

Feeding for the future: Challenging dogmas in calf nutrition



DAIRY 
at GUELPH

Michael A. Steele
Professor

Department of Animal Biosciences

UNIVERSITY of GUELPH



Outline

1. Opportunities
2. Neonatal
3. Preweaning
4. Weaning

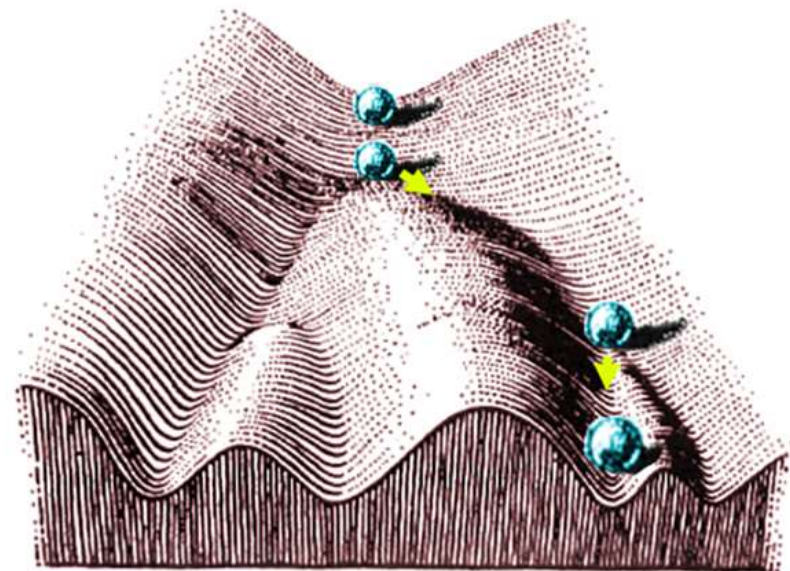
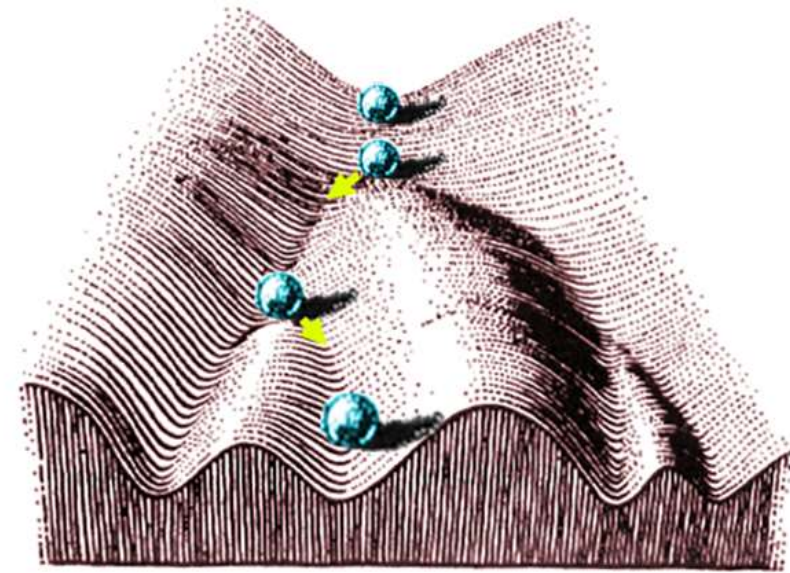


“Early Life Programming”

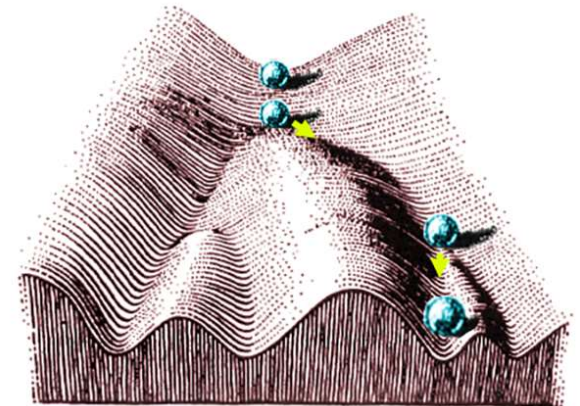
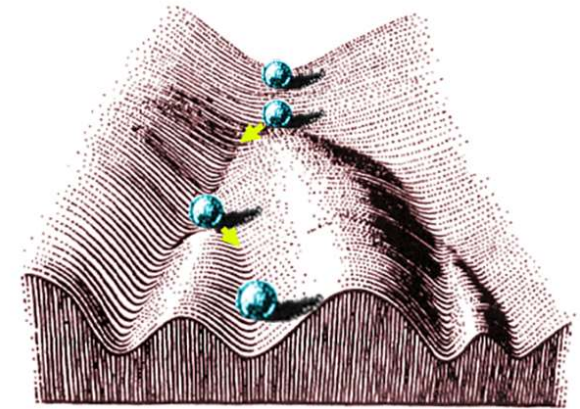
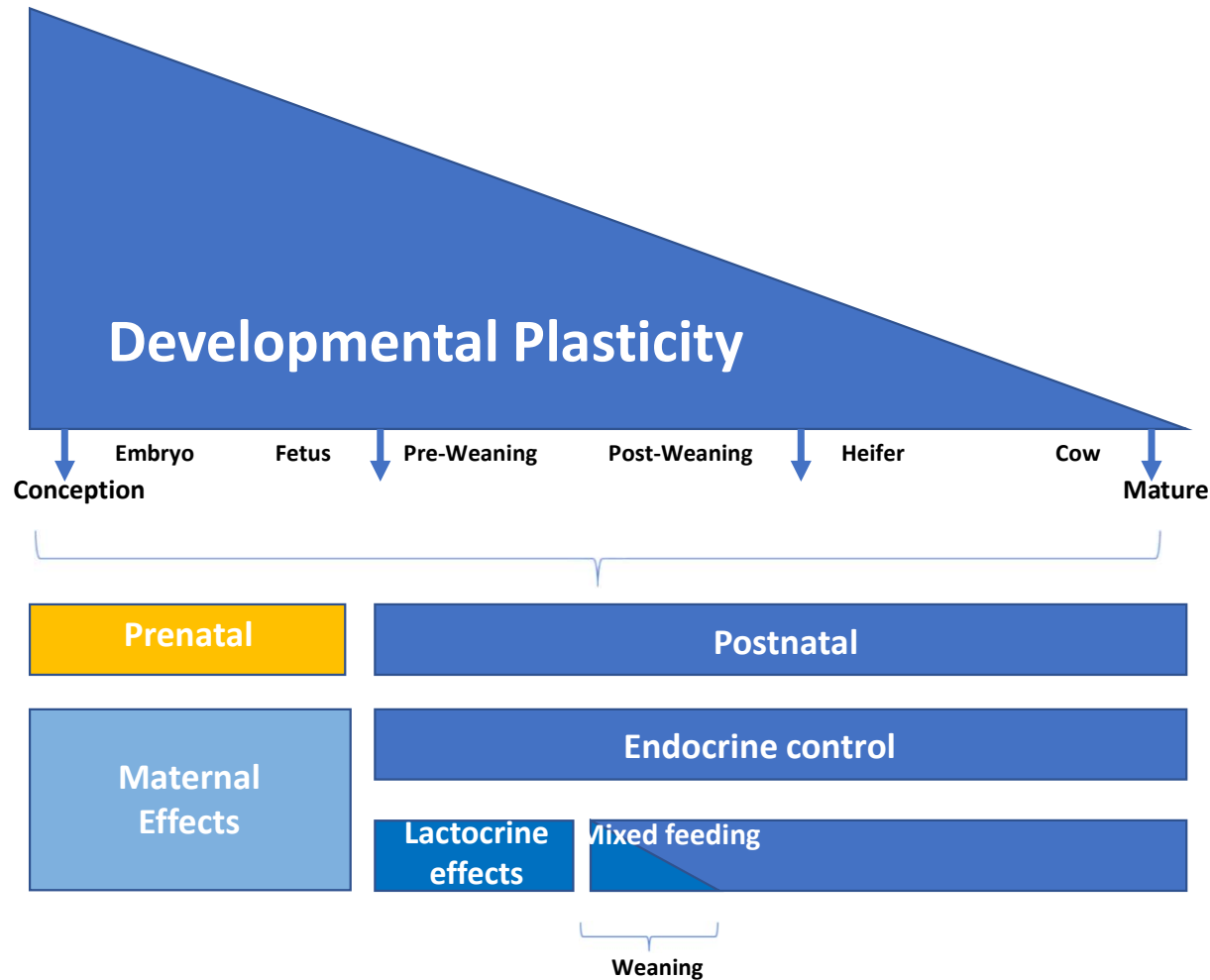
“...early adaptation to a stress or stimuli that permanently changes the physiology and metabolism of the organism and continues to be expressed even in the absence of the stimulus/stress that initiated them...”

Patel and Srinivansan, 2002

Adapted from Conrad's Waddington epigenetic landscape



Developmental Plasticity



Adapted from Bartol et al., 2013

Early Life Nutrition

- Dietary regimes in early life influence lifetime productivity
- 1 kg of pre-weaning ADG = 1,540 kgs of milk in first lactation



Soberon et al., 2012

Milk Feeding...

What Are We Doing?



VS



Calf nurses:

6-8 times

1-3 times

Time per meal:

5-10 min.

1-3 min.

Milk consumption:

16%-24% BW as milk

8%-10% BW as milk

Milk intake DM:

Up to 1.59 kg

Around 0.45 kg

Feeding method:

Teat

Teat or Bucket

Weaning method:

Gradually (4-6 mths)

Abrupt (6-8 wks)

