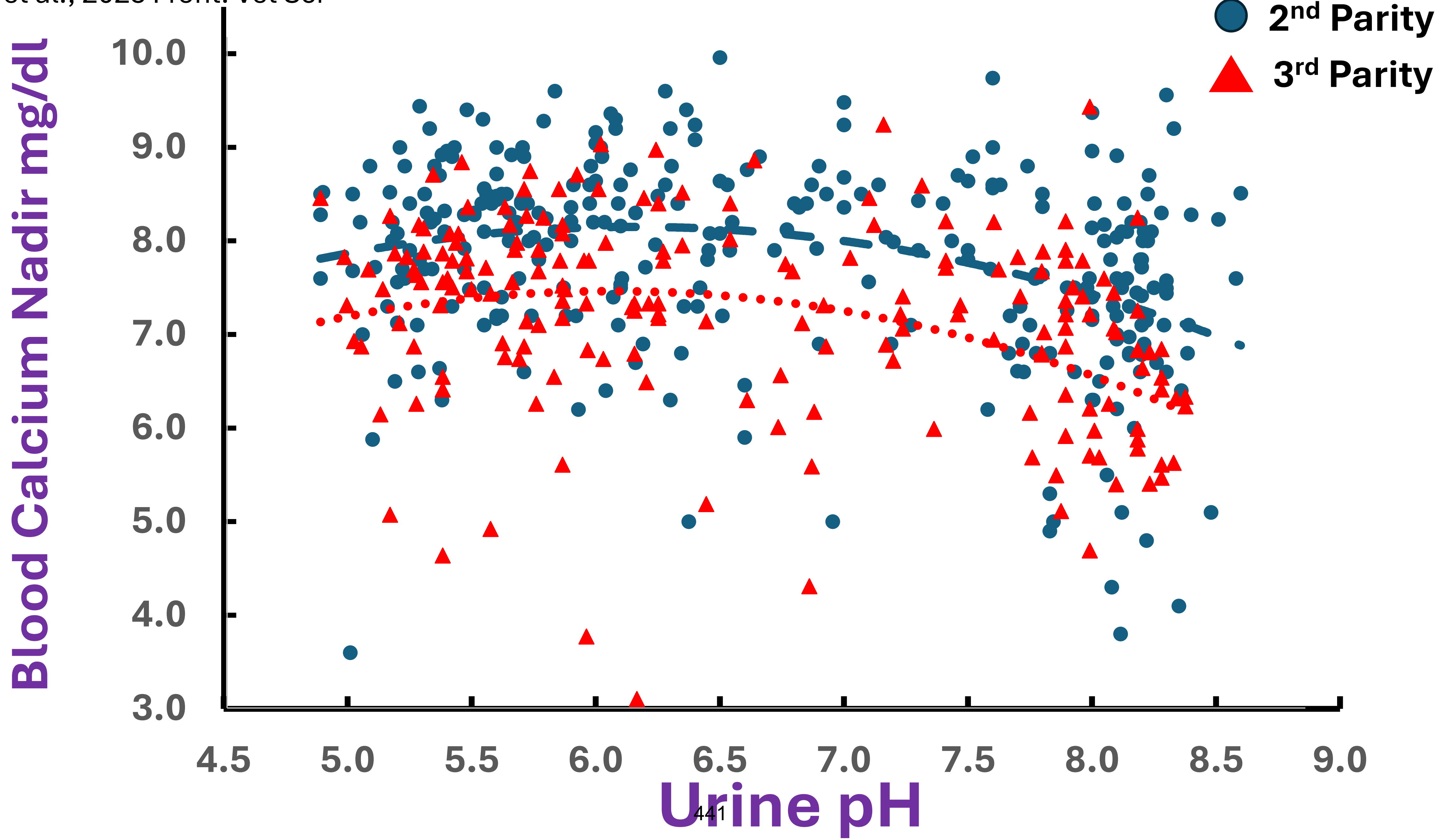
How low should urine pH be to reduce hypocalcemia?

How much calcium should be in the anionic diet?

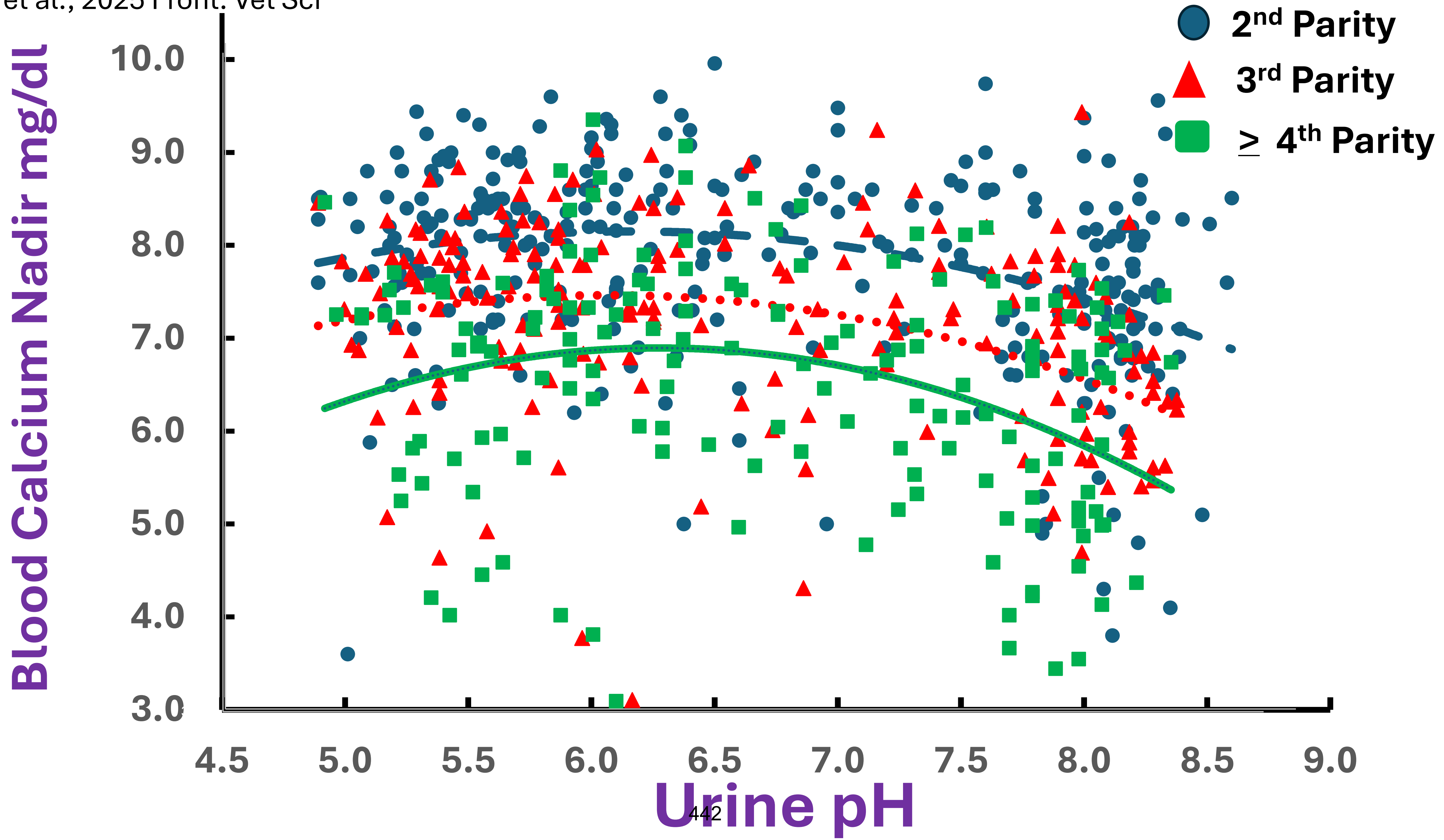
Goff et al., 2025 Front. Vet Sci



Goff et al., 2025 Front. Vet Sci



Goff et al., 2025 Front. Vet Sci

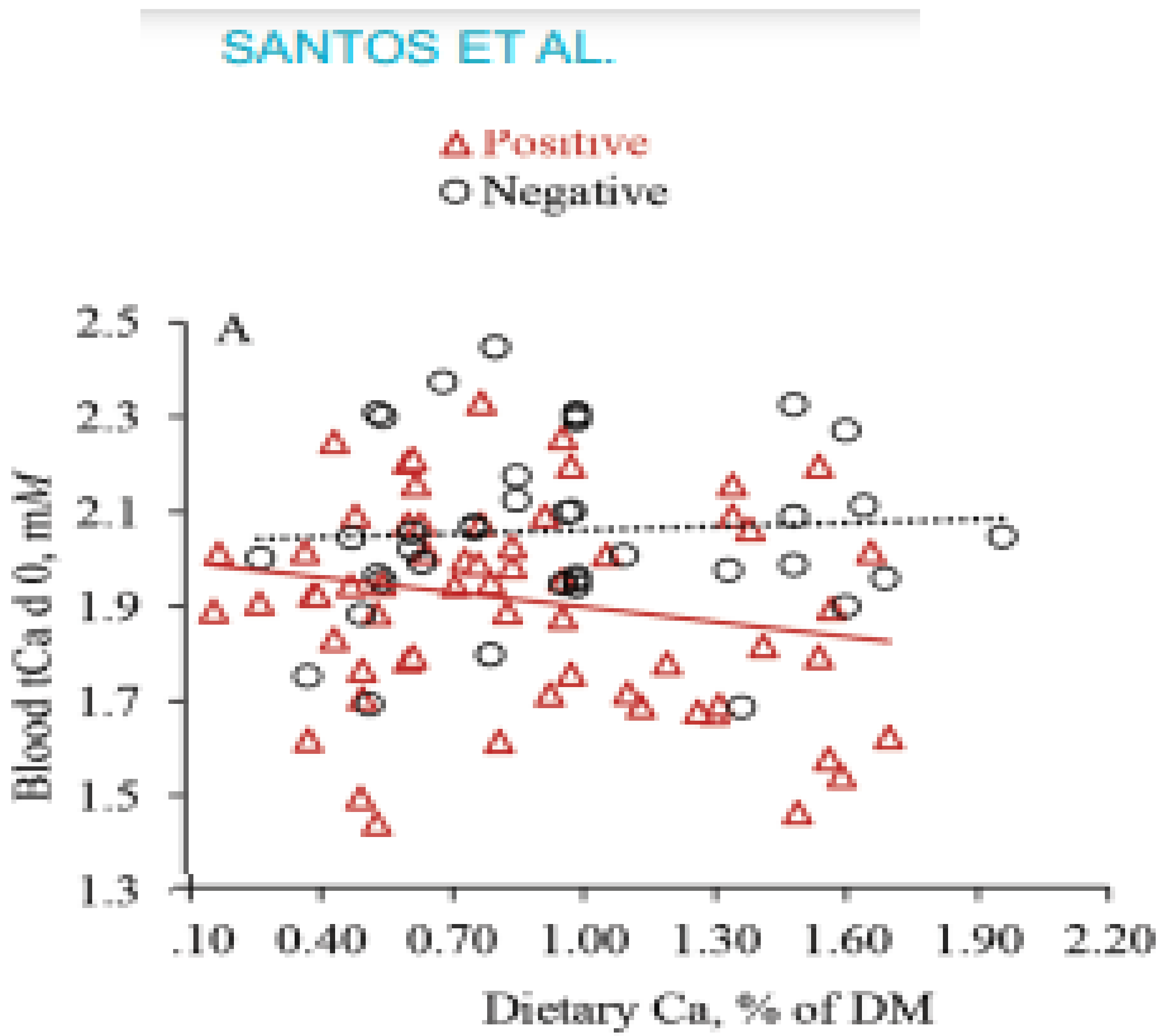


Blood Ca Concentration Nadir and % SCH observed at varying Prepartum Urine pH cut-points

SCH < 8 mg/dl

URINE PH CATEGORY	CA NADIR ALL COWS	CA NADIR 2ND PARITY	CA NADIR 3RD PARITY	CA NADIR ≥4TH PARITY
≥ 7.76	6.76 ± 1.3^{b} N=177 (80.2)^{c}	7.28 ± 1.2^{b} N=79 (68.4)^{c}	6.68 ± 1.4^{b} N=49 (83.7)^{c}	6.08 ± 1.5^{b} N=49 (95.9)^{c}
7.26 TO 7.75	7.52 ± 1.2^{a} N=58 (67.2)^{d}	7.88 ± 0.9^{ab} N=25 (52.0)^{cd}	7.64 ± 0.7^{ab} N=14 (71.4)^{d}	6.72 ± 1.0^{ab} N=19 (84.2)^{cd}
6.76 TO 7.25	7.64 ± 1.1^{a} N=47 (53.2)^{d}	8.12 ± 1.0^{a} N=19 (26.3)^{d}	7.32 ± 1.3^{ab} N=14 (71.4)^{d}	7.28 ± 1.0^{a} N=14 (71.4)^{d}
6.26 TO 6.75	7.84 ± 1.3^{a} N= 64 (51.6)^{d}	8.08 ± 1.2^{a} N=28 (42.9)^{d}	7.84 ± 1.0^{a} N=16 (43.8)^{d}	7.4 ± 1.1^{a} N=20 (70.0)^{d}
5.76 TO 6.25	7.76 ± 1.2^{a} N=100 (51.0)^{d}	8.16 ± 0.8^{a} N=45 (35.6)^{d}	7.48 ± 1.4^{ab} N=30 (56.7)^{d}	7.32 ± 1.6^{a} N=25 (72.0)^{d}
≤ 5.75	7.64 ± 1.0^{a} N=163 443 (52.7)^{d}	8.04 ± 0.9^{a} N=83 (36.1)^{d}	7.6 ± 1.1^{ab} N=51 (56.9)^{d}	6.4 ± 1.4^{ab} N=29 (93.1)^{c}

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



Santos et al., 2019 Meta Analysis

○ = Negative DCAD diet

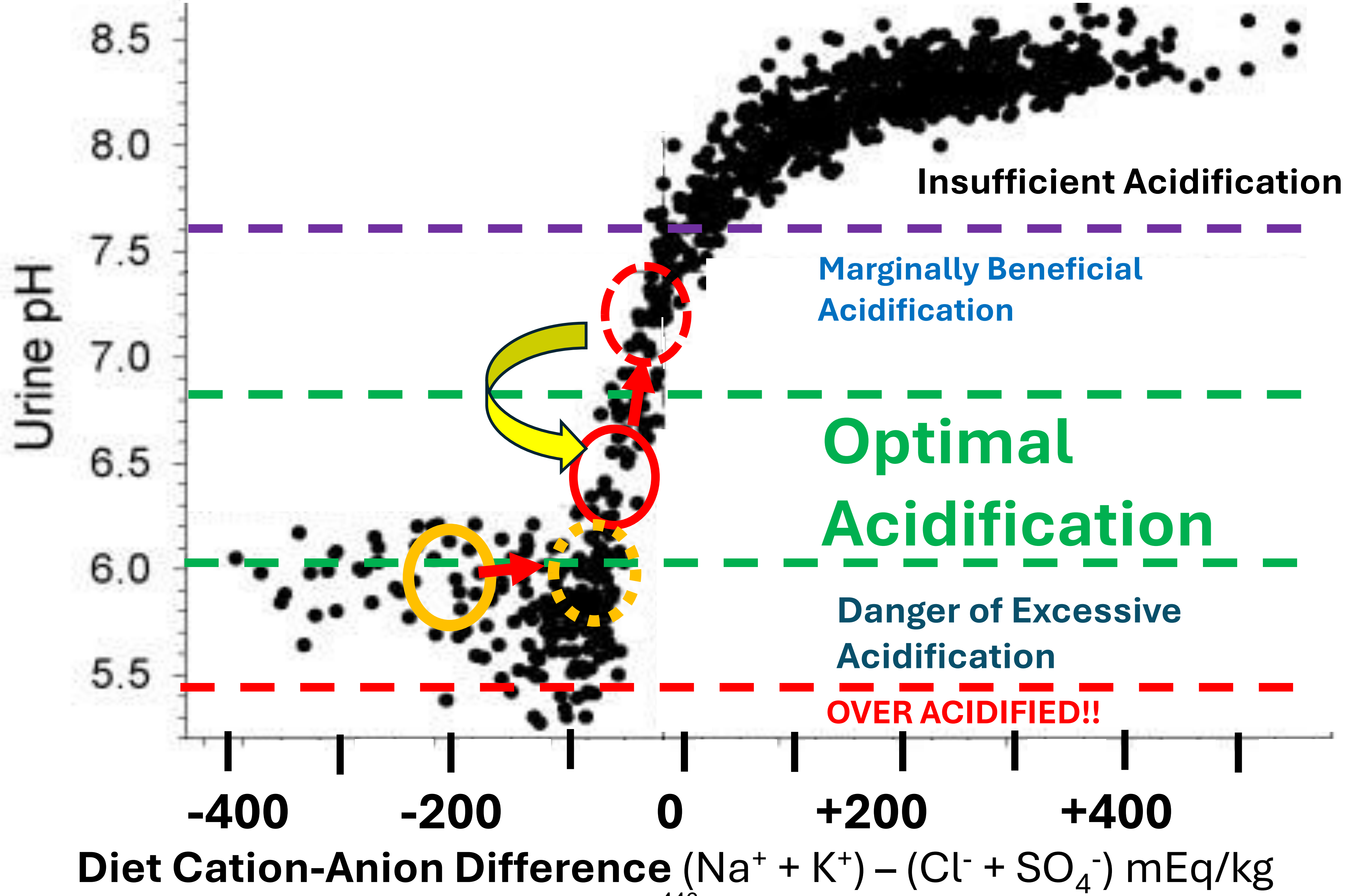
No effect of diet Ca on blood Ca in cows around calving

Δ = positive DCAD diet

Slight decrease in blood Ca when high diet Ca is fed

Limestone has an alkalinizing effect!!!

Add alkalinizing $CaCO_3$ + buy more anions to return urine pH to target level.



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

Impact of Reducing DCAD to Improve Periparturient Blood Ca concentration on health and milk production

Lean et al., 2019. Santos et al., 2019.

Meta-analyses indicate significant beneficial effects ($P<0.02$) on:

Milk Fever, Blood Ca (the day of calving and "postpartum"), Retained Placenta, Metritis, and risk of Multiple Health Events

Milk Production

Multiparous → + 737 to 1139 lbs milk / lactation

Profit: 737 lbs X $0.20/lb = $147

$$$$ Retained Placenta, Metritis $$$$

Cost of Anionic Diet – $17-23

Impact of Reducing DCAD to Improve Periparturient Blood Ca concentration on health and milk production

Lean et al., 2019. Santos et al., 2019.

Meta-analyses indicate significant beneficial effects (P<0.02) on:

Milk Fever, Blood Ca (the day of calving and "postpartum"), Retained Placenta, Metritis, and risk of Multiple Health Events

Milk Production

Multiparous → + 1.1 to 1.7 kg/day (737 to 1139 lb/ lactation)

Heifers → - 1.28 to - 1.4 kg/day (-858 to -939 lb/ lactation)

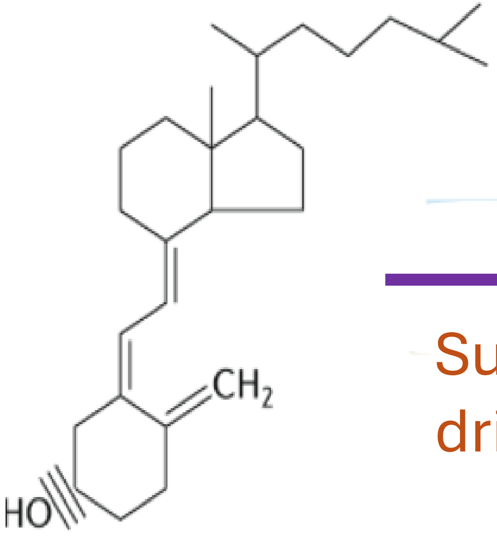
1. Diets High in potassium causing alkalosis→ bone & kidney PTH resistance

Anionic diets ↓ alkalinity of blood allowing parathyroid hormone to work!

2. Diets High in phosphorus block enzyme producing 1,25 (OH)2 vitamin D in kidney via FGF23.

Vitamin D3

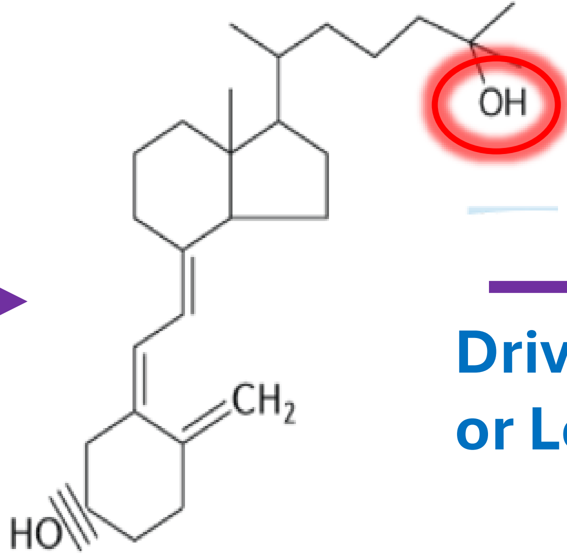
Diet or Skin



Substrate driven

25-HydroxyVitamin D3

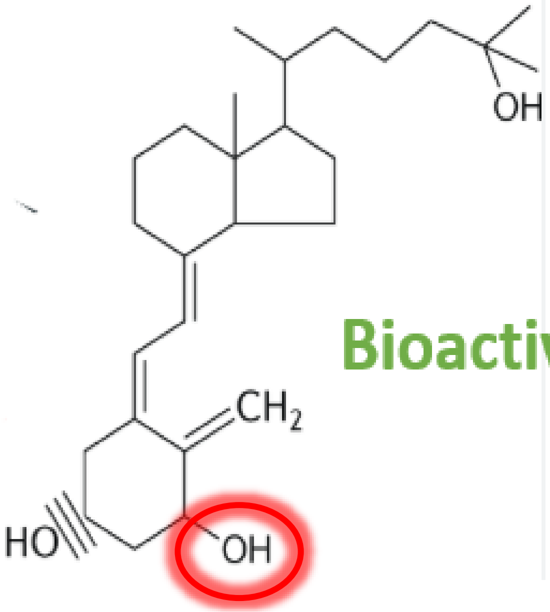
Made in Liver



Driven by PTH or Low blood P

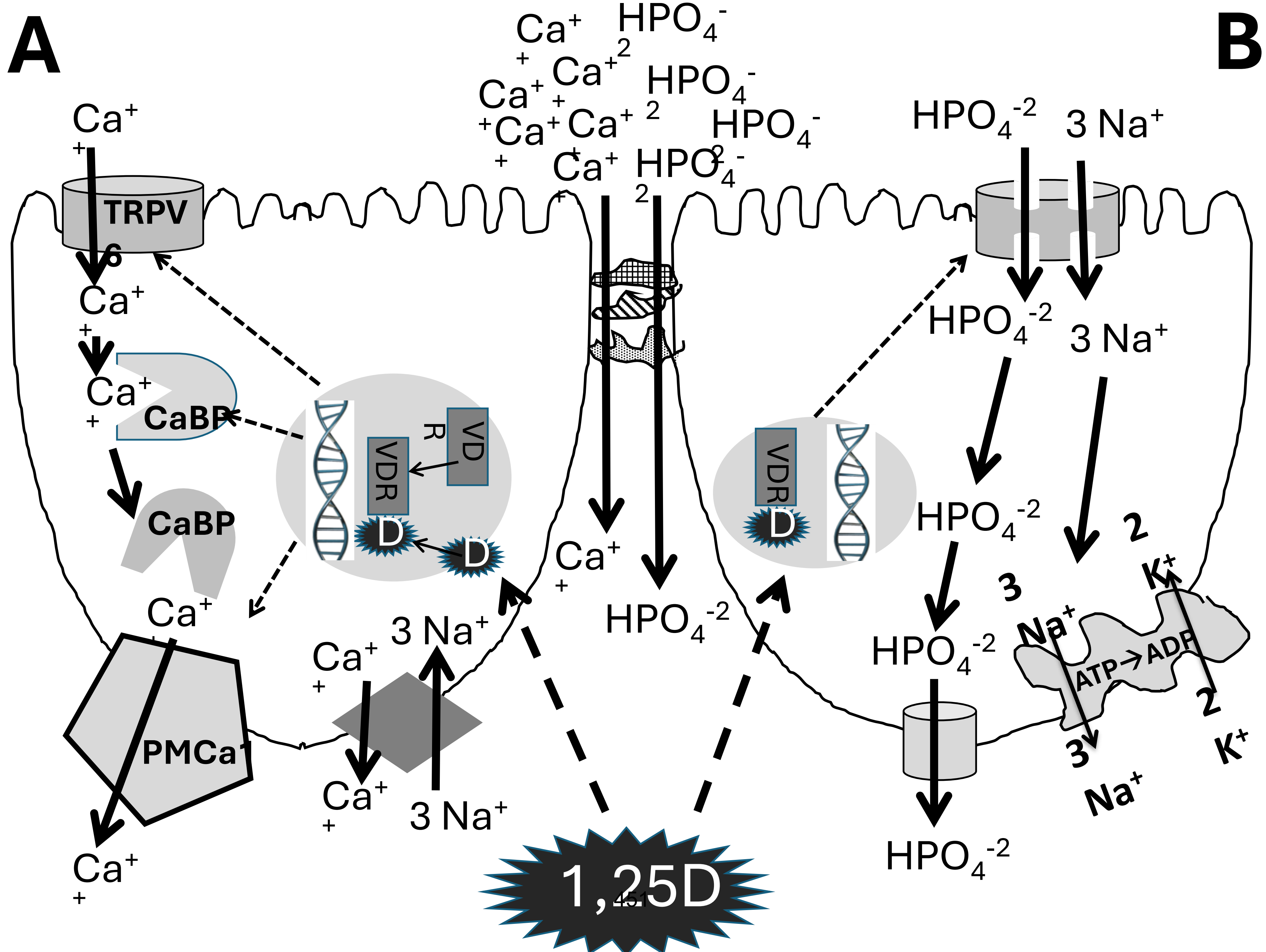
1,25-DihydroxyVitamin D3

Made in Kidney



Bioactive

Only 1,25-DihydroxyVitamin D is able to act on intestinal cells to stimulate production of proteins needed for Transcellular Calcium and Phosphorus absorption.

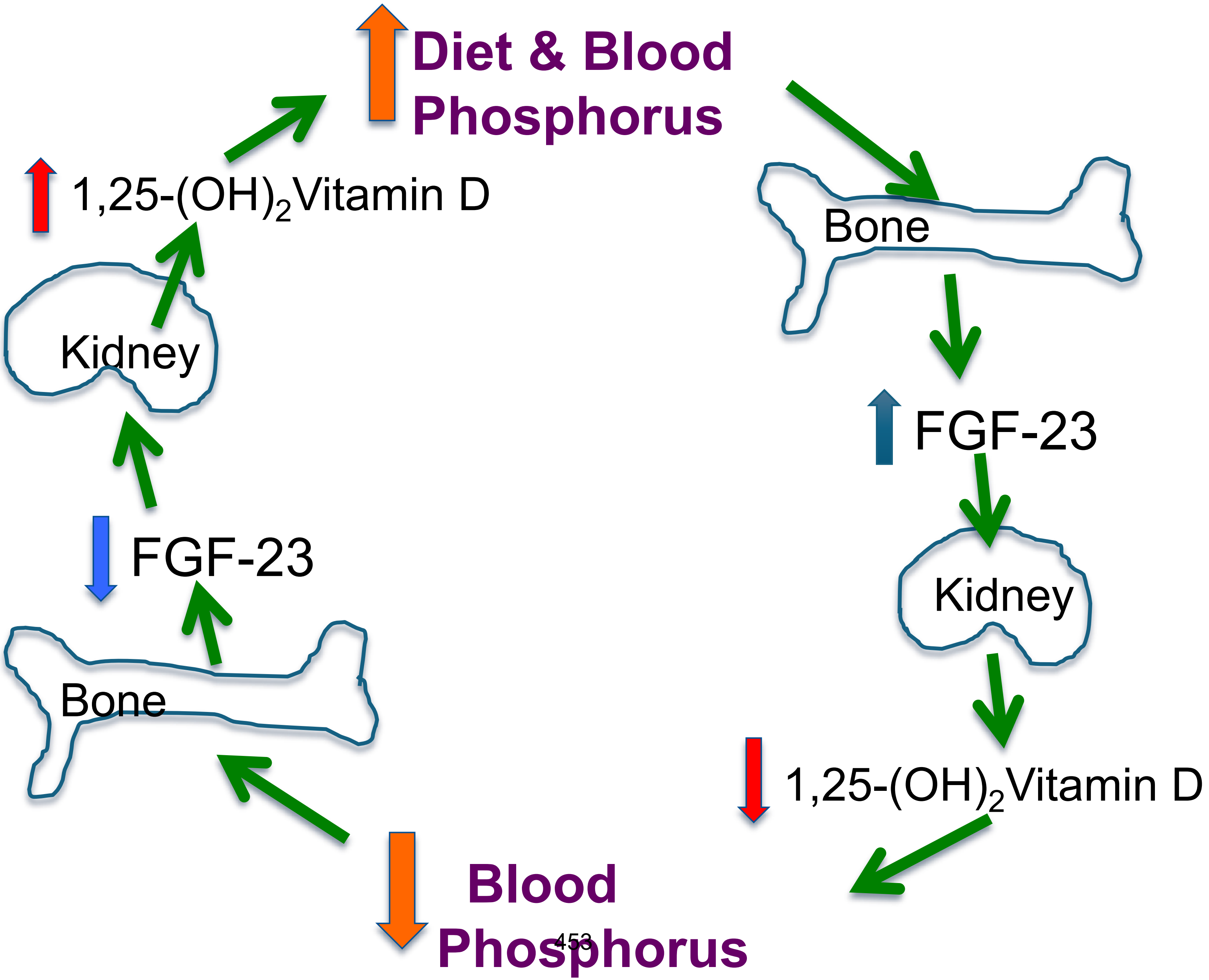

A
B
TRPV6
CaBP
CaBP
PMCa1
VDR
VDR
VDR
D
D
D
1,25D
451
Ca++
HPO4-2
3 Na+
2 K+
3 Na+
2 K+
ATP→ADP

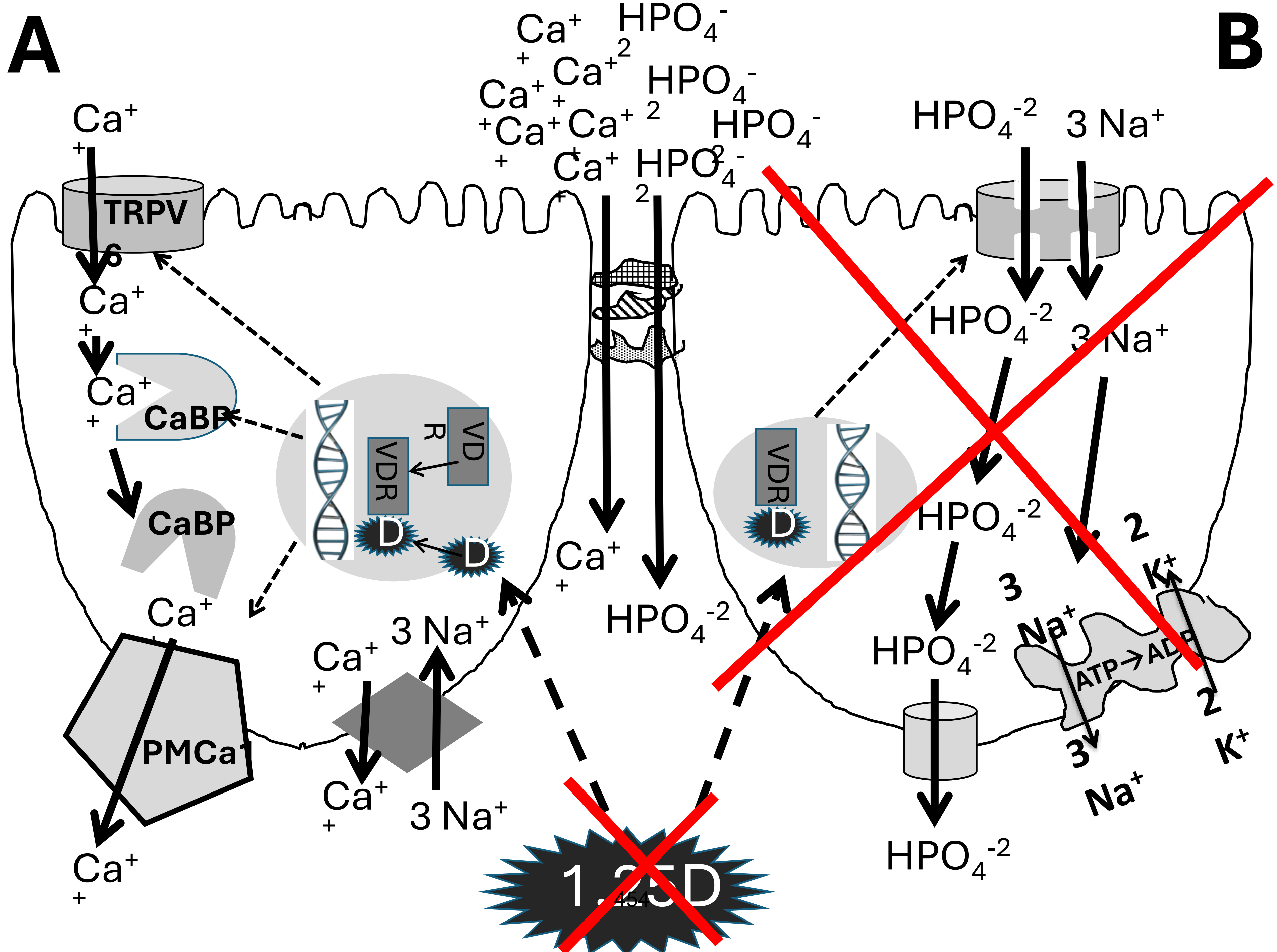
1. **Diets High in potassium causing alkalosis→ bone & kidney PTH resistance**

Anionic diets ↓alkalinity of blood allowing parathyroid hormone to work!

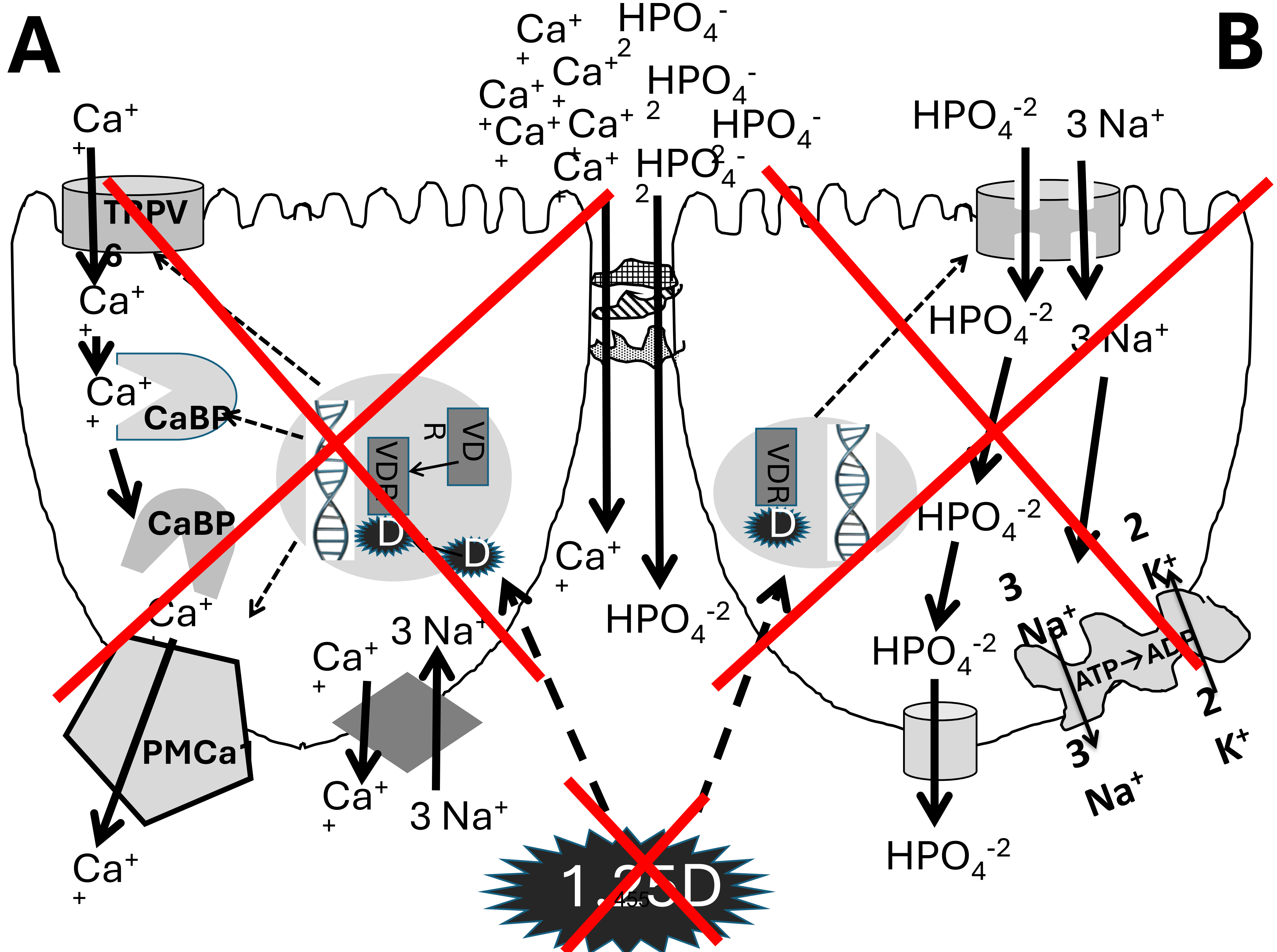
2. **Diets High in phosphorus block enzyme producing 1,25 (OH)2 vitamin D in kidney via FGF23 made by bone cells.**

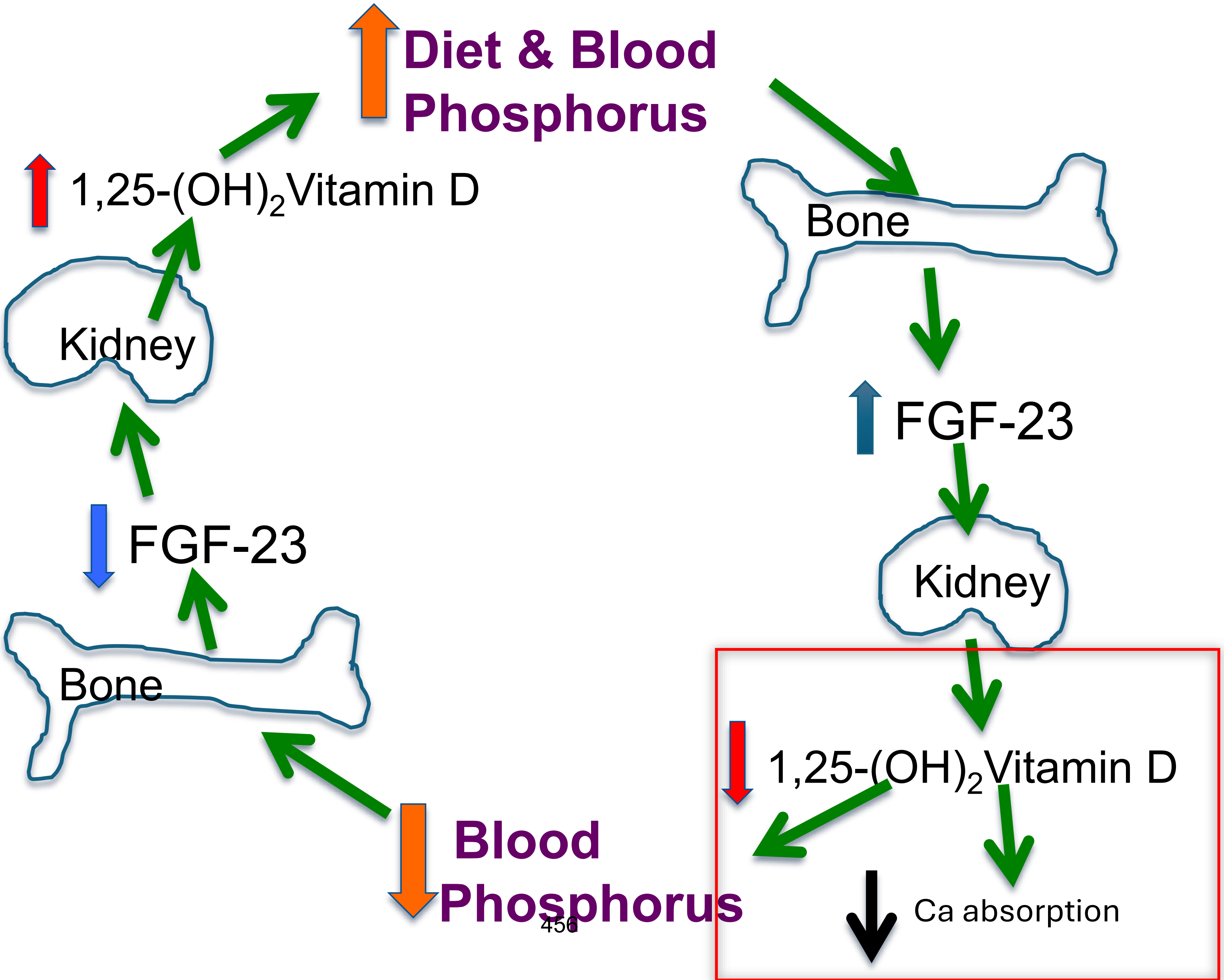
Phosphorus Homeostasis


Diet & Blood Phosphorus
Bone
FGF-23
Kidney
1,25-(OH)$_2$Vitamin D
Blood Phosphorus
Bone
FGF-23
Kidney
1,25-(OH)$_2$Vitamin D



A
B
TRPV6
CaBP
VDR
VD R
D
PMCa1
3 Na+
HPO4-2
ATP→ADP
3 Na+
2 K+
1,25D


A
B
Ca++
HPO4-2
TRPV6
CaBP
VDR
VD R
D
PMCa1
3 Na+
2 K+
ATP→ADP
1,25D


Diet & Blood Phosphorus
Bone
FGF-23
Kidney
1,25-(OH)2Vitamin D
Ca absorption
Blood Phosphorus
Bone
FGF-23
Kidney
1,25-(OH)2Vitamin D

1. Diets High in **potassium** causing alkalosis→ bone & kidney PTH resistance

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2. Diets High in **phosphorus** block enzyme producing 1,25 (OH)2 vitamin D in kidney via FGF23.

Zeolite or Binder diets ↓ blood Phos, eliminating the inhibition of conversion of 25-OHD to bioactive 1.25(OH)2 vitamin D

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Zeolite or Binder diets ↓ blood Phos, eliminating the inhibition of conversion of 25-OHD to bioactive 1.25(OH)2 vitamin D

3. Low in magnesium- inhibits secretion and action of PTH

Add soluble Mg to diet! Get to 0.4% Mg diets

Magnesium Metabolism

Diet Mg can only be absorbed across the rumen wall.

Only ionized (soluble) Mg can be absorbed.

Magnesium – ONLY ABSORBED ACROSS RUMEN WALL

Pre-calving

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

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

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

MgO must become soluble to be available for absorption by rumen wall!!!!

Testing Magnesium Oxide Availability

Weigh out 3 g MgO into large vessel.

Add 40 ml of 5% acetic acid (white vinegar) slowly!!

Cap container and shake well and let sit 30 minutes. Check the pH.

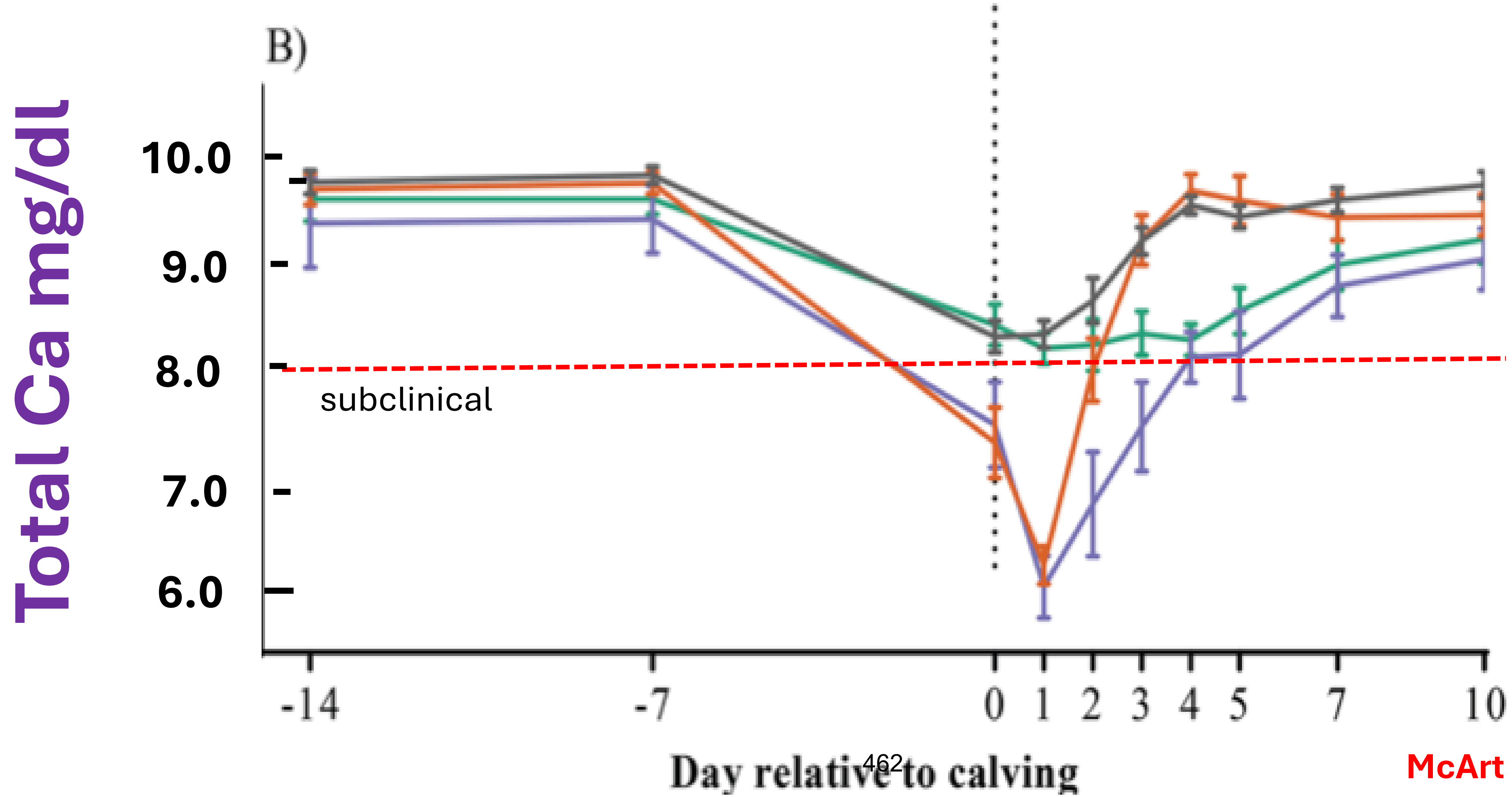
Vinegar will be pH 2.6-2.8!

The best MgO will bring the pH up to 8.2.

The worst to just 3.8.

pH is a log scale so this represents >10,000 fold difference in buffering action.

Some cows do not develop any subclinical hypocalcemia (black).
Transient hypocalcemia (red) associated with higher milk production.
Persistent hypocalcemia (purple) associated with higher cull rate.
Delayed -A few cows develop hypocalcemia after day 2 of lactation (green).



McArt et al., 2020 J D S

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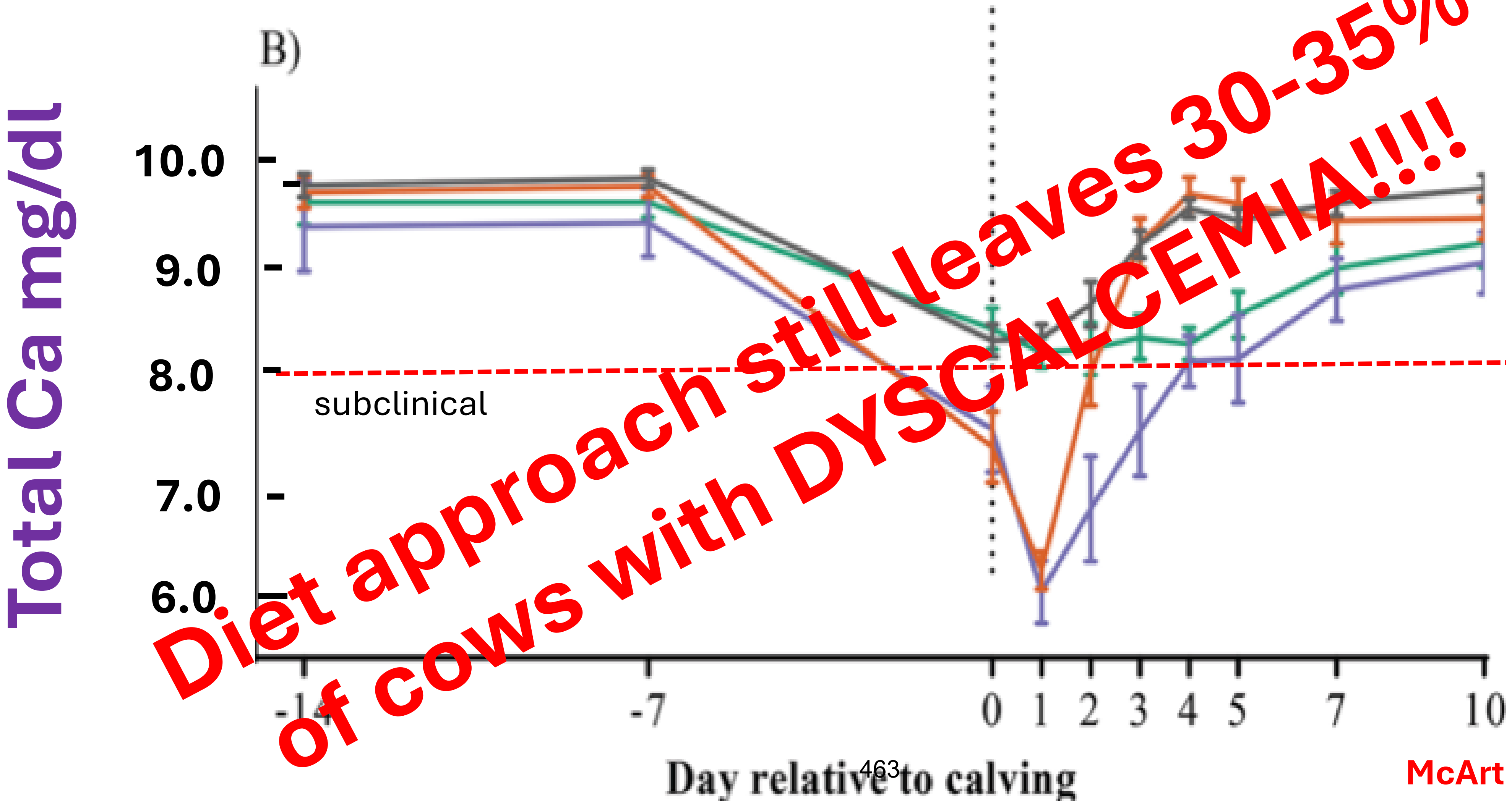


McArt et al., 2020 J D S

Oral Calcium Boluses

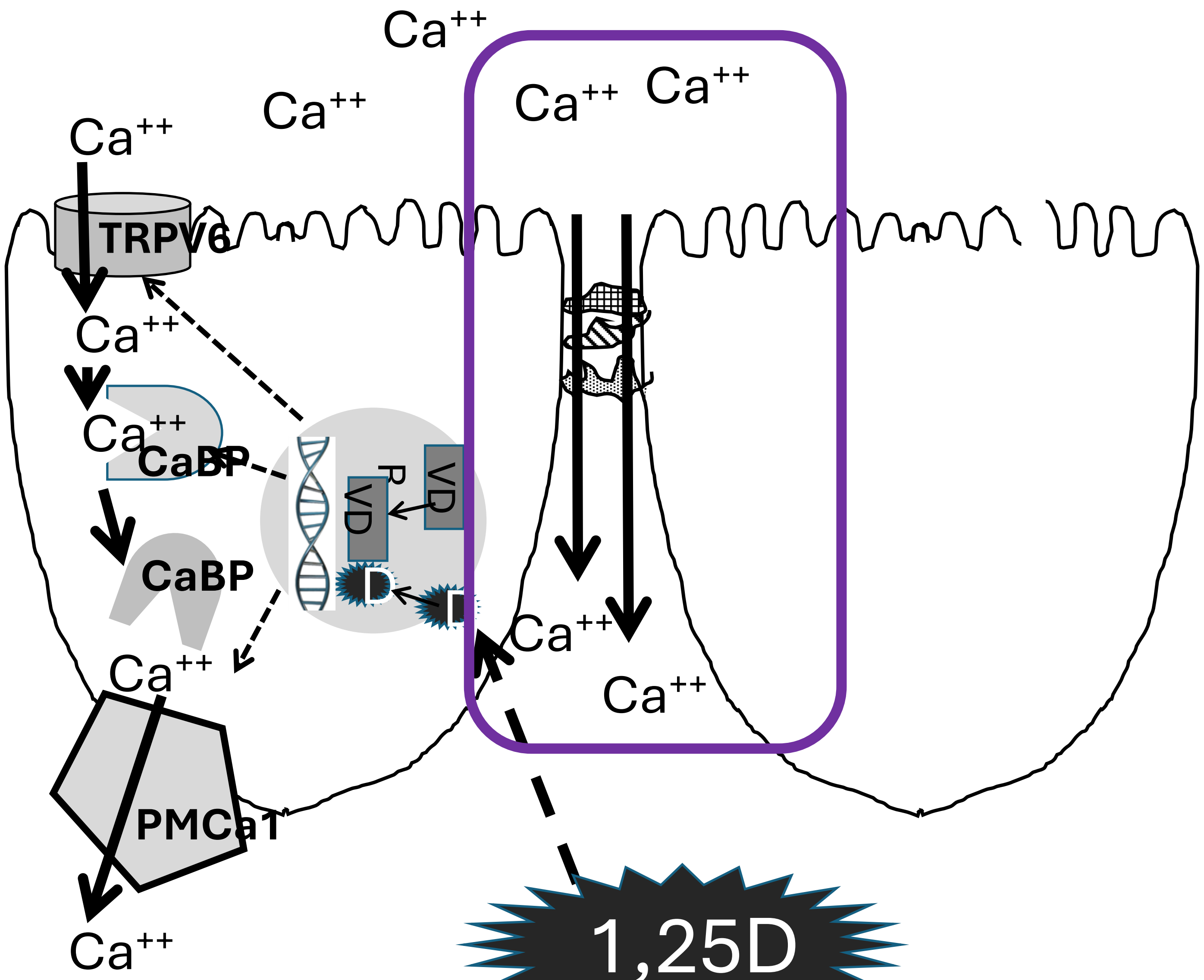
Typically each bolus supplies 30-45 g Ca in a highly soluble form, often as calcium chloride, to permit passive vitamin D independent absorption of Ca into the blood

- effect lasts JUST 3-6 hrs

Convenient, easy to use – give to multiparous cows at calving and often again 12-24 hours later

85% of dairies with less than 125 cows use Ca boluses

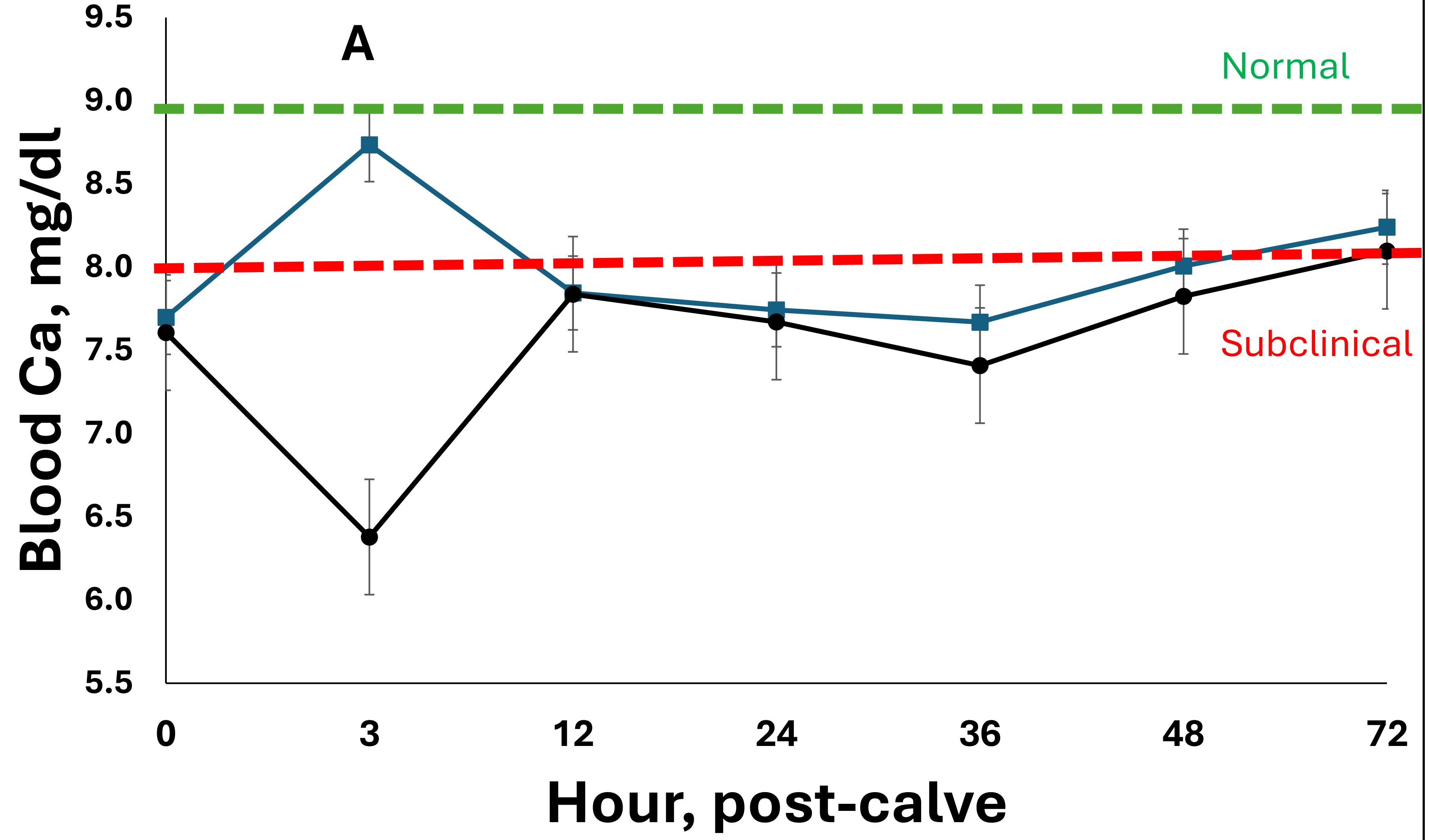
60% of dairies that feed an anionic diet use Ca boluses.



INEFFICIENT VITAMIN D INDEPENDENT PARACELLULAR CALCIUM ABSORPTION

Only ~ 4 g Ca from a 50 g Ca bolus gets into the blood!!!

Reduce milk fever by about half in cows, but Little effect on subclinical hypocalcemia



Oral Ca Boluses

Acidifying – each Ca Cl_2 based bolus can contain ***nearly ½ of the daily anions*** needed to create a low DCAD pre-calving diet

- maybe a good thing in cows NOT fed anions!

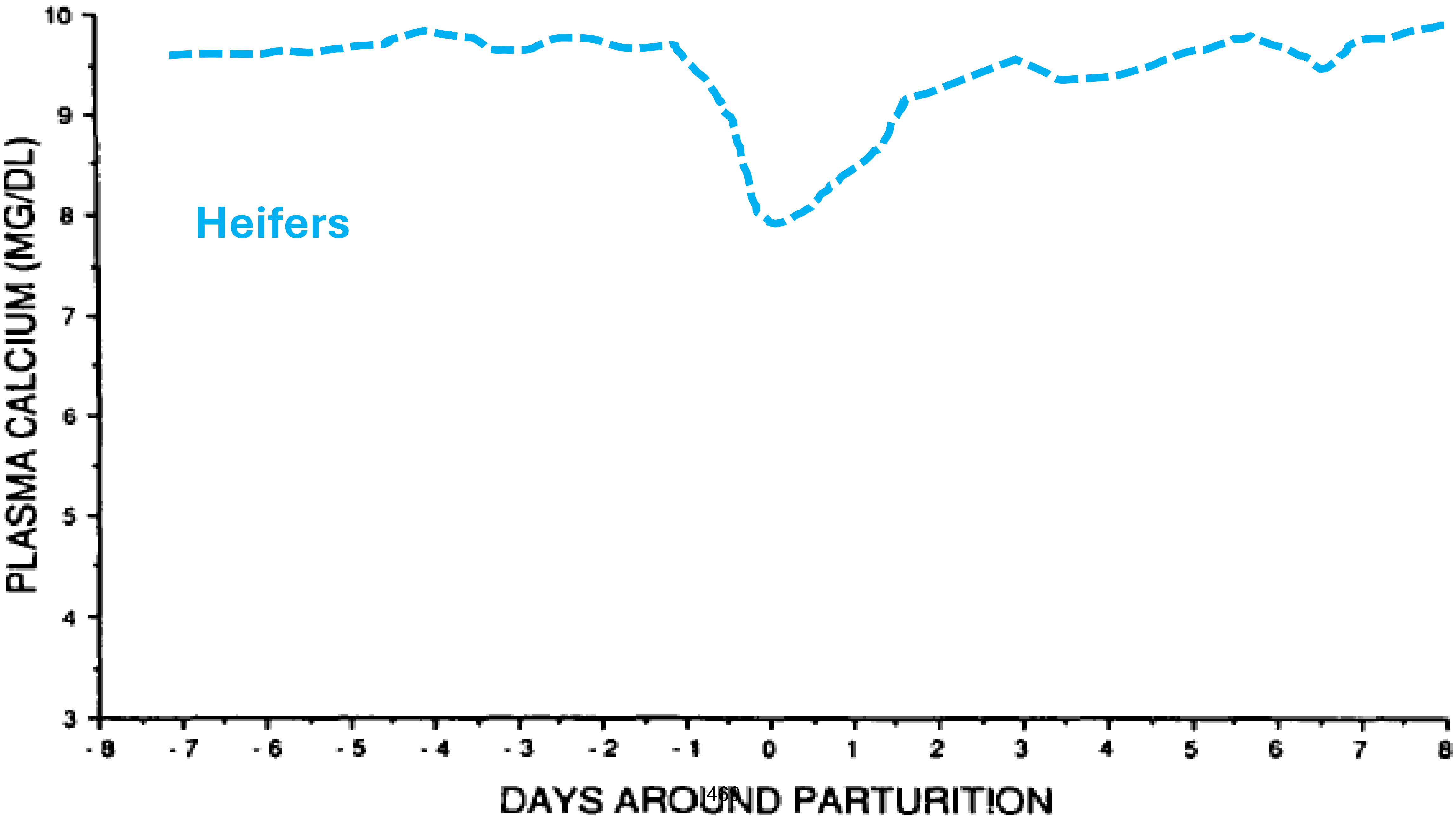
  - **may enhance tissue responsiveness to PTH**

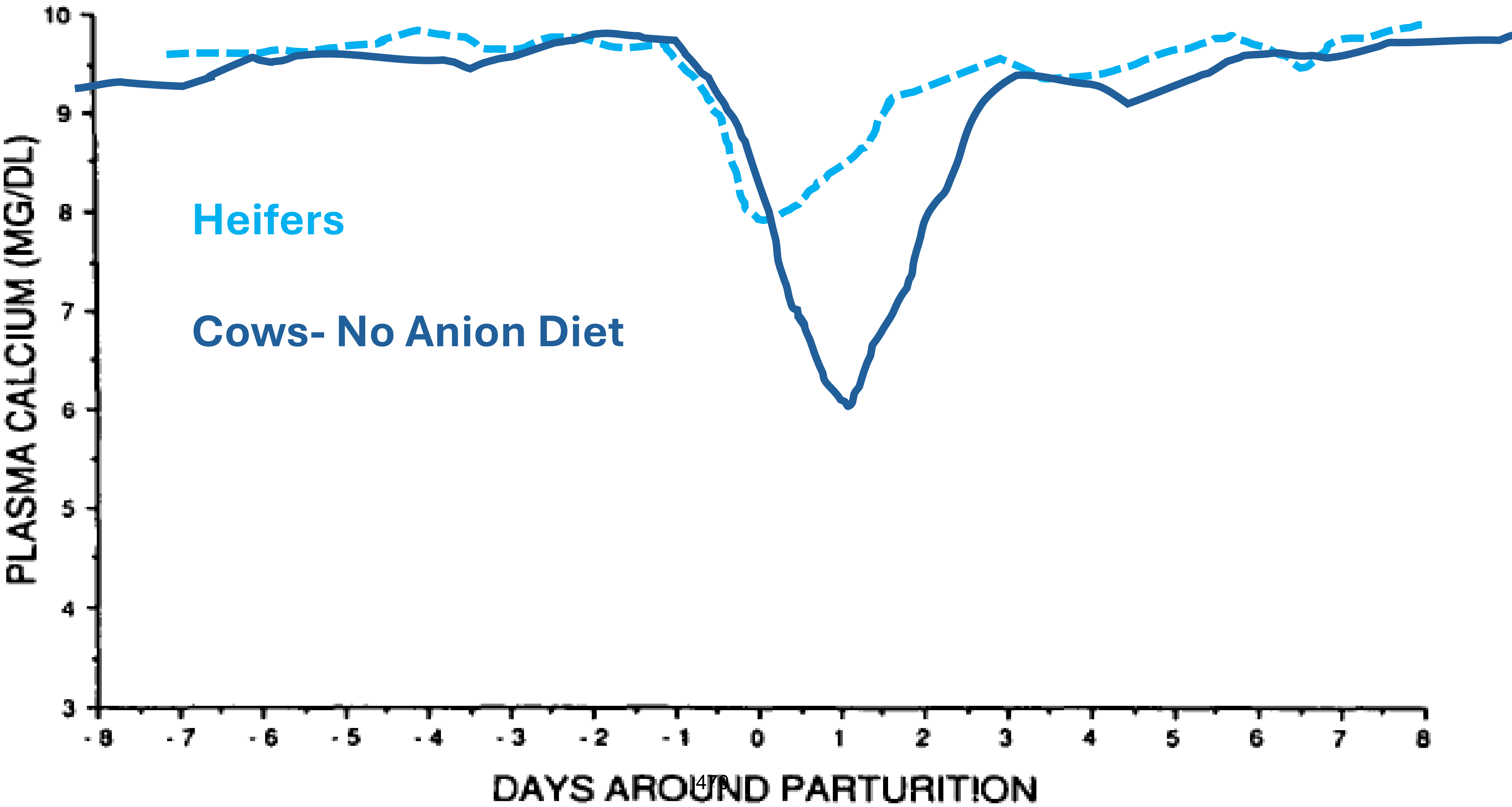
Might cause an uncompensated metabolic acidosis in cows already fed an anionic diet!!

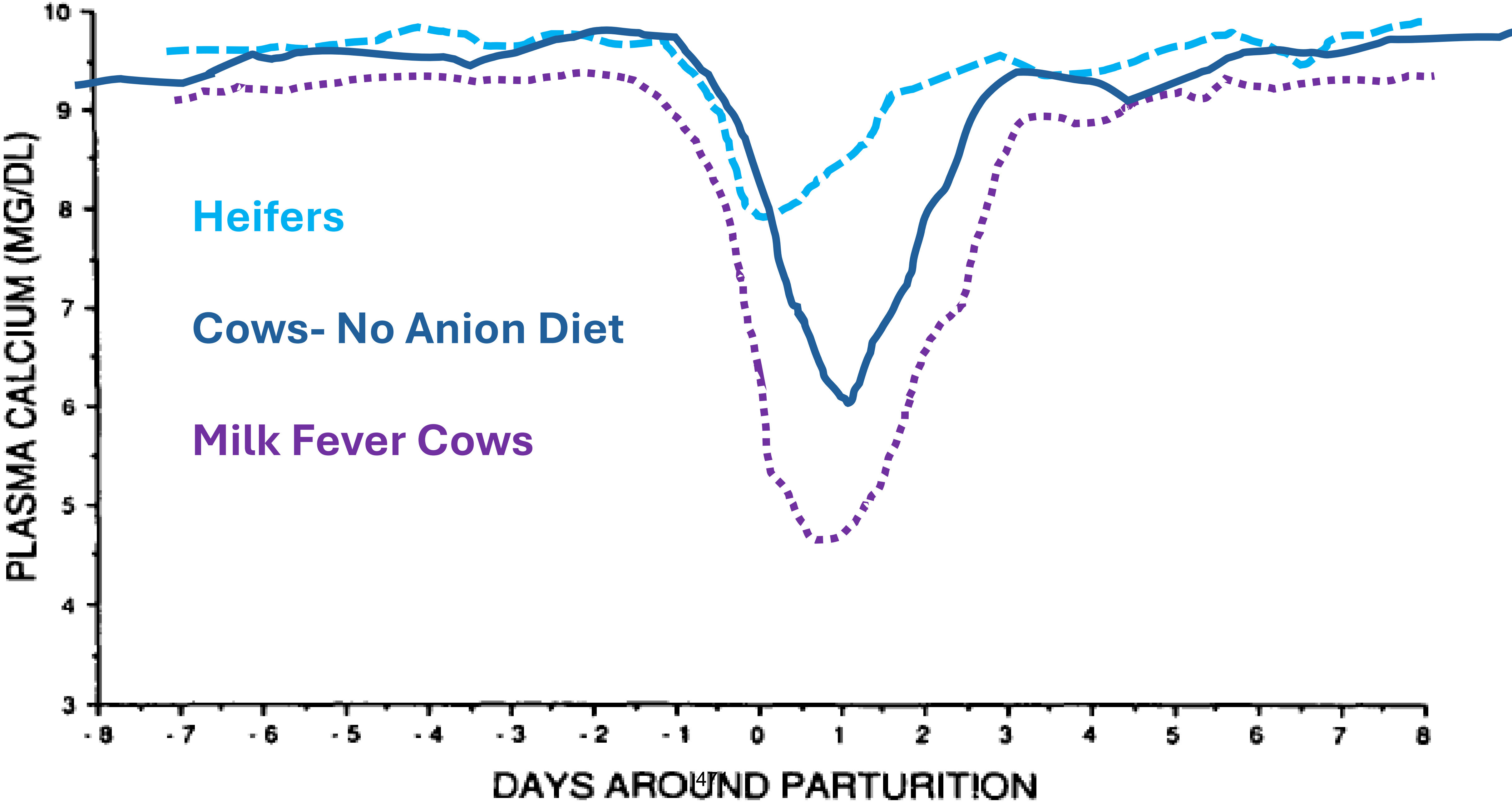
Blood Ca and blood 1,25-vit D concentrations as heifers and cows go thru the onset of lactation.

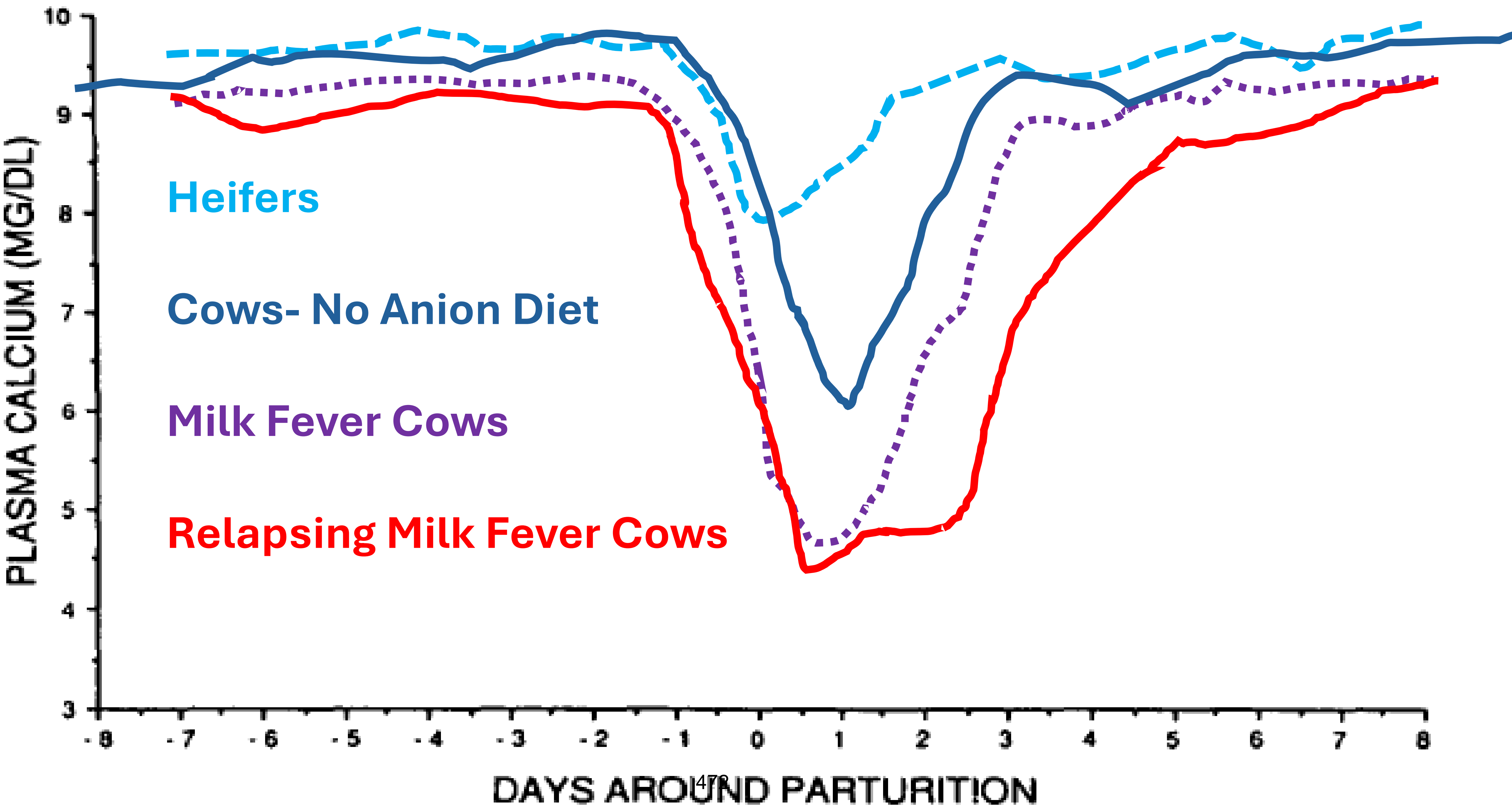
Data from Horst et al, 1977; Goff et al., 1989; Gaynor et al., 1989; Goff and Horst, 1997;

Older cows struggle to produce adequate amounts of 1,25-dihydroxyvitamin D quickly enough to prevent hypocalcemia

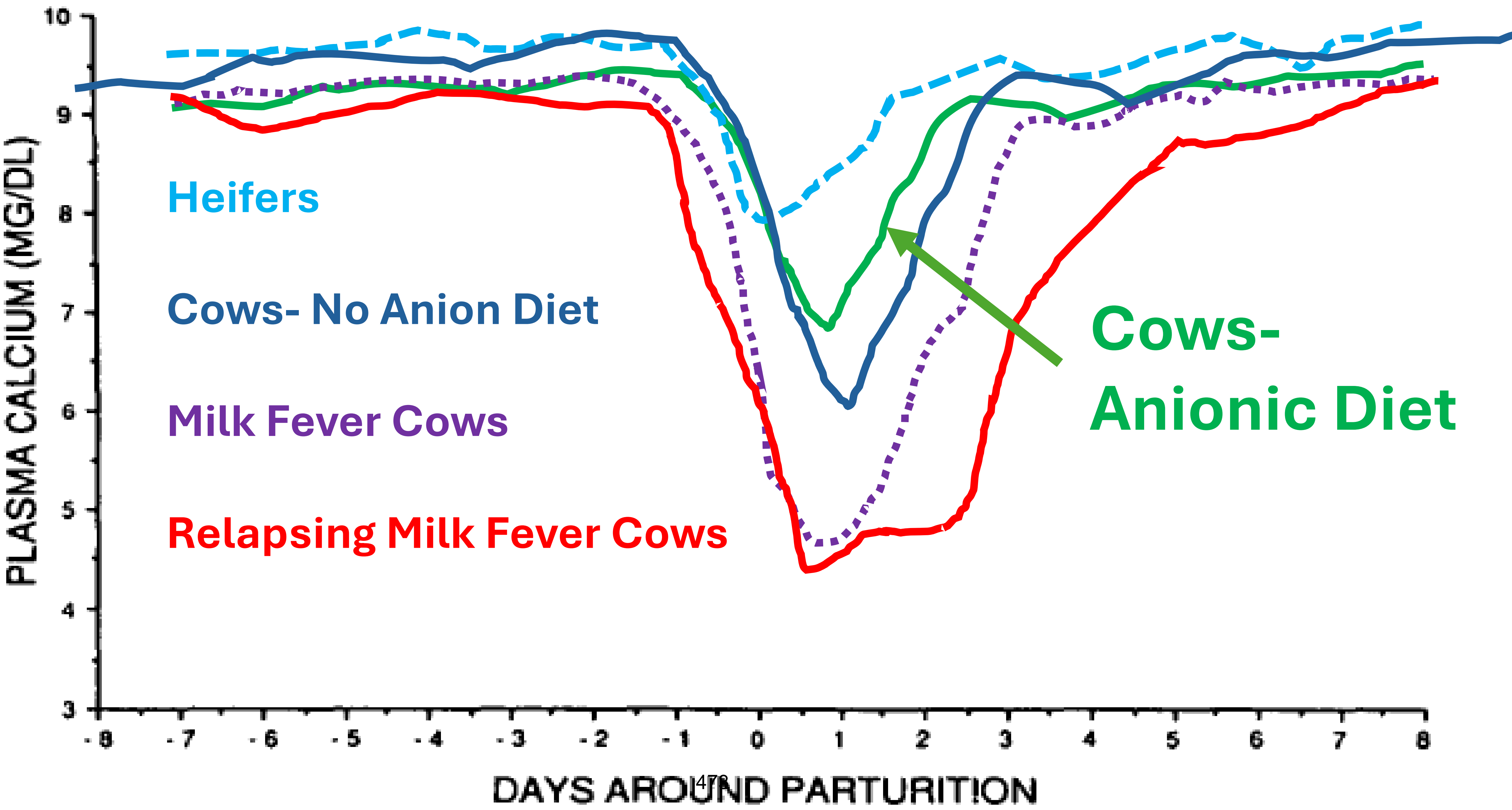

PLASMA CALCIUM (MG/DL)
10
9
8
7
6
5
4
3
Heifers
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION