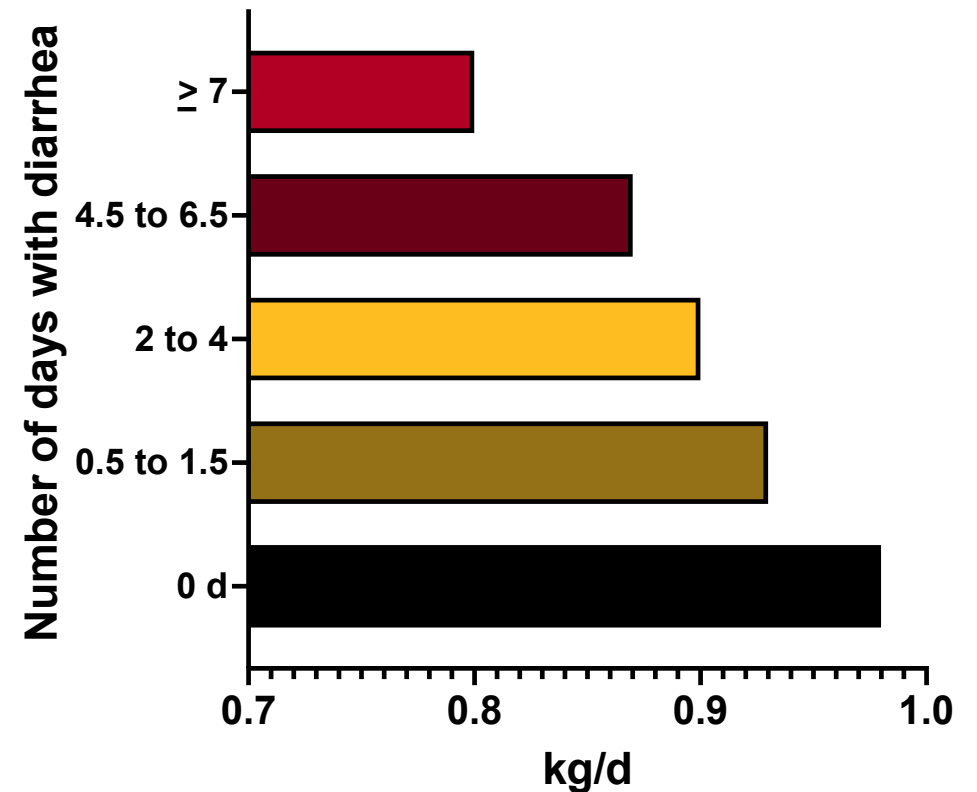
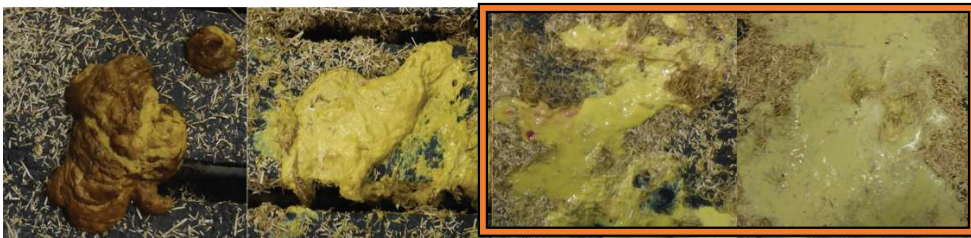
Gut Health During Preweaning Period

- Mortality and Morbidity:
 - **5% mortality, 32% due to digestive disorders**
 - Mean age: 18.3 ± 2.3 d old
 - **38% morbidity, 56% due to digestive disorders**
- Immune Status:
 - 24% of calves failed passive transfer
- Antibiotic Use:
 - **26.8% of calves receive antibiotics**
 - 48.4% for digestive disorders



Diarrhea and Calf Growth

- Fecal scored (0-3) 2,616 calves daily for the first 28 d after arrival to a calf research facility
- Evaluated the impact on mortality, antimicrobial treatment, and growth in 77 d at facility