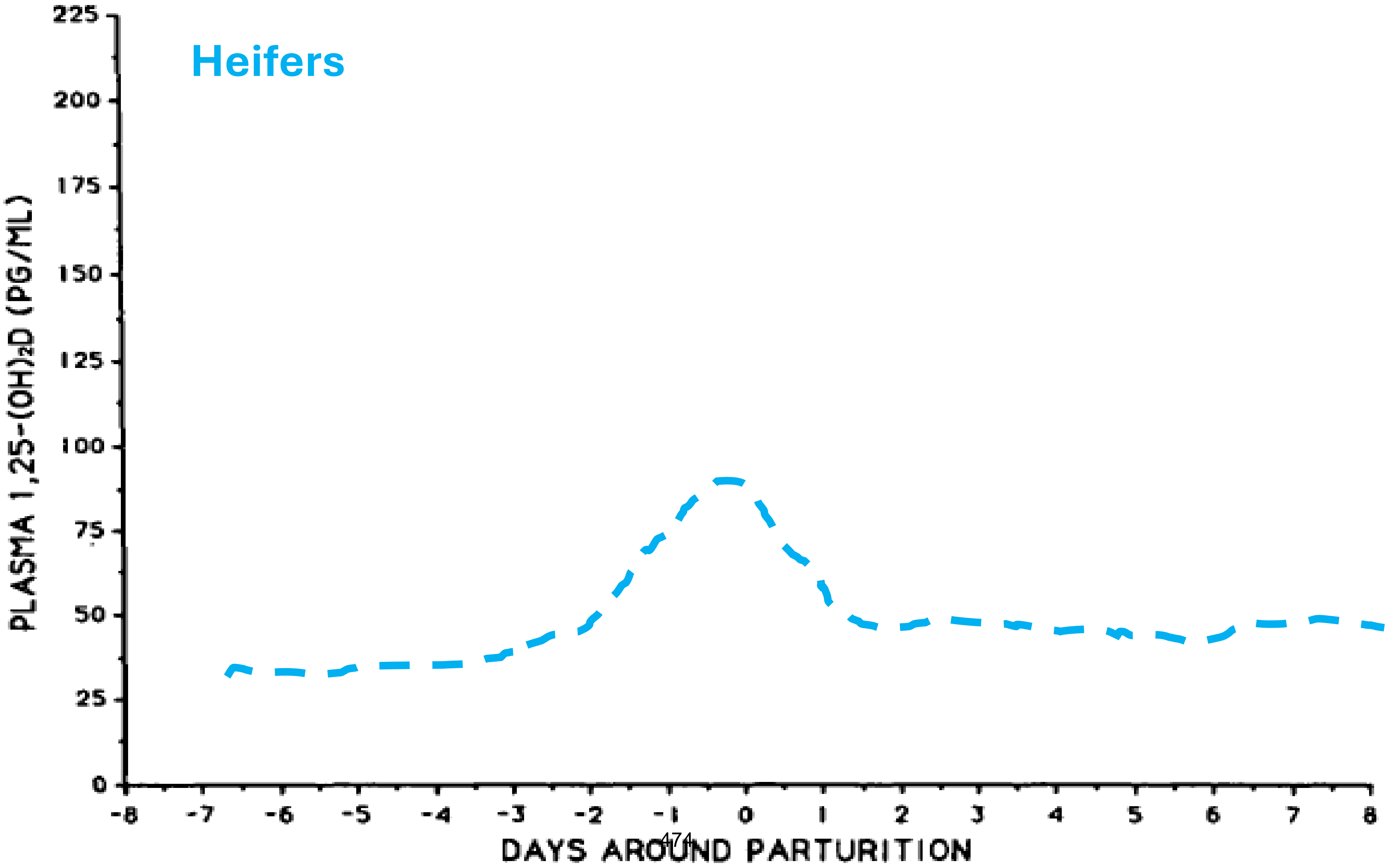

PLASMA CALCIUM (MG/DL)
10
9
8
7
6
5
4
3
Heifers
Cows- No Anion Diet
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION

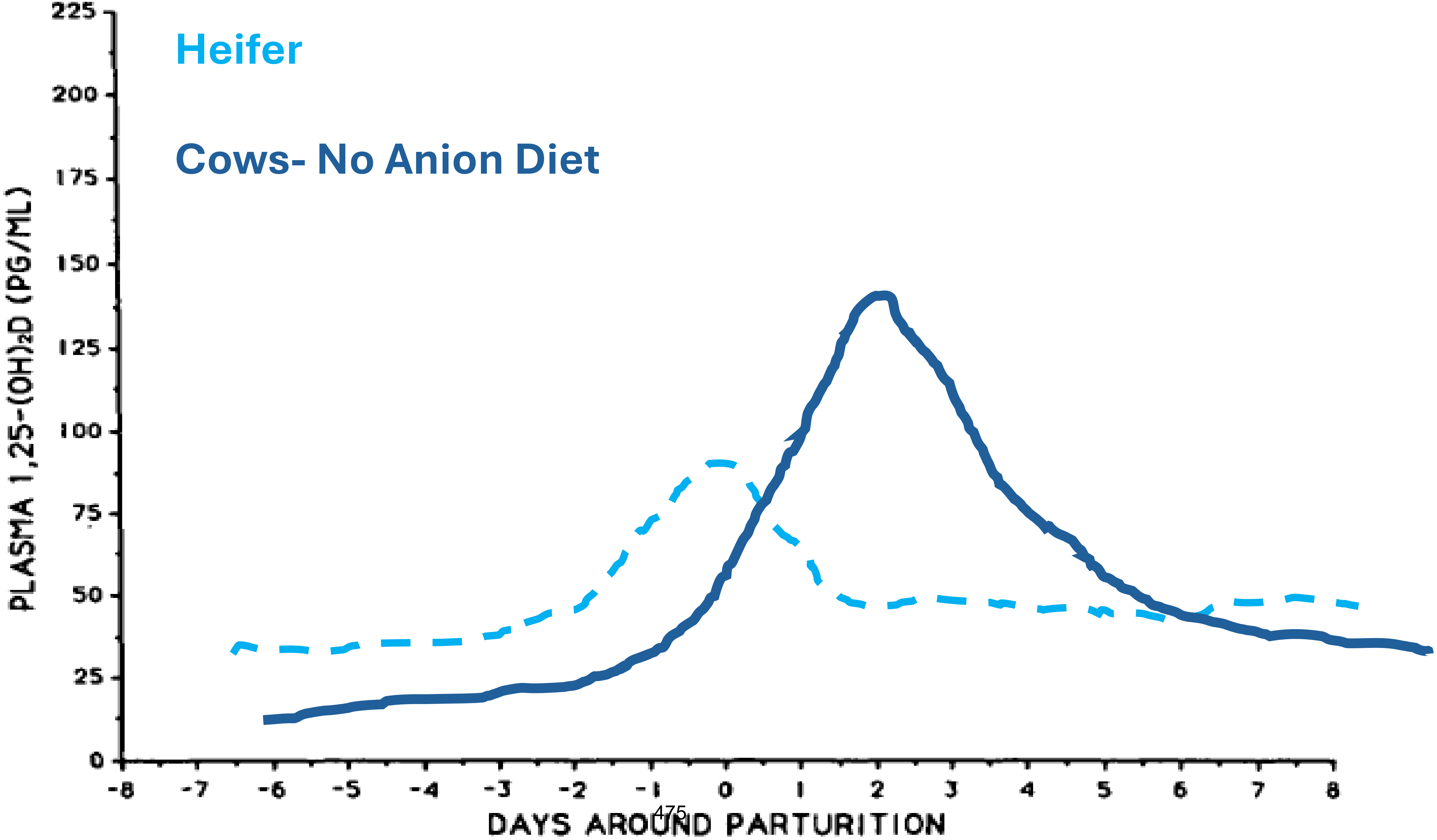

Heifers
Cows- No Anion Diet
Milk Fever Cows
PLASMA CALCIUM (MG/DL)
10
9
8
7
6
5
4
3
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION

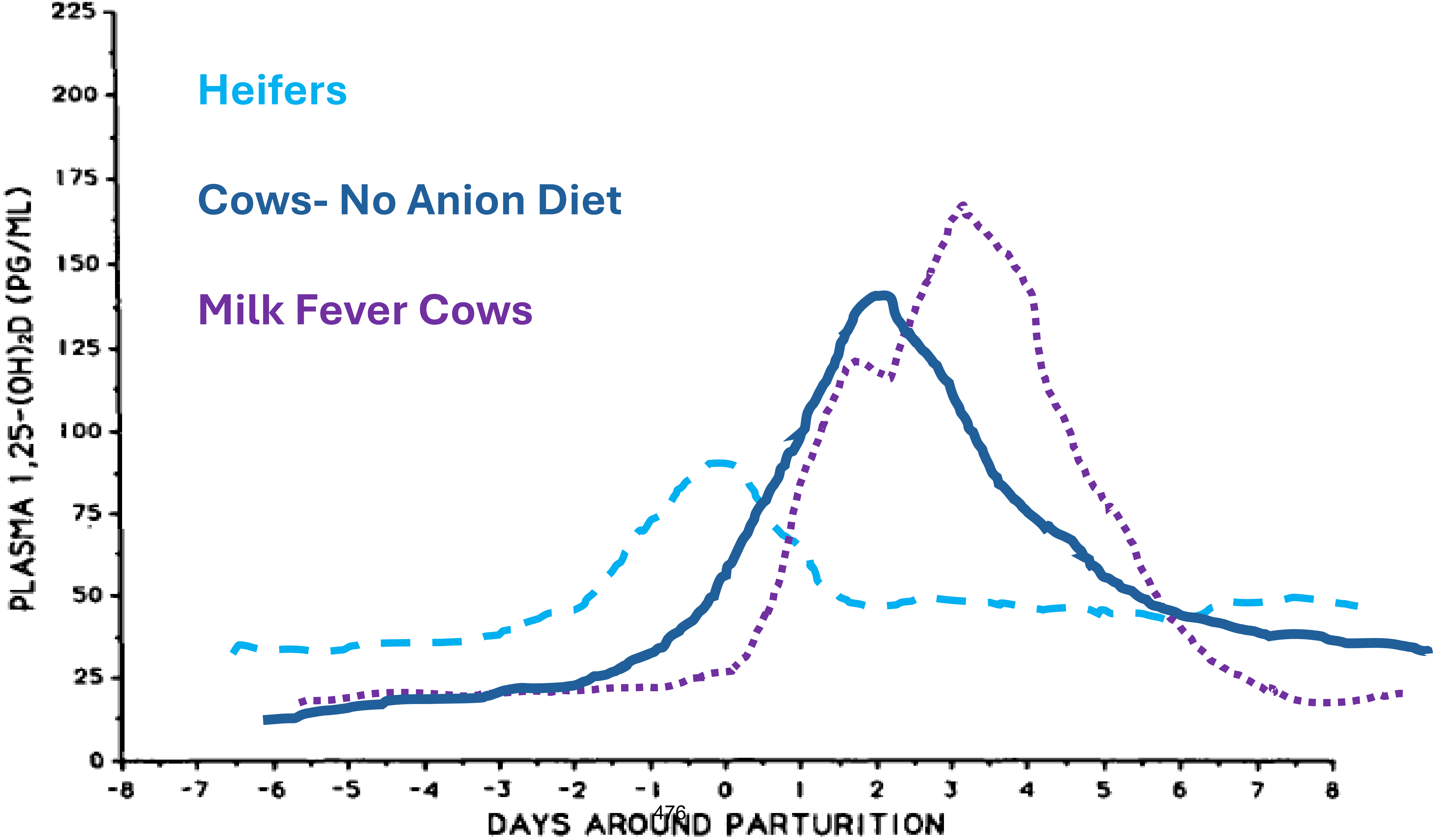


Heifers
Cows- No Anion Diet
Milk Fever Cows
Relapsing Milk Fever Cows
PLASMA CALCIUM (MG/DL)
10
9
8
7
6
5
4
3
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION

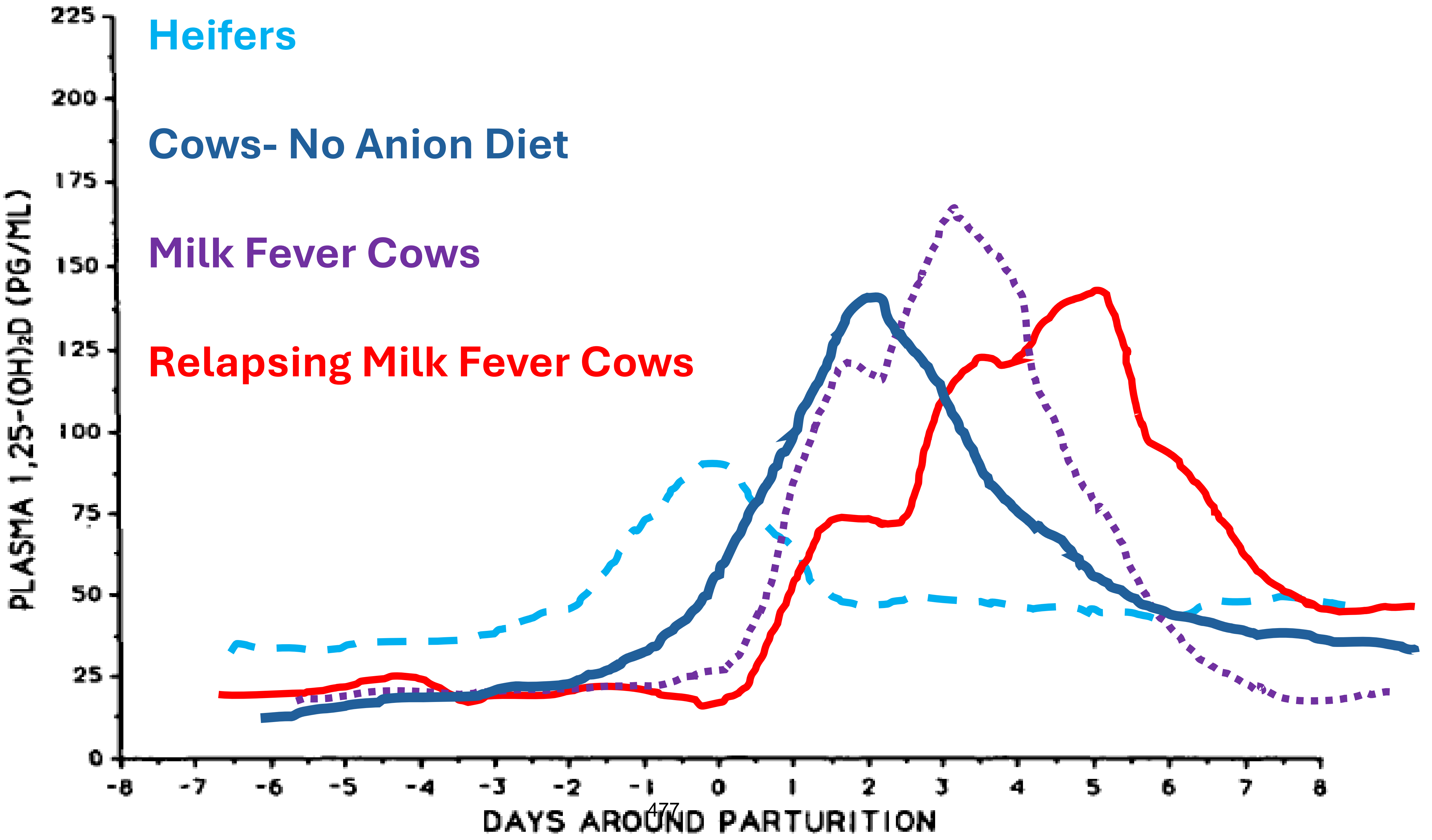

PLASMA CALCIUM (MG/DL)
10
9
8
7
6
5
4
3
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION
Heifers
Cows- No Anion Diet
Milk Fever Cows
Relapsing Milk Fever Cows
Cows- Anionic Diet

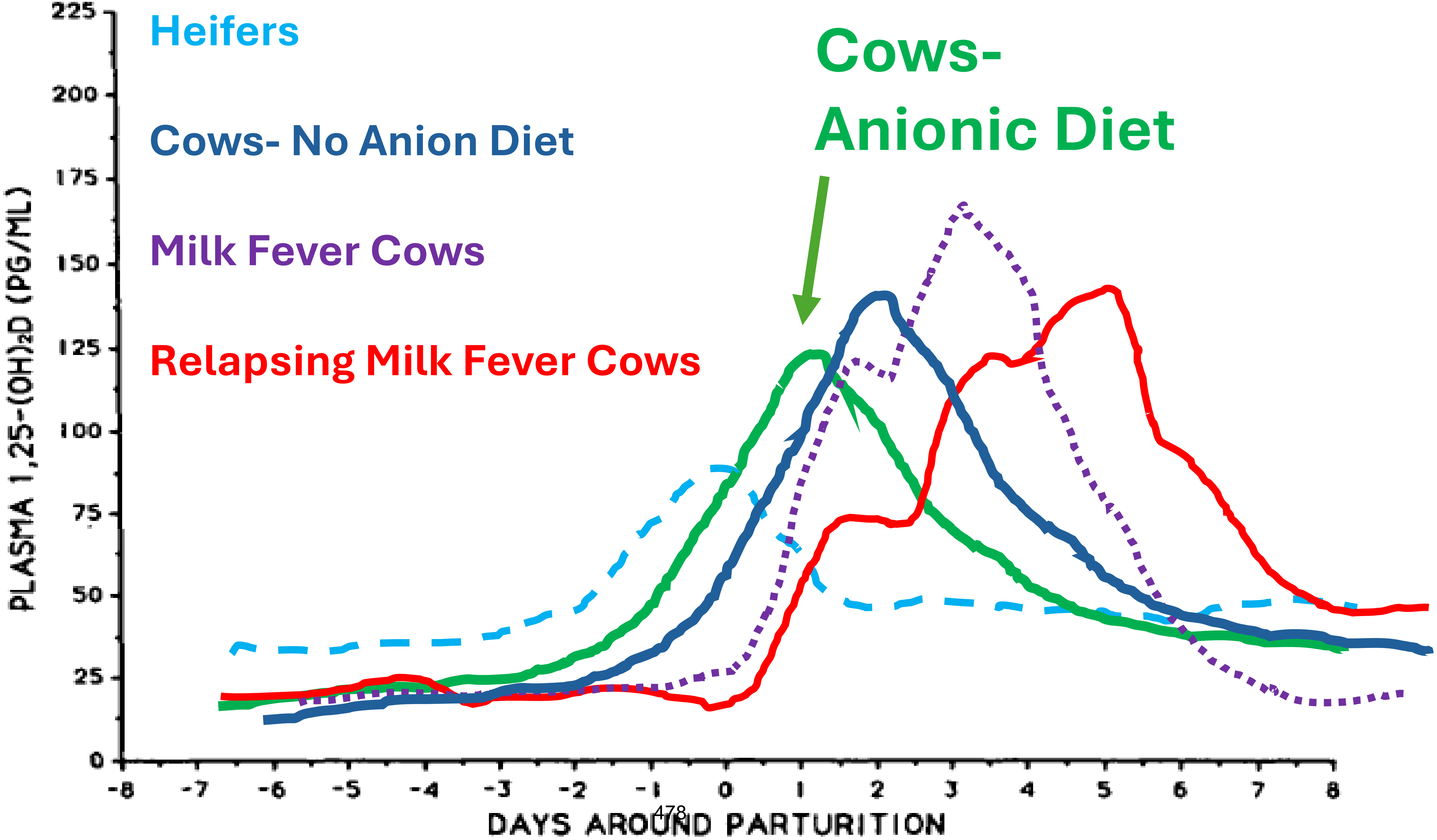

Heifers
PLASMA 1,25-(OH)2D (PG/ML)
225
200
175
150
125
100
75
50
25
0
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION


Heifer
Cows- No Anion Diet
PLASMA 1,25-(OH)₂D (PG/ML)
225
200
175
150
125
100
75
50
25
0
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION



Heifers
Cows- No Anion Diet
Milk Fever Cows
PLASMA 1,25-(OH)₂D (PG/ML)
225
200
175
150
125
100
75
50
25
0
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8
DAYS AROUND PARTURITION


Heifers
Cows- No Anion Diet
Milk Fever Cows
Relapsing Milk Fever Cows
PLASMA 1,25-(OH)₂D (PG/ML)
225
200
175
150
125
100
75
50
25
0
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION

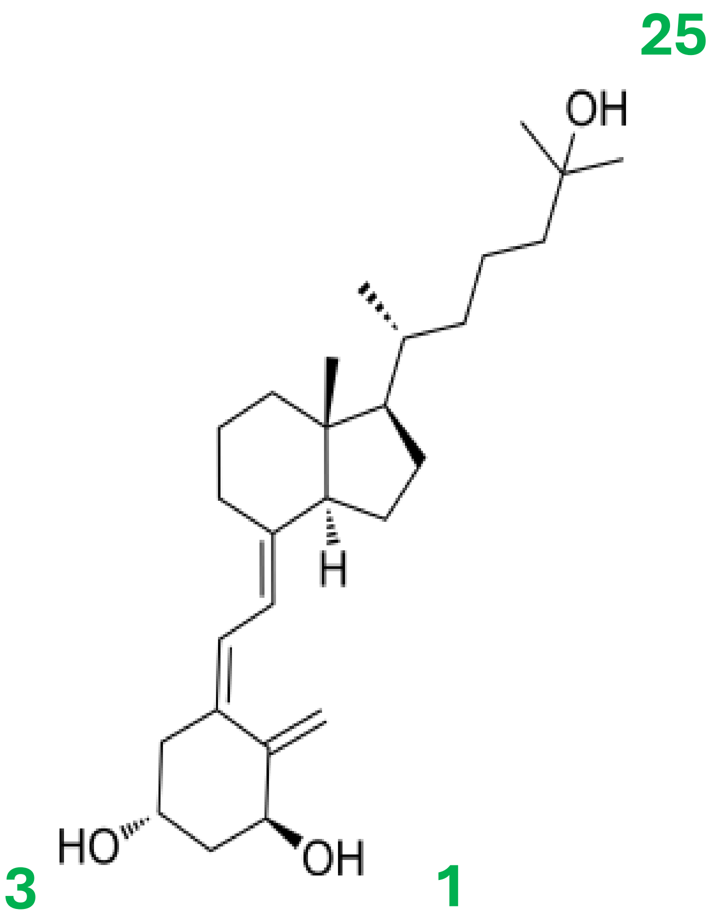


Heifers
Cows- No Anion Diet
Milk Fever Cows
Relapsing Milk Fever Cows
Cows-
Anionic Diet
PLASMA 1,25-(OH)₂D (PG/ML)
225
200
175
150
125
100
75
50
25
0
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8
DAYS AROUND PARTURITION

Failure to produce 1,25-dihydroxyvitamin D quickly enough and in an adequate amount is a major factor contributing to hypocalcemia and Milk Fever

Solanum glaucophyllum

Plant that produces glycosides of 1,25-$(OH)_2$vitamin D_3.

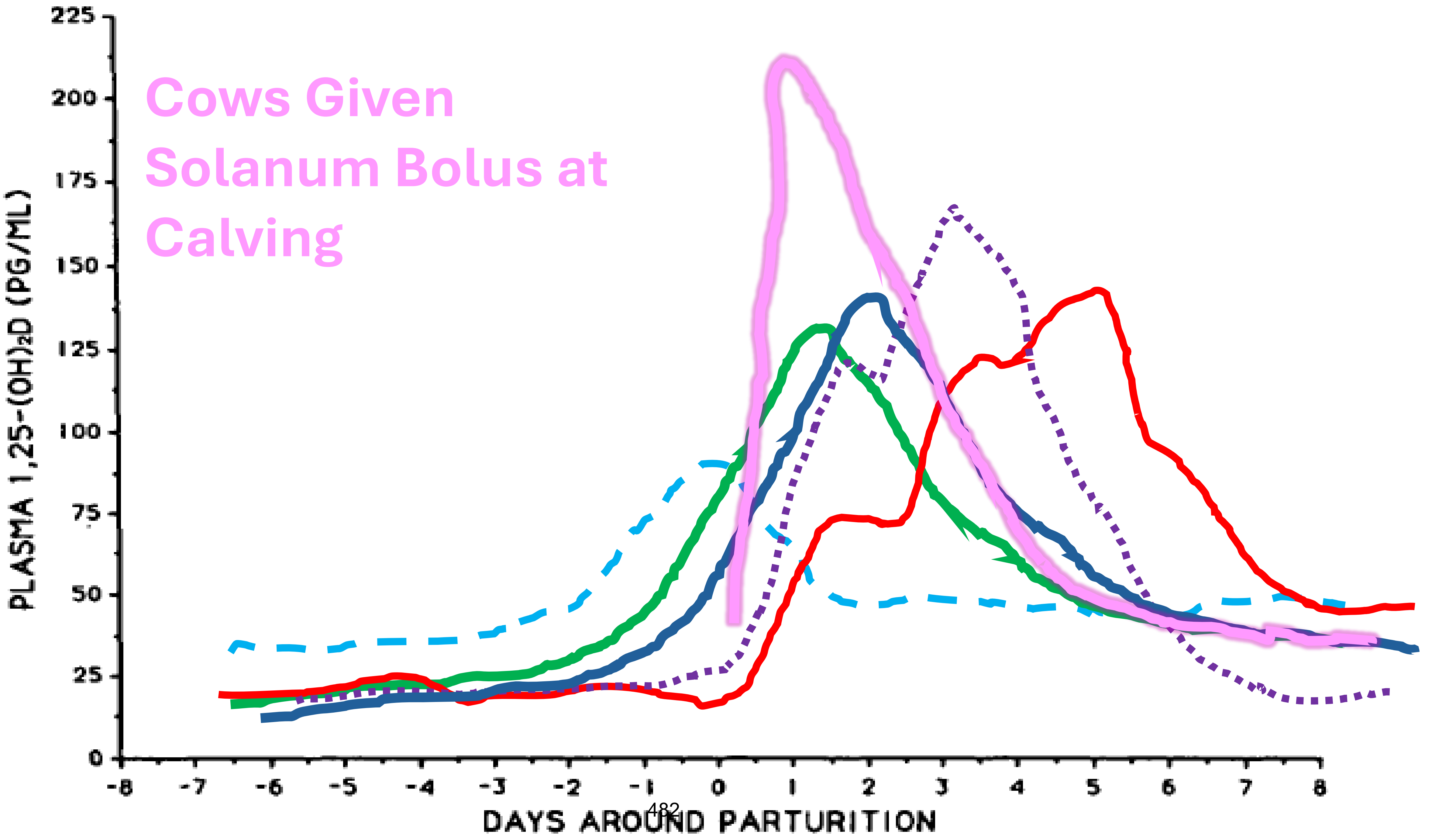


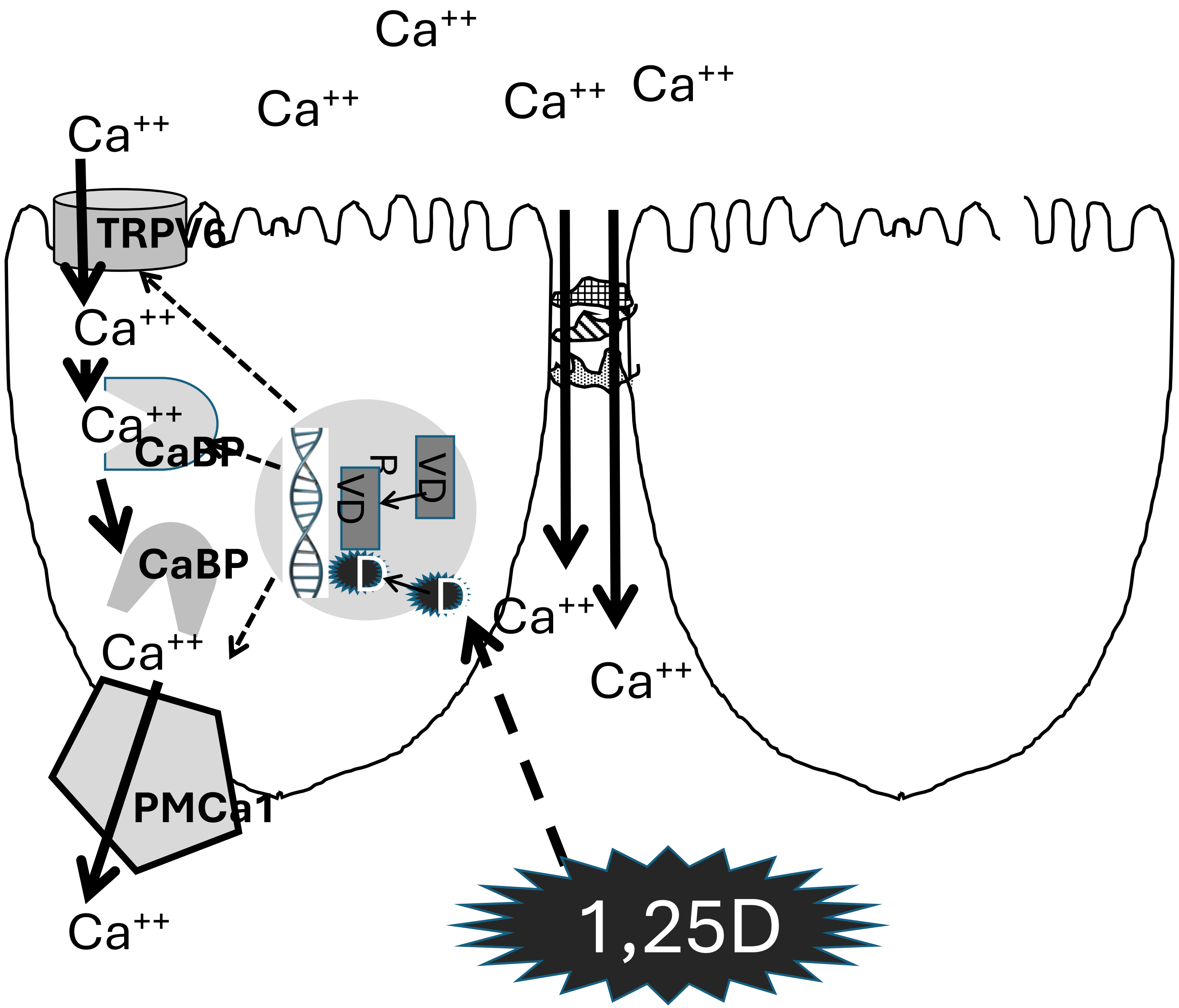
Where OH on carbons 1,3 or 25 are replaced by 1-8 glucose molecules.

Glucose cleaved off in rumen liberating active form of vitamin D!!!

Failure to produce 1,25-dihydroxyvitamin D quickly enough and in an adequate amount is a major factor contributing to hypocalcemia and Milk Fever

Can S. glaucophyllum supply a natural bioactive form of vitamin D to maintain more normal blood calcium concentrations in early lactation??

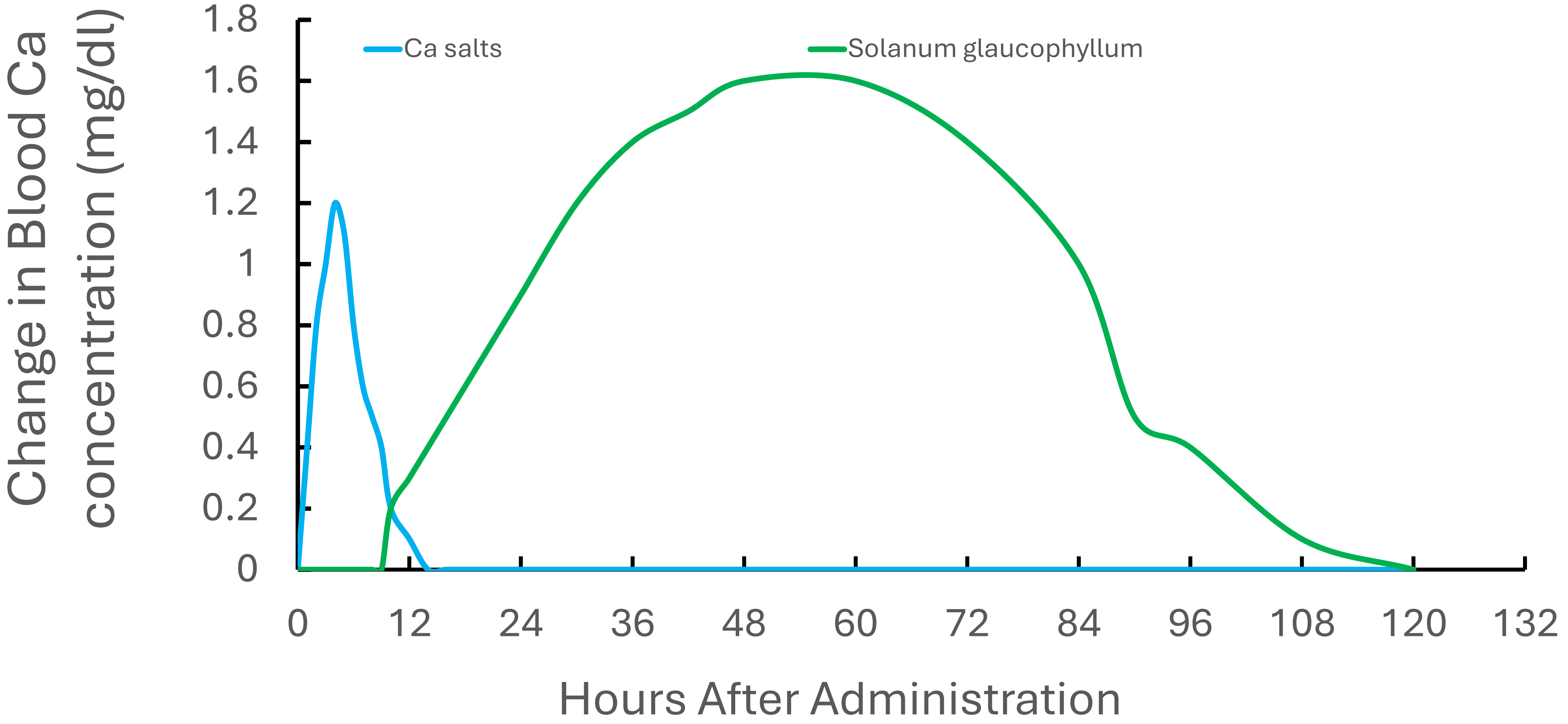

Cows Given
Solanum Bolus at
Calving
PLASMA 1,25-(OH)₂D (PG/ML)
225
200
175
150
125
100
75
50
25
0
-8 -7 -6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6 7 8
DAYS AROUND PARTURITION



Efficient Absorption of Diet Calcium Requires 1,25 VitD to stimulate production of Ca transporter proteins

Requires about 10-12 hours for 1,25 Vit D to turn on the intestinal cells

Change in blood Ca concentration following administration of Solanum Boluses



Solanum glaucophyllum (SG) / Calcium Bolus

1. **SG Bolus For Use with ANIONIC DIETS.**

Uses alkalinizing calcium lactate and calcium acetate and a smaller amount of acidifying Calcium chloride to provide readily soluble Ca.

2. **SG Bolus For Use in NO ANION DIETS & ZEOLITE diets**

Uses more acidifying calcium chloride with smaller amounts of calcium lactate and acetate to provide readily soluble Ca. **ADMINISTERED TOO LATE TO PREVENT PRE-CALVING MILK FEVER.**

Administered as two Ca + SG boluses at calving only – no repeat treatment.

Study "No Anion Diet" Trial

Torreon, MX Dairy not feeding an anionic diet.

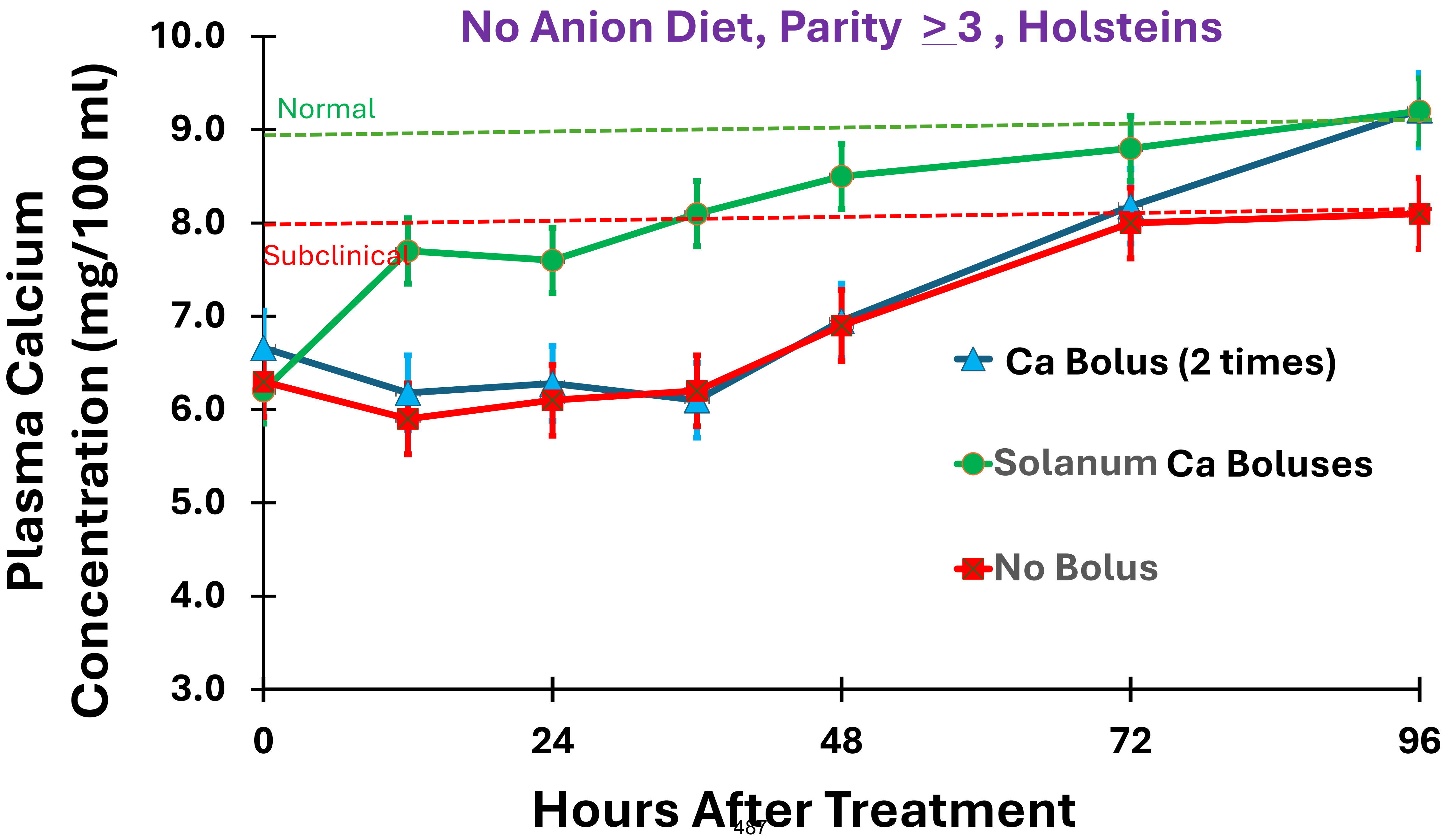
Blood from Holsteins entering their $\geq$ **3rd** lactation.