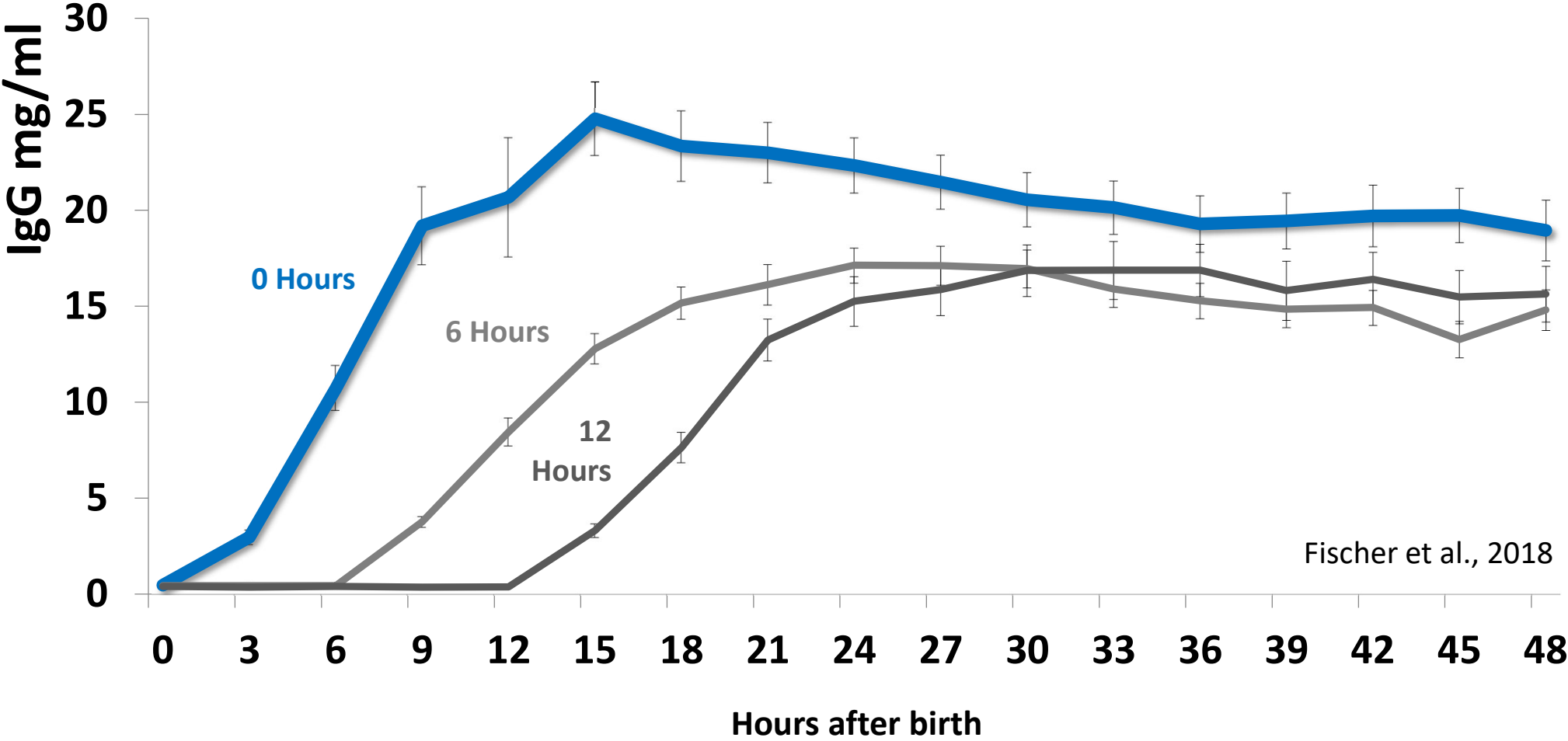


Outline

1. Opportunities
2. Neonatal
3. Preweaning
4. Weaning

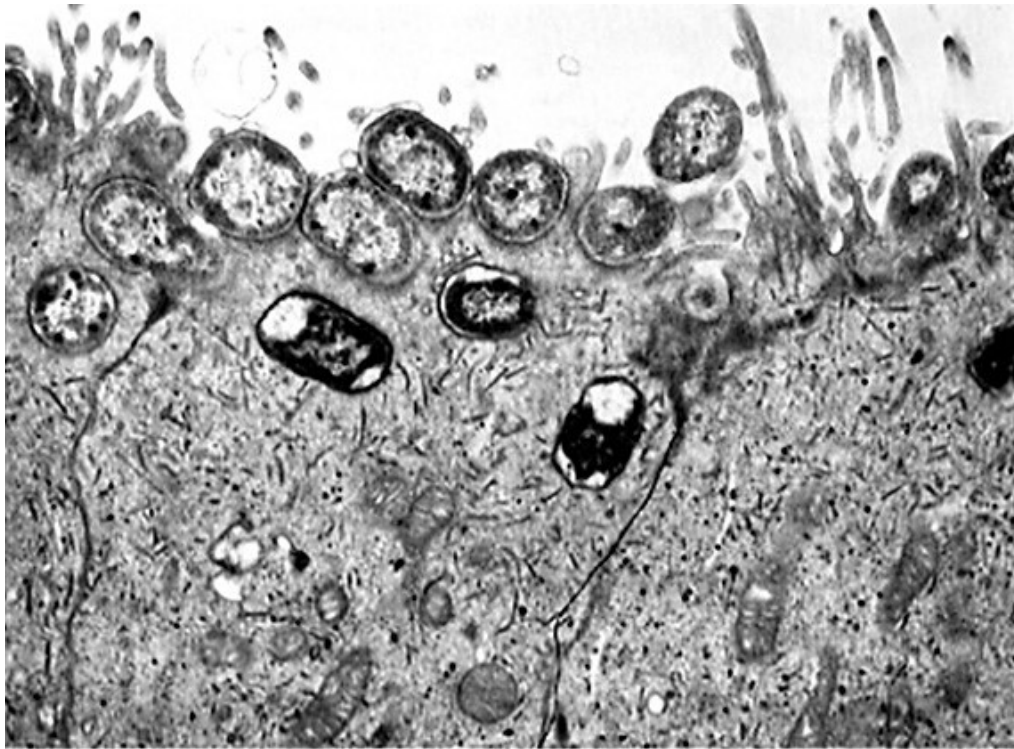


Delayed Colostrum Feeding



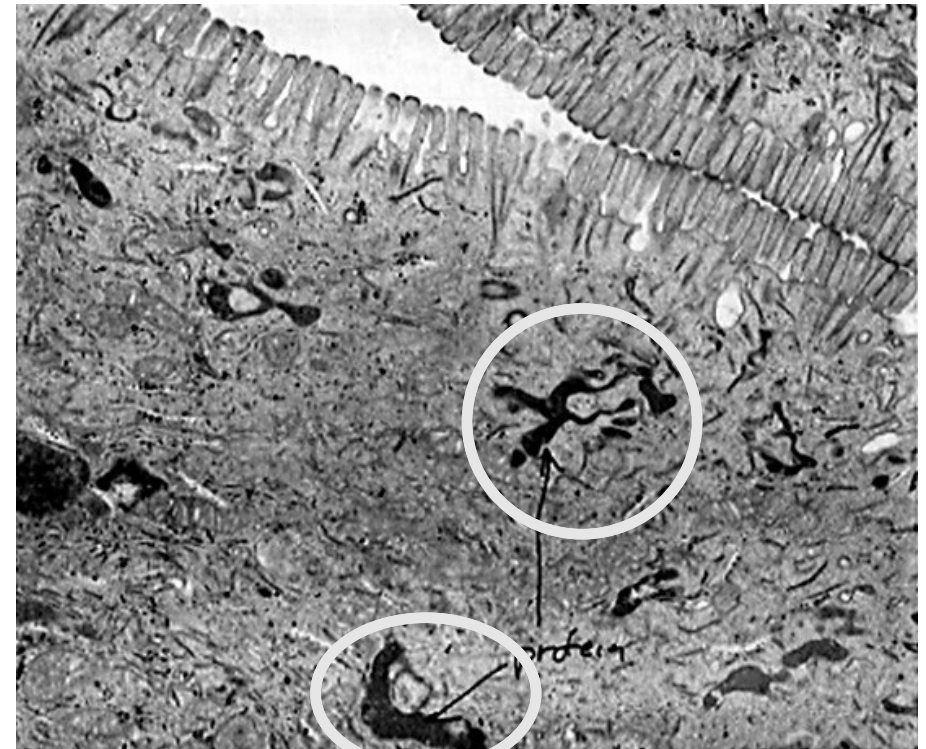
Fischer et al., 2018

E. Coli entering intestine epithelial cell
Destruction of microvilli



Colostrum deprived calf

Dark areas represent absorbed Ig

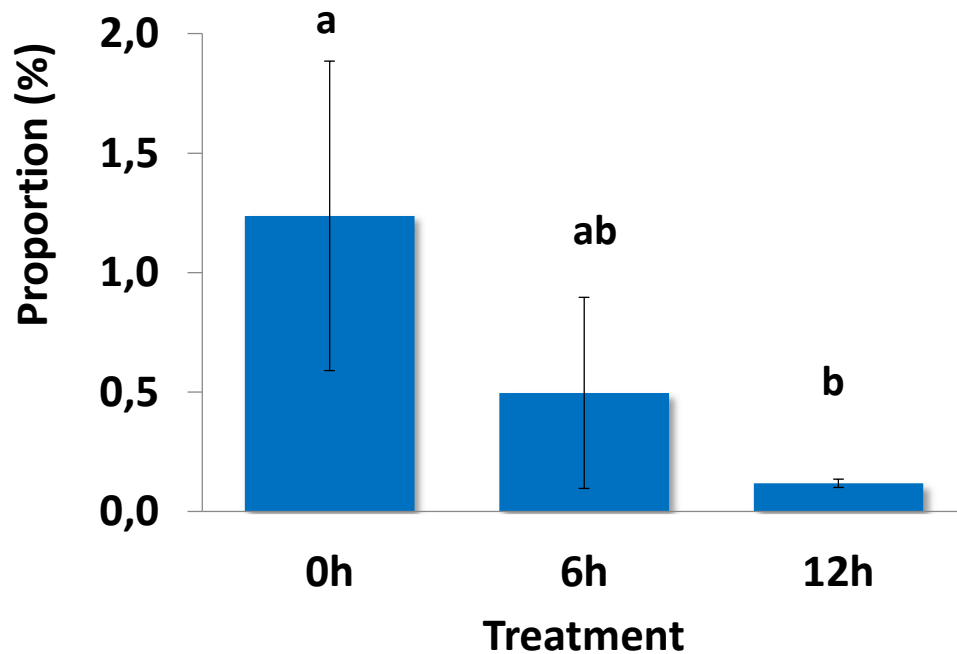


Colostrum fed calf

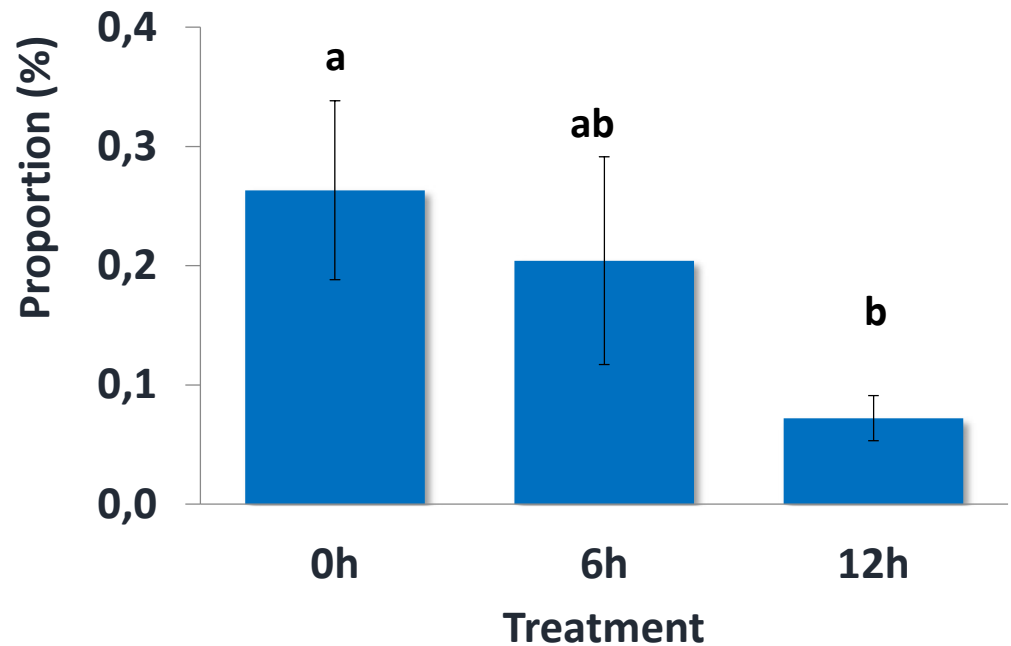
Slide Courtesy of Dr. James

Delayed Colostrum Feeding

Bifidobacteria associated with colon mucosa

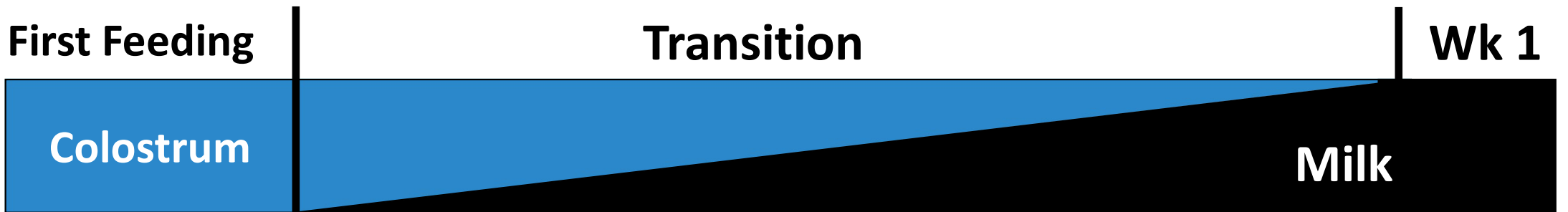


Lactobacillus associated with colon mucosa

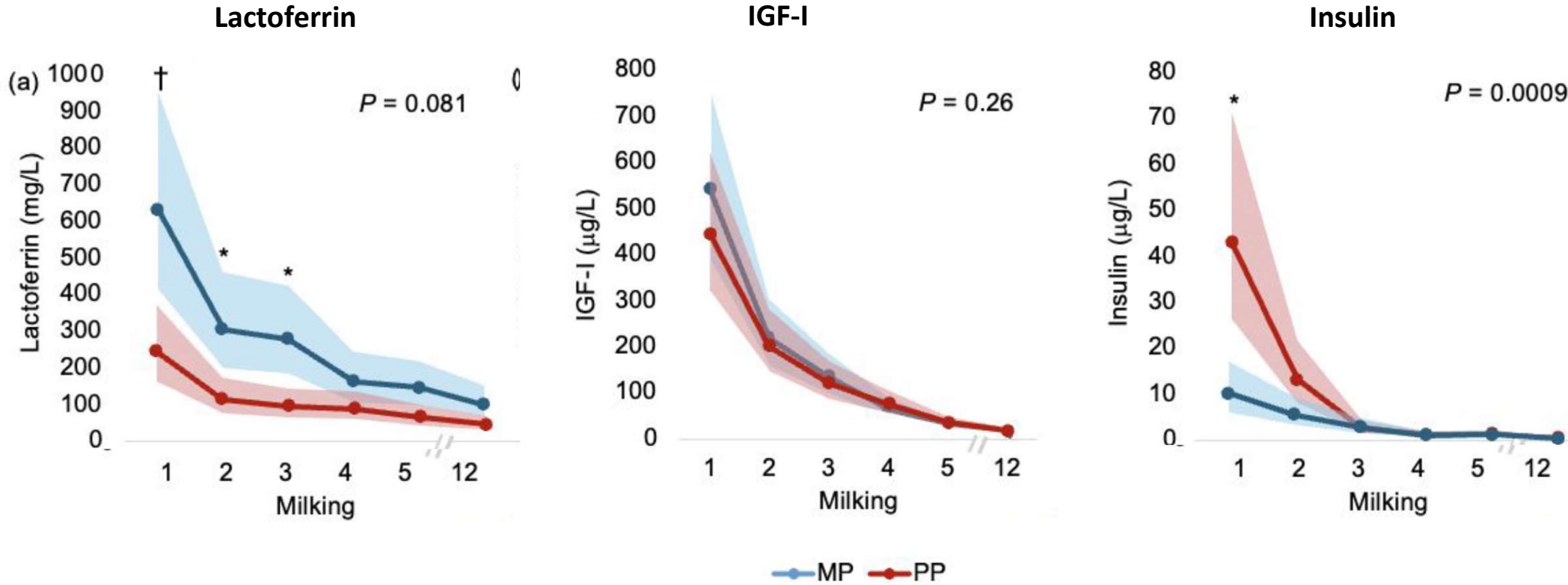


- Delaying the first colostrum meal may delay the colonization of beneficial bacteria to the calf intestine

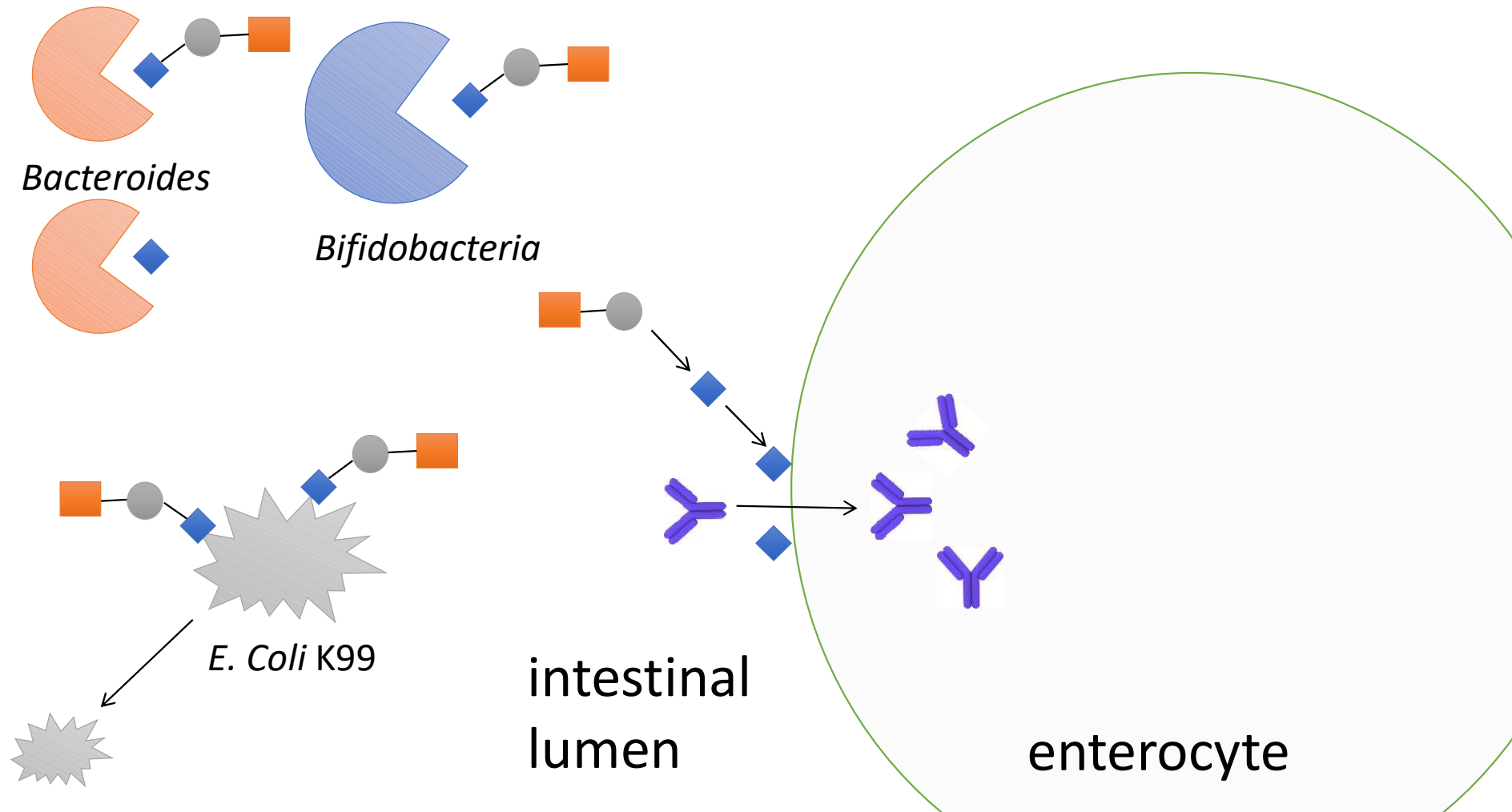
From Colostrum to Milk



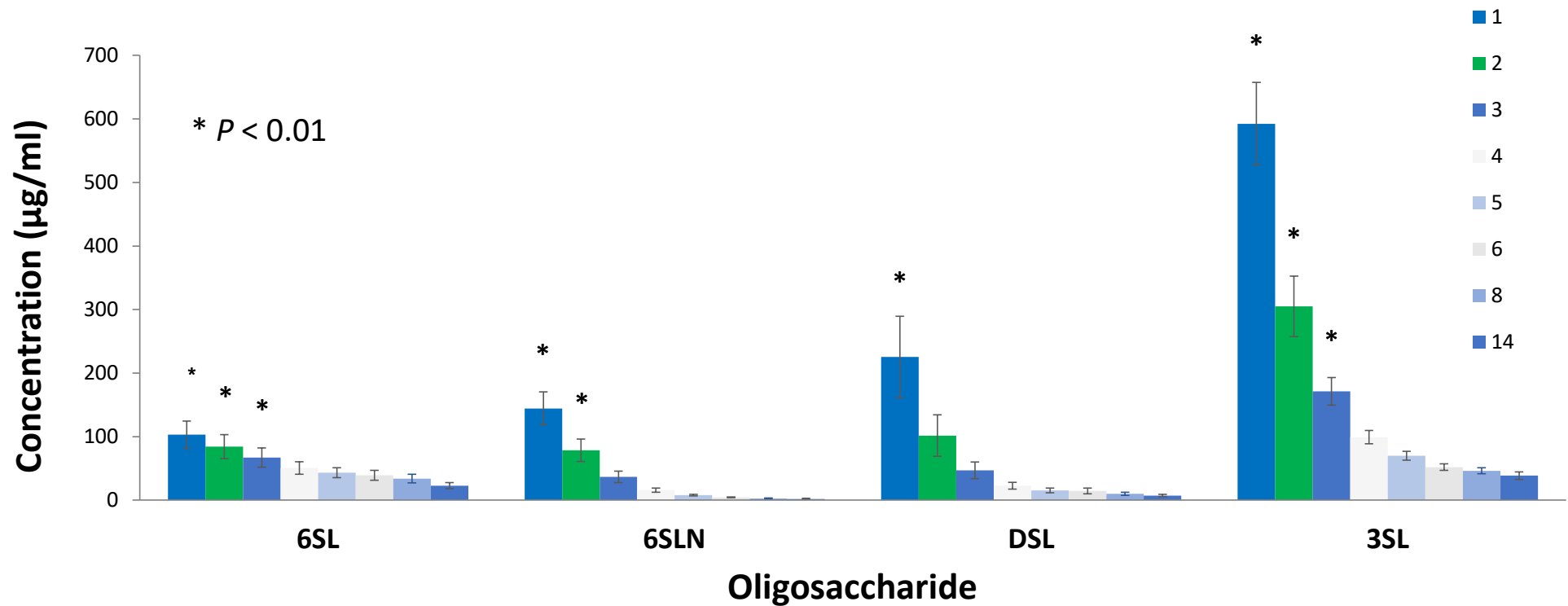
Colostrals Peptides



Colostrum Oligosaccharides

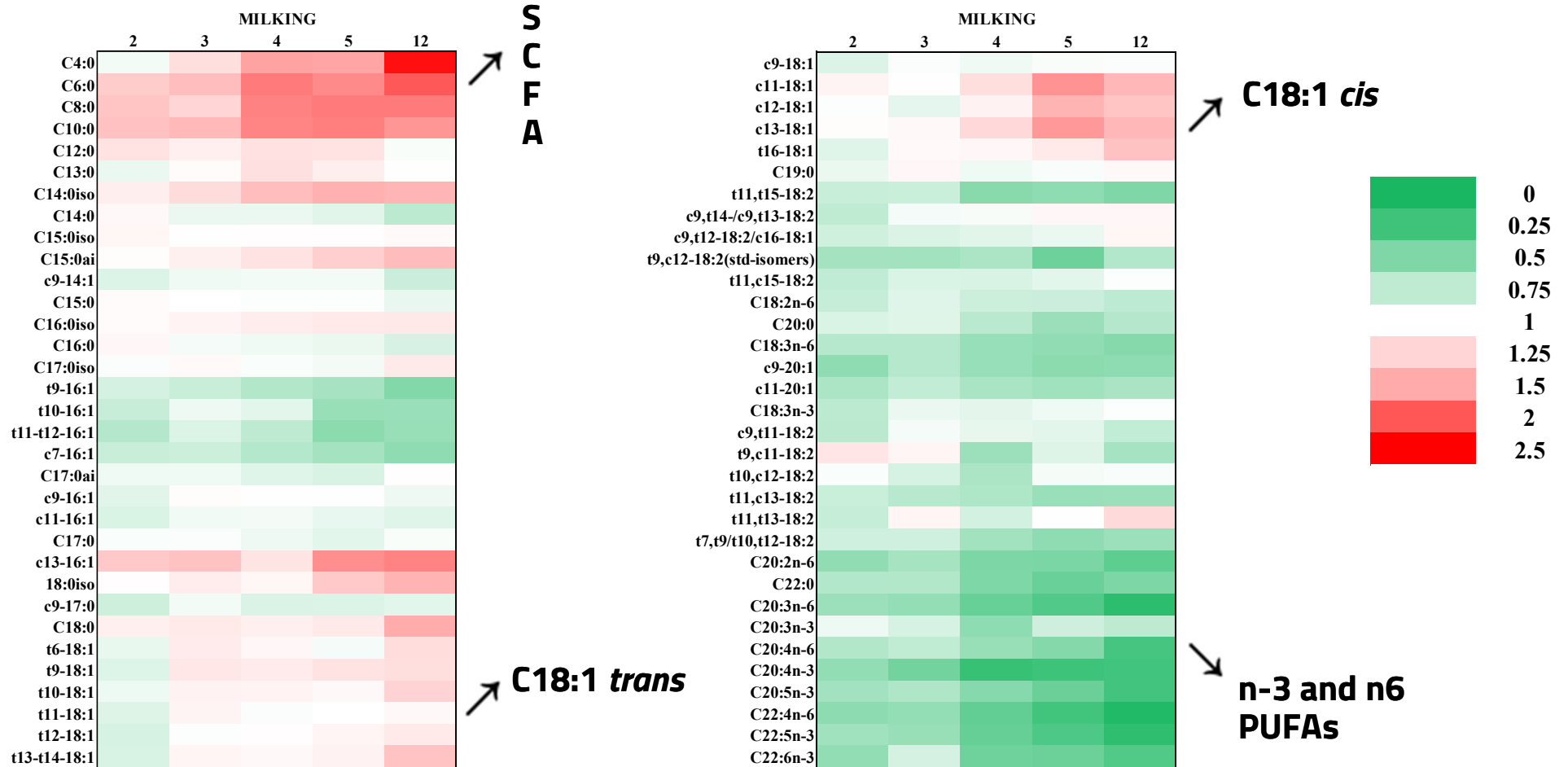


Colostrals Oligosaccharides



Oligosaccharides are produced in higher concentrations in milkings 1-3 compared to milking 8+