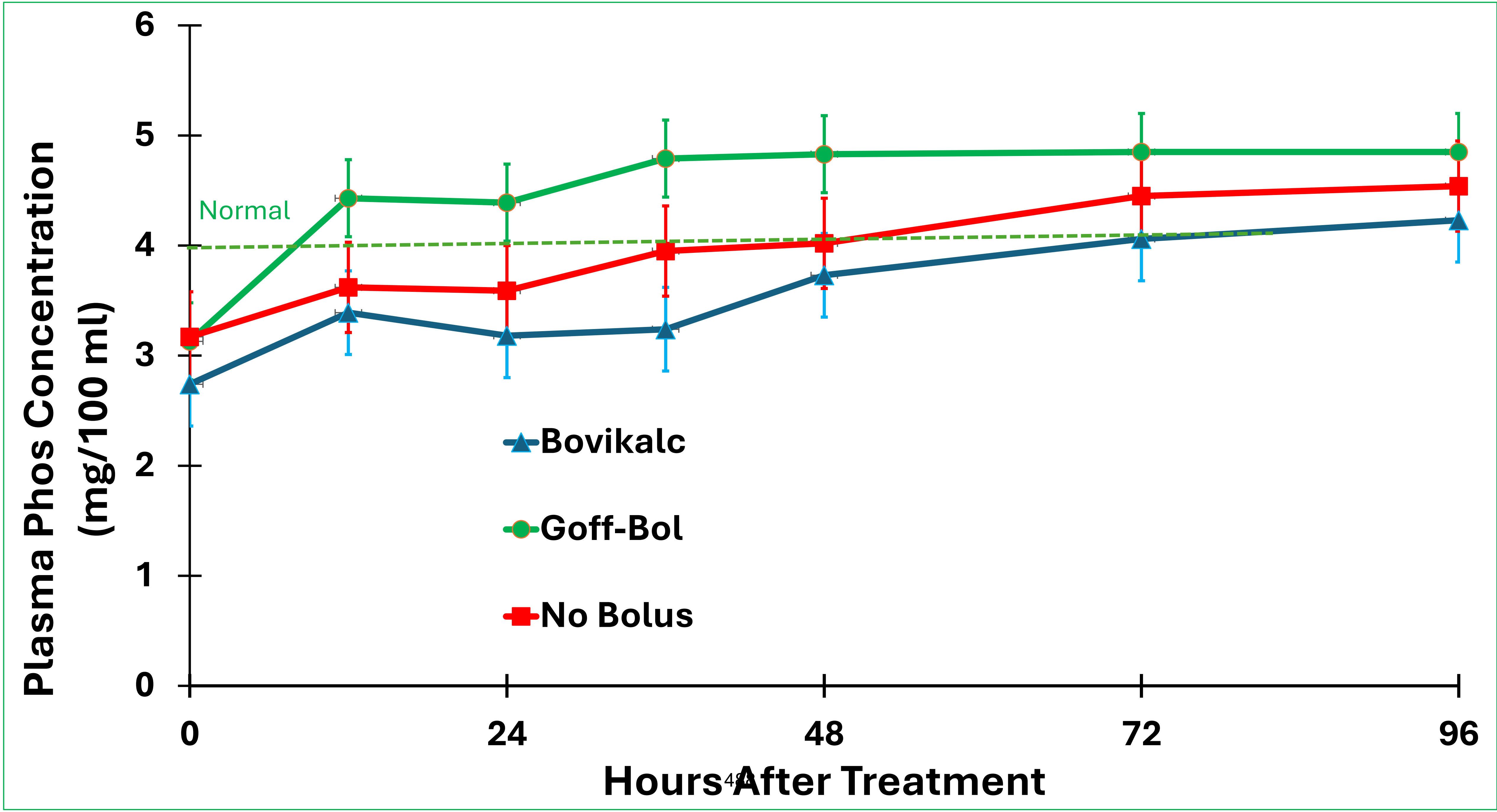
Treatments

2 Solanum glaucophyllum Calcium boluses at calving, N=18 (0/18 MF)

Commercial Ca Bolus – 1st bolus at calving and 2nd 12-20 hrs later, N= 12 (1/12 MF)

No Oral Ca Bolus, N= 12 (2/12 MF)


No Anion Diet, Parity ≥ 3 , Holsteins
Plasma Calcium Concentration (mg/100 ml)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
Normal
Subclinical
0
24
48
72
96
Hours After Treatment
Ca Bolus (2 times)
Solanum Ca Boluses
No Bolus



Plasma Phos Concentration (mg/100 ml)
6
5
4
3
2
1
0
Normal
Bovikalc
Goff-Bol
No Bolus
0
24
48
72
96
Hours After Treatment

Five No Anion Diet Farms- cows $\geq$2 lactation

5 small MN Farms that did not use an anionic diet. Data pooled.

Treatments

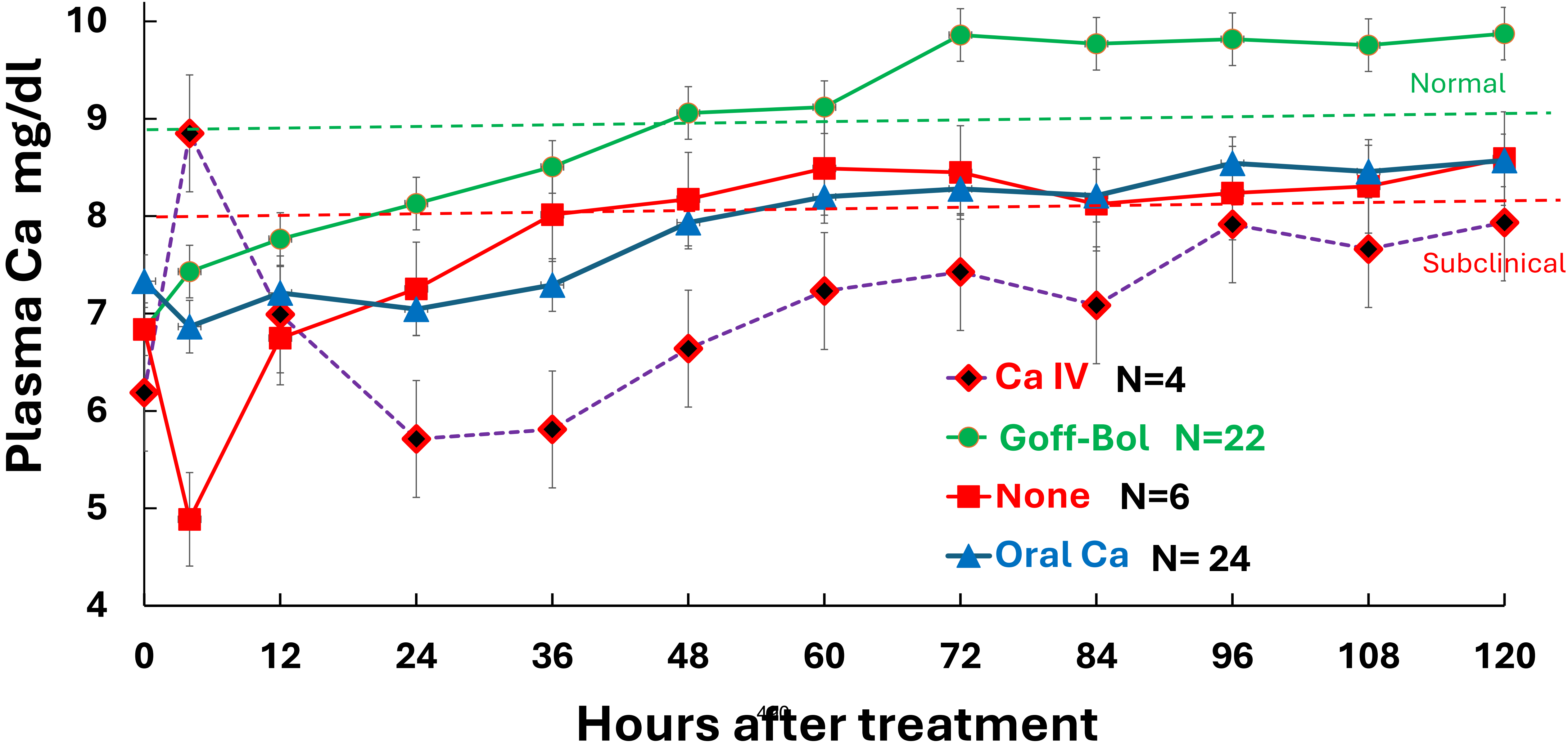
24 Cows -Commercial Ca boluses based on $CaCl_2$ (43-45 g Ca/bolus)

22 Cows- Two Goff-Bol MAX Solanum boluses at calving

4 Cows - two farms gave IV Ca to 3rd and greater lactation cows.

6 Cows -NO Bolus Treatment, # limited due to 33% milk fever (2/6)

≥2 lactations, No Anion Diet cows, combined data from 5 farms



Cuttance et al., 2026 Front Vet Sci

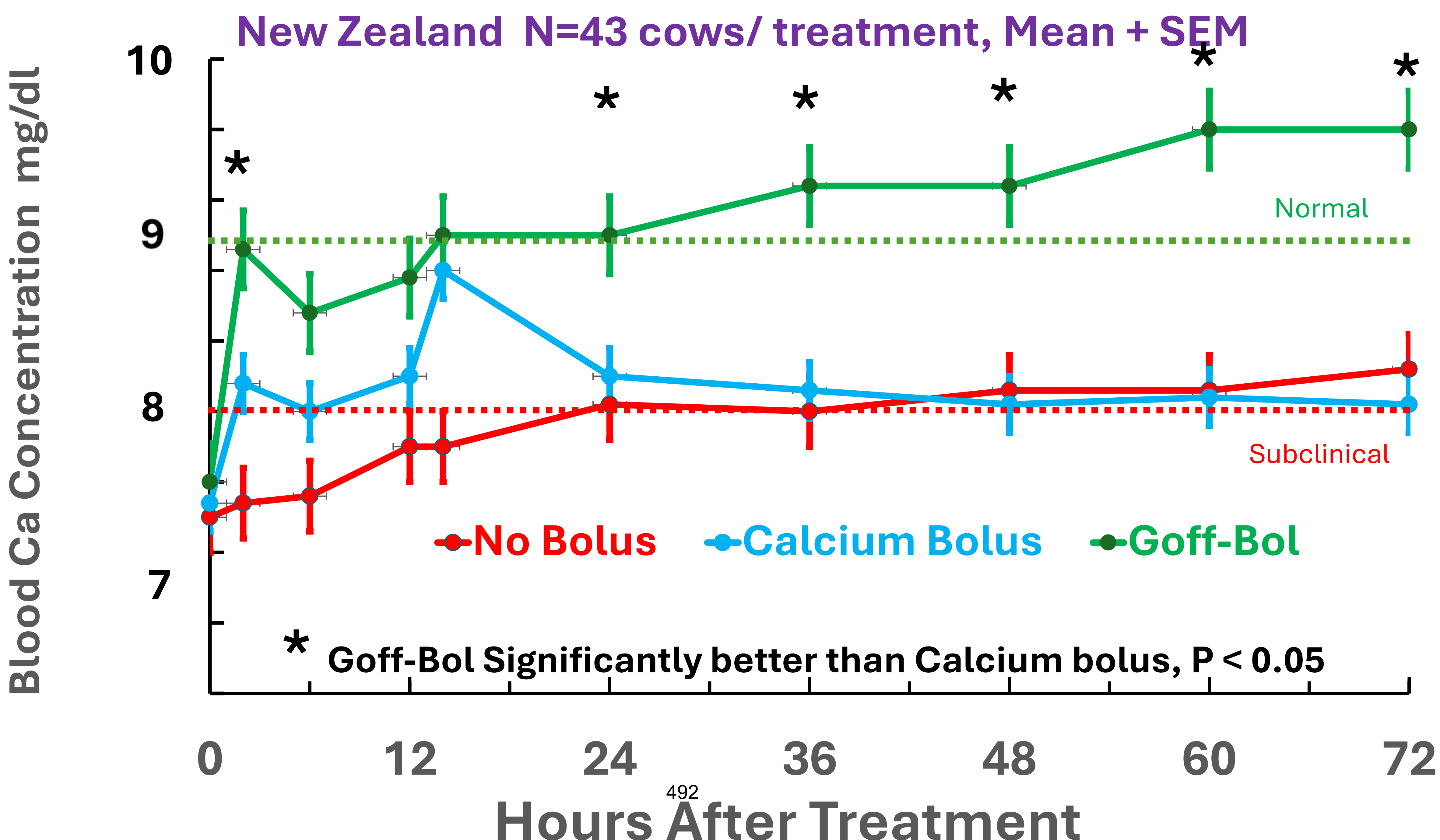
New Zealand - Goff-Bol Max, 2 farms , one fed anions ($MgSO_4$, urine pH 7.3) and one fed none

Cows assigned to treatments based on parity

43 cows/ treatment. All calved within a 30 day period

Blood sampled at calving, then 2, 6, 12, 14, 24, 36, 48, 60 and 72 hours after bolus administration

8 mg/dl = **cutpoint for subclinical hypocalcemia**


New Zealand N=43 cows/ treatment, Mean + SEM
Blood Ca Concentration mg/dl
10
9
8
7
Normal
Subclinical
No Bolus
Calcium Bolus
Goff-Bol
* Goff-Bol Significantly better than Calcium bolus, P < 0.05
0
12
24
36
48
60
72
Hours After Treatment

Study Design Using only Multiparous cows on U Missouri dairy

Cows assigned to treatments based on lactation # (entering 2nd or ≥ 3rd)

- farm was feeding Anionic diet with Urine pH around 6.0

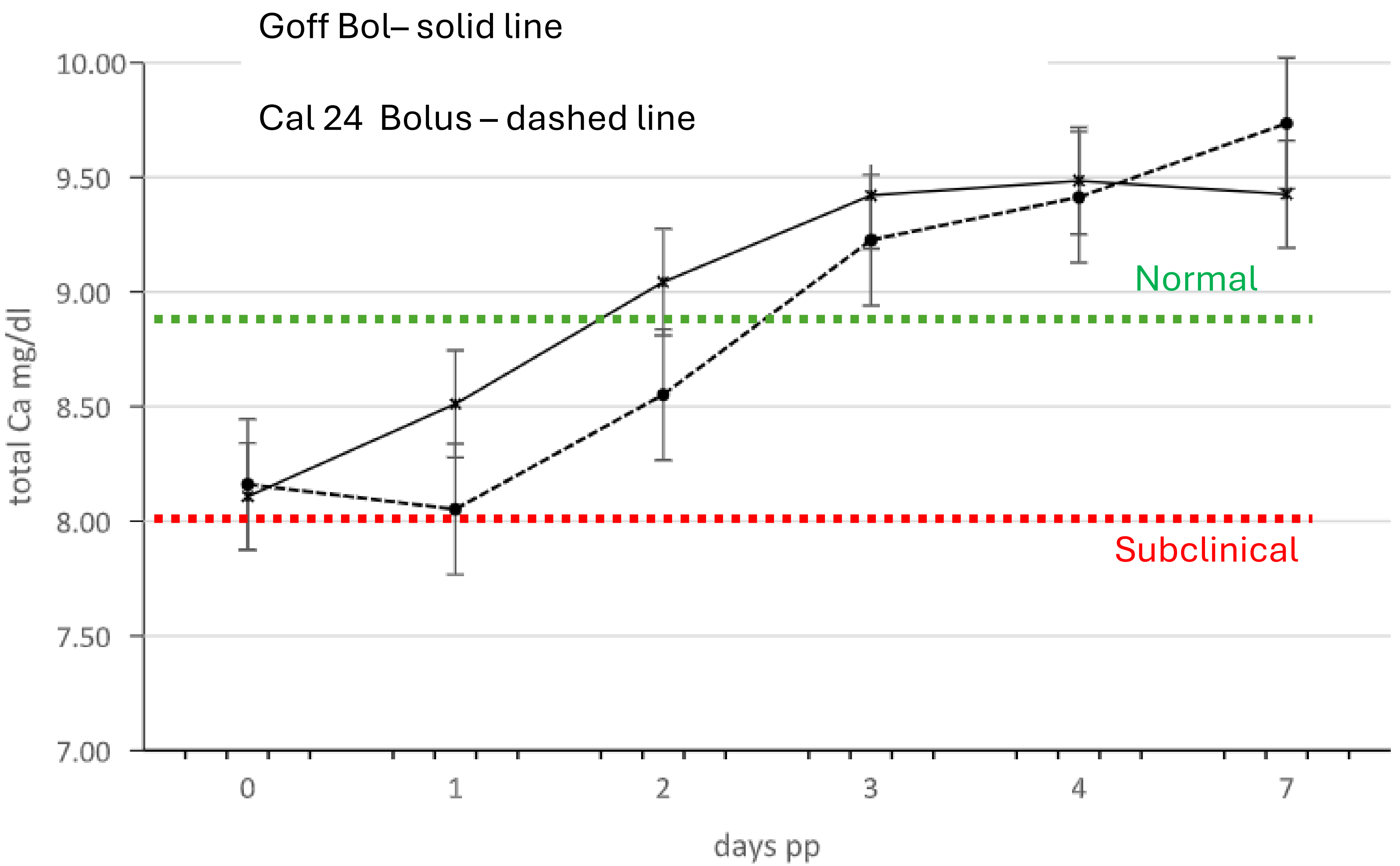
ORAL BOLUS TREATMENTS ADMINISTERED WITHIN 6 hrs Of calving

1. Two Goff-Bol Boluses – supplied 78 g Ca + S.G. leaf,   N= 26 cows

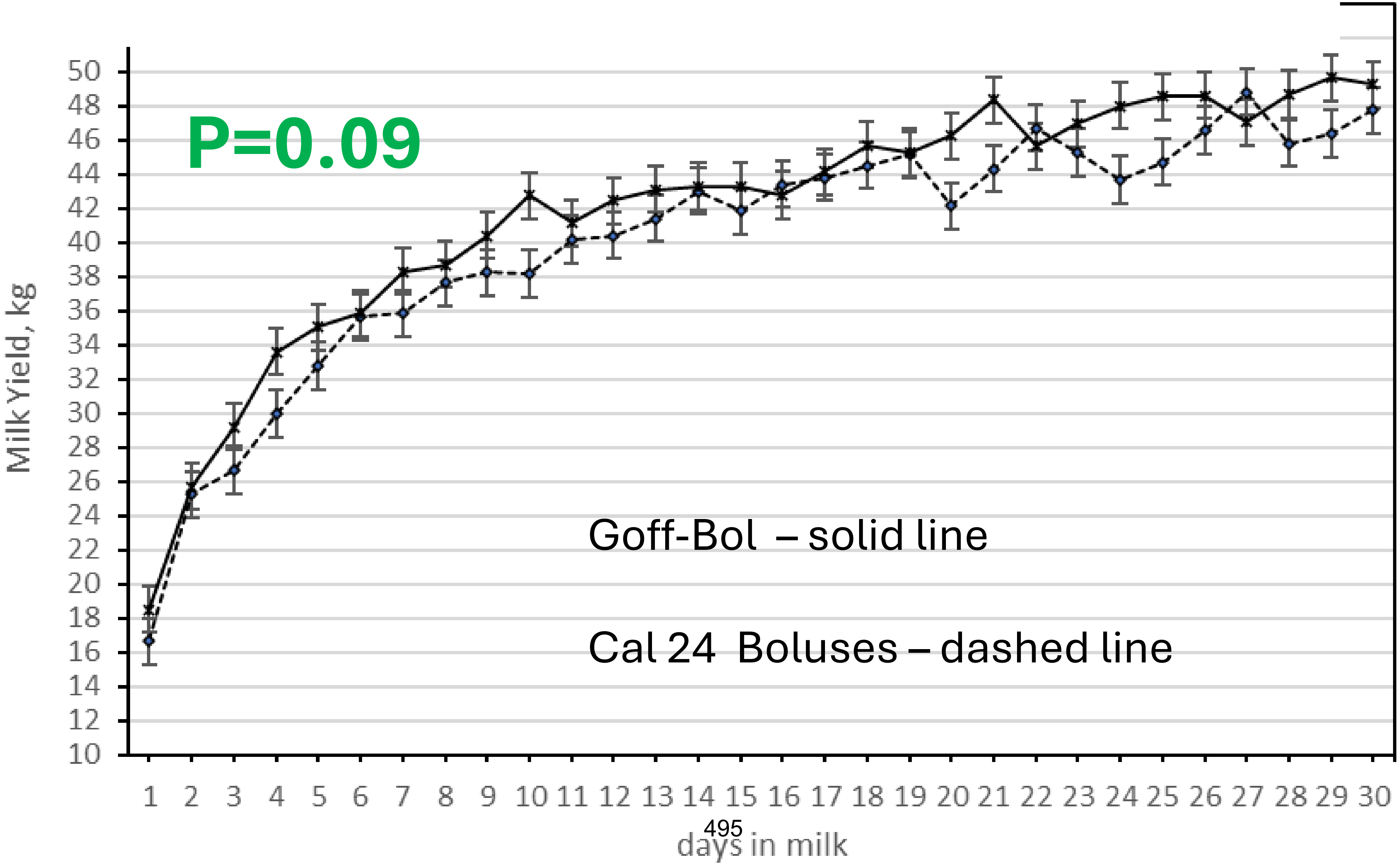
2. Two Ca boluses (CAL24™, GENEX) – supplied 100 g Ca, N= 23 cows

Blood samples obtained from cows just before treatment and 1,2,3,4 and 7 days after calving

Mizzou cows Total Plasma Ca (mg/dl)



Milk production data 1st 30 days



Wisconsin dairy – anionic diet urine pH ~ 6-6.5, started July 2025

Paired cows matched by parity, and previous ME 305 milk.

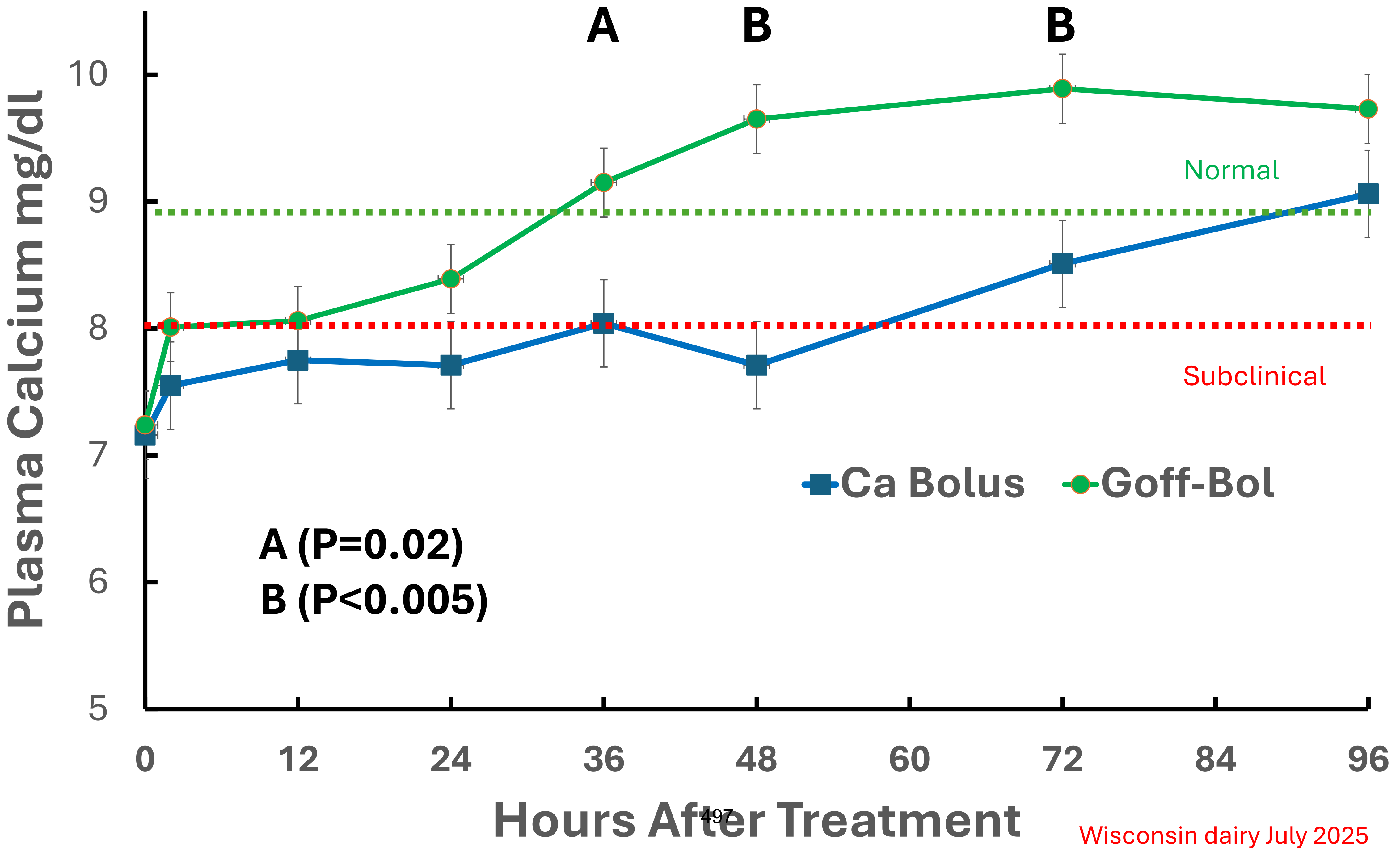
One of each pair received oral ca boluses per label, and other cow received 2 Goff-Bol shortly after calving

Blood obtained from a subset of 3rd and greater parity cows only

Goff-Bol – 9 cows

Bovikalc – 5 cows

Milk production and health records followed out for several months. Results as of December 1, 2025 on 200 cows on each treatment.



A
B
B
10
9
8
7
6
5
Plasma Calcium mg/dl
Normal
Subclinical
Ca Bolus
Goff-Bol
A (P=0.02)
B (P<0.005)
0
12
24
36
48
60
72
84
96
Hours After Treatment
Wisconsin dairy July 2025

Wisconsin Dairy Trial – Health/ Milk

EVENTS < 31 DIM	GOFF-BOL % (N= 210)	Ca Boluses % (N=211)	P- Value
Diarrhea	18	24	0.09
Ketosis	22	31	0.03
Metritis	2	2	0.99
Retained Placenta	7	3	0.12
Milk Fever	0	1.4	0.08
SOLD/DIED at 60 DIM	3	6	0.10
Milk WK 1 ECM	91.5	91.9	0.90
WK 2 ECM	116.4	113.9	0.55
WK 3 ECM	115.6	116.3	0.89
HEALTH ALERTS Cow Manager 1-10 DIM	31	49	0.0002

Wi Dairy Total Lactation Milk by Treatment. Culled cows make little milk!

After 60 DIM there are 204 of the 210 Goff-Bol cows left - lets say making 100 lbs milk /day

- 204 cows X 100 lbs/d X 305 d = 6,222,000 lbs
- and 6 cull cows X maybe 75 lbs milk/d X 30 days= 13,500 lbs

Total = 6,235,500 lbs

After 60 DIM there are 198 of 211 Bovikalc cows left – 100 lbs milk / day

- 198 cows X 100 lb/d X 305 d = 6.039,000 lbs
- And 13 cull cows X 75 lbs/d X 30 d = 29,250 lbs

Total = **6,068,250 lbs**

Difference = 167,250 lbs milk at $20 / cwt = $33,440 extra in milk money

COST 210 cows X $17/Goff-bol dose = $3570

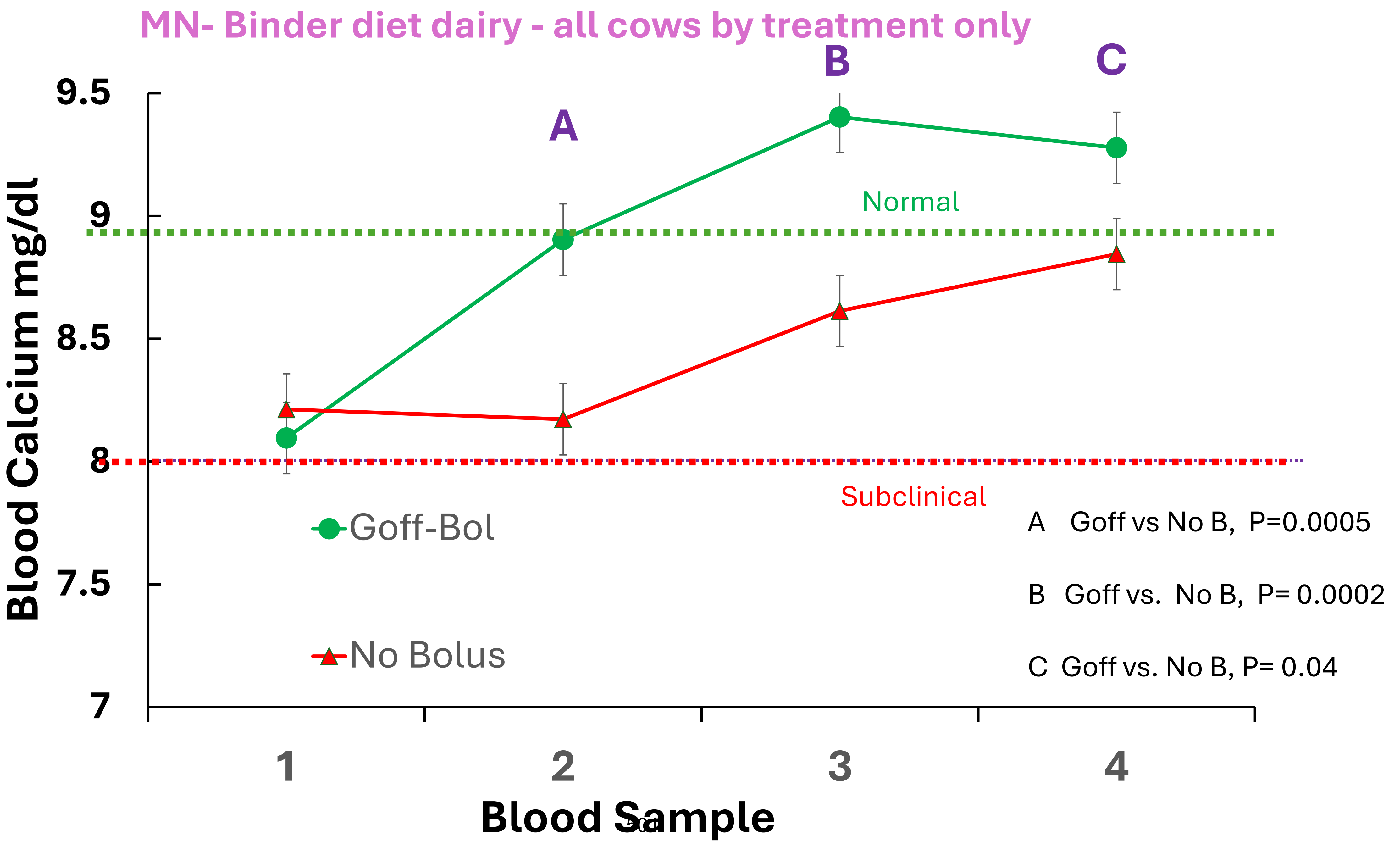
MILK = about a 10 :1 return on the cost of the boluses.

MN Farm on Zeolite P Binder Diet

24 No Bolus cows – 9-3rd parity, 7- 4th parity, 8- 5 Plus parity

24- Goff-Bol cows - 9-3rd parity, 7- 4th parity, 8- 5 Plus parity

Blood Sampled at time 0 (Before Boluses) and at 1, 2,and 3 days after treatment.



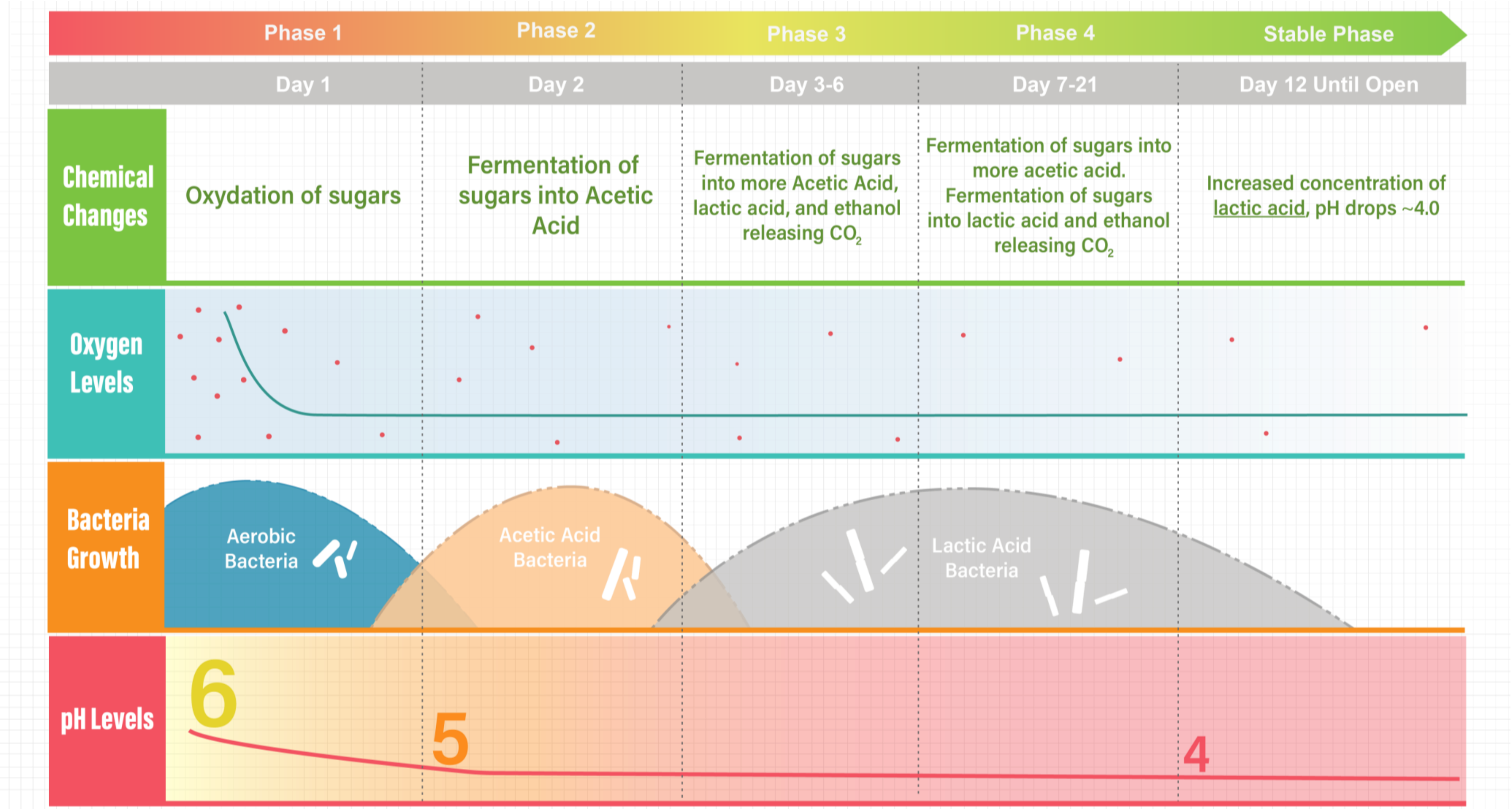
MN- Binder diet dairy - all cows by treatment only
Blood Calcium mg/dl
9.5
9
8.5
8
7.5
7
A
B
C
Normal
Subclinical
Goff-Bol
No Bolus
A Goff vs No B, P=0.0005
B Goff vs. No B, P= 0.0002
C Goff vs. No B, P= 0.04
1
2
3
4
Blood Sample

Implementing Quality Control in Corn Silage Before, During and After Harvest

Hugo A. Ramírez Ramírez, Ph. D.
International Silage Consulting

- The silage business, simple but not easy
- From a process to a system
- Quality management systems
- Defect-free manufacturing
- Preserving quality through feed out
- Take-home messages

Ensiling forages is simple…but not easy



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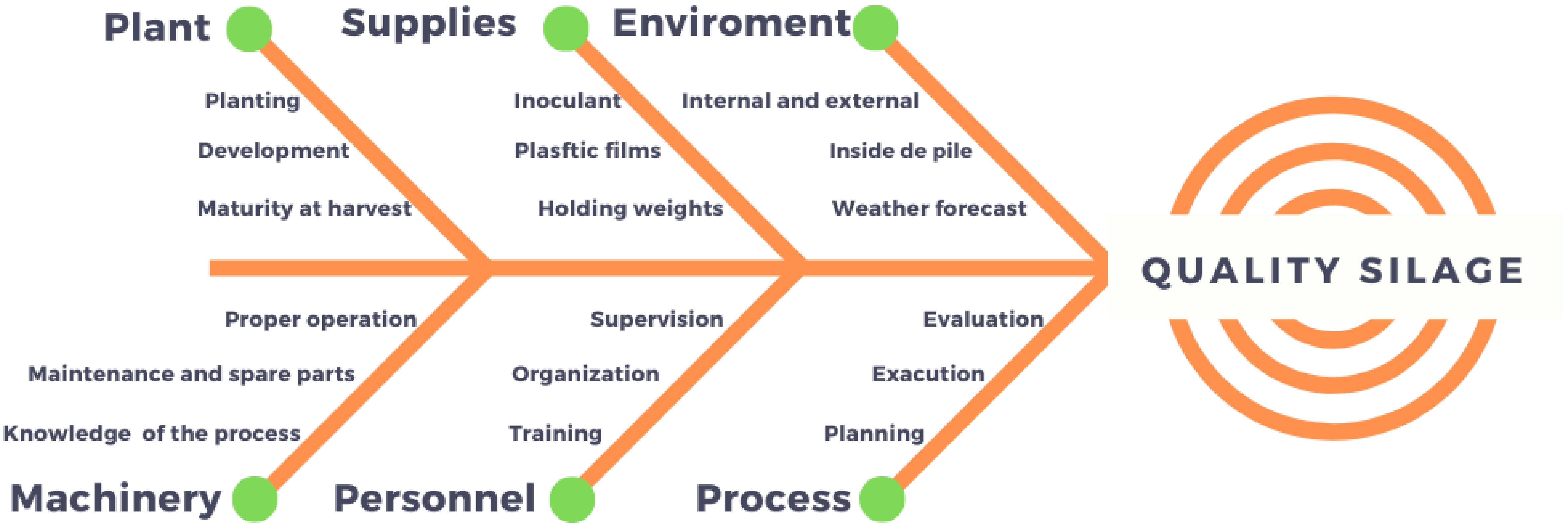
Ensiling forages is simple...but not easy



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The conservation process should capitalize the efforts from planting to harvesting

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Most common consumer in our business

Corn Silage for TMR

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Same product, different type of business

Fermented corn silage for sale in the "local" market

Bales of dehydrated corn silage for export market

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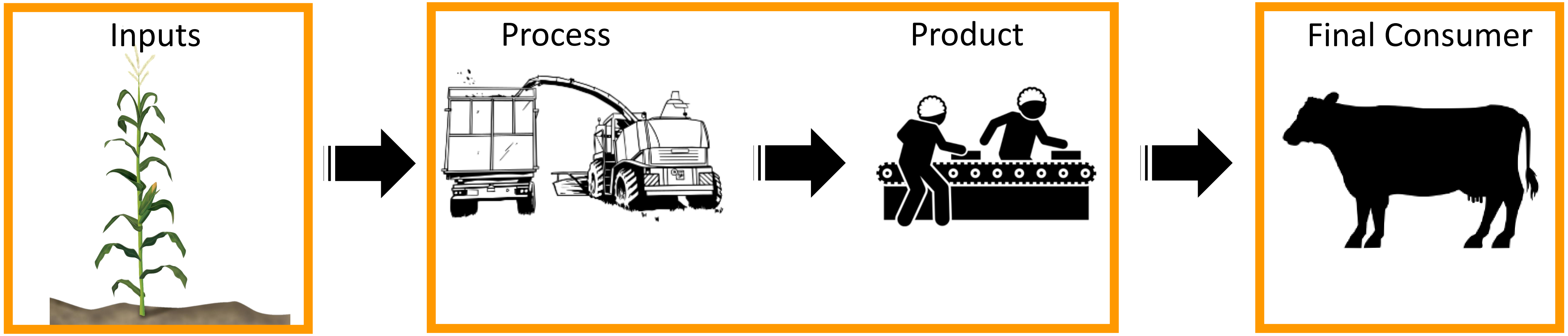
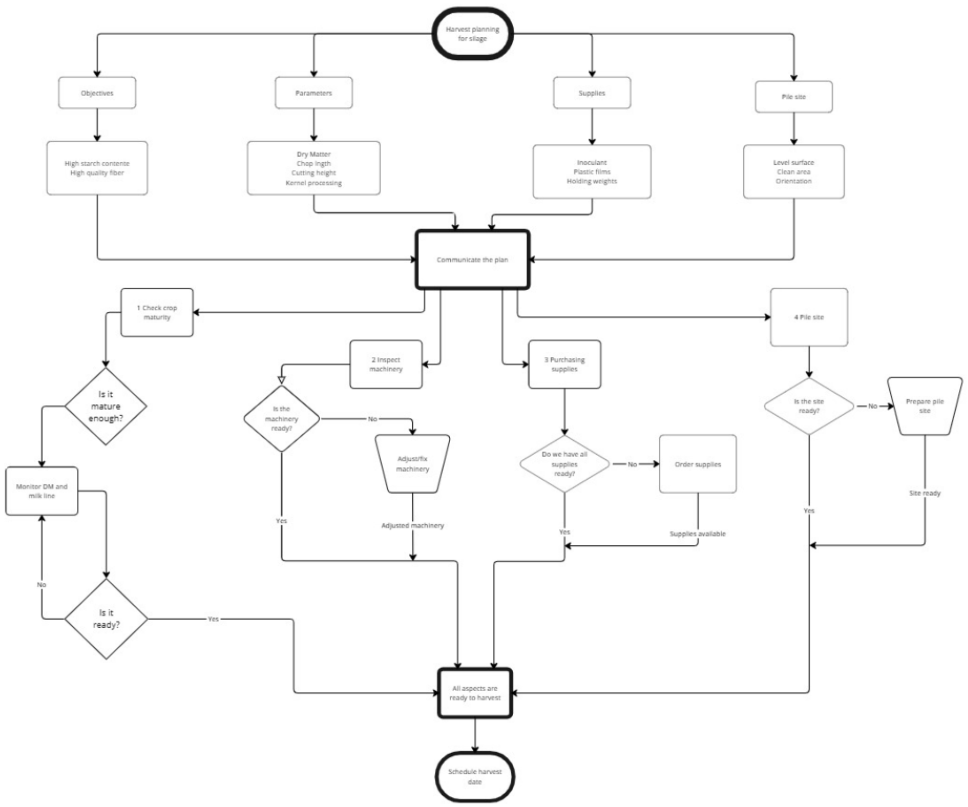
Silage-making as a manufacturing process