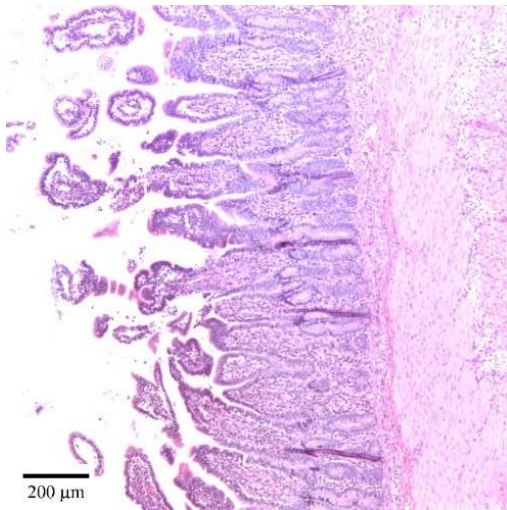
Colostral Fatty Acids



Extended Colostrum Feeding

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

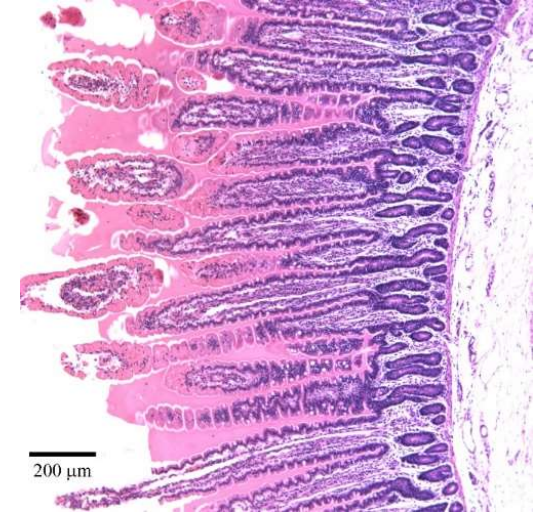
Pyo et al., 2020



Milk

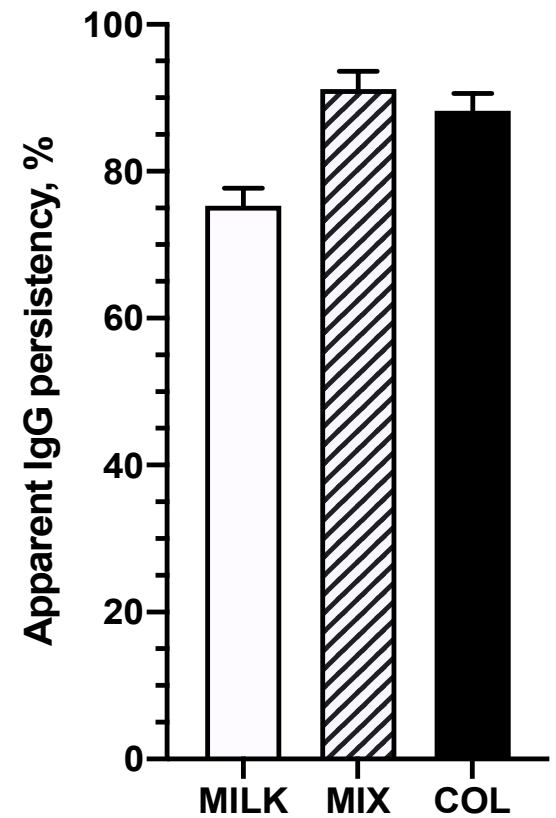
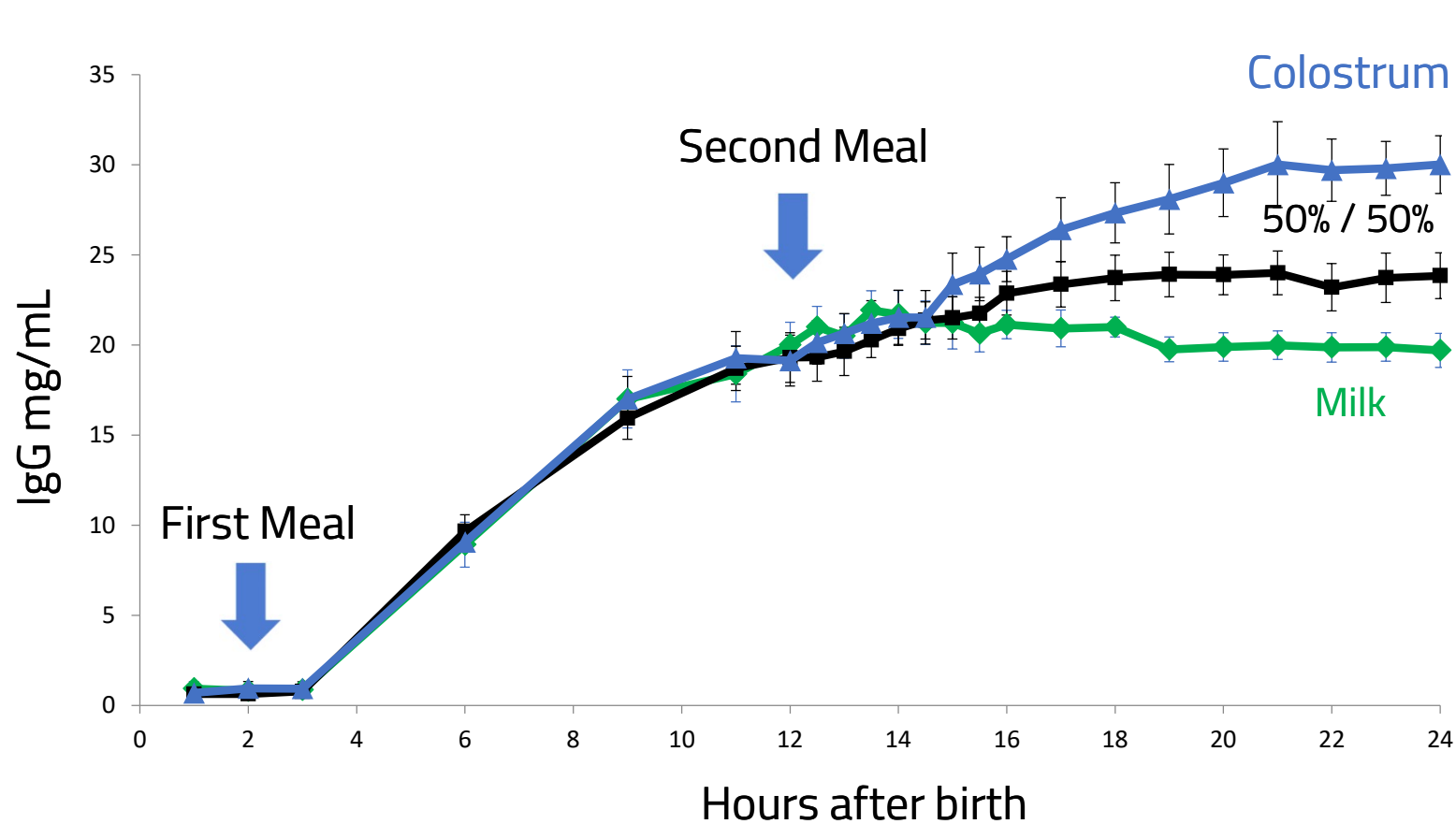


50%/50%



Colostrum

Extended Colostrum Feeding



Hare et al., 2020

Extended Colostrum Feeding

50% Colostrum/50% Milk

Days 2-3

↑ intestinal development

↑ IgG after 12h of life

↓ risk of mortality

10% CR/90% MR

Days 2-14

↑ body weight

↑ average daily gain

↓ risk of mortality

Outline

1. Opportunities
2. Neonatal
3. Preweaning
4. Weaning



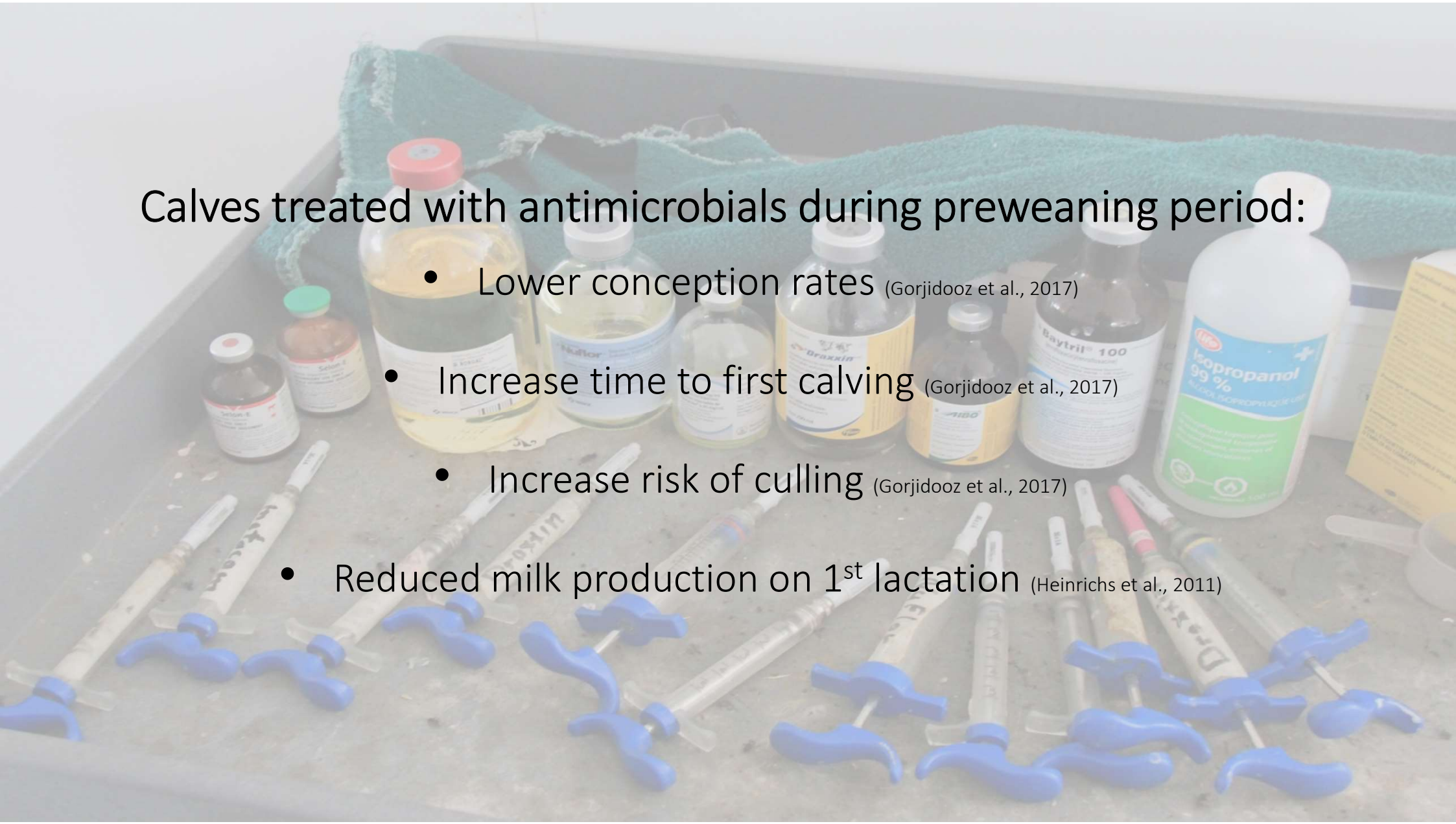
Gut Health During Preweaning Period

- Mortality and Morbidity:
 - **5% mortality, 32% due to digestive disorders**
 - Mean age: 18.3 ± 2.3 d old
 - **38% morbidity, 56% due to digestive disorders**
- Immune Status:
 - 24% of calves failed passive transfer
- Antibiotic Use:
 - **26.8% of calves receive antibiotics**
 - 48.4% for digestive disorders

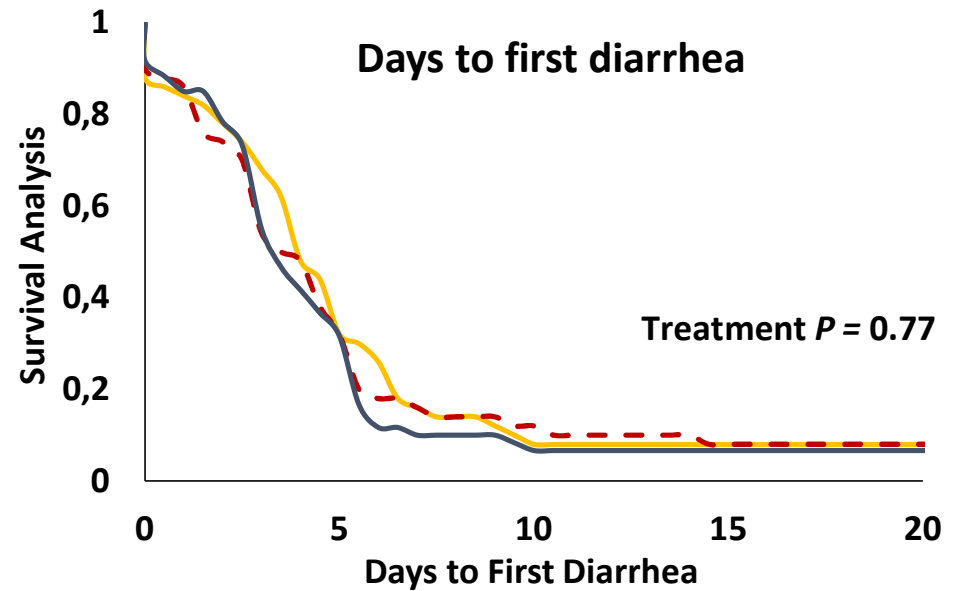
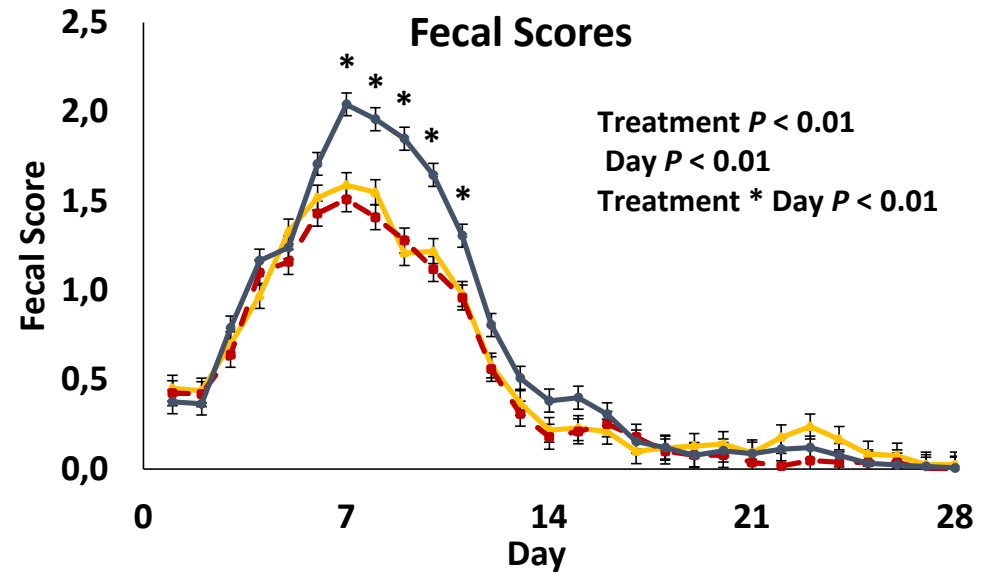
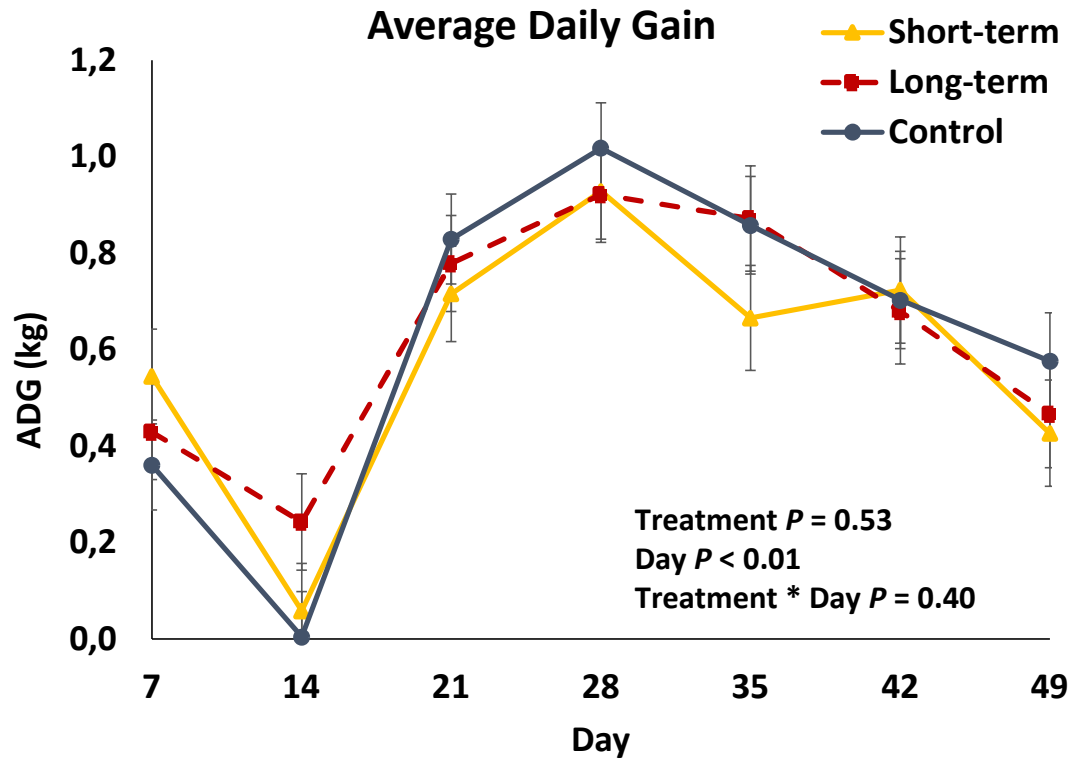


Calves treated with antimicrobials during preweaning period:

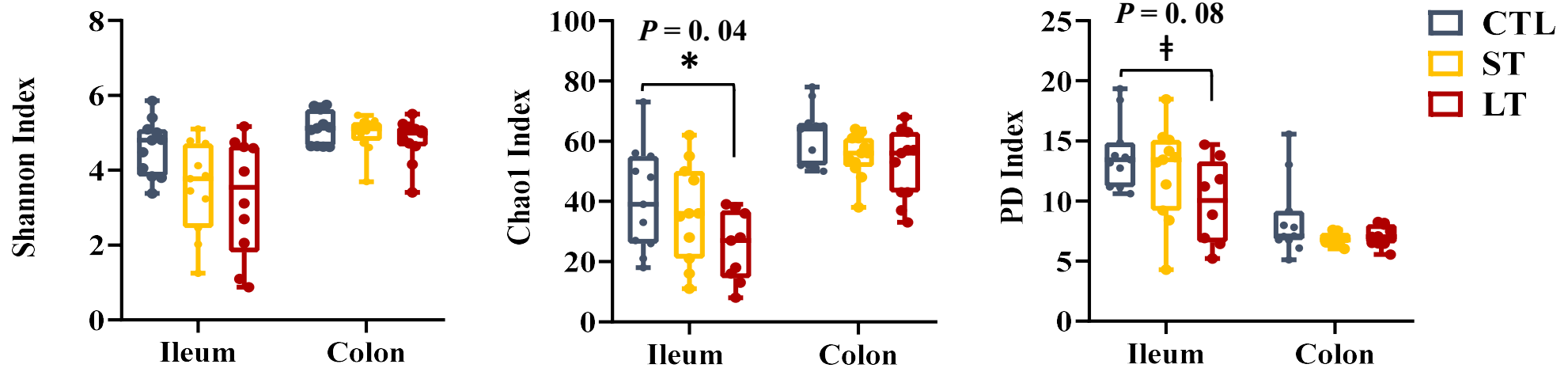
- Lower conception rates (Gorjidooz et al., 2017)
- Increase time to first calving (Gorjidooz et al., 2017)
- Increase risk of culling (Gorjidooz et al., 2017)
- Reduced milk production on 1st lactation (Heinrichs et al., 2011)



Prophylactic Neomycin



Neomycin Host-Microbial Interactions

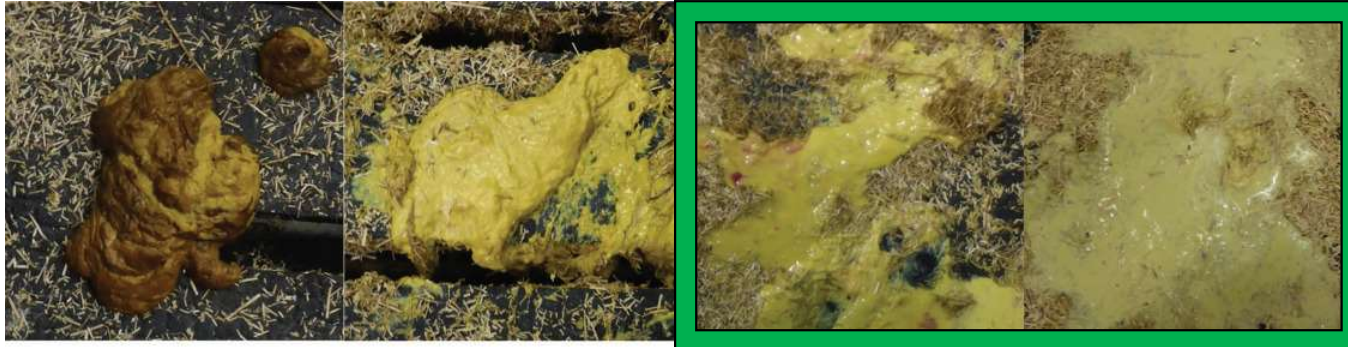


• Impacts on the Host

- Increases gut permeability in calves
- Alters metabolism of calves
 - Bile acids in tissues and circulation
 - Expression of metabolism and immune genes in adipose tissue



Evaluating Colostrum as a Therapy for Diarrhea



01. Fecal consistency scoring

Calves were evaluated daily after arrival to a calf rearing facility in Ontario.

02. Randomly assigned to 3 groups

Calves randomly assigned to control group, short-term colostrum supplementation (2 days), or long-term supplementation (4 days).

03. Followed for 56 d after enrollment

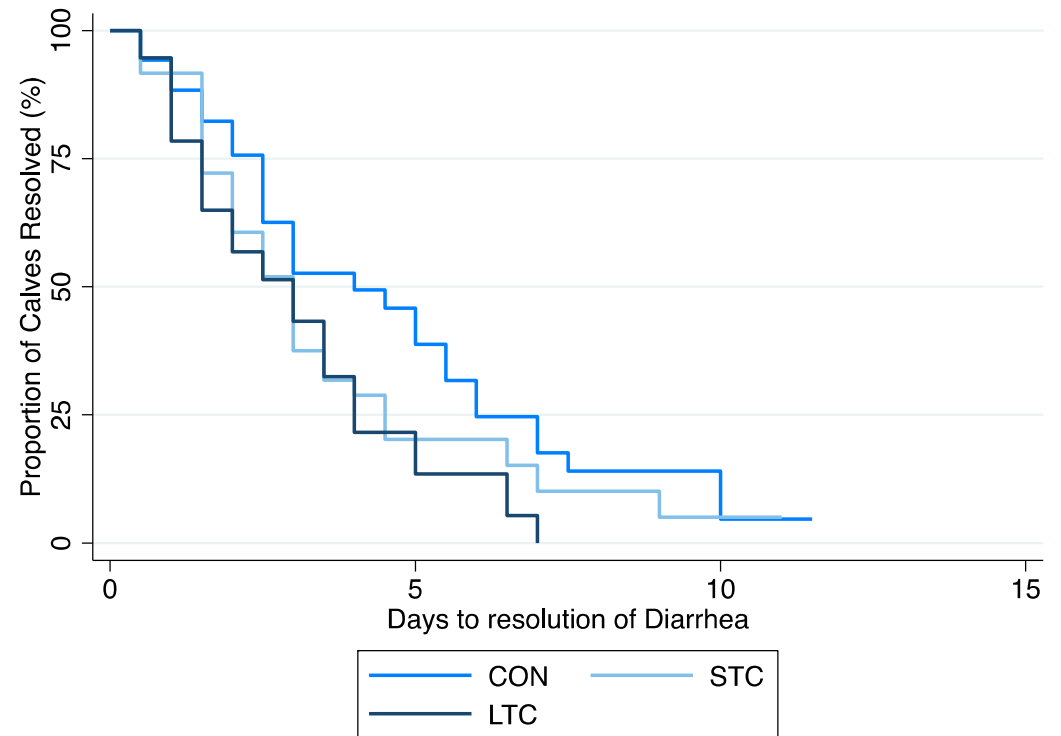
Calves fecal and respiratory scored daily and had body weight collected weekly.