As any manufacturing **process**, silage-making should be considered a **transformation** process:

From crop to feed

From a process to a system

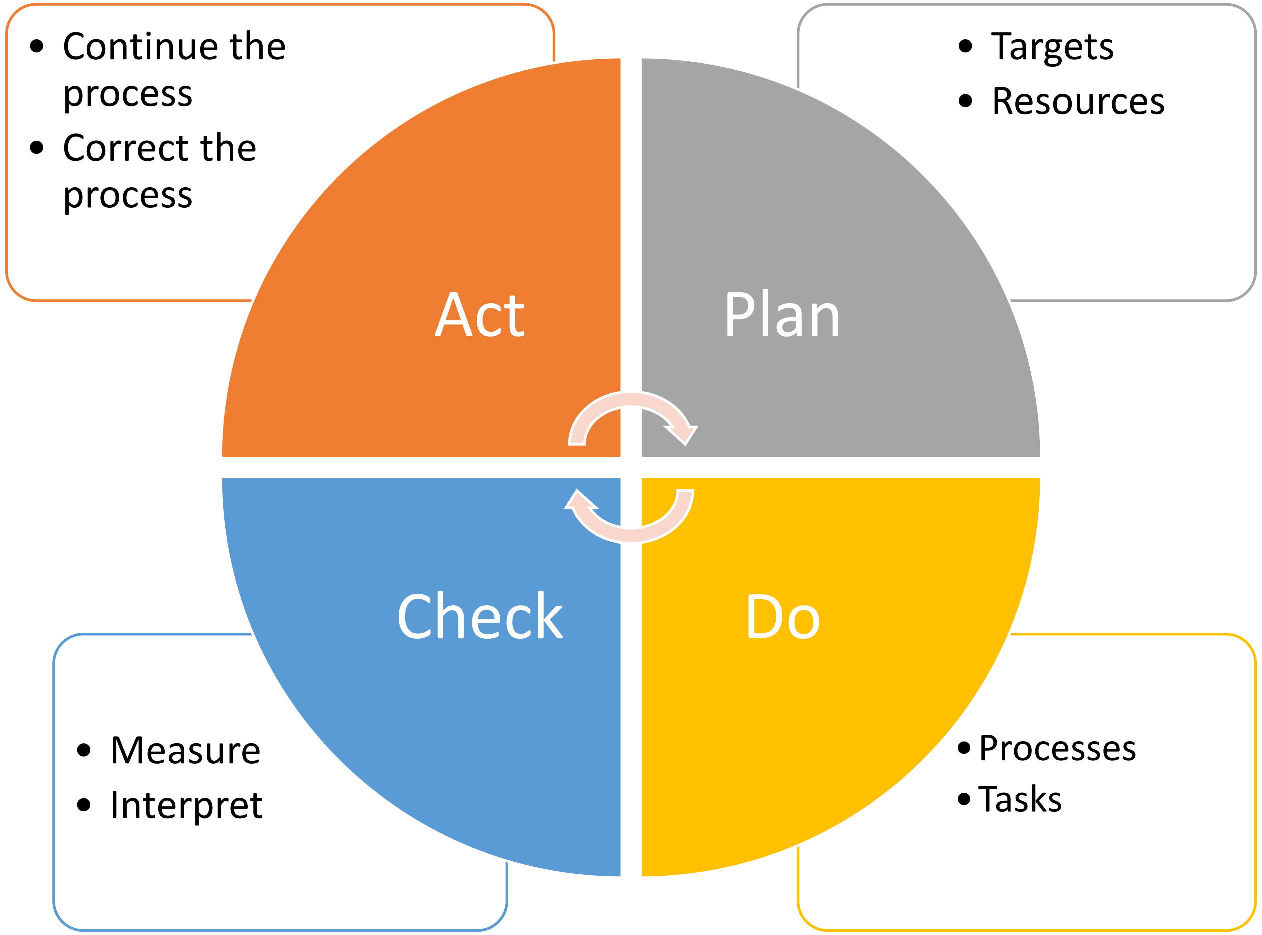


Integrated framework of processes, tools, and people designed to produce:

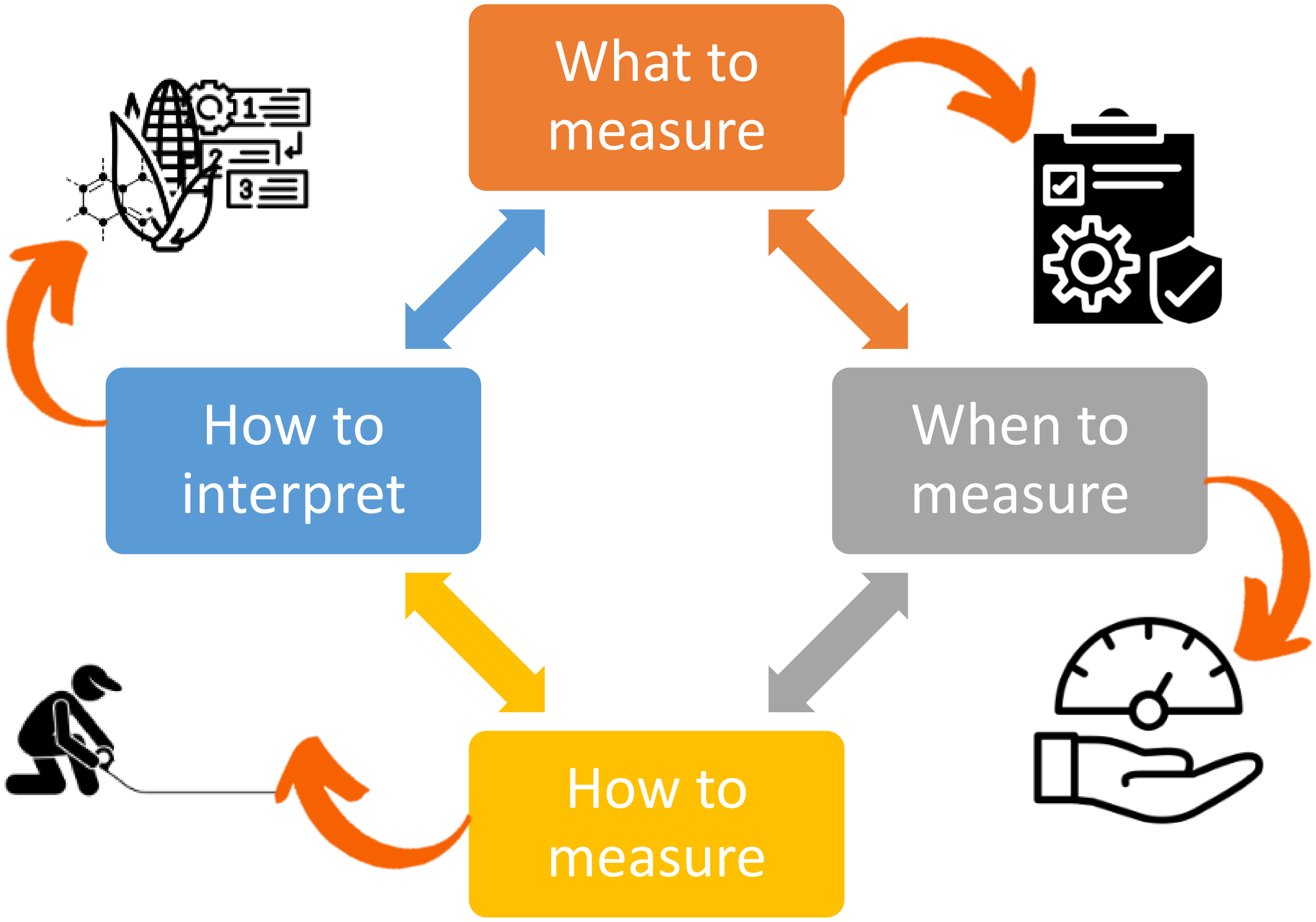
- *Consistent*
- *Strategic*
- *Defect-free*

} Outcome

Deming Circle: Quality control applied to silage making



Monitoring Quality Parameters



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Monitoring raw material before manufacturing

- Spectral data to predict DM content of standing corn

- Drone or satellite images are collected and the **NDVI index** is estimated as per usual monitoring

- Equations and algorithms correlate **NDVI data with DM content**

Janoušek et al. (2023)

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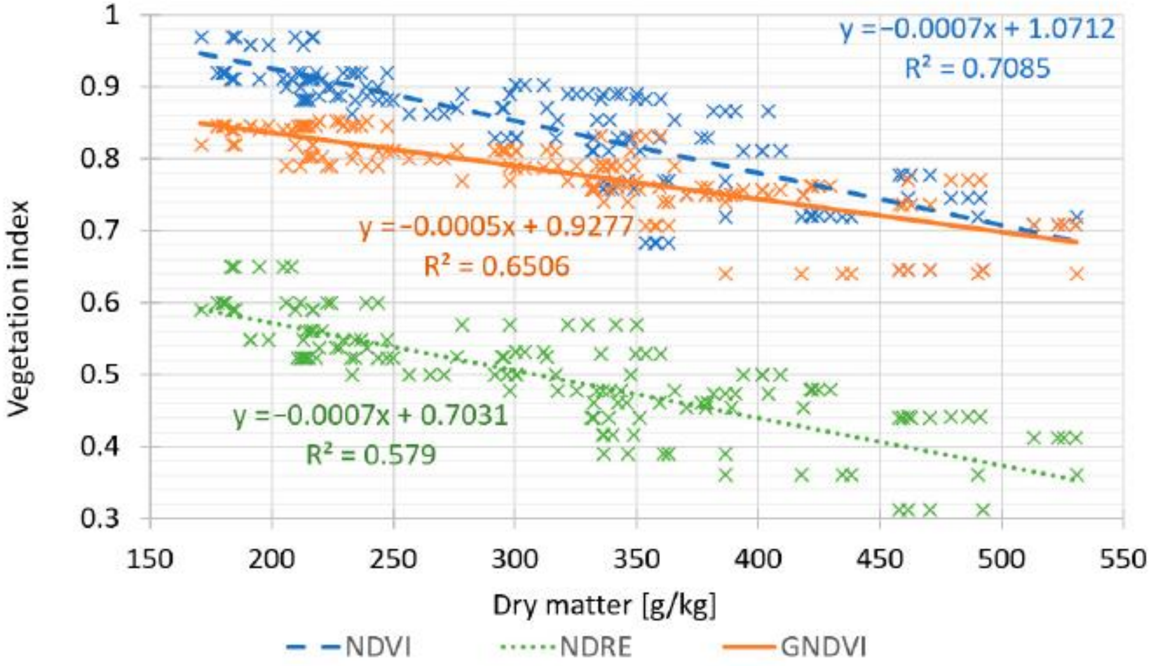
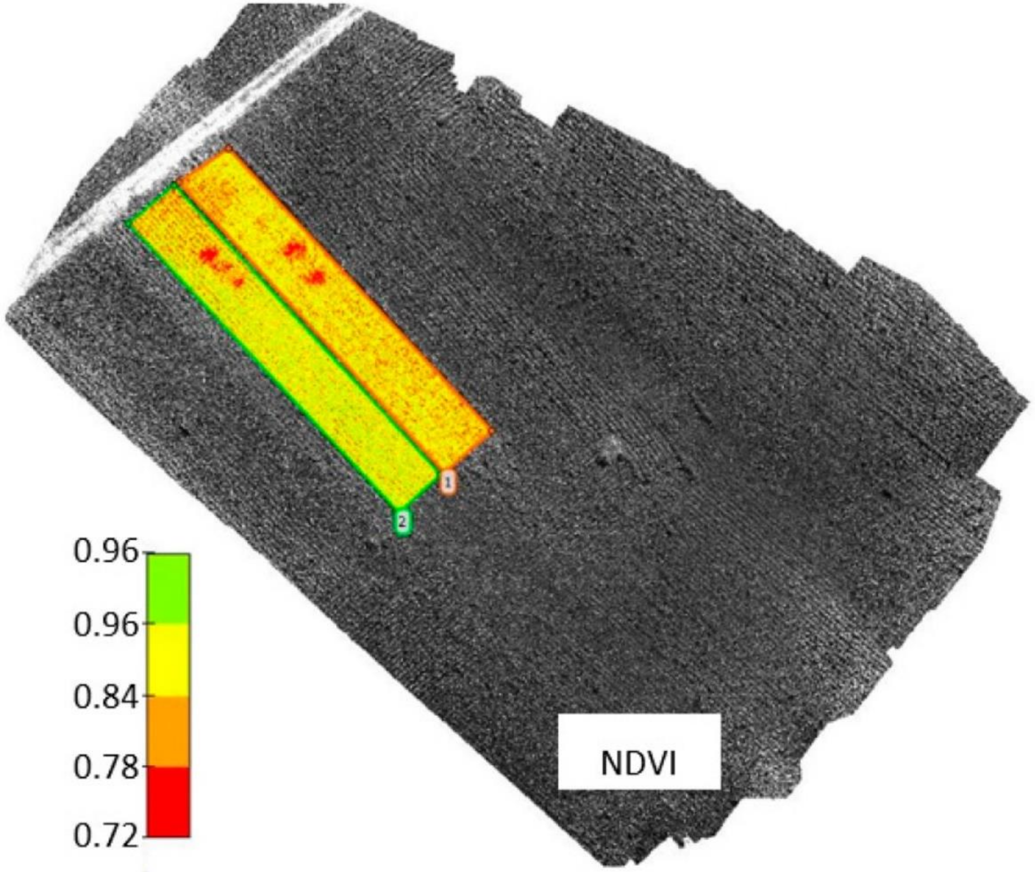
Characterizing and predicting DM content





Janoušek et al. (2023)

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Characterizing and predicting DM content

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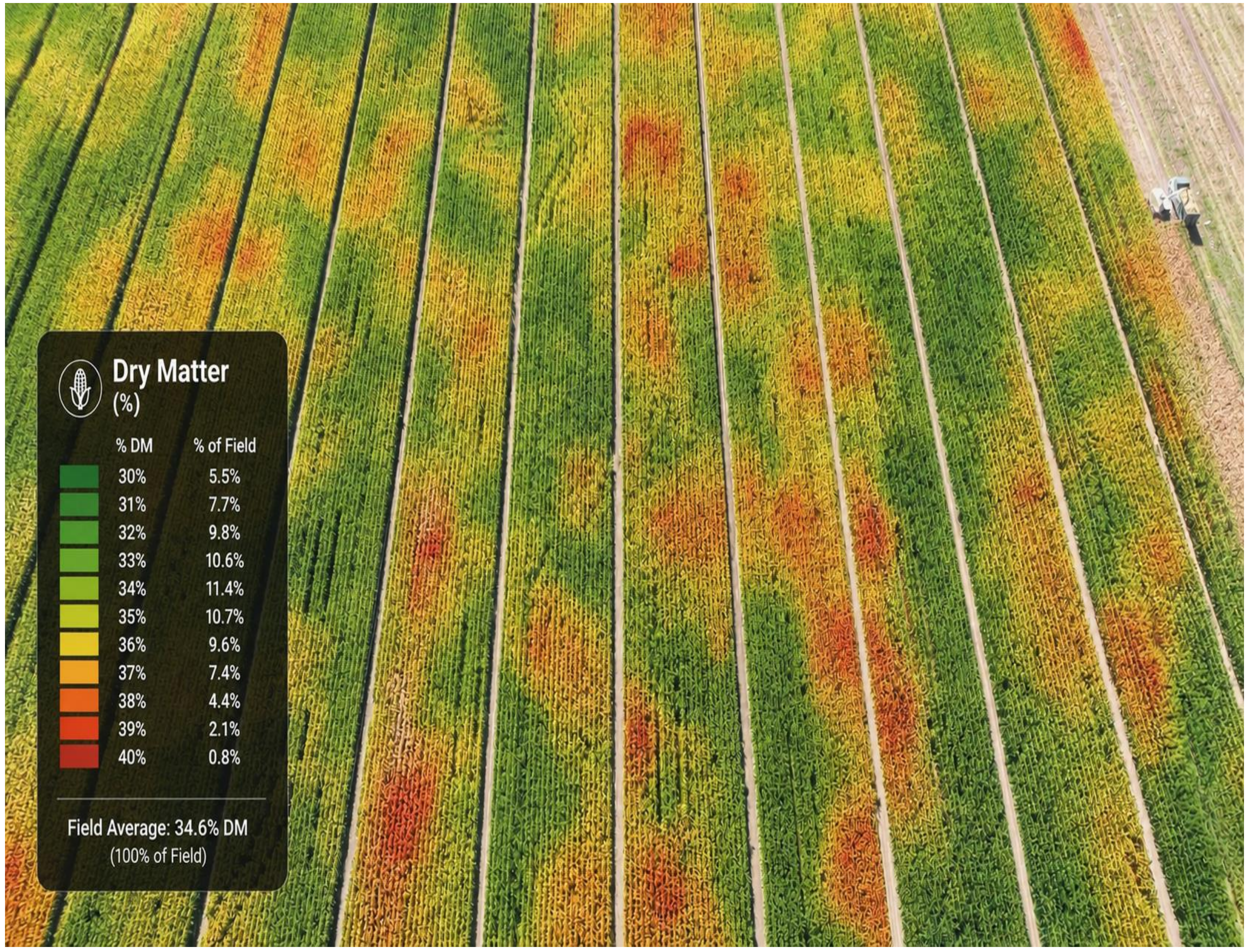
Information for timely decisions



- Harvest sequence
- Chop length
- Classifying fields
- Incoulant type
- Etc.

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Monitoring during harvest

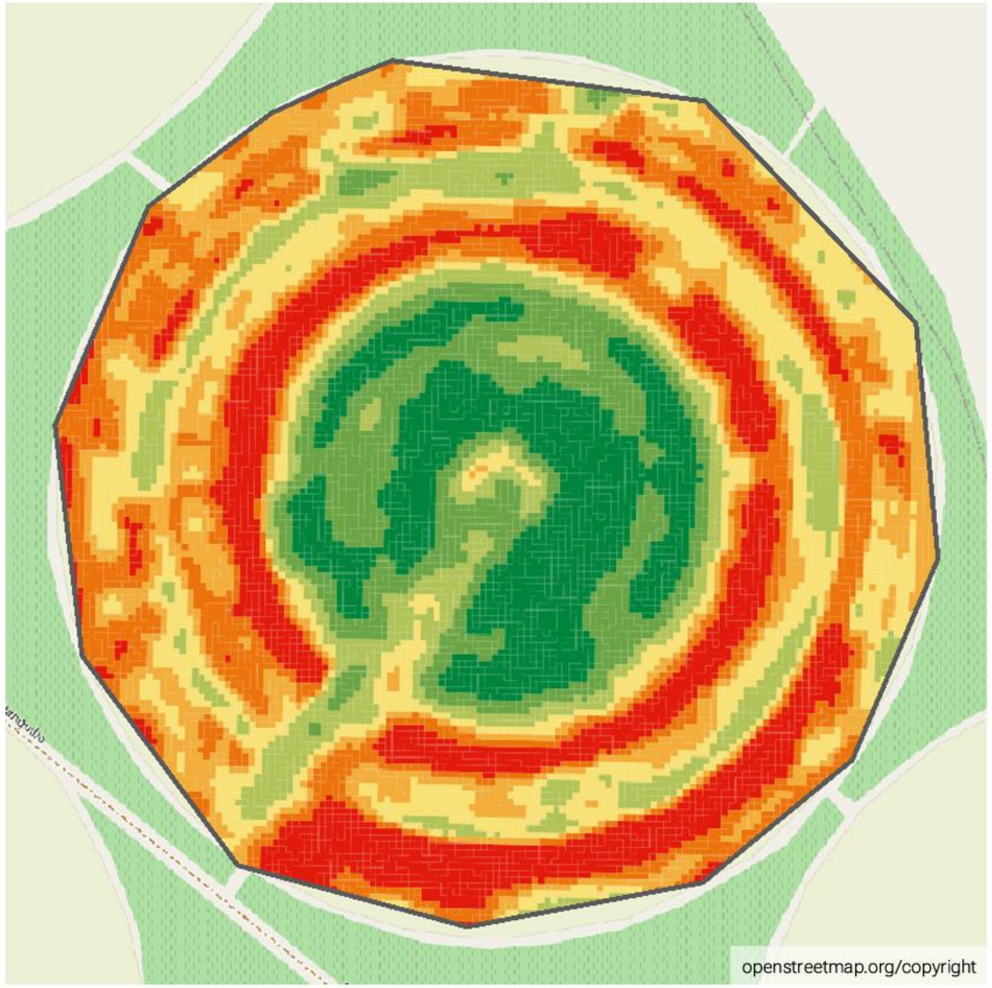

Photo courtesy of Cerio de Ensilados (Spain)

Finalizado

Cosechas y praderas Bárboles

30 abr 2026 09:04 – 30 abr 2026 19:49

Pastizal (PA)

JAGUAR 980 5, 990

Parcela (1)

N.°	Nombre	Superficie cultivada	Superficie trabajada	Porción de superficie	Cultivo	Explotación
18	Bárboles	34,9120 ha	42,6511 ha	122,17 %	Pastizal (PA)	DA

Material de cosecha (1)

Material de cosecha	Nombre	Cultivo	Superficie trabajada	Cantidad/ha	Cantidad total
Planta integral	Ensilado de hierba	Pastizal	42,6511 ha	8,736 t	372,604 t

Masa seca (With 0% moisture)

Humedad	Contenido de materia seca	Cantidad/ha	Cantidad total
51,35 %	48,65 %	4,250 t	181,259 t

Parámetros de calidad

Contenido de fibra bruta	29,55 %	Contenido de proteína bruta	15,07 %

Monitoring Particle Size

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Origin of the Penn State Particle Separator

From costly, cumbersome and delayed to low cost, practical and timely

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Evaluation of kernel processing

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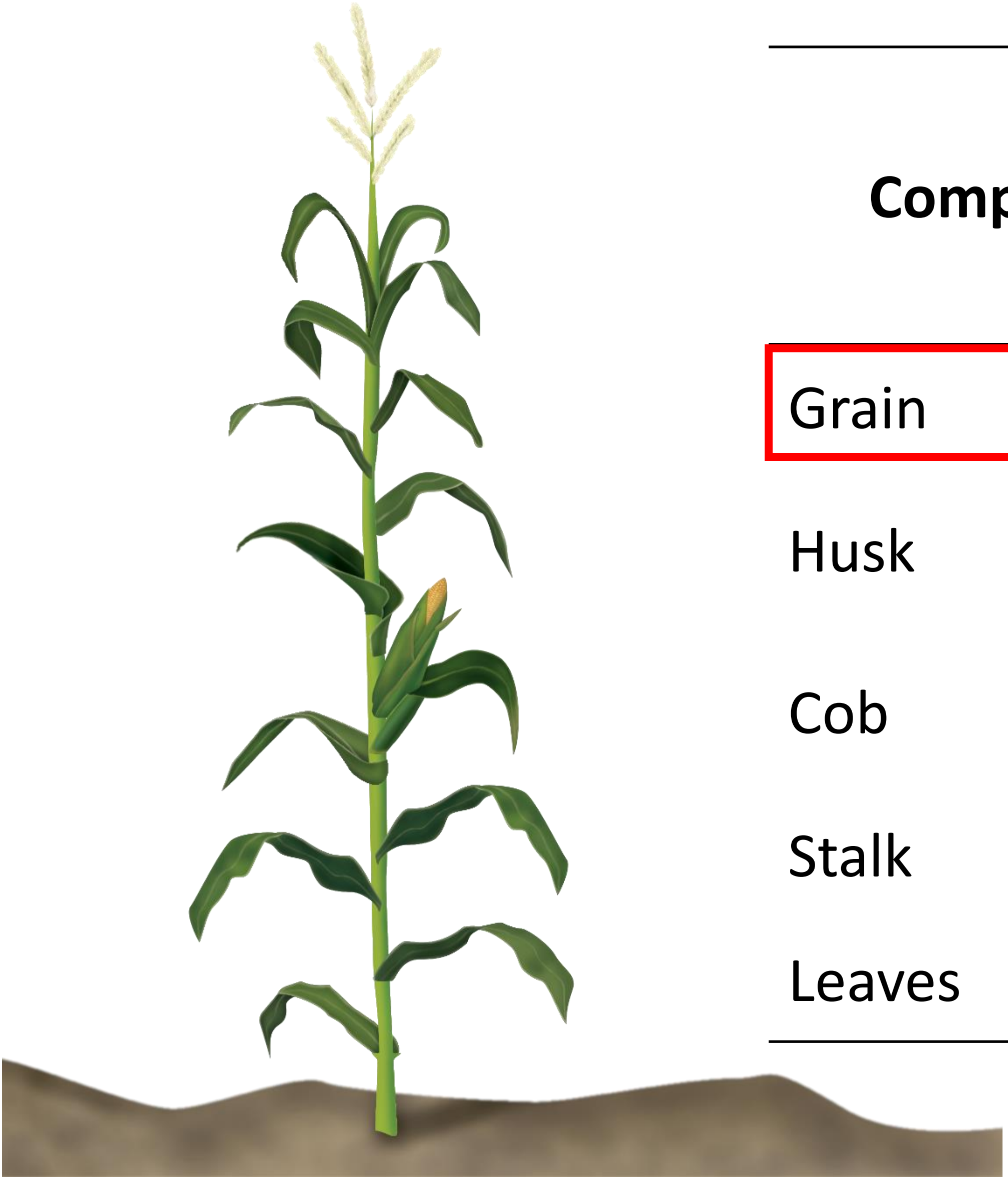
Corn plant components at harvest maturity for silage



Component	% weight (dry basis)	
	Kuehn et al. (1982) 35% DM	Pereira et al. (2012) 39% DM
Grain	41	44
Husk	6.7	8.5
Cob	8.9	8.1
Stalk	30.4	21.5
Leaves	13.0	18.2

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Kernel Processing Score

- KPS, also known as Corn Silage Processing Score (CSPS)
- Sample sieving in the lab using a Ro-tap
- Critical size 4.75 mm
- The technique measures the % of starch that passes through the 4.75 mm sieve relative to total starch in sample.

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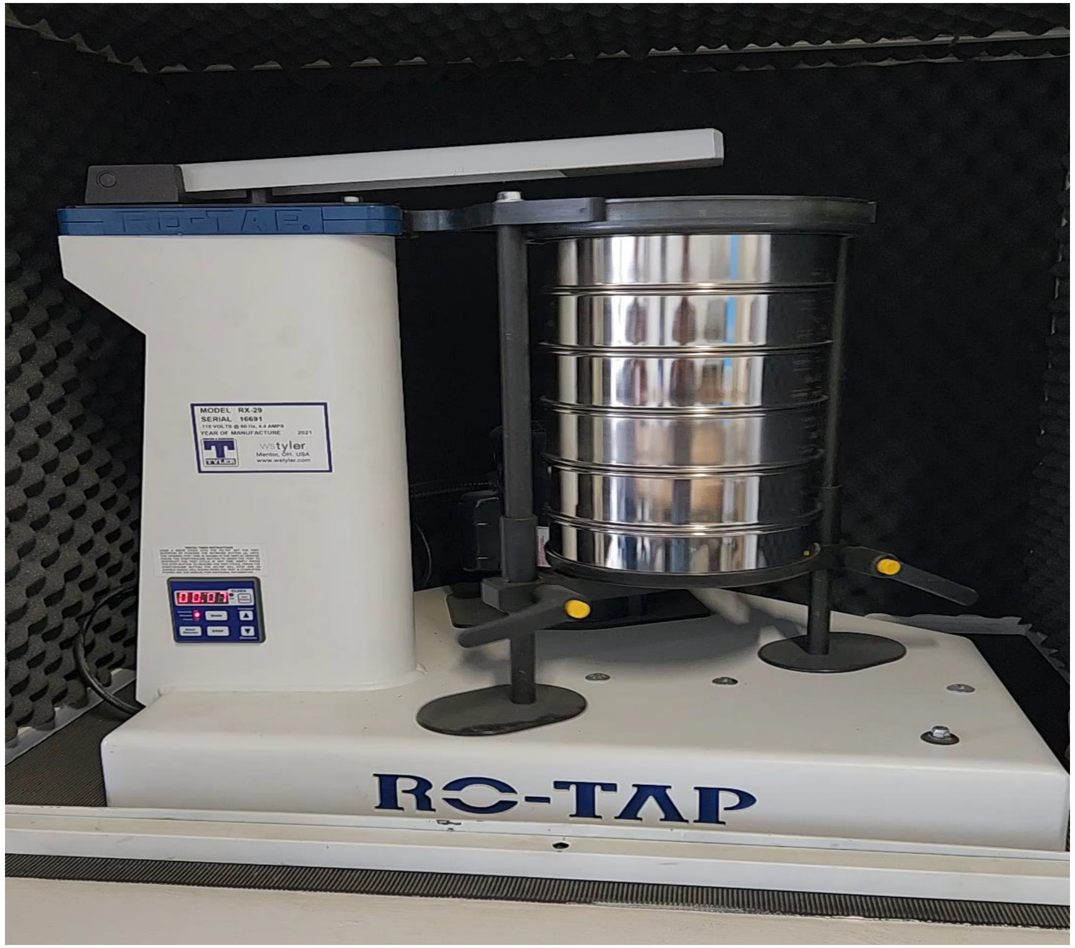
Kernel Processing Score



- Example:
- 100 g of dry sample, 35% starch
- That is 35 g of starch in initial sample
- 10 min in Ro-Tap
- 43.72 g pass through the 4.75 mm sieve, 60% starch
- That is 26.23 g starch passing through the 4.75 mm sieve
- CPG= (26.23/35) × 100 = 74.9

Kernel processing score

CORN SILAGE PROCESSING EVALUATION ANALYSIS:

SAMPLE RESULTS

% OF STARCH PASSING THROUGH 4.75 mm SCREEN	74.94%

PROCESSING SCORE INDUSTRY GUIDELINES:

GREATER THAN 70%	OPTIMAL
50% TO 70%	ADEQUATE
LESS THAN 50%	INADEQUATE

OTHER RESULTS:

% OF STARCH >4.75 mm	25.06%
% OF STARCH 1.18 mm TO 4.75 mm	60.27%
% OF STARCH <1.18 mm	14.67%
% OF COARSE PARTICLES	28.76%
% OF MEDIUM PARTICLES	58.03%
% OF FINE PARTICLES	13.21%
% OF STARCH <4.75 mm	74.94%

Less than 50%	50 to 70%	Greater than 70%
Inadequately Processed	Adequately Processed	Optimally Processed

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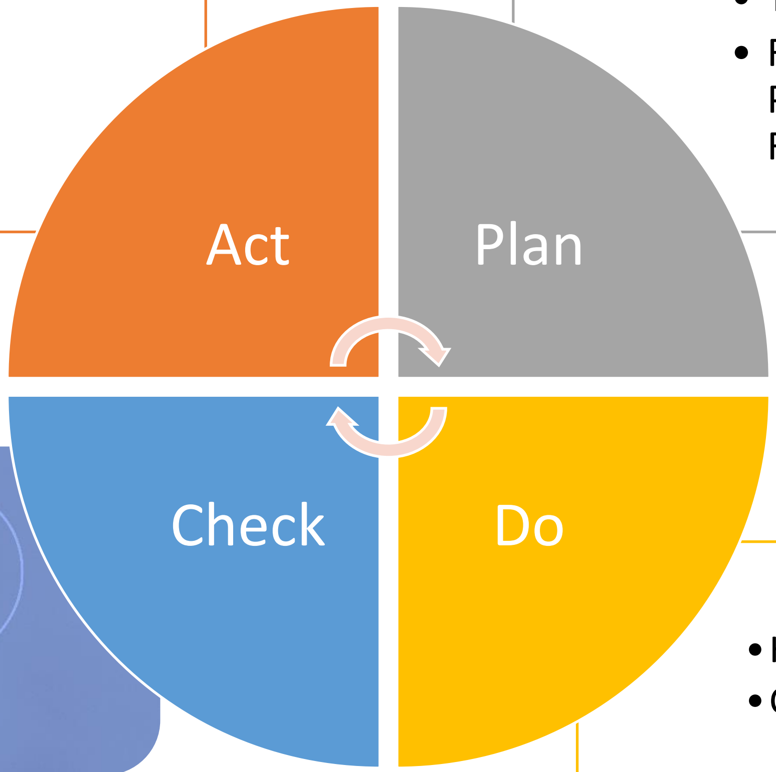
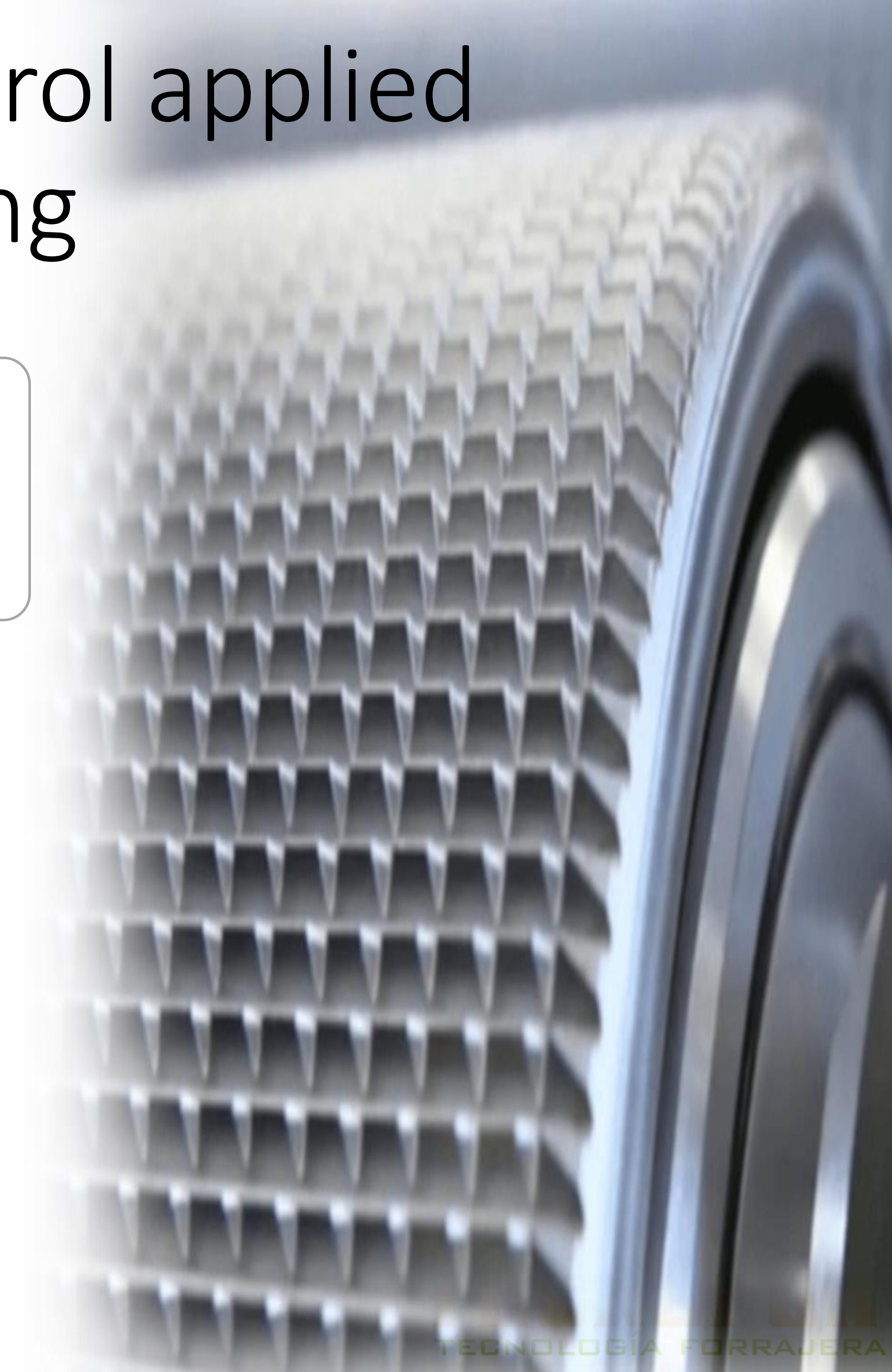
Deming Circle: Quality control applied to kernel processing

- Continue as usual or implement changes

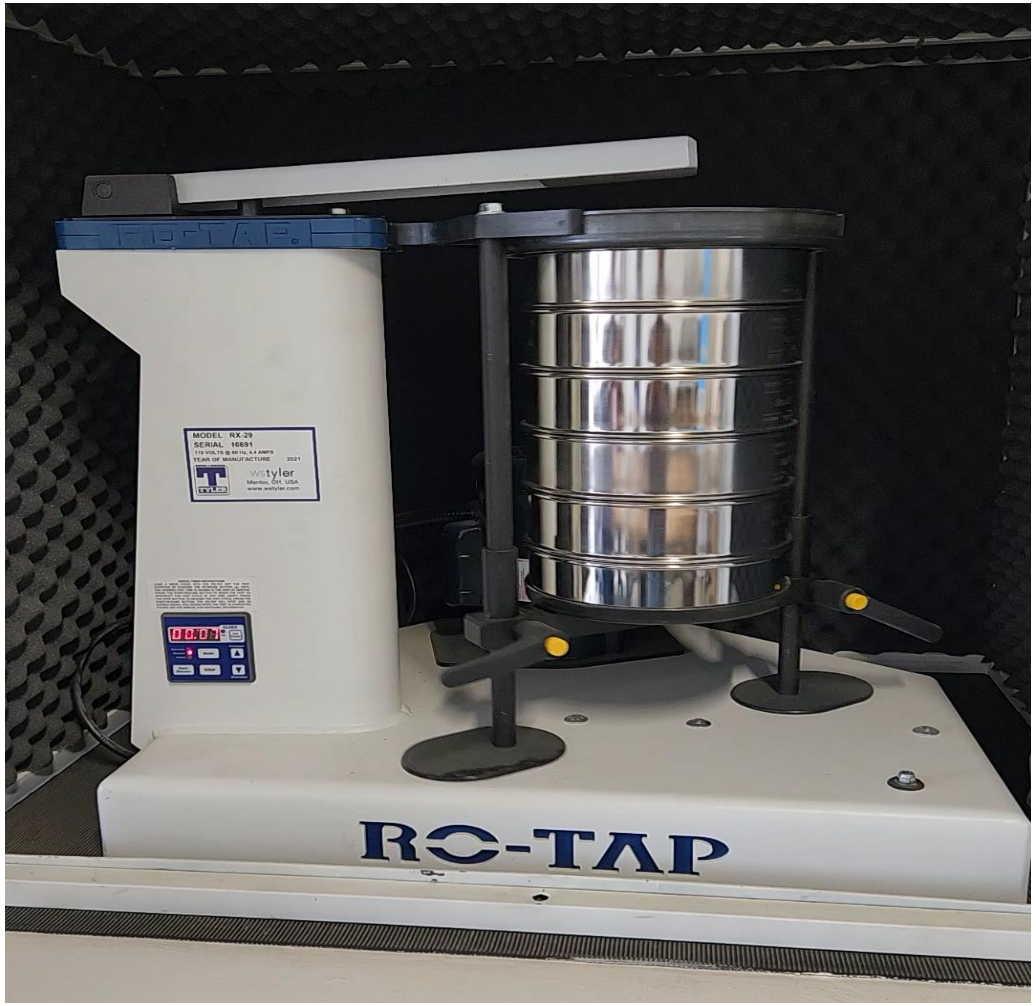
- Target: KPS ≥ 65%
- Resources
  Processing rolls
  Roll gap 1 to2 mm