Colostrum as a Diarrhea Treatment

50% Colostrum/50% Milk at onset of diarrhea for 2 days (STC) vs 4 days (LTC)

↑ diarrhea resolution



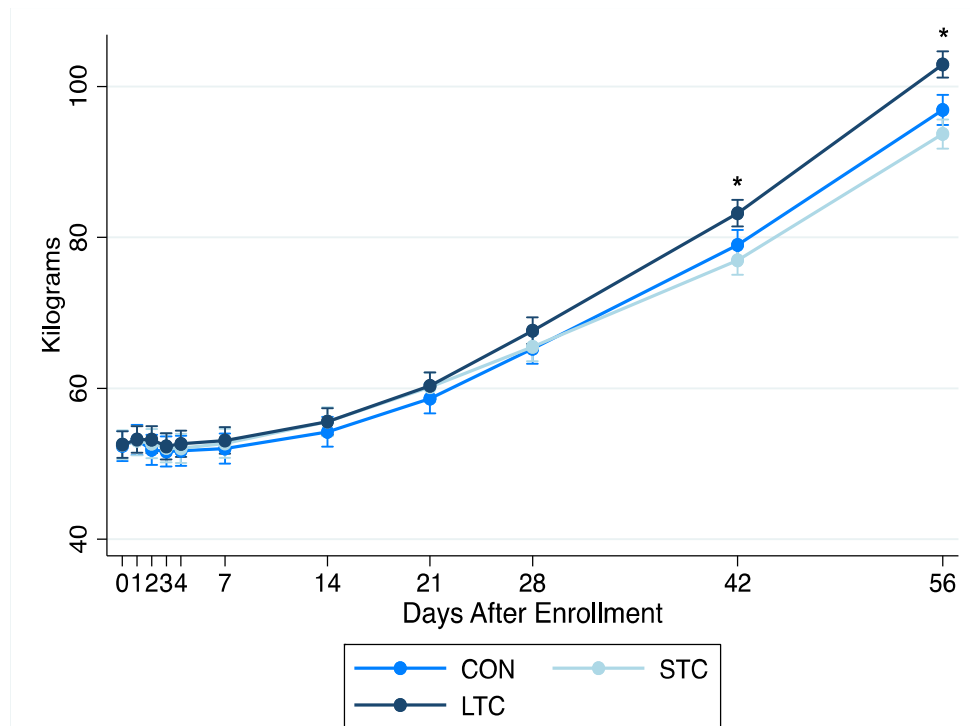
Carter et al., 2022

Colostrum as a Diarrhea Treatment

50% Colostrum/50% Milk
at onset of diarrhea for 2 days
(STC) vs 4 days (LTC)

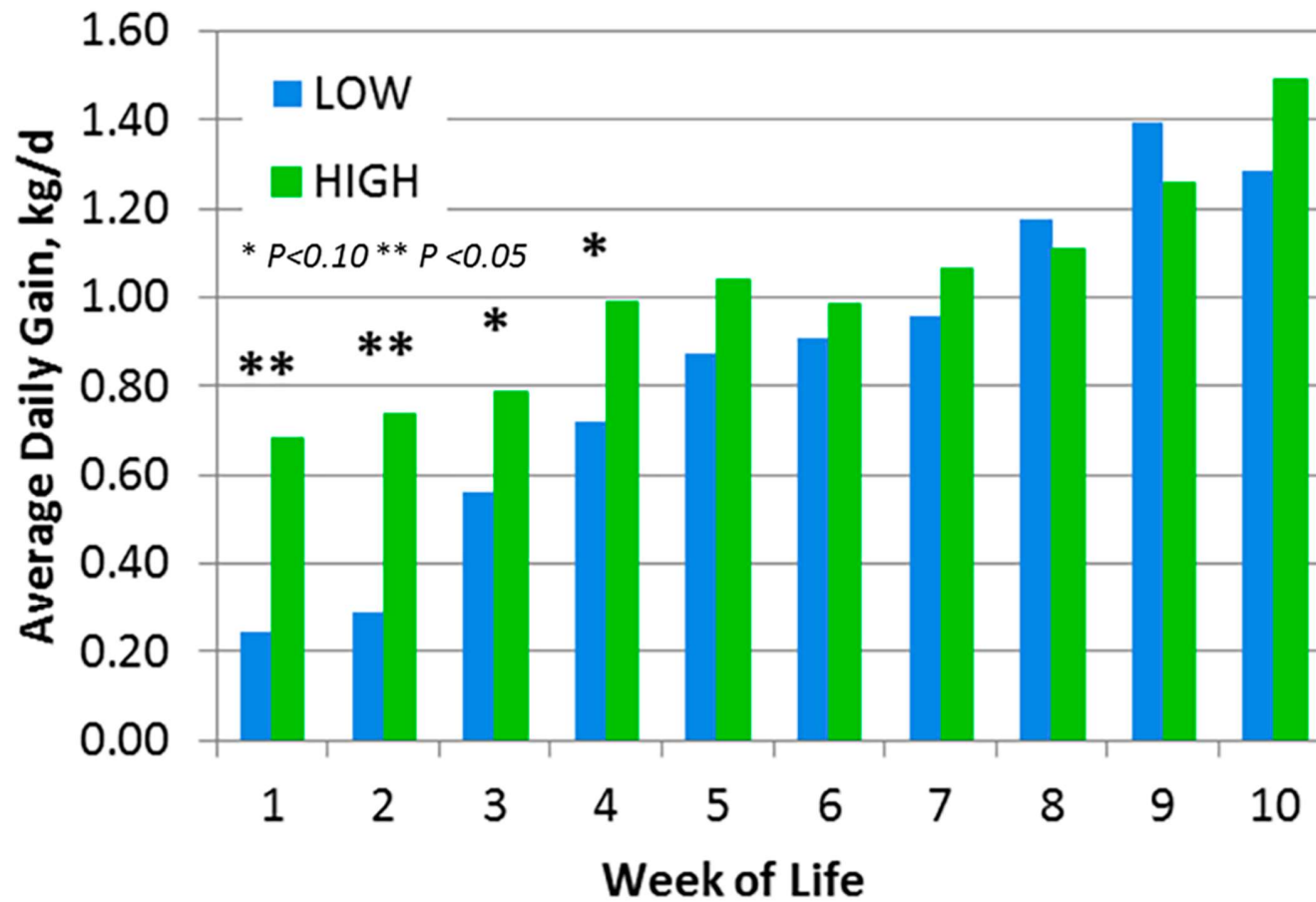
↑ diarrhea resolution

↑ preweaning ADG



Carter et al., 2022

5 (Low) vs 10L (High)

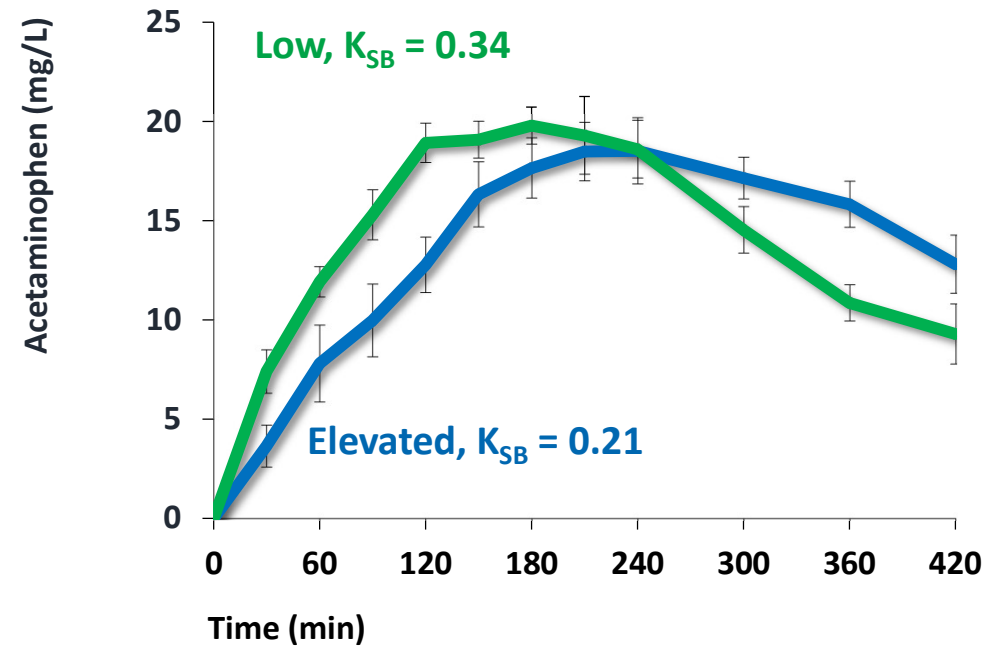
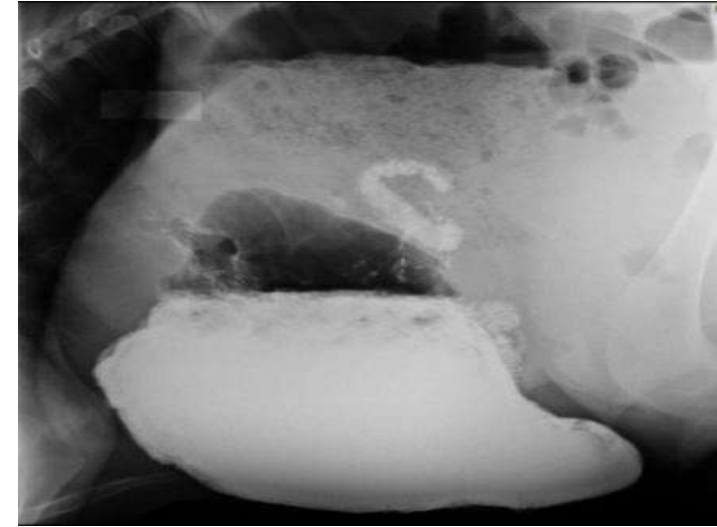