- Harvest
- Collect sample



From costly, cumbersome and delayed to low cost, practical and timely



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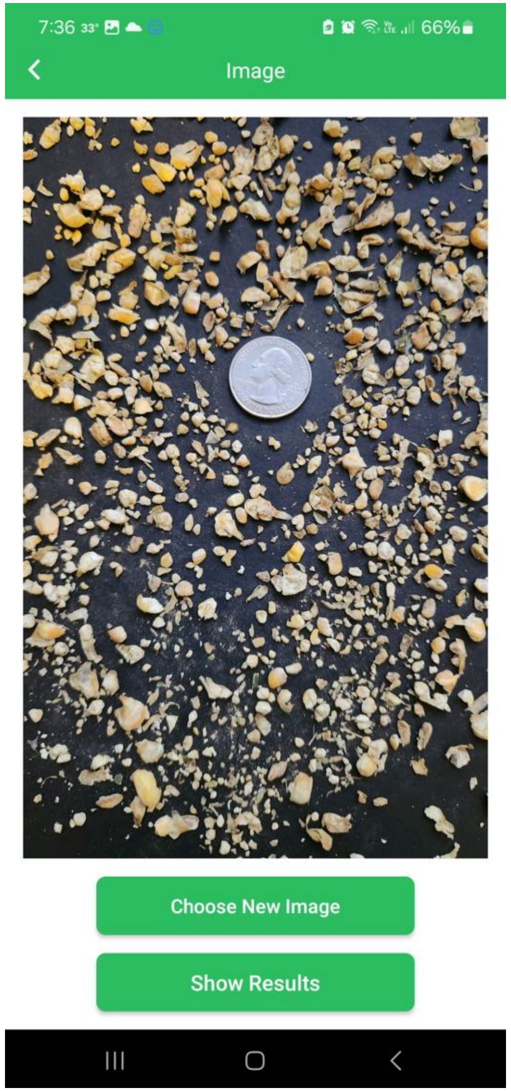
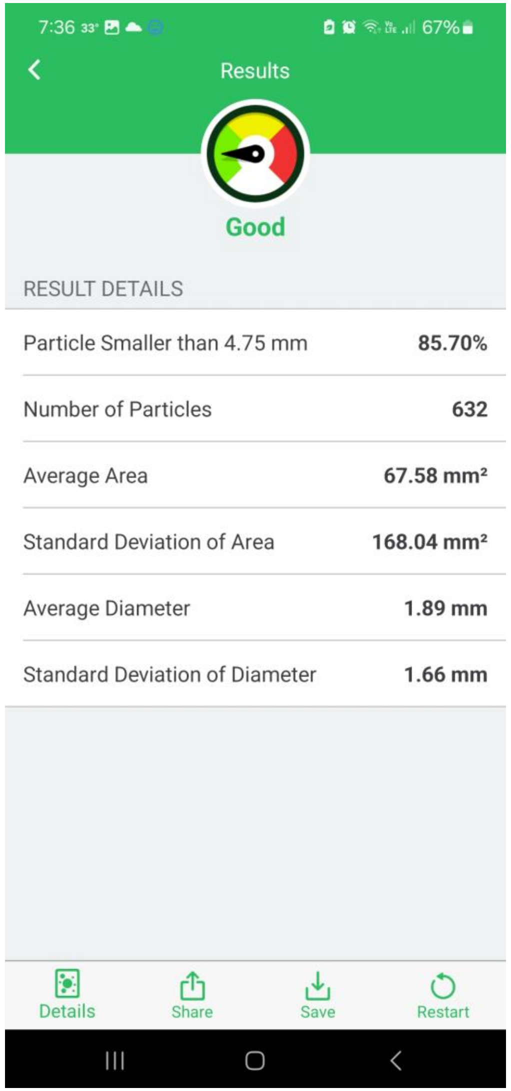
KPS with image analysis





Results on-farm KPS

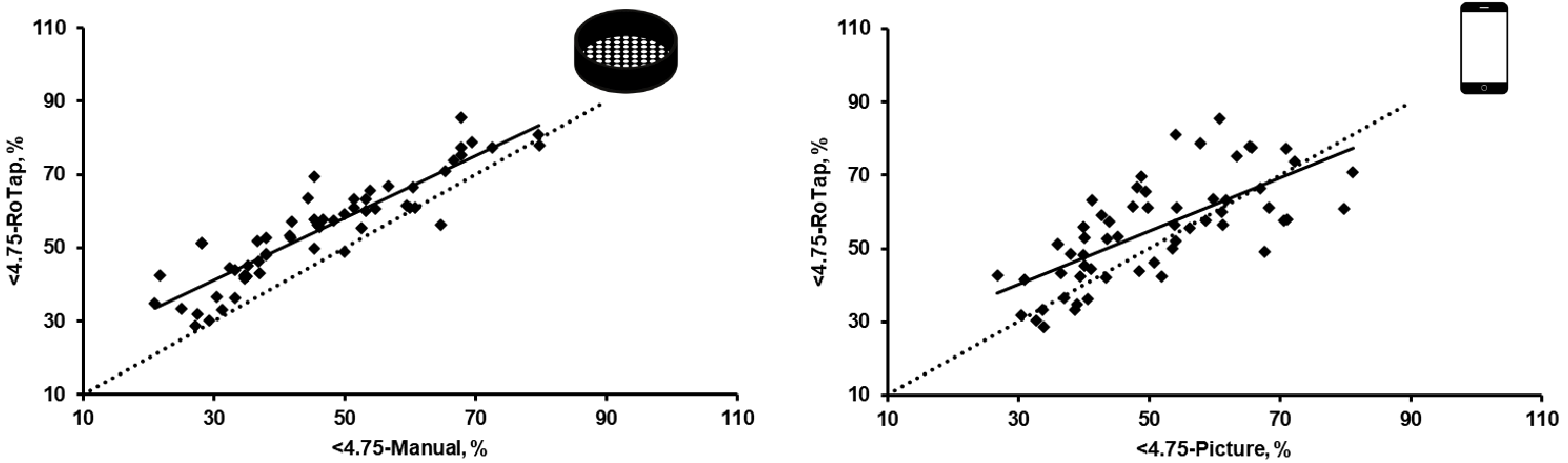


Figure 1. Relationships between the proportion of kernels passing through a 4.75-mm sieve measured on lab by Ro-Tap shaker (<4.75-RoTap) and on farm by manual sieving (<4.75-Manual) or Silage Snap app (<4.75-Picture) techniques. <4.75-RoTap, % = 15.5 + 0.853 × (<4.75-Manual); *P*<0.001; RMSE = 5.91; R^2 = 0.823; CCC = 0.764. <4.75-RoTap, % = 18.3 + 0.727 × (<4.75-Picure); *P*<0.001; RMSE = 10.1; R^2 = 0.484; CCC = 0.659. Dotted line indicates Y = X.

(Pinto et al., 2025)

Results on-farm KPS 89.9%

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Results on-farm KPS 42.0%

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On-farm KPS methodology

Dehydrate 300 – 400 g of freshly chopped material (30 min @ 120°C)

Hydrodynamic separation, grain fragments sink, stover floats

Discard the stover portion

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On-farm KPS methodology

Pour water out, an additional rinse may be needed

Recover de grain portion from the bottom of the pail

Dry the grain portion (15 min @ 120°C)

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On-farm KPS methodology

Record the weight of the dry grain portion

Run through sieve, 10 sec in each direction, 2X

Record the weight of the material that passed through

KPS = (20.4/27) × 100 = 75.55

Less than 50%	50 to 70%	Greater than 70%
Inadequately Processed	Adequately Processed	Optimally Processed

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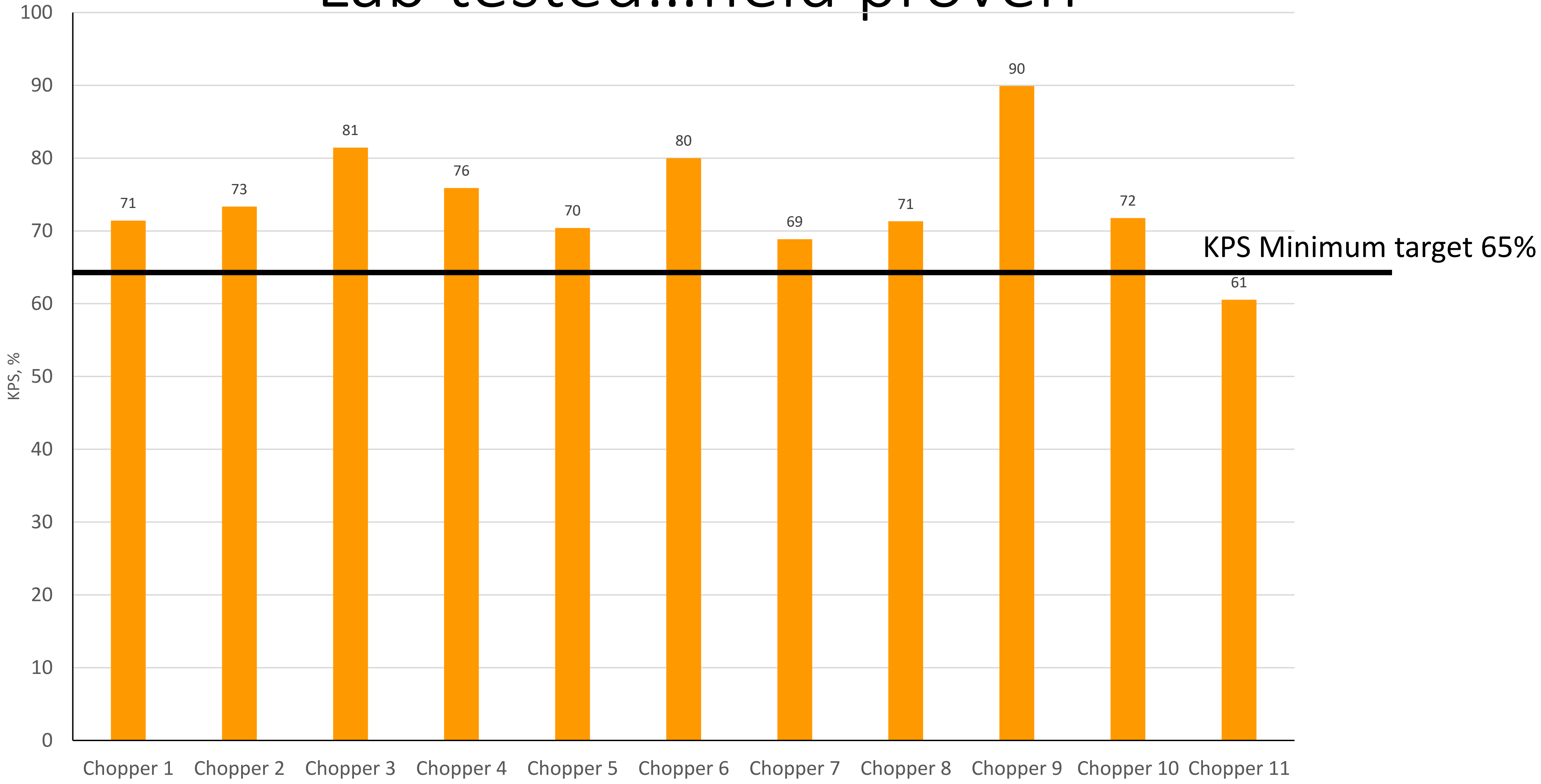
Lab tested…field proven



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Deming Circle: Quality control applied to kernel processing

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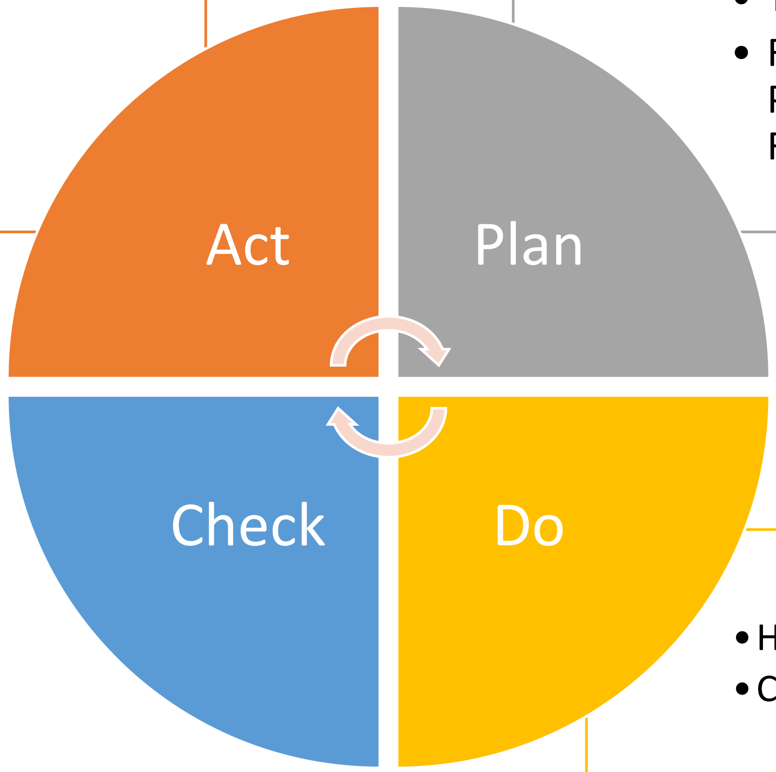
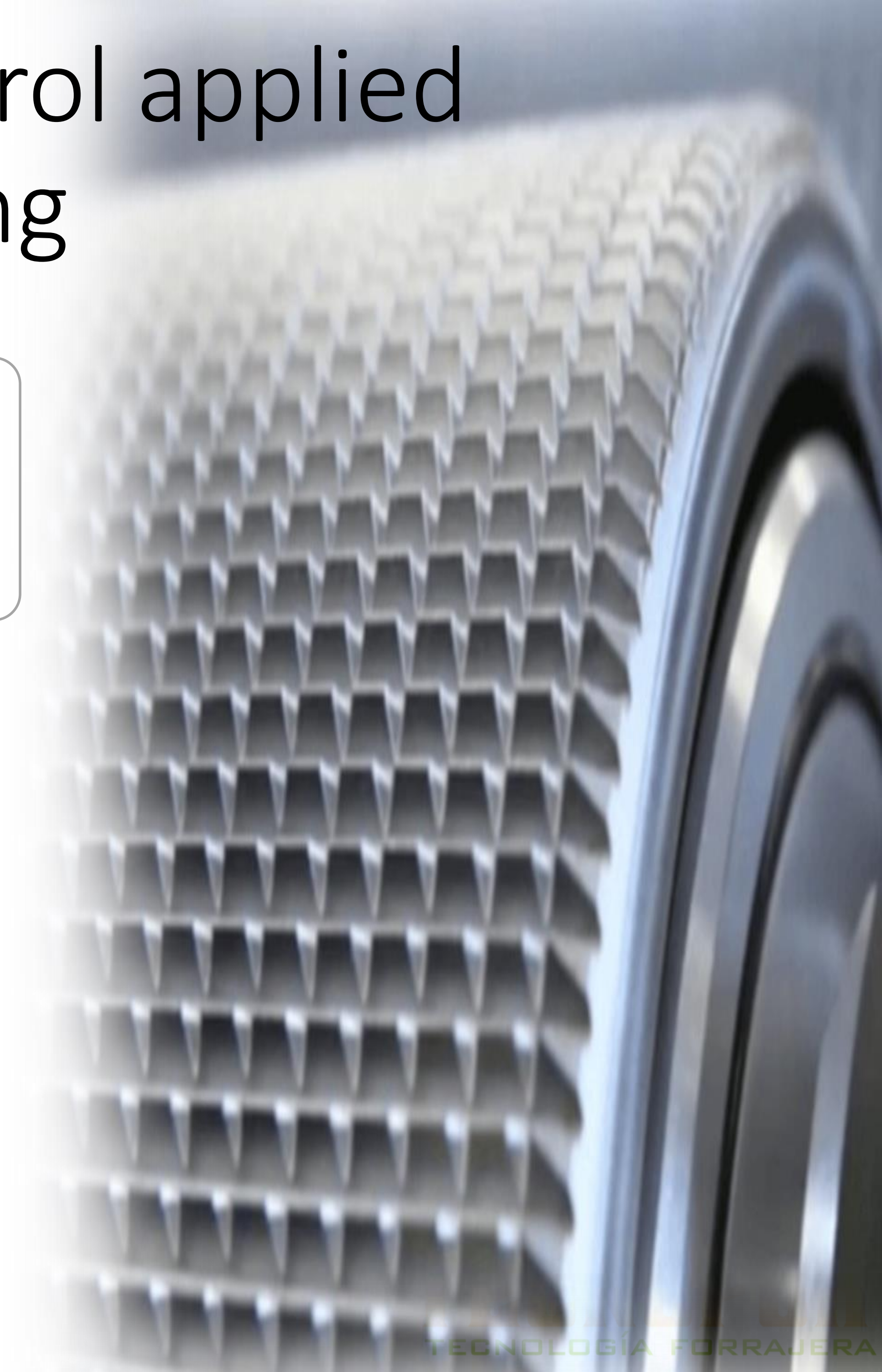


- Harvest
- Collect sample

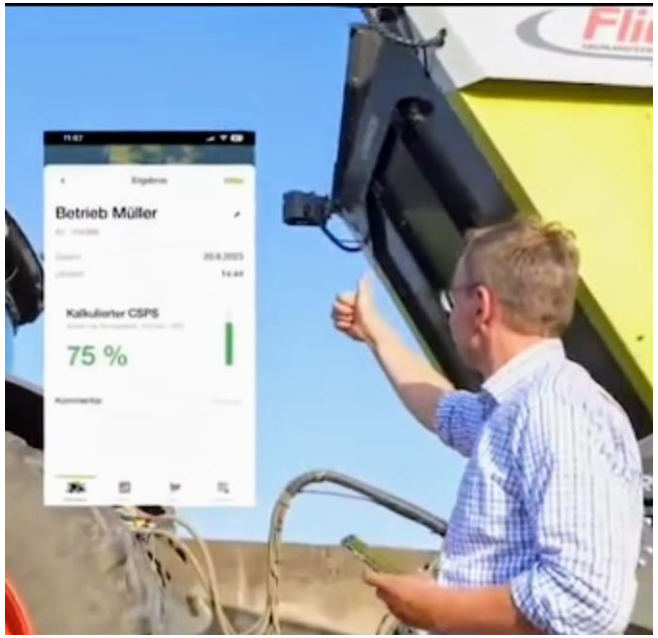


Semi-automation of real-time KPS

Service provided by SPFH manufacturer

A fresh sample is placed on this blue tray

A picture is taken and sent to the server for analysis



The images are analyzed in the server and the result is returned in a few minutes

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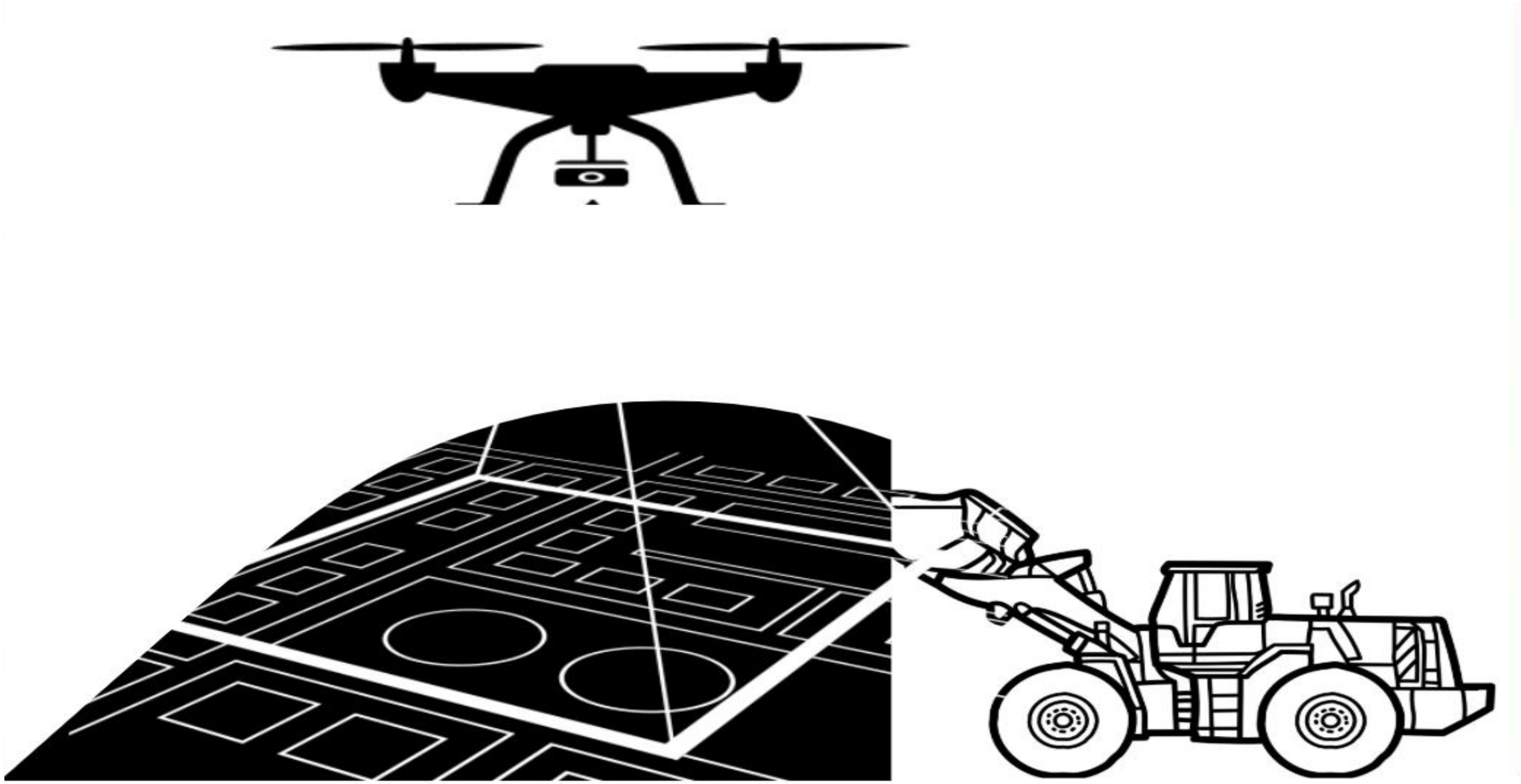
Consider using drone technology: safe, accurate, efficient



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Monitoring during feed-out

Applications of drone technology – 3D models for cover inspection

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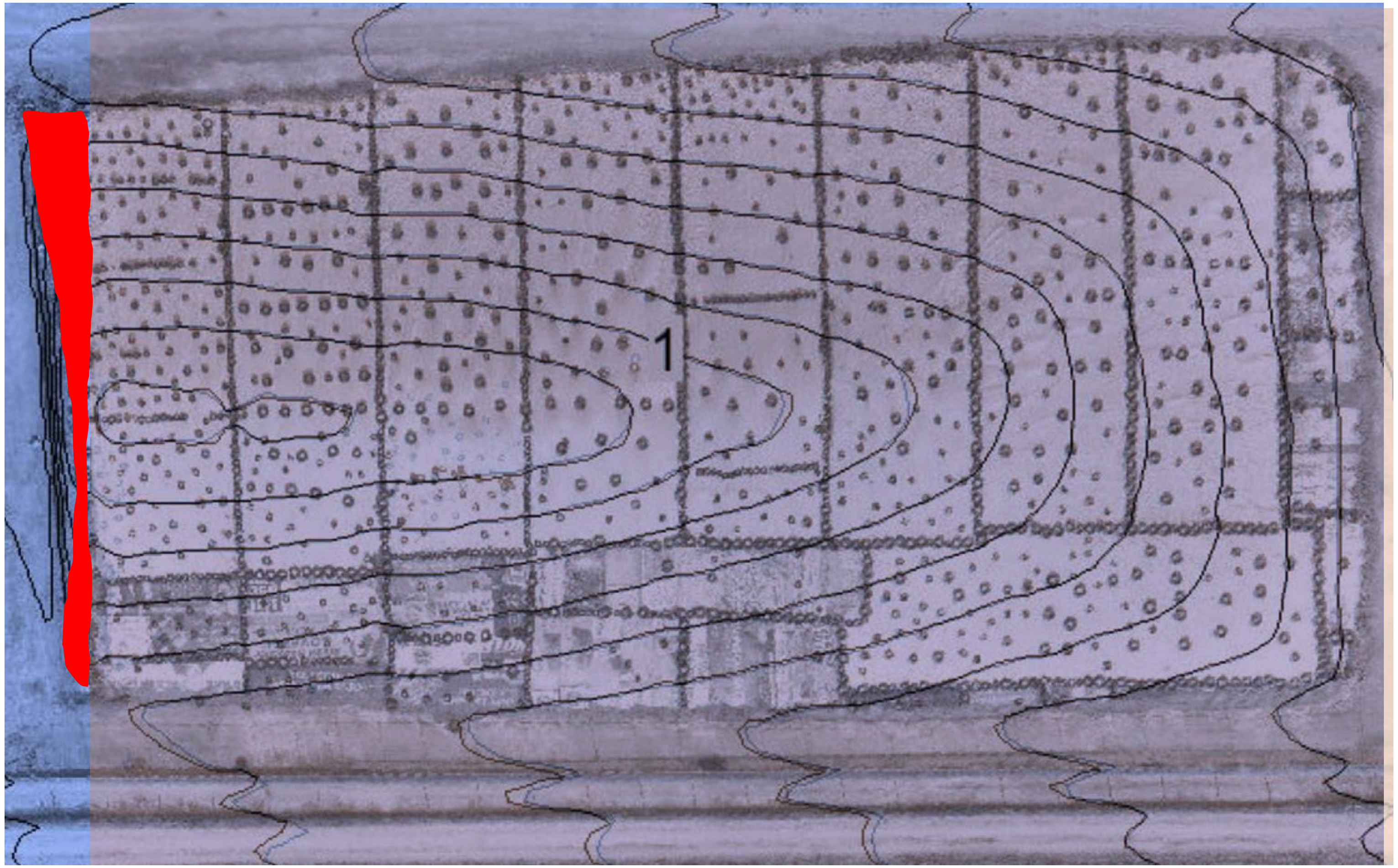
Applications of drone technology – Density and inventory management



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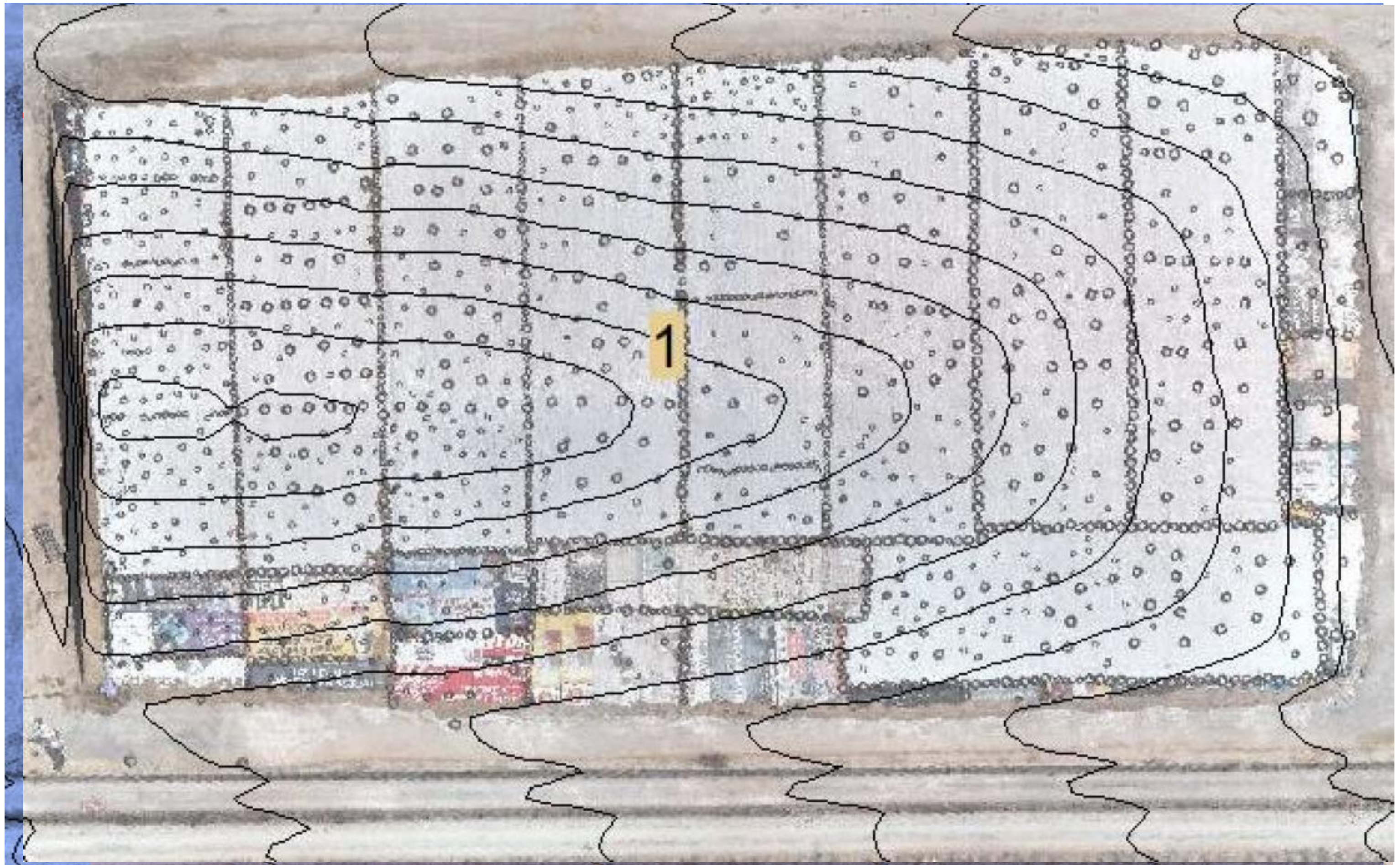
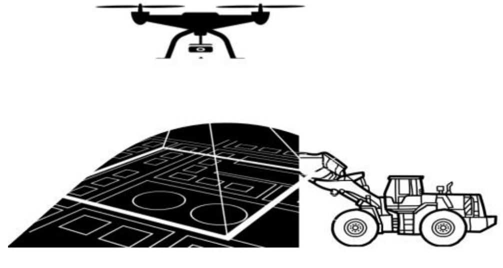
Applications of drone technology – Density and inventory management



As with any parameter, data accuracy is critical

Density = Weight / Volume



On-farm data

- Records of feed consuption are needed
- Accuracy of weights
  - TMR management software
  - On-farm scale
- When was the last scale calibration?

Drone

- Accurate for volumetric estimation
- Regardless of shape and structure, the volume is determined

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Take-home messages

- Real time measurements allow implementation of a full quality control program.

- Quick data for fast and informed decisions on the go.

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Take-home messages

- Automation, AI, and machine learning for real-time measurements seem plausible in the near future but…

- …training and education will continue to be the foundation of a solid silage program.

- Boots on the ground and field work are key aspects to bring timely, novel and useful solutions to livestock producers.

Making silage is like meeting someone new; there is only one opportunity to make a first impression. Make it count.

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How SOPs, Records, and Training Protect Cow Performance

Bridging the gap between ration formulation and execution

Michelle Schack, DVM
DairyKind

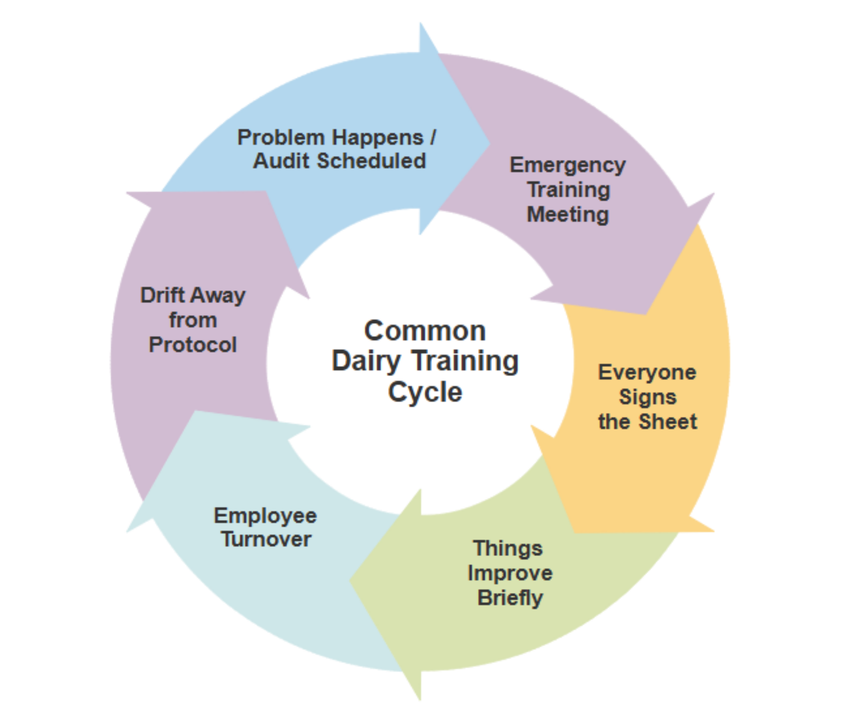
CANC 2026

Does this look familiar?

Everyone gathers around
Someone translates
People nod and smile
Everyone signs the sheet

...and three weeks later things are exactly the same.

The Dairy Training Cycle



If training only happens when something goes wrong, the cycle never stops.

The average turnover rate for surveyed dairies in 2019 was 38.8%

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Only 23.4% of U.S. dairy farms conducted annual employee training

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Only 23.4% of U.S. dairy farms conducted annual employee training

But we expect perfect nutritional consistency.

A Knowledge Gap Exists

Study of 112 milkers across 16 dairies showed...

average knowledge score: 49.3%

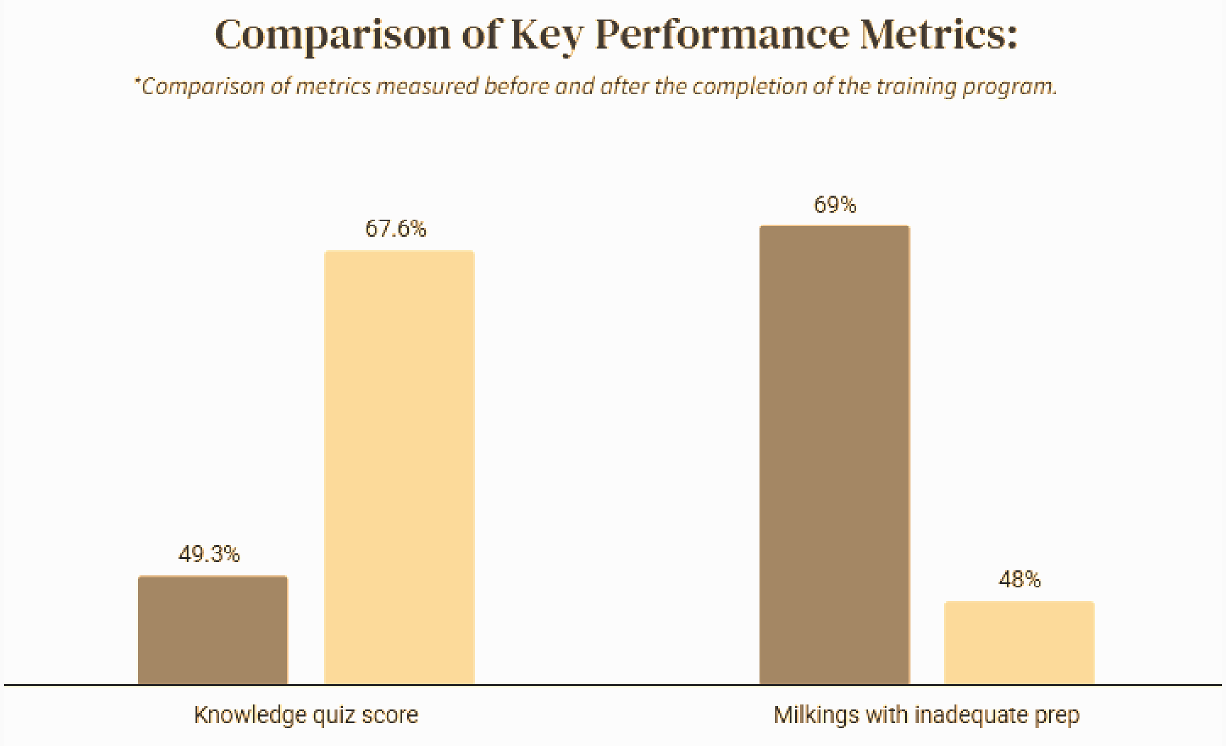
A Knowledge Gap Exists

Study of 112 milkers across 16 dairies showed...

average knowledge score: 49.3%

Do you think the feeding team on your farm understands the rumen?

Training Improves Results



Training didn't just improve knowledge — it improved what actually happened in the parlor.
What happens when we apply that to the feeders?

The 3 Rations on a Dairy Farm

The ration on paper	The ration delivered	The ration consumed
		

Don’t formulate for the spreadsheet.

Train for execution.

Nutrition on paper vs in practice

On paper

- Once a year training
- Balanced ration
- Perfect numbers
- Meets targets

In practice

Nutrition on paper vs in practice

On paper

Once a year training

Balanced ration

Perfect numbers

Meets targets

In practice

Onboarding training

Consistent mixing

Accurate loading

Repeatable delivery

Cow response

Your ration doesn't fail on paper. It fails in execution.

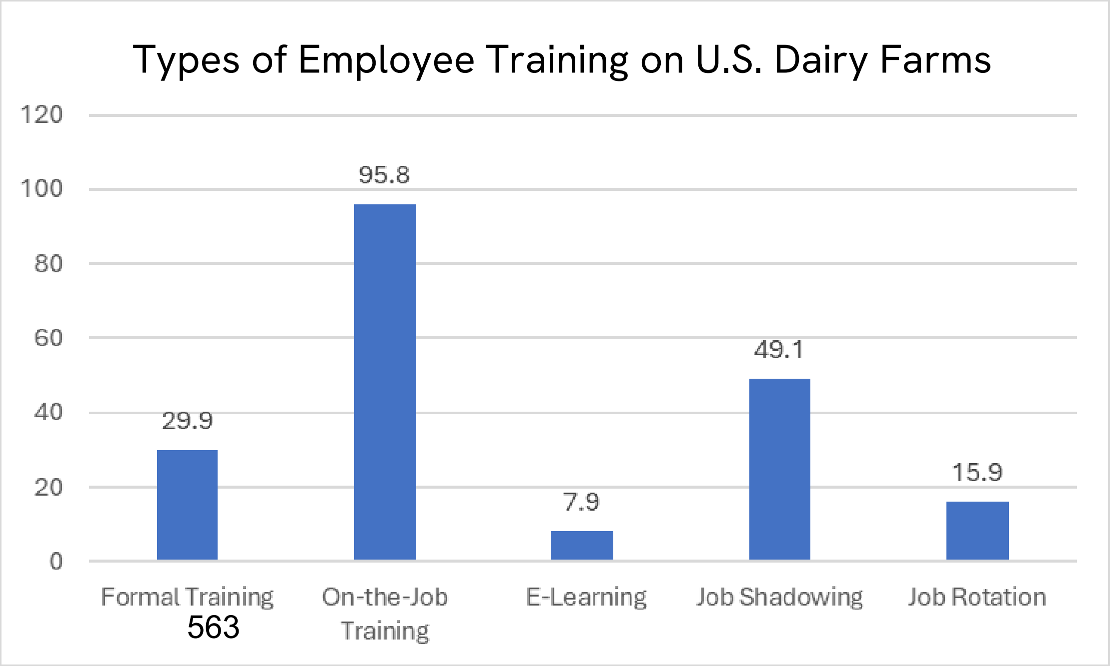
The ration doesn't fail on paper.

It fails in execution.

Training that sticks is multimodal

How many of these do you do?

- Protocols
- Onboarding Training
- Video Training
- Classroom Training
- On-the-job Training



Training goals

Multimodal Training

Training that sticks is multimodal

How many of these do you do?

- Protocols
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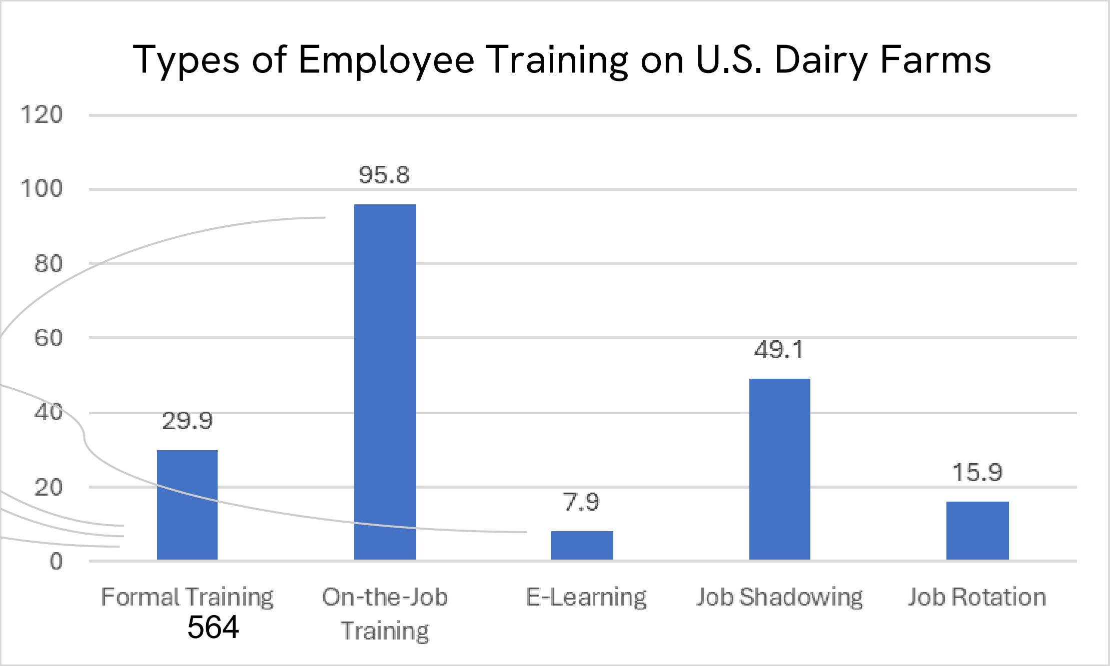


Protocols define the standard

- Protocols
  - Ingredient order
  - Mix time
  - Load accuracy
  - Cleaning procedures
  - Biosecurity
- Without protocols:
  - Everyone creates their own version.

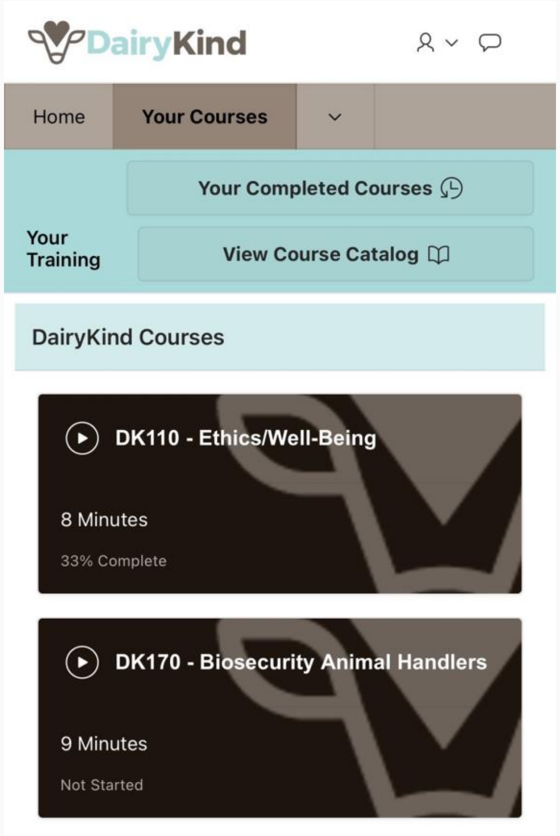
Onboarding Shapes Habits

- The first days of employment:
  - set expectations
  - build routines
  - prevent bad habits

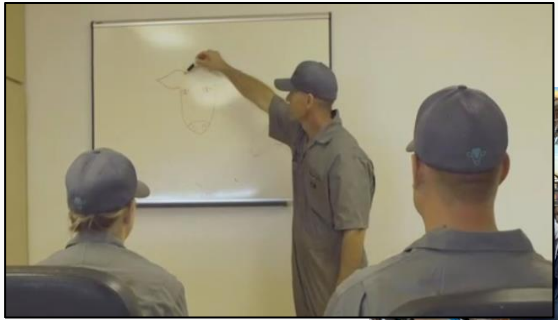
If a feeder learns the wrong technique on day 1, that now becomes your ration

Video Training Reinforces Learning

- Benefits:
  - available anytime
  - consistent message
  - repeatable training
  - useful for new hires



Classrooms Build Understanding



- Allows:
    - Discussion
    - Questions
    - Biology (ie rumen)
    - Explanation of "why"

But it cannot stand alone

On-The-Job Gives Practical Training

- Employees need:
    - Demonstration
    - Practice
    - feedback

If training only happens in the meeting room, it won’t survive the barn.

What's wrong with this picture?

Training is a System

	1 Protocols	2 Onboarding	3 Videos	4 Classroom	5 On-the-job
BENEFITS	Clear, consistent	Immediate, supportive, nobody missed	Clear, repeatable, accessible	Interactive, opportunity for discussion	Hands-on, opportunity to troubleshoot
LIMITATIONS	Not practical for daily use on the farm	One time, large amount of information	Not hands-on or interactive	Not consistent, takes planning, one time, long	Not consistent, focused on task and not learning

Training is a System

1 **Protocols**

Clear, consistent

2 **Onboarding**

Immediate, supportive, nobody missed

3 **Videos**

Clear, repeatable, accessible

4 **Classroom**

Interactive, opportunity for discussion

5 **On-the-job**

Hands-on, opportunity to troubleshoot

Do you want something that is

Clear, consistent, immediate, supportive, repeatable, accessible, interactive, and hands-on, with the opportunity to discuss and troubleshoot and not miss anybody?

Training is a System

	1	2	3	4	5
	Protocols	Onboarding	Videos	Classroom	On-the-job
BENEFITS	Clear, consistent	Immediate, supportive, nobody missed	Clear, repeatable, accessible	Interactive, opportunity for discussion	Hands-on, opportunity to troubleshoot
LIMITATIONS	Not practical for daily use on the farm	One time, large amount of information	Not hands-on or interactive	Not consistent, takes planning, one time, long	Not consistent, focused on task and not learning

WHERE DOES DOCUMENTATION FIT IN?

Documentation Turns Training Into Systems

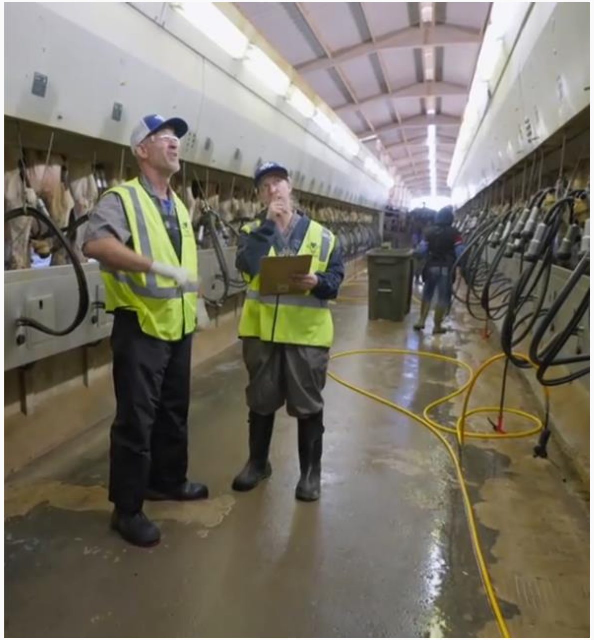
In the last round of the FARM Program,

the top 5 MCAPs all were about documentation.

3 of the top 5 were for training.

What People Think Documentation Is For

- Auditors
- Inspectors
- Compliance
- Paperwork



When people think documentation is just paperwork, it gets treated like paperwork.

What Documentation Is Actually For

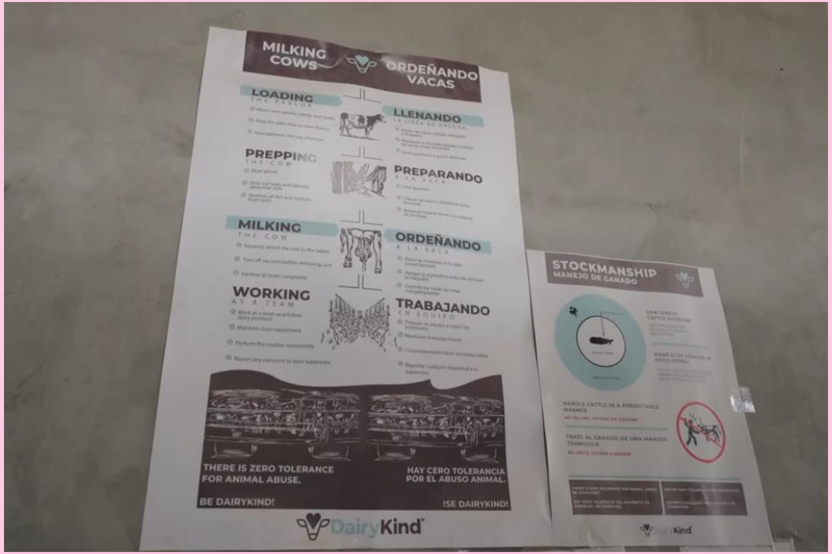
- Clarity
- Consistency
- Communication
- Coverage
- Continuous Improvement

Documentation is a management tool

Documentation Provides Clarity

- Create clear reference for expectations
- Reduce confusion
- Improves decision making

What goes in the mixer?



When the standard isn't visible or recorded, every shift slowly creates its own version.

Documentation Provides Consistency

- Connects shifts with logs and records
- Creates equal opportunity for employees to succeed if everyone receives timely, consistent training

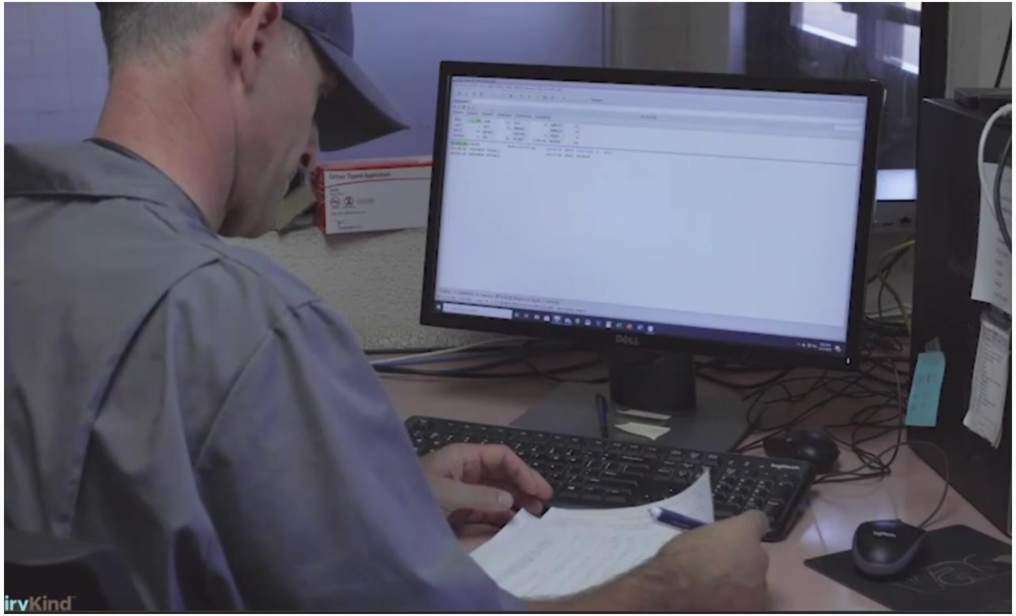
Same ration every shift

Documentation Provides Communication

With documentation:

- everyone sees what happened
- everyone knows what comes next

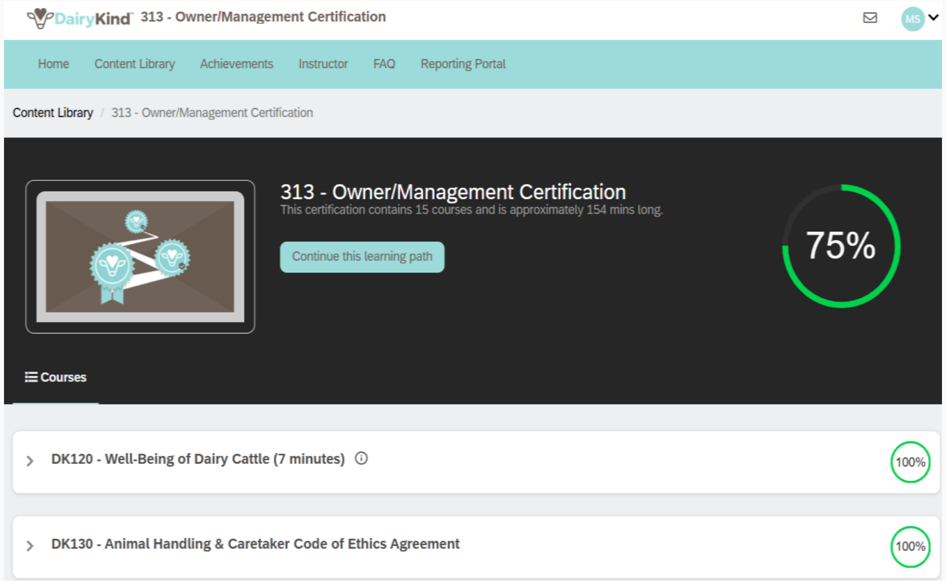
Nutritionist knows substitutions



Documentation Provides Coverage

Documentation protects:

- animals
- employees
- owners
- retailers
- brands



Protects the cows and performance!

Documentation Provides Continuous Improvement

When training is recorded, farms know:

- how employees are doing on training
- when they are due for a re-training

When data is recorded, farms can track:

- milk production
- feed intakes, refusals, sorting
- ingredient use

Only 11.6% of dairies offer employee development or continuing education programs

Most dairy audits require annual training

How does THIS..... become THIS?

The cow jumped over the moon

The cow jumped over the moon

The clown jumped only the moon

The cow jumped over the moon

The clown jumped only the moon

The clown dumped only the moon

"Protocol Drift"

The cow jumped over the moon → The clown jumped only the moon → The clown dumped only the moon → The clown dumped only the moose

“Protocol Drift”

Add ingredients in this order and drop at high milk cow pens → Add ingredients in order and drop at high milk cow pens as quickly as possible → Mix the ingredients quickly and drop in high milk pens as soon as possible → Mix the ingredients quickly and drop in pens 1-3 as soon as possible

Same intention. Completely different ration.

The cow jumped over the moon → The clown jumped only the moon → The clown dumped only the moon → The clown dumped only the moose

Great Nutrition Programs Rely on Systems

Great nutrition programs use:

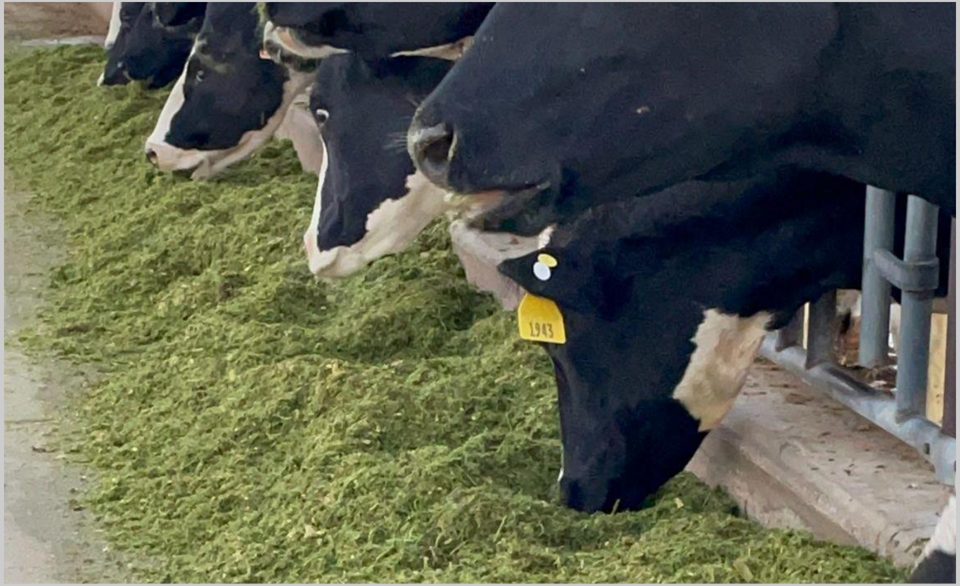
- clear protocols
- multimodal training
- documentation systems
- reinforcement

DairyKind®

At DairyKind, our motto is:
Quality Dairies Start with Trained Professionals

The Nutritionist's Role is Changing

- Not just formulation
- Evaluate execution
- Observe feeding
- Understand training systems



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How Training Turns Into Results

Training

Protocols
Onboarding
Videos
Classroom
Hands-on

Documentation

SOPs
Records
Checklists
Training
Logs
Visible systems

Systems

Consistency:
Same procedures
Every shift
Every day

Better Outcomes

Better animal care
Stronger teams
Stable intakes
Better rumen health
Consistent milk

Cows don’t eat rations.
They experience systems.

Please scan this to give feedback on this talk!

If you want better nutrition outcomes,
Don’t just change the ration.
Change the system delivering it.

Final thoughts

To improve nutritional consistency:

Standardize SOPs

Train for understanding

Track execution

Communicate deviations

Observe the system

Please scan this to give feedback on this talk!

Final thoughts

Please scan this to give feedback on this talk!

Thank you!

Please scan this to give feedback on this talk!

DairyKind®
www.dairykind.com

Contact me at
michelle@dairykind.com
@Dairy Doc on social media

Artem Timanov
Cattle Care, Inc.
Marina del Rey, California, USA

I. The Introduction

Current Cattle Care coverage: 186 dairy operations and over 730,000 cows daily monitored. Introduction of co-founders of the company. As our industry consolidates, we face a paradox: we have better genetics and nutrition than ever before, yet we have less human time per cow than at any point in history. The "eyes-to-cow" ratio has plummeted. In this gap between the owner's intent and the reality of the dairy farm lies the greatest threat to animal welfare and profitability. My premise today is simple: To achieve "What's Best for Her," we must optimize the performance of the humans responsible for her care.

II. The Pivot: From Cow Tracking to People Optimization

Cattle Care did not start as a labor analytics company. Initially, we were swept up in the IoT revolution, attempting to use cameras instead of wearable tags to track individual animals. We wanted to know how much a cow walked, ate, ruminated, if she is in heat. But we hit a wall of pragmatism. Large producers told us, "I don't need a camera to tell me a cow has a problem; I need to know *why*."

We realized the variable was the employee. A high-genetic-merit heifer can be ruined in one lactation by inconsistent milking or a badly balanced ration. We realized that if we want to make cows happy, we have to manage the people touching them. We pivoted away from "cow tracking" (which sensors do well) to "process optimization" (which only vision can do). Initially we focused on the parlor because it is the farm's economic engine and the highest-risk zone for human-animal interaction.

III. Deep Dive: Computer Vision in the Parlor, Animal Welfare, Maternity/Calf Areas, and Feed Yard

Parlor:

- Protocol drift
- Individual statistics of every employee
- Prep lag time
- Stimulation time

Animal Welfare Module:

- Detection of aggressive interactions between people and cows
- System of scoring

Maternity/Calf barn areas:

- Calf handling
- Calf feeding
- Post-calving procedures
- Navel dipping

Feed Yard:

- Picking wrong ingredients
- Scale manipulations
- Feed inventory
- Push ups consistency

Examples of our reports.

IV. How is this data used further?

The data is useless if it doesn't change behavior. We use gamification, bonus systems and targeted training to transform farm culture.

V. The tech under the hood: The "Waymo" of the Parlor

How does it work? Think of Tesla FSD (Full Self-Driving) or Waymo. A self-driving car uses cameras to perceive the world: it identifies the lane, the pedestrian, and the stop sign. It predicts behavior: "Is that pedestrian about to step out?"

We built a somewhat similar architecture for the dairy barn. Combination of object detection, segmentation, tracking, classic computer vision techniques, as well as one-shot learning, VLMs, human-in-the-loop systems for training and edge cases.

Data privacy – our multi-layered strategy for safeguarding sensitive data.

VI. The Competitive Landscape of Computer Vision for dairy

Without naming names, here is what's on the market today:

- Lameness.
- BCS.
- Calving detector.

VII. The Future (2030): The Augmented Worker

Where is this going?

1. **Integration:** The future is not "Vision vs. Sensors." It is "Vision + Sensors." Imagine a system where a bolus detects a fever, a camera sees a gait anomaly, and the parlor system detects a kick-off. Combined, this creates a holistic health profile.
2. **The Augmented Worker:** We will not replace humans. We will make them "super-humans." Real-time audio feedback in the parlor ("Slow down, you're missing the strip") or AR glasses that flag cows needing attention.
3. **Predictive Welfare:** Moving from reactive ("You hit a cow") to predictive ("This milker is fatigued and showing signs of frustration, rotate them out").

Conclusion:

AI Video Analytics is the modern "Eye of the Master." It ensures that "What's Best for Her" is executed not just when the boss is watching, but 24/7, every shift, every cow.

Evaluation of prebiotic supplementation on growth performance in weaned lambs

S.A. Benitez[1], M. Officer[2], C.R. Phillips[1] K.L. DeAtley[1], B.J. Duran[1]

[1]*California State University, Chico,* [2]*Pacer Technology Inc., Murtaugh, ID*

Weaning is a period of adverse growth effects on lambs, often leading to reduced feed intake, slowed growth, and increased susceptibility to illness. Previous research in dairy calves showed that prebiotic supplement of *Lactobacillus* a*cidophilus* fermentation products improved rumen development and growth outcomes, but its effects in lambs have not been studied. The objective of this study was to evaluate the effect of prebiotic (Pacer Technology, Murtaugh, ID) on pre- and post- weaning growth rates of black-face lambs. This study utilized a completely randomized design where ewes and lambs were assigned to one of two treatment groups: prebiotic (PRE; n=17 ewes, 28 lambs; standard maintenance lamb grain with prebiotic) or control (CON; n=19 ewes, 30 lambs; standard maintenance lamb grain). Lambs were sorted into treatment groups (10 days) then exposed to treatment until weaning (65 days) through creep feeding. After weaning, lambs in both treatments were fed in individual stalls twice daily for 30 days and had *ad libitum* access to hay and water. Prebiotics were administered to lambs only at a rate of 1.5 g/head/day during pre-weaning creep feeding (10 and 65 days) and post-weaning (65 and 95 days). Individual lamb weights were recorded weekly. Growth performance was assessed by calculating average daily gain (ADG) pre-weaning and post-weaning. Data were analyzed using a generalized linear mixed model in SAS. There was no difference in birth weight ($P > 0.1$) between the treatments. Weaning weight was different ($P = 0.04$) between CON (26.0 ± 0.7 kg) and PRE (23.7 ± 0.9 kg) lambs. Final weight tended to be different ($P = 0.06$) between CON (29.9 ± 0.8 kg) and PRE (27.8 ± 1.0 kg) lambs. There was no difference ($P > 0.1$) in ADG between treatments over the 30-day post-weaning period, whereas ADG over the course of study tended to be different ($P = 0.08$) between CON (0.28 ± 0.01 kg) and PRE (0.26 ± 0.01 kg) lambs. Prebiotic supplementation did not improve growth performance in lambs during pre- or post-weaning under the conditions of this study. Future research could evaluate alternative formulations, management conditions, and seasonal influences that may affect its efficacy in lamb production systems.

Keywords: prebiotic supplementation, weaning lambs, growth performance, average daily gain

Magnesium source selection and quality concerns in lactating dairy cow diets: a survey of U.S. dairy nutritionists

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Magnesium (Mg) is an essential mineral for lactating dairy cows; however, limited information exists on commercial Mg source preferences, formulation practices, seasonal potassium (K% of DM) inclusion, and dairy nutritionists' perceptions of Mg source quality. This study aimed to characterize factors influencing Mg source selection, target dietary Mg and K concentrations, and concerns about Mg quality and solubility. An anonymous online survey was distributed using Qualtrics (Provo, UT, US) to dairy nutritionists through the American Registry of Professional Animal Scientists listserv from April 2025 to September 2025. Responses (n = 32) were summarized using descriptive statistics. Respondents were from the Midwest (n = 14), West (n = 11), Northeast (n = 6), and South (n = 1) of US. The number of lactating cows for which respondents formulated diets ranged from ≤10,000 (52%) to ≥50,000 (36%) lactating dairy cows. Feed mill availability was the primary factor influencing Mg source selection (54%), followed by perceived quality (33%) and price (13%). More than half of respondents (56%) expressed concerns regarding Mg source quality, whereas 31% reported no concerns. Interest in Mg in vitro solubility information was high, with 84% indicating strong interest and 16% indicating moderate interest. Regarding Mg sources used, respondents could select multiple sources; magnesium oxide (MgO; 62%) and calcium magnesium carbonate [$CaMg(CO_3)_2$; 41%] were the most common, and 8% reported not knowing the specific source used. Most respondents targeted dietary Mg concentrations between 0.30 and 0.40% of DM (76%), with fewer targeting 0.20–0.30% (19%) or 0.40–0.50% (5%). Dietary K targets were generally below 1.5% of DM during both summer (53%) and winter (79%); however, 16% of respondents reported feeding K concentrations greater than 1.75% during summer. Most respondents (71%) reported no cases of mid-lactation milk fever, whereas 17% reported occasional cases. These findings indicate a strong interest among nutritionists to better understand Mg source quality to support formulation decisions.

Keywords: Magnesium-solubility, dietary-magnesium, dietary-potassium

Microclimate Monitoring for Advanced Dairy Herd Management

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Temperature Humidity sensors have been widely used in the dairy industry to monitor environmental conditions and evaluate their effects on cow activity and health. This study focuses on exploring the relationship between Temperature Humidity Index (THI) fluctuations and changes in dairy cow performance, including rumination, milk yield, milk composition, and body condition over a four-month period. Heat stress is a significant factor affecting dairy cattle productivity and welfare, with behavioral and physiological changes occurring when THI values exceed approximately 68. Elevated THI levels are associated with reduced dry matter intake, decreased rumination, and lower milk production, as well as increased standing time and reduced lying behavior. By examining correlations between THI fluctuations and performance indicators, this study aims to identify patterns that could support more proactive herd management strategies. For this study, 37 lactating Holstein cows were observed for a four-month period. During that time, temperature humidity sensors were constantly recording data from five locations within the pen. In addition, daily rumination minutes and milk weights were recorded. Milk composition was analyzed monthly through DHIA testing. Body condition of each cow was evaluated by multiple researchers every three to four weeks for a total of five collection periods during the study. Data will be analyzed using R version 4.5.2 and a linear mixed effects model. Fixed effects will be Days in Milk, Lactation, and the Days in Milk x Lactation interaction, with the cow as the random effect. Improved understanding of these relationships may allow producers to anticipate performance declines during periods of environmental stress, such as heat waves or cold spikes, and adjust feeding or management practices accordingly. Early detection of these changes could help mitigate production losses, improve animal welfare, and support more efficient dairy herd management.

Key words: Dairy Cattle, THI, Data Driven Management

Postpartum temporal patterns of subclinical ketosis and their association with prepartum indicators in primiparous dairy cows

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Although subclinical ketosis (SCK) has been extensively studied in multiparous dairy cows, it also occurs in primiparous cows but is less well characterized. The objective of this study was to characterize temporal patterns of SCK in primiparous dairy cows and to evaluate associations with prepartum body condition score (BCS), serum β-hydroxybutyrate (BHB) and serum non-esterified fatty acids (NEFA). Body condition scores and concentrations of BHB and NEFA were measured in 19 primiparous cows (Holsteins, n=8 and Jerseys, n=11) that were enrolled as late gestation heifers and followed through their first calving into early lactation. Data were collected from 28 d before expected calving through 28 d postpartum (n = 14 observations per animal, with more frequent sampling around parturition). Subclinical ketosis (SCK) was defined as postpartum BHB concentrations ≥ 1,200 µM. Fifteen of 19 cows experienced SCK at least once, indicating a high overall prevalence. Logistic regression using biologically defined windows of time showed that the probability of detecting SCK was highest during early postpartum (0–3 d; 38%) and declined thereafter (7-14 d; 24% and 21-28 d; 22%), indicating a narrow high-risk temporal window. After accounting for postpartum timing, both increased prepartum BCS and increased maximum prepartum BHB were associated ($P < 0.01$) with increased SCK risk. Adjusted odds ratios associated with these factors were 2.6-fold (95% CI: 1.3–5.3) for 0.25 unit increase in BCS and 2.1-fold (95% CI: 1.5–3.1) for a 200 µM increase in BHB. Prepartum maximum NEFA concentrations did not discriminate SCK risk, likely reflecting generally elevated NEFA concentrations in this cohort (i.e., maximum prepartum serum NEFA = 1,263 ± 597 µM, mean ± SD). Jerseys lost more body condition entering calving than Holsteins at comparable prepartum BCS, but breed was not independently associated with SCK occurrence. These results indicate that SCK in primiparous cows is temporally concentrated very early postpartum, with elevated prepartum BCS and BHB conferring additional susceptibility.

Keywords: subclinical ketosis, body condition score, bhb

Associations between genetic selection indices and PBMC mitochondrial enzyme activities in prewean dairy heifer calves

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Mitochondria serve as the primary source of energy for biosynthesis and mitochondrial function has been shown to be associated with milk fat production and predict longevity in dairy cows. The objective of this study was to determine whether mitochondrial enzyme activity rates of peripheral blood mononuclear cells (PBMC) in dairy heifers are associated with genetic selection indices (GSI) used in dairy cattle breeding and bull selection. Twenty-two Holstein dam x Jersey sire (F1) and 22 calves from Holstein dam x Jersey sire, dams bred to Holstein sires (F2) were randomly selected for blood collection from a commercial dairy farm. Blood samples were collected at a single timepoint between age 5 to 9 d for determination of mitochondrial enzyme activities of complexes I, IV, and V of the respiratory chain using kits from Abcam (Cambridge, MA). Data were analyzed using General Linear Models procedure of SAS (v.9.4) regressing enzyme activities of complexes I, IV, and V on the GSI with genotype (F1 vs F2), passive transfer status, and age at sampling. These variables were eliminated from the regression equations using forward selection and all residuals were normally distributed. Two calves died of scours from the F2 group during the prewean period. An increase in Complex I activity was associated with a decrease in genomically enhanced predicted transmitting ability for fat (GPTAF; $P = 0.01$, CI (Confidence Interval) -0.000750 to -0.00110) and an increase in genomic breeding program index (GBPI; $P = 0.02$, CI 0.00000497 to 0.0000511) ($P < 0.03$, $R^2 = 0.18$). Complex IV activity was not associated with any GSI. An increase in Complex V activity was associated with an increase in genomic selection for somatic cell score (GSCS; $P = 0.001$, CI 0.004001 to 0.0150, $R^2 = 0.26$). Mitochondrial respiratory chain complex activities are associated with 3 GSI, but since mitochondrial activities were measured in prewean calves, it remains to be seen if these associations continue as adults.

Keywords: mitochondria function, genomic selection index, crossbred calves, respiratory chain enzyme activity

Effect of Breed on Performance, Backfat Fatty Acid Composition, and Enteric Methane Emissions of Angus, Angus Holstein Cross, and Holstein Steers

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The objective of this research was to determine the impact of breed on methane emissions and beef fatty acid composition, particularly the cis-monounsaturated to saturated fatty acid ratio (cMUFA:SFA), which contributes to both beef flavor and human healthfulness. Eight Angus (ANG; initial BW = 404 ± 13 kg), eight Angus × Holstein crossbreds (CRS; 384 ± 13 kg), and eight Holsteins (HOL; 375 ± 13 kg) were used in a randomized incomplete block design during a 168-d finishing trial (n = 8). Cattle were blocked into three pens by body weight with three head of two breeds and two head of one breed per pen for a total of eight head per pen. All steers received the same finishing ration and individual dry matter intake (DMI) was recorded using Roughage Intake Control Systems (RICS; Hokofarm Group, Netherlands). Enteric emissions were collected using a GreenFeed (GF; C Lock Inc., Rapid City, SD) every two weeks. Cattle were brought to the GF for sampling over a 3-day period during staggered time windows to encompass a full 24-hour enteric emissions reading. Backfat samples collected between the 12th and 13th rib at harvest were standardized and analyzed for fatty acid composition using gas chromatography. Data were analyzed using PROC MIXED in SAS. ANG steers had greater final BW ($P < 0.01$) than CRS and HOL, and DMI was 12% and 11% higher ($P < 0.05$), respectively. Breed did not affect CH_4 production (g/d), yield (g/d/kg DMI), intensity (g/d/kg BW), or H_2 production ($P > 0.05$). However, ANG had lower H_2 yield (31–32%) and H_2 intensity (44%) compared with CRS and HOL ($P \leq 0.05$). No breed differences were observed for cMUFA, SFA, n-3 PUFA, oleic acid (cis-9 18:1), or the cMUFA:SFA ratio. ANG backfat contained lower trans MUFA, n-6 PUFA, trans-18:1, and PUFA:SFA ratio than HOL ($P \leq 0.01$), while CRS were intermediate and not different from either breed. ANG also had a lower n-6:n-3 PUFA ratio ($P < 0.01$). Previous research suggests longer high-grain feeding increases cMUFA:SFA ratios, which would suggest higher values in calf-fed CRS and HOL cattle. The lower H_2 yield and intensity observed in ANG may relate to reduced trans-18:1 biohydrogenation intermediates, indicating a potential hydrogen sink mechanism. Overall, performance and fatty acid composition shows differences between beef on dairy cattle and their native and Holstein counterparts while methane emissions are not different. Expansion of this research should evaluate this with high-yielding and low-yielding beef on dairy cattle.
This work was supported by a private animal nutrition company.

Keywords: Beef on dairy, enteric emissions, fatty acid, performance

Maternal 3-NOP supplementation during the dry period and its effects on offspring methane emissions in dairy cattle

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Enteric methane (CH_4) production from the ruminant sector accounts for 30% of California's total CH_4 emissions. This study evaluates whether supplementing dairy cows with 3-NOP during the dry period induces epigenetic changes that influence gaseous emissions in their offspring. Dams were blocked on parity, previous milk yield and pre-experimental CH_4 emissions and assigned to one of three dietary treatments: control (0 mg 3-NOP/kg DM; CON; n=9), low dose (40 mg 3-NOP/kg DM; 40NOP; n=5) or high dose (80 mg 3-NOP/kg DM; 80NOP; n=8). Dry periods were on average 57.8, 57.1, 58.1 ± 1.8 days for CON, 40NOP, and 80NOP treatments, respectively. Following parturition, heifer calves (n=22; only heifer born calves were enrolled) were removed from their dams, individually housed in hutches, and fed milk replacer containing 26% crude protein and 24% fat. Body weight was recorded from birth until 120 days of age every two weeks. Calves were weaned approximately 65 days of age and subsequently moved to group pens with ad libitum access to a total mixed ration (TMR) and free access to water. Between 90 and 120 days of age, enteric gaseous emissions were monitored using the GreenFeed Emissions Monitoring system (GEM) (C-Lock; Rapid City, SD). Concentrate was used as bait in the GEM. GreenFeed measurements were reported at two-week intervals. Linear mixed models in R v.4.5.2 were utilized with the fixed effects of treatment, week, and calf as random effect. Calf birthweights and weaning weights were similar between treatments and heifer calf growth rates were similar throughout preweaning and postweaning periods (Mean ± SE; 120 d weight; 129.3 vs. 125.1 vs. 124.8 ± 4.26 kg; CON vs. 40NOP vs. 80NOP; $P = 0.83$). There was no difference for enteric CH_4 production between treatments (82.3 vs. 87.9 vs. 77.1 ± 10.4 g CH_4/d; CON vs. 40NOP vs. 80NOP; $P = 0.19$) with no impact on enteric hydrogen or carbon dioxide emissions. Treatment did not impact enteric emission intensity (gas/kg body weight) across all gases measured. Heifers born to 3-NOP supplemented dams experienced no impact on growth performance or emission profiles through the first 120 days of life.

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KEYWORDS: calf, 3-NOP, methane, body weight

Effects of monoglycerides supplementation in drinking water on growth performance, diarrhea and mortality of weanling pigs experimentally infected with enterotoxigenic *Escherichia coli* F18

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This study investigated the effects of monobutyrin (MB) and monovalerin (MV) supplementation in drinking water on growth performance, diarrhea, and mortality of weanling pigs infected with enterotoxigenic *Escherichia coli* (ETEC) F18. Sixty weaned pigs (body weight = 6.38 ± 0.92 kg) were individually housed and randomly allotted to four treatments (15 pigs/treatment): a basal diet (CON), CON + 0.045% MB or MV in drinking water, or 50 mg/kg of antibiotic (carbadox) in feed. The experiment lasted 28 days, including 7 days before and 21 days after the first inoculation (d 0). All pigs were orally inoculated with ETEC F18 (10^{10} CFU/3 mL) for 3 consecutive days. Body weight was recorded on d –7, 0, 5, 14, and 21 post-inoculation (PI). Feed and water intake were measured throughout the experiment. Fecal scores were recorded twice daily (1 = normal to 5 = watery diarrhea). Data were analyzed by ANOVA using the PROC MIXED of SAS with pig as the experimental unit. The frequency of diarrhea and mortality rate were analyzed using the Chi-square test. Pigs fed antibiotic had higher ($P < 0.05$) body weight on d 5 PI than MB or MV and showed a higher ($P < 0.05$) average daily gain (ADG) from d 0 to d 5 PI than other groups. However, CON or MV had higher ($P < 0.05$) ADG from d 5 to 14 PI than pigs fed antibiotic. Feed efficiency was higher ($P < 0.05$) in pigs fed antibiotic or CON from d 0 to d 5 PI, whereas pigs fed antibiotic had lower ($P < 0.05$) feed efficiency than other groups from d 5 to 14 PI. The frequency of diarrhea was 62.5% in CON, 47.3% in MB, 51.4% in MV, and 31.4% in antibiotic group on d 0 to d 5 PI. The mortality rate was 40% in CON, 0% in MB, 6.7% in MV, and 6.7% in antibiotic group. In conclusion, supplementation of monobutyrin or monovalerin in drinking water reduced the frequency of diarrhea and the mortality rate in weaned pigs challenged with ETEC F18.

Keywords: enterotoxigenic *Escherichia coli* F18, monoglycerides, weaned pigs

The effect of feeding *Bacillus subtilis* on gut microbiome functional pathways of weaned pigs

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Our previous research observed that dietary supplementation of *Bacillus subtilis* reduced the frequency of diarrhea and enhanced growth performance of weaned pigs experimentally infected with a pathogenic *Escherichia coli* (*E. coli*). The aim of this study was to further investigate the effects of dietary *Bacillus subtilis* or carbadox on the microbiome functional pathways in feces collected from weaned pigs in this research project. The four experimental treatments were: 1) negative control, pigs fed with control diet without *E. coli* challenge, 2) positive control, pigs fed with control diet with *E. coli* challenge, 3) antibiotic group, pigs fed diet supplemented with 50 mg/kg of carbadox with *E. coli* challenge, and 4) probiotics group, pig fed diet supplemented with 2.56 x 10^9 CFU/kg of *Bacillus subtilis* probiotics with *E. coli* challenge. A total of 32 (N=32) fecal samples were directly collected from the rectum of pigs on day 21 after the first *E. coli* inoculation, with 8 pigs (n=8) per treatment group. Total microbial community DNA was extracted from fecal samples and then submitted to UC Davis Genome Center for Whole Genome- Shotgun Sequencing (NovaSeq S4 PE150) on the Illumina platform. Quality-checked reads were input into Humann3 and compared with Metacyc and KEGG for functional annotation. A total of 451 potential pathways were detected in fecal samples. The most abundant pathways were related to energy production, nucleotide metabolism, and protein synthesis. After applying analysis in MaAsLin3, a multi-omic statistics R-package, pathways with significant ($P < 0.05$) differences in relative abundance across treatments were selected and categorized by functional role. In major carbon metabolism, antibiotic supplementation reduced ($P < 0.05$) the relative abundance of pathways like glycogen degradation, D-galactose degradation, and starch biosynthesis, likely due to decreased contributions from *Bifidobacterium boum* and *Lactobacillus amylovorus*. Overall, fermentation pathways involving acetylene, acetyl-CoA, and homolactic fermentation had lower ($P < 0.05$) relative abundance in the antibiotic-treated group compared to other treatments, likely due to key contributions from *Coprococcus*, *Lactobacillus* spp., and *E. coli*. For essential amino acid biosynthesis, the antibiotic-treated group showed lower ($P < 0.05$) *L-methionine* and *L-lysine* biosynthesis among all groups but increased ($P < 0.05$) *L-valine* biosynthesis comparing to probiotic group and negative control. *Bacillus subtilis* supplementation reduced ($P < 0.05$) pathways for branched-chain amino acids, *L-histidine*, and *L-valine* biosynthesis compared to the positive control. Antibiotic treatment increased ($P < 0.05$) *L-histidine* degradation to the highest level while reducing ($P < 0.05$) *tryptophan* degradation to the lowest level. Additionally, antibiotics downregulated ($P < 0.05$) biosynthesis pathways for non-essential amino acids, including *L-glutamine, L-alanine, L-cysteine, L-aspartate,* and *L-asparagine*, likely due to differences in *Bifidobacterium* spp. and *Prevotella* spp. abundance. In conclusion, dietary *Bacillus subtilis* and carbadox have distinct impacts on the functional pathway profiles in the feces of weaned pigs.
Keywords: *Bacillus subtilis,* metagenomic analysis, weaned pigs

Effects of short chain fatty acids derivatives on the ileal digestibility of amino acids in weanling pigs challenged with f4 and f18 enterotoxigenic *Escherichia coli*

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The objective of this study was to investigate the effects of short-chain fatty acid derivatives, specifically monobutyrin (MB) and monovalerin (MV), on the ileal digestibility of amino acids in weanling pigs experimentally infected with F4 and F18 enterotoxigenic *Escherichia coli* (ETEC). A total of 176 pigs (7.14 ± 1.12 kg BW) were housed individually and randomly allotted into 11 treatment groups (n = 16). The treatments included a negative control without ETEC infection, a positive control (PC) with ETEC, and 9 additional groups supplemented with 0.005% carbadox, 0.25% zinc oxide (ZnO), 0.10% sodium butyrate, 0.10% or 0.15% MB, 0.10% or 0.15% MV, a combination of 0.05% MB and 0.05% MV, and a combination of 0.075% MB and 0.075% MV, respectively. All percentages indicate the amount of additives supplemented in percentage of diet composition. Titanium dioxide was added to all dietary treatments as an indigestible marker. The experiment lasted for 28 days, including 7 days of adaptation and 21 days of post inoculation (PI). After the adaptation, piglets in treatment groups were inoculated with 10^10 CFU/3 mL oral dose containing equal amount of F4 and F18 ETEC on day 0, 1, 2 PI. Ileal digesta (n = 10 per treatment) were collected on d 21 PI to calculate the apparent ileal digestibility (AID) of amino acids. The standardized ileal digestibility (SID) values were calculated by correcting the AID with basal endogenous losses. Data were analyzed by ANOVA using PROC MIXED of SAS with a randomized complete block design, and pairwise comparisons among treatment means were performed using Fisher's least significant difference (LSD) test. Pigs supplemented with high dose combination of monobutyrin and monovalerin had the highest ($P < 0.01$) SID of Lys among all treatments. Pigs supplemented with 0.10% and 0.15% monobutyrin, 0.10% monovalerin, low dose and high dose combination had similar or greater ($P < 0.05$) SID of Arg, His, Glu, Ile, Leu, Phe, Ser, Tyr, and Val compared with pigs in carbadox and NC groups. Pigs in carbadox group and high dose combination of monobutyrin and monovalerin group had significantly higher ($P < 0.05$) SID of dispensable and indispensable amino acids compared with pigs in 0.10% sodium butyrate and 0.15% monovalerin groups. In conclusion, dietary supplementation of monobutyrin, low dose monovalerin, or their combination enhanced the ileal digestibility of amino acids in weaning pigs infected with ETEC F4 and F18.

Keywords: monobutyrin, monovalerin, weaned pigs

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Effects of sire, age, and immune cells on PBMC mitochondrial enzyme activity in pre-wean dairy heifers

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Mitochondria are central to metabolism, nutrition, health and are the primary energy producers for all biosynthesis. The objective of this study was to determine if mitochondrial enzyme activities of peripheral blood mononuclear cells (PBMC) were associated with sire, age, breed, or death. Twenty-two heifer calves from Holstein dam x Jersey sire (F1) and 22 heifer calves from Holstein dam x Jersey sire, dams bred to Holstein sires (F2) were randomly selected for blood collection from a commercial dairy farm. Blood samples were collected at a single timepoint between age 5 to 9 d for hematology and determination of mitochondria enzyme activities of complexes I, IV and V of the respiratory chain using kits from Abcam (Cambridge, MA). Data were analyzed using the General Linear Models procedure of SAS (v.9.4) regressing enzyme activities of complex I, IV and V on the calf variables age, breed, sire, percent Holstein, total protein, number of medical treatments, and hematology. Variables were eliminated from the regression equations using forward selection and all residuals were normally distributed. Two calves died of scours from the F2 group during the pre-wean period. Complex I activity increased with total protein concentration ($P < 0.01$); ($P < 0.01$, $R^2 = 0.3$). Complex IV activity increased with complex V activity ($P = 0.01$), hemoglobin ($P = 0.002$), and red blood cell counts ($P = 0.01$); ($P < 0.01$, $R^2 = 0.3$). Complex V activity increased with increased complex IV activity ($P = 0.03$) and decreased with increased white blood cell counts ($P = 0.04$); ($P = 0.02$, $R^2 = 0.2$). These findings suggest that lower passive transfer and immune challenge during early life are associated with mitochondrial function in PBMC. Increasing red blood cell development and maturation could improve respiratory chain function to improve energy supply in pre-wean heifers.

KEYWORDS

mitochondria function, respiratory chain enzyme activity, red blood cells

Modeling serum total calcium concentrations in the transition period: effects of breed, parity, and inflammatory status

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Periparturient hypocalcemia in dairy cows is characterized by an abrupt decline in serum total calcium around calving, but the severity of this decline varies among cows. The objective of this study was to develop a simple modeling approach that treats the postpartum calcium decline as a discrete event and evaluates how its magnitude varies with parity and breed. Inflammatory activity has been linked to altered calcium homeostasis, so we also evaluated the relationship between inflammatory status and serum calcium dynamics. 63 cows were enrolled in an observational study with serial blood samples obtained from 28 d prepartum to 28 d postpartum, with frequent sampling around calving. Approximately 14 blood samples were obtained per cow (n= 31 Holsteins and 32 Jerseys, blocked into parity groups 1, 2, 3, and ≥4). Data were analyzed using linear mixed models with cow-level random effects and separate prepartum and postpartum time trends. A discrete postpartum decline term spanning d 0 to 3 postpartum was included to capture the abrupt decrease in serum calcium at calving, with the magnitude of this decline varying by parity group and breed. Inflammatory status was assessed using a log-transformed colorimetric serum haptoglobin assay (mg/L) and ELISA tumor necrosis factor alpha (pg/mL) as time-varying covariates. Inclusion of the postpartum decline term improved fit and eliminated systematic residual structure around calving, indicating an average serum calcium decrease of approximately 1.25 mg/dL during days 0-3 that was not captured by smooth time trends alone. The magnitude of this decline increased with parity (postpartum decline × parity group, $P < 0.001$) but did not differ among breeds. Independent of parity and breed, higher serum haptoglobin concentrations were associated with lower calcium concentrations across the periparturient period ($P < 0.05$). These results demonstrate that periparturient hypocalcemia is characterized by a discrete postpartum decline whose severity increases with parity, while inflammatory status is independently associated with overall serum calcium concentrations.

Keywords: hypocalcemia, transition cow, inflammation

Long-term effects of 3-nitrooxypropanol supplementation on enteric methane emissions in dairy cows

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Enteric methane (CH_4) emissions from the dairy sector contribute to 30% of the total methane emission in California. Supplementing dairy cows with 3-nitrooxypropanol (3-NOP) has been shown to effectively reduce CH_4 emissions in dairy cows but most of these studies have been conducted in short-term studies. Therefore, the objective of this study was to evaluate the efficacy of feeding 3-NOP to dairy cows over a 525-day period. A total of 66 cows were enrolled in the study – 30 multiparous, 36 primiparous – 57.6 ± 1.8 days prior to parturition. Cows were assigned to one of three treatments: CON (0 mg 3-NOP/kg DMI); 40NOP (40 mg 3-NOP/kg DMI); 80NOP (80mg 3-NOP/kg DMI) in a randomized complete block design. Cows were blocked on previous lactation yield (dams in the case of primiparous animals), parity, and covariate CH_4 production. Dry matter intake (DMI), milk yield, CH_4 and hydrogen emissions (production, yield, intensity), were analyzed using linear mixed models with treatment and days in milk as fixed effects and cow as random effect. Supplementation with 3-NOP had no effect on DMI (25.5, 24.9, and 24.7 kg/d for CON, 40NOP, and 80NOP, respectively; $P = 0.62$) or milk yield (42.3, 42.9, and 42.5 kg/d, respectively; $P = 0.93$). The inclusion of 3-NOP decreased daily CH_4 production (g/d) by 30% and 42% for 40NOP, and 80NOP, respectively (CON, 445; 40NOP, 313; and 80NOP 271 g/d SEM 1.74; $P < 0.001$). Similarly, CH_4 yield (CH_4/DMI, g/kg) was reduced by 33% and 43% for 40NOP, and 80NOP, respectively, (CON, 8.87; 40NOP, 5.97; 80NOP, 5.18 g/d SEM 0.18 DMI; $P < 0.001$), while CH_4 intensity (CH_4 /milk yield, g/kg) was 31% and 40% for 40NOP, and 80NOP, respectively, (CON, 5.06; 40NOP, 3.58; 80NOP, 3.17 g/kg milk SEM 0.032; $P < 0.001$). Hydrogen production increased with 3-NOP supplementation H_2 production (g/d) by 106% and 120% for 40NOP, and 80NOP, respectively (CON, 3.70; 40NOP, 7.94; and 80NOP 8.32 g/d SEM 0.0628; $P < 0.001$). The preliminary results from this study demonstrate that 3-NOP can effectively reduce enteric CH_4 emissions over longer periods, while having no adverse effects on production performance in dairy cows.

Keywords: enteric methane, dairy cow, 3-nitrooxypropanol

Effects of Dietary L-glutamate, L-aspartate, and Their Combination on Growth Performance and Diarrhea Severity of Weaned Piglets Challenged with F18 ETEC

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L-glutamate (Glu) and L-aspartate (Asp) are functional amino acids essential for intestinal function. This study investigated effects of Glu, Asp, and their combination on growth performance and diarrhea of weaned pigs challenged with enterotoxigenic *Escherichia coli* (ETEC). Sixty-five weaned pigs (7.59 ± 1.11 kg BW) were individually housed and randomly assigned to one of five treatments (*n*=13): a control (CON), CON + 1% Glu (GLU), CON + 1% Asp (ASP), CON + 1% Glu + 1% Asp (GAC), and CON + 50 mg/kg carbadox (ABX) supplementation. All pigs were orally challenged with F18 ETEC for 3 consecutive days (10^{10} CFU/day). The study was conducted from d -7 to d 21 post-inoculation (PI). Body weight (BW), feed intake, diarrhea scores, and fecal samples were collected repeatedly over time and analyzed using PROC MIXED of SAS with pig as experimental unit. BW and diarrhea scores were analyzed as repeated measures. Diarrhea frequency (% of observations with score ≥3) was analyzed by Chi-square test, and means were separated using Tukey's adjustment. Compared with CON, ASP increased (P < 0.05) BW on d 14 PI, and ASP or GAC increased (P < 0.05) BW on d 21 PI. From d -7 to d 14 PI, ASP enhanced (P < 0.05) average daily gain (ADG) compared with CON. Additionally, GLU, ASP, or GAC improved (P < 0.05) ADG from d -7 to d 21 PI, compared with CON. ASP also increased (P < 0.05) average daily feed intake from d 0 to d 14 PI, compared with CON. Furthermore, GLU, ASP, or GAC enhanced (P < 0.05) gain:feed ratio from d -7 to d 21 PI, compared with CON. Moreover, GLU or ASP reduced (P < 0.05) diarrhea frequency compared with CON (15.24 to 20% vs. 29.65%). In addition, ASP or GAC reduced (P < 0.05) fecal β-hemolytic shedding on d 7 PI compared with CON. These findings were comparable to those observed in ABX. In conclusion, Glu, Asp, or their combination supplementation improved growth performance and reduced diarrhea in ETEC-challenged piglets, indicating enhanced disease resilience.

Keywords: glutamate, aspartate, weaned pigs, ETEC F18

Ethical and Transparency Notes:

- **AI disclosure**: AI-assisted editing for grammar
- **Funding acknowledgment**: This work was supported by the Novo Nordisk Foundation under the grant number NNFSA210073688

Effects of Lipid Supplements High in Palmitic Acid or Linoleic Acid on Animal Performance and Meat Quality in Feedlot Lambs

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This study evaluated the effects of two different lipid supplements (rich in palmitic acid, C16:0, or linoleic acid, C18:2n-6) on growth performance, carcass characteristics, and meat quality in feedlot lambs. In a randomized complete block design, 24 wethers (40± 5.4 kg BW) were blocked by breed and randomly assigned within block to one of three dietary treatments, with initial body weight included as a covariate. Animals were housed in individual pens and fed their respective diets for 35 days. Treatments consisted of a grain-based diet with no added fat (CTL), a grain-based diet supplemented with 6% high-palmitic fat prill (PAL), or a grain-based diet supplemented with 6% high-linoleic corn oil (COR). Lambs were weighed weekly, intake was monitored daily, and carcass traits were measured at harvest. Fatty acid composition was determined in backfat and the loin muscle using gas chromatography (GC). Meat quality parameters including cooking loss, Warner-Bratzler shear force (WBSF), instrumental color, and malondialdehyde (MDA) concentration as an index of lipid oxidation, were evaluated on day 0 and day 7 aged loin samples.

Lambs fed COR exhibited improved performance, with a 16% lower feed-to-gain ratio (4.94 vs. 5.90 kg/kg; $P = 0.027$) and a 0.83 kg greater hot carcass weight compared with PAL (26.64 vs. 25.81 kg; $P < 0.01$). The COR diet led to an increase ($P < 0.01$) in biohydrogenation intermediates, including trans-18:1 and conjugated linoleic acid (CLA) isomers. Specifically, the COR diet resulted in increased ($P < 0.01$) trans-10,cis-12 CLA (a CLA isomer with potent anti-lipogenic properties) in backfat, but not in the loin ($P > 0.1$). The higher trans-10,cis-12 CLA in backfat coincided with a lower concentration of C16:0, suggesting reduced de novo lipogenesis in the backfat of COR-fed lambs.

Meat quality parameters were not affected by dietary treatments. Aging time was the only factor influencing cooking loss, WBSF, instrumental color, and MDA concentration, with no significant effects of treatment or treatment × day interactions observed for any of these measurements. These results indicate that feeding COR, compared with PAL, can improve feedlot lamb performance, particularly the feed-to-gain ratio and hot carcass weight. Further studies are needed to elucidate the mechanisms underlying these effects.

There was no direct funding provided for this project. However, the authors would like to acknowledge the support of Superior Farms Inc.

AI-assisted editing for grammar. Authors are responsible for all content and interpretation.

Keywords: feed efficiency, meat quality, linoleic acid, feedlot lamb

Technical Symposium
Speaker Biographies

Jesse Goff DVM, PhD, President- GlycoMyr, Inc. 2020 to present
Dedicated to discovering new uses for plant based vitamin D compounds in man and animals. Developing improved methods of supplementing piglets with vitamin D and E. Developing oral calcium boluses with vitamin D glycosides for hypocalcemia reduction in cows.

Iowa State University and USDA-ARS, National Animal Disease Center; 1985-2020. conducted research on metabolic diseases of animals and the effect these diseases had on infectious disease resistance, with emphasis on dairy cows. Also did basic and applied research on milk fever and other mineral disorders of dairy, swine and poultry. This work included demonstration that diet potassium, not calcium causes milk fever and the effect of potassium can be overcome with adding anions to the diet. Working on Solanum glaucophyllum boluses to help reduce hypocalcemia in dairy cows.

Examining potential of plant derived vitamin D analogs to prevent/treat cancer and immune mediated disease. Also pursuing research to develop methods to improve immune function in the dairy cow around the time of calving to prevent diseases such as mastitis, metritis and retained placenta. Continue to do work on the effects of subclinical hypocalcemia and other mineral disorders in the periparturient cow.

Teach nutrition courses, Physiology and Histology Courses, and teach 4th year students during Dairy Production Medicine rotations.

Served on National Research Council (NRC) committees to revise the 7th edition of the Nutrient Requirement of Dairy Cows and 2nd edition of Mineral Tolerance of Domestic Animals

Section Editor and author of “Duke’s Physiology of Domestic Animals”
Board Certified – American College of Veterinary Nutrition

Published 140 peer reviewed research papers.

EDUCATIONAL BACKGROUND

1978-86 Iowa State University, Ames, IA (MS, DVM, Ph.D.).
Majors: Veterinary Physiology (Physiol. Pharm Dept) and Nutritional Physiology (Animal Science)
1973-77 Cornell University, Ithaca, NY (B.S.)
Major: Microbiology

José Eduardo P. Santos, DVM, PhD, is a Research Foundation Professor in the Department of Animal Sciences at the University of Florida. He received his DVM degree from São Paulo State University (Brazil), completed the MS and PhD degrees at the University of Arizona, a clinical residency in Dairy Production Medicine at the University of California Davis, and a sabbatical at the University of Sydney (Australia). Before joining the University of Florida, José was a professor in the School of Veterinary Medicine at the University of California Davis with clinical and research responsibilities. José has been the major professor of 41 graduate students and he has hosted 12 post-doctorates and sabbatical visitors, and another 132 visiting students. He has published 316 manuscripts in the peer-reviewed scientific literature, 16 book chapters, and has given more than 450 presentations in technical and scientific meetings and received over $17 million in research funds. José is a Fellow of the American Association for Advancement of Science, Fellow of the American Dairy Science Association, and he has been awarded the Young Scientist Award, the Physiology Award, the Extension Award, and the Applied Dairy Nutrition Award all from the American Dairy Science Association, among other awards from the University of California Davis and the University of Florida. José's research seeks to develop technologies that enhance efficiency of dairy production, in particular improvements in peripartum health and reproduction. The research is highly integrative, combining components of basic cellular biology, whole animal physiology, and applied interventions that are adopted by dairy producers worldwide.

Dr. Emma Wall, holds a Ph.D. in lactation physiology with a focus on dairy cow physiology and management. After completing a post-doctoral fellowship in endocrinology, Emma left academia to be closer to industry. She has spent nearly 20 years working in the feed additive industry in R&D, technical marketing, and development of custom solutions. Her area of expertise is physiology of medicinal plants and how they alter production animal physiology, resilience, & performance. At Nutreco (parent company of Selko US), Emma is the Director of Discovery & Development for Nutreco Exploration. Emma and the entire Nutreco Exploration team work closely with the technical and marketing teams of Selko US, Skretting, and Trouw Nutrition to discover and co-develop proprietary solutions for feed, leveraging both plants and bacteria. Emma is based in Vermont (USA).

Lance H. Baumgard, is a Distinguished Professor and the Normal Jacobson Professor of Nutritional Physiology in the Department of Animal Science at Iowa State University. He is from a farrow to finish hog and row-crop from in Minnesota. He did his BS and MS at the University of Minnesota and his PhD at Cornell. He was on faculty at the U of Arizona from 2001 to 2009 and has been at Iowa ever since. He and his group are describing how immune activation alter nutrient trafficking and ultimately reduce farm animal productivity.

CANC Speaker Biographies

Victor E. Cabrera, Ph.D., is an professor and extension specialist in dairy management at the University of Wisconsin-Madison Dairy Science Department. Dr. Cabrera combines applied research, interdisciplinary approaches, and participatory methods to deliver practical, user-friendly, and scholarly decision support tools for dairy farm management. These scientific tools are aimed to improve dairy farm profitability, environmental stewardship, and long-term sustainability of the dairy farm industry. During his short career, Dr. Cabrera has developed more than 40 decision support tools, published 54 refereed articles, and 5 book chapters, presented in more than 100 scientific sessions, and given talks in more than 170 extension meetings in Wisconsin, other States, and several other countries. Dr. Cabrera work in the past 8 years has been pivotal to attract more than $4.0 million to support his research and extension initiatives. Dr. Cabrera has been distinguished with the University of Wisconsin-Madison Vilas Faculty Mid-Career Investigator Award, Second Mile Extension award of the Wisconsin Association of County Agricultural Agents, the Pound Extension Award and the Alfred Toepfer Faculty Fellow Award from the University of Wisconsin College of Agriculture and Life Sciences, the Distinguished Achievement Award from the University of Florida School of Natural Resources and Environment, and the Foundation Scholar Award in Dairy Production from the American Dairy Science Association.

Dr. Greg Penner, Dr. Greg Penner is a Professor in the Department of Animal and Poultry Science at the University of Saskatchewan. He was hired in 2009 after obtaining his bachelor’s degree (2004) and M.Sc. degree (2006) at the University of Saskatchewan, and his PhD from the University of Alberta (2009). Dr. Penner’s research focuses on forage utilization, beef and dairy cattle nutrition, and regulation of gastrointestinal function in ruminants. Many of the students and post-doctoral students trained in Dr. Penner’s program now work as nutritional consultants, or have obtained faculty positions in the USA, Canada, Brazil, or Poland. As a result of the research activity, Dr. Penner has authored or co-authored nearly 200 papers in peer-reviewed journals and is a highly sought out speaker providing over 180 invited presentations since appointment. Greg also serves as co-Editor in Chief for the Canadian Journal of Animal Science. In recognition of his research program, Dr. Penner has been awarded with several awards internal to the University of Saskatchewan, National level awards through the Canadian Society of Animal Science, and international awarded through the American Society of Animal Science and American Dairy Science Association. Greg is also actively involved in teaching at the undergraduate and graduate levels within the Animal Science program in the College of Agriculture and Bioresources. As part of his outreach, Dr. Penner participates as an organizing committee member for the Western

Canadian Dairy Seminar, SaskMilk Dairy Info Day, and he sits as a board member for Saskatchewan Verified Beef Plus.

Dr. Kirby Krogstad Kirby Krogstad is an Assistant Professor of Dairy Nutrition at The Ohio State University (Wooster, OH). He earned his BS in Dairy Production from South Dakota State University, his MS from the University of Nebraska–Lincoln, and his PhD from Michigan State University. Kirby's research centers on dairy cattle nutrition and health, with particular emphasis on the interplay between diet and inflammation. His current research focuses on rumen health and rumen tissue inflammation, exploring how dietary inputs shape rumen function and cow well-being. Complementing his research, Dr. Krogstad maintains an active extension program aimed at helping dairy producers optimize nutritional management practices to enhance animal health and improve production efficiency.

Greg L. Bethard, Ph.D., grew up in New Jersey USA and developed a passion for agriculture at a young age. He received his BS, MS, and Ph.D. degrees from Virginia Tech in dairy nutrition and management and has spent his entire career in the dairy industry. He has served on faculty at New Mexico State University and North Carolina State University, and as a technical services specialist for Monsanto Dairy Business. From 2000 to 2014, Greg and his wife Rachel operated G&R Dairy Consulting, Inc., an international dairy consulting business based in Blacksburg, VA. Greg consulted with dairy producers and allied industry throughout the US and around the globe, working in Europe, Asia, and Australia. Greg spent a few years in Wisconsin, serving as CFO for the Pagel Family Businesses in Kewaunee, WI from 2014 to 2016. In 2017 Greg moved to Kansas and realized his lifelong dream of becoming a dairyman. Since 2017 he has been managing partner at High Plains Ponderosa Dairy in Plains KS and currently serves as CEO.

Hugo A. Ramírez, Ph. D.., is an international technical consultant specializing in silage quality management, forage preservation, and dairy cattle nutrition. He holds a degree in Agronomy with a specialization in Animal Science from Chapingo Autonomous University (Mexico), and M.S. and Ph.D. degrees from the University of Nebraska–Lincoln, with academic training focused on forage quality, fiber utilization, and ruminant nutrition. He has held academic and extension appointments at Texas A&M AgriLife Research, Tarleton State University, and Iowa State University, where he conducted research, teaching, and outreach activities related to silage management and dairy production systems. His consulting work emphasizes personnel training, supervision of ensiling processes, and the application of science and technology to improve forage quality across dairy systems. Dr. Ramírez regularly contributes to technical conferences and professional training programs on silage and dairy nutrition in multiple countries. He also maintains active collaborations with academic institutions, including the Dairy Academy and the National University of Córdoba (Argentina), where he teaches the Forage Preservation course, and Tecnológico de Monterrey (Mexico), where he served as lead researcher on a sustainable dairy nutrition project.

Dr. Michelle Schack is a dairy veterinarian with 11 years of experience working with commercial dairies in the Western United States. She is the co-founder of DairyKind, an education and training company focused on improving animal well-being by supporting the

people who care for livestock. She can also be found on social media as the DairyDoc online and speaking at various conferences.
Dr. Schack's work sits at the intersection of animal health and well-being, documentation systems, and employee training. She focuses on practical, on-farm solutions that improve consistency, reduce risk, and enhance both cow performance and workforce sustainability.

Artem Timanov is the CEO and Founder of Cattle Care (https://cattle-care.com/), a Computer Vision and AI solution for dairy farms. With a focus on optimizing farm labor performance, the company works to bridge the gap between protocol and execution. Currently, 720,000 cows at 179 farms across 28 US states are under monitoring. Artem holds M.Sc. in Applied Mathematics from Saint Petersburg State University.

California Animal Nutrition Conference
2026 Steering Committee

Chairperson: Tricia Wood, Ph.D., Lallemand Animal Nutrition
Tricia Wood was raised on a farrow-to-finish hog operation and was active in 4-H in her youth. Her bachelor, masters, and Ph.D. degrees were all awarded from the Iowa State University focusing on animal physiology. Her graduate school research all centered around calf immune system development and nutritional supplements that can affect development and efficiency of the immune system (pre/probiotics). She has over 15 years of experience in the dairy feed additive and feed industries where she has formulated milk replacer and provided sales and technical support for dairy calf and feed additive products. She is a member of the Ruminant Technical Services team with Lallemand Animal Nutrition, North America. In her current role, she provides technical support, product expertise and industry knowledge alongside the Lallemand territory business managers for the western United States. She has consulted on numerous calf ranches in the Western half of the country, as well as in the Midwest. Tricia resides in resides in Caldwell, Idaho, with her husband and two sons on a small farm where they raise horses and chickens.

Vice Chairperson: Samantha Pearle, M.S., PAS
Samantha has been in the feed and nutrition industry for 12 years and currently serves the California dairy industry providing bypass fat solutions.

Ex-Officio: Carlyn Peterson, Ph.D., P.A.S., Selko USA
Carlyn Peterson is a Dairy Technical Manager for Selko USA (formerly Micronutrients) primarily covering the Western region of the US. Carlyn specializes in sustainable dairy systems and their interaction with dairy nutrition. Prior to joining Selko in 2022, Carlyn provided technical support for the Smartline category with Adisseo for two years. Between 2013 to 2020 she worked with Dr. Frank Mitloehner at the University of California, Davis, to complete a Master's degree and PhD in Animal Biology with a focus on Sustainability and Ruminant Nutrition. Carlyn is passionate about improving sustainability in the dairy sector. The title of her dissertation is "Effects of Feed and Waste Additives on Dairy Cattle's Impact on Greenhouse Gasses and Air Quality." Her research focused on reducing the environmental impacts of dairy while maintaining production. Carlyn also holds a Bachelor's degree in Animal Science, emphasis in Livestock and Dairy, from UC Davis. She is originally from San Diego County where she got her start in agriculture through participating in the FFA.

Committee Members:

Leslie Jacobsen, M.S., P.A.S., Phibro Animal Health Corporation
Leslie Jacobsen is an Account Manager with Phibro covering the Southern California region. In 2022 she completed her Master's degree in Animal Biology with a focus on Ruminant Nutrition with Dr. Heidi Rossow at University of California, Davis. After obtaining her Master's degree, she worked as a Nutrition Consultant for Nutri-Systems INC. from 2022 – 2023. She is also on

the board of the American Registry for Professional Animal Scientists as Director at Large. Leslie also holds a Bachelor's degree from Fresno State, with an emphasis in Dairy Production.

Dr. Kelly Nichols, UC Davis – Department of Animal Science
Kelly Nichols is a ruminant nutritionist and Assistant Professor in the Department of Animal Science at the University of California, Davis. Her research program focuses on characterizing the digestive and metabolic flexibility of dairy cattle to elevate the understanding of dietary protein and energy interactions, mammary gland metabolism, and nutrient utilization to improve the transfer of dietary nutrients into milk. Kelly's research career began at the University of Guelph in Canada where she completed her MSc focused on amino acid and energy metabolism in dairy cattle. She then moved to the Netherlands to carry out her PhD at Wageningen University on a project focused on reducing nitrogen losses in dairy cattle in collaboration with the Dutch feed industry. Prior to her move to UC Davis, Kelly led a strategic research area on nitrogen and carbon efficiency in the Ruminant Research Center of Trouw Nutrition R&D.

Jesse Govea, Pine Creek Nutrition Services, Inc
Jesse is a consulting dairy nutritionist with Pine Creek Nutrition Service, Inc. He is a graduate of Michigan State University with a degree in Animal Science, and Fresno State University where he completed his MBA. Jesse maintains years of experience focused on many areas of dairy management including, milk parlor efficiency, labor organization, and on-farm nutrition implementation strategies. He is excited to bring this experience to the CANC steering committee for his first term as a committee member.

Andy Riordan, Nutri-Systems Inc.
Andy Riordan is President/ Co-Owner of Nutri-Systems Inc., in Clovis, California. He has been consulting since 2008 after receiving a Bachelor's of Science degree (2006), and a Master's of Science degree (2009) both in Animal Science from California State University, Fresno. Andy was very involved in the dairy at Fresno State where he milked and fed dairy cows along with assisting in feed trial work with other students. He also was President and Vice President of Fresno States Dairy Club. His involvement also included Judging at FFA Field day at Fresno State and participating in the first ever Dairy Challenge in California. He is a member of California American Registry of Professional Animal Scientists (ARPAS) which is a professional organization that commits itself to continuing education, research and providing scholarships for young students looking to pursue a career in animal agriculture. In that organization he served on the research committee, Director at large, Secretary along with helping to develop a video to educate future animal science professionals about this national organization.

Noelia Silva-del Rio, Ph.D., University of California, Davis Veterinary Medicine School
Noelia Silva del Rio is the UC Davis Cooperative Extension Dairy Specialist at the veterinary medicine school. She is located at the Veterinary Medicine Teaching and Research Center in Tulare. She earned her veterinary degree from the University of Santiago de Compostela in Spain in 1998. She practiced for two years in the northwest region of Spain by supporting dairy

producers with the implementation of reproduction, nutrition, and herd health programs. In 2007, she obtained her Ph.D. in Dairy Science from the University of Wisconsin with focus on nutrition and reproduction. Soon after graduation, she joined UCCE as a Tulare Dairy Advisor, a position she held for over three years before joining the UC Davis SVM as a Specialist in 2012. Her extension program aims to improve herd health through management from feeding to treatment decisions, with special focus on finding management solutions to mitigate transition cow disorders and calf health issues.

JJ Degan – Selko, USA
JJ Degan is the Marketing Director of Selko, USA.

CANC Chairperson History

YEAR	CHAIRPERSON	COMPANY AFFILIATION
2026	Tricia Wood, Ph.D.	Lallemand Animal Nutrition
2025	Dr. Carlyn Peterson	Selko, USA
2024	Dr. Kyle Thompson	College of the Sequoias
2023	Mr. Ruben Almada	Turlock Dairy & Refrigeration
2022	Mr. Zachery Meyer	Rock River Laboratory, Inc.
2021	Jennifer Heguy, M.S., P.A.S.	University of California, Coop. Ext.
2020	NO CANC CONFERENCE	
2019	David Ledgerwood, M.S., P.A.S.	Chr-Hansen
2018	Jason Brixey, M.S., P.A.S.	Pine Creek Nutrition Service
2017	Dr. Phillip Jardon, DVM, MPVM	Elanco Animal Health
2016	Dr. Phillip Jardon, DVM, MPVM	Elanco Animal Health
2015	Mr. Ben Tarr	Adisseo USA Inc.
2014	Dr. Jeffrey M. DeFrain	Zinpro Performance Minerals
2013	Mr. Doug DeGroff	Diversified Dairy Solutions, LLC
2012	Mr. Eduardo Galo	Novus International, Inc.
2011	Dr. Michael A. DeGroot	DeGroot Dairy Consulting
2010	Dr. Jim Tully	Pine Creek Nutrition Service, Inc.
2009	Mr. Michael Braun	Phibro Animal Health
2008	Dr. Luis Rodriguez	Zinpro Corporation
2007	Dr. Marit Arana	A.L. Gilbert Company
2006	Mr. Dennis Ervin P.A.S.	Prince Agri Products, Inc.
2005	Dr. Lawson Spicer	Nutri Management Inc.
2004	Dr. Luis Solorzano	Purina Mills, Inc.
2003	Dr. Alfonso Mireles, Jr.	Foster Farms
2002	Mr. Edmund Vieira	Pine Creek Nutrition Service, Inc.
2001	Dr. Melinda Burrill	California State Polytechnic University - Pomona
2000	Mr. Dave Fischer	Foster Farms
1999	Dr. M. Steven Daugherty	California State Polytechnic University - SLO
1998	Dr. Doug Dildey	Alltech, Inc.
1997	Ms. Carla Price	Nutritionist
1996	Dr. H.John Kuhl, Jr.	Nest Egg Nutrition
1995	Mr. Dennis Ralston	M. Rinus Boer Co., Inc.
1994	Dr. Doug Dildey	Alltech, Inc.
1993	Dr. Mark Aseltine	ConsultingAnimal Nutritionist
1992	Dr. Carl Old	MacGowan-Smith Ltd.
1991	Mr. Nick Ohanesian	Ohanesian & Associates
1990	Mr. Rod Johnson	M. Rinus Boer Co., Inc.
1989	Mr. Timothy Riordan	Nutri-Systems, Inc.
1988	Dr. Russ W. Van Hellen	Great West Analytical
1987	Dr. John E. Trei	California State Polytechnic University, Pomona
1986	Dr. A.A. Jimenez	Ancon, Inc.
1985	Dr. Wm. A. Dudley-Cash	Foster Farms
1984	Dr. Joel Kemper	Penny-Newman Co.

CANC Chairperson History Continued

YEAR	CHAIRPERSON	COMPANY AFFILIATION
1983	Dr. Alex J. Kutches	O.H. Kruse Grain & Milling Co.
1982	Dr. Howard Waterhouse	Bell Grain & Milling
1981	Mr. Don Ulrich	Diamond Shamrock Chemical Co.
1980	Mr. Tom Geary	PMS-West, Inc.
1979	Dr. Frank Parks	Kemlin Industries
1978	Mr. Fred Pfaff	Zacky Farms
1977	Mr. Rene Lastreto	Diamond Shamrock Chemical Co.
1976	Mr. Rene Lastreto	Diamond Shamrock Chemical Co.
1975	Dr. R.D. Hendershott	Nulaid Foods
1974	Dr. R.D. Hendershott	Nulaid Foods
1973	Dr. Leland Larsen	Nutri-Systems, Inc.
1972	Dr. Leland Larsen	Nutri-Systems, Inc.
1971	Mr. Rene Lastreto	Diamond Shamrock Chemical Co.
1970	Mr. Fred Pfaff	Balfour Guthrie
1969	Mr. Fred Pfaff	Balfour Guthrie
1968	Mr. Fred Pfaff	Balfour Guthrie
1967*	Mr. Gary L. Frame	J.G. Boswell Co.
1966*	Mr. Gary L. Frame	J.G. Boswell Co.
1965*	Mr. Arne Jalonen	Topper Feed Mills
1964*	Mr. Arne Jalonen	Topper Feed Mills
1963*	Dr. W.P. Lehrer	Albers Milling Co.
1962*	Dr. H.J. Almquist	The Grange Co.
1961*	Dr. H.S. Wilgus	The Ray Ewing Co.
1960*	Mr. Bert Maxwell	Nulaid Foods
1959*	Mr. Bert Maxwell	Nulaid Foods
1958*	Mr. Robert Caldwell	Anderson Smith Milling Co.
1957*	Mr. Emery Johnson	P.C.A., Los Angeles
1956*	Mr. Emery Johnson	P.C.A., Los Angeles
1955*	Dr. H.J. Almquist	The Grange Co.
1954*	Dr. H.J. Almquist	The Grange Co.
1953*	Mr. Clifford Capps	California Milling Co.
1951*	Mr. Dolph Hill	Golden Eagle Milling Co.
1950*	Dr. H.J. Almquist	The Grange Co.
1949*	Dr. H.J. Almquist	The Grange Co.
1948*	Dr. H.J. Almquist	The Grange Co.

* California Animal Industry Conference

History of the
California Animal Nutrition Conference

The California Animal Nutrition Conference (CANC) originated in the 1940s as the California Animal Industry Conference, sponsored by the California Grain & Feed Association (CGFA). CGFA wanted to expand the continuing education program into a forum encompassing animal health, nutrition, and management. The expectations were that communications between (nutritionists) industry, educational institutions, and regulatory agencies would be improved. In 1972, CGFA discontinued sponsoring the Animal Industry Conference.

After the conference was discontinued, a small group of nutritionists began meeting annually in Fresno. Two or three invited speakers from industry or the universities presented information on nutrition, especially poultry.

In 1975 a set of organizational bylaws were developed by the steering committee. CANC was established and was provided support by CGFA. The CGFA Board of Directors appointed a chairperson annually and approved the steering committee. In 1978, Dr. Frank Parks, the Chairperson, requested that CANC be granted independent status and be established as a self-governing committee of CGFA. This request was granted.

For a few years, meetings were held in Fresno and Corona, California. For a couple of years starting in 1978, CANC published “Nutri-Facts,” a “newsletter” consisting of articles on animal production.

In 1979, donations were requested from industry companies to help keep registration fees low. During the 1980s and through the 1990s the attendance at CANC continued to grow as the quality of the conference improved and the conference became known nationwide. In the 1990s a pre-symposium was added. The pre-symposium is sponsored by a company selected by the CANC Steering Committee and this process allows the selected company to showcase its research and products. In the year 2000, posters on research by students were included.

Attendance at the conference has grown from 50 in the 1970s to over 300 attendees. To encourage attendance, different activities have been tried such as keynote speakers, skiing expeditions, and a very successful barbeque dinner put on by the Animal Science Department at California State University, Fresno.

The California Grain & Feed Association has supported and allowed CANC to work and grow. The premise of the CGFA and CANC relationship is to work together to educate the feed industry with information for problem-solving and to disseminate valuable research information. CANC is not an industry, university, or government entity, but a committee collectively working together for the good of agriculture in California.