Larger Meal Size and Insulin Sensitivity

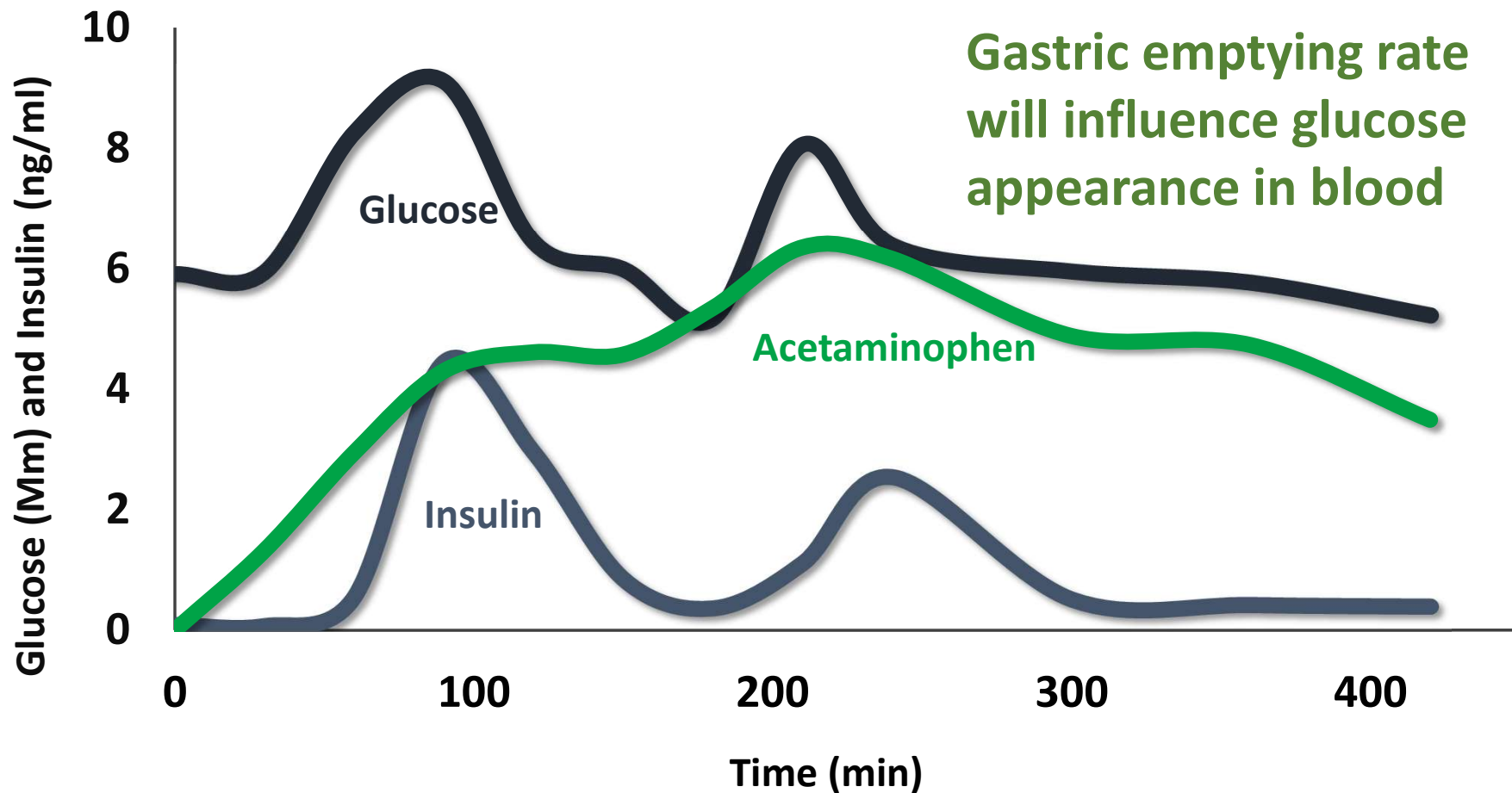
Compared calves fed elevated (8L/d) vs low (4L/d) plane of milk 2x per day

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

MacPherson et al., 2016

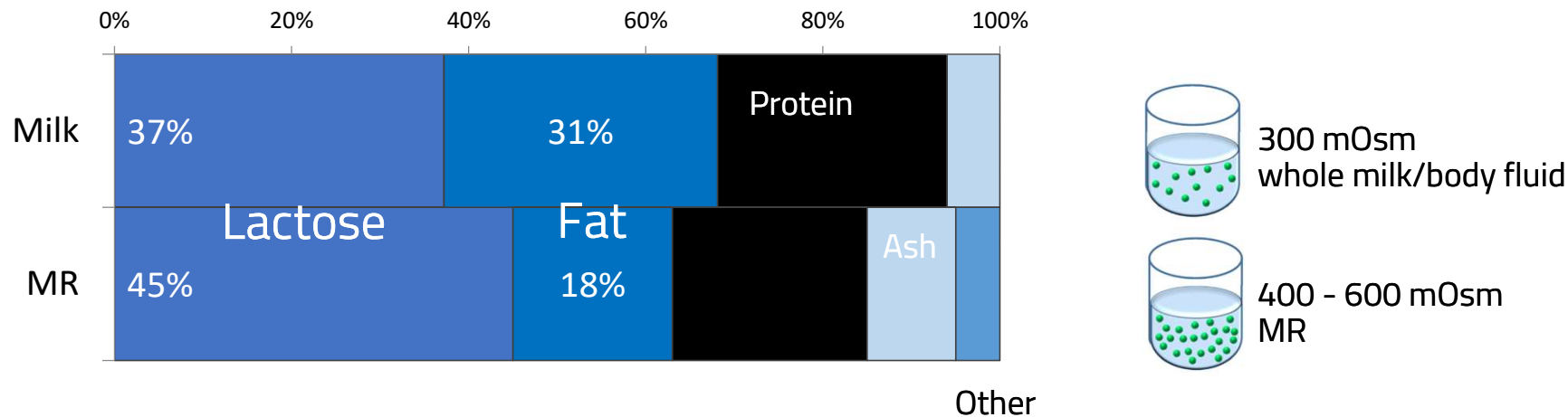


Gastric Emptying and Glucose-Insulin Dynamics



Whole Milk vs. Milk Replacer

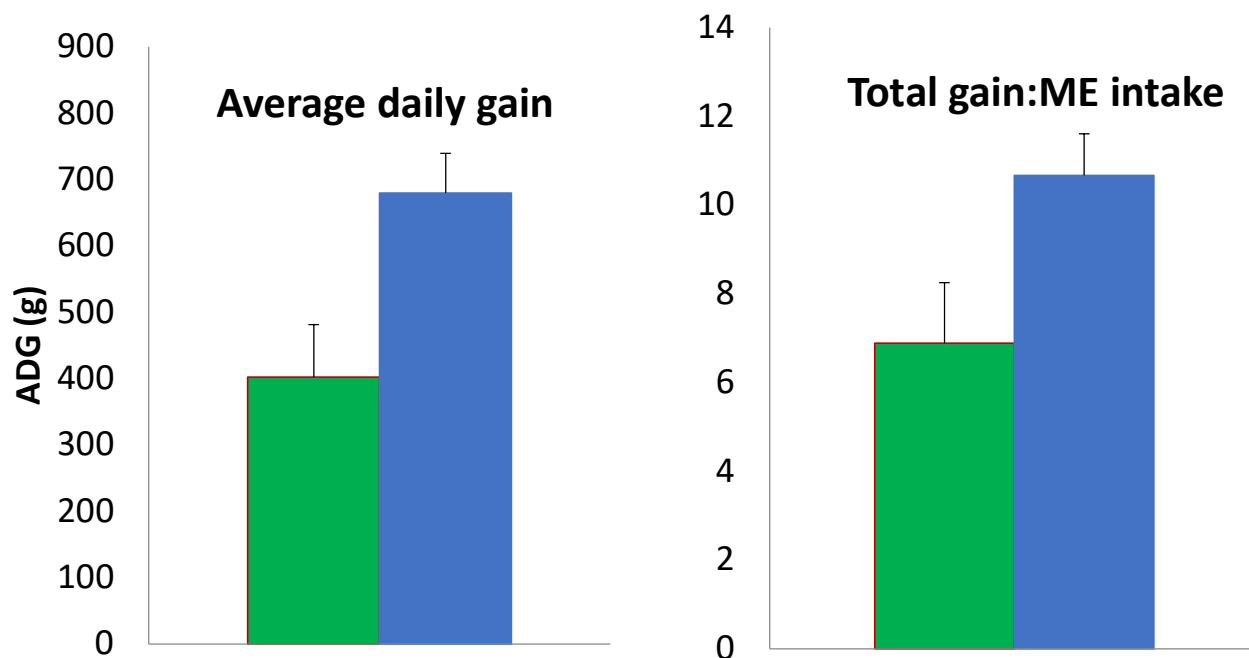
Most MR are high in lactose and low in fat compared to whole milk



- Hypertonic MR increases gut permeability
- High lactose milk replacers impacts insulin sensitivity

High Fat vs. High Lactose: First Week of Life

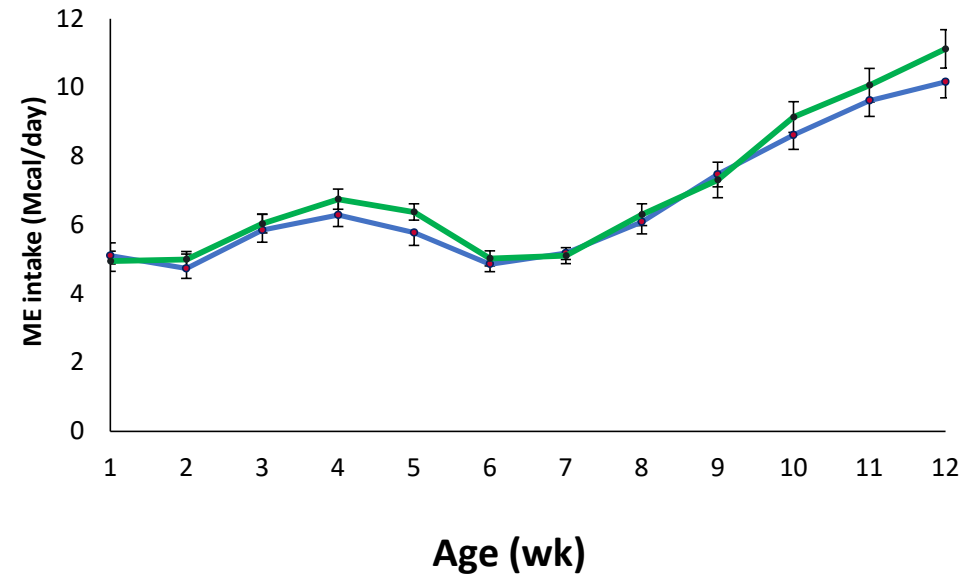
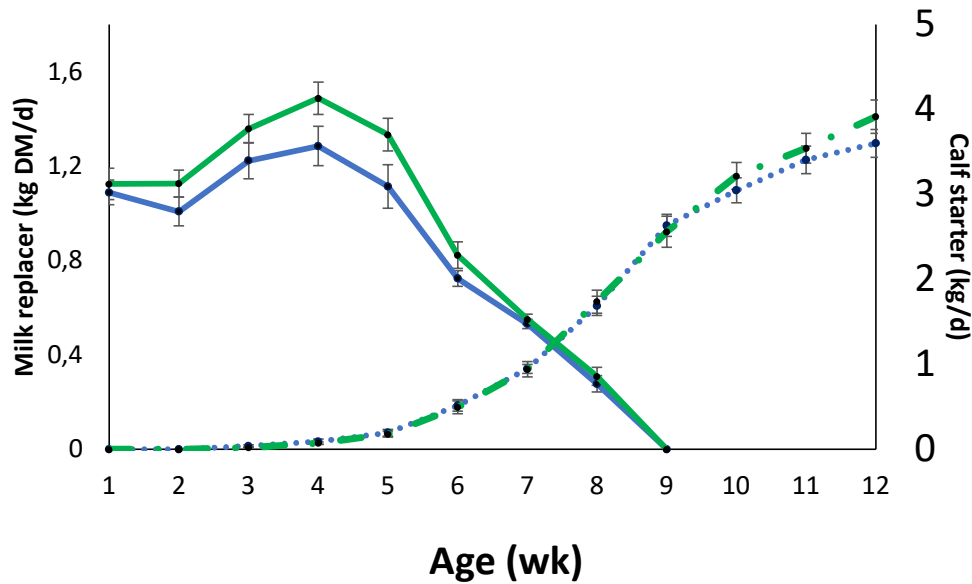
High Fat vs. High Lactose



- Calves fed the high fat MR gained more per unit of ME intake
- More energy was available to be retained

High Fat vs. High Lactose: Ad libitum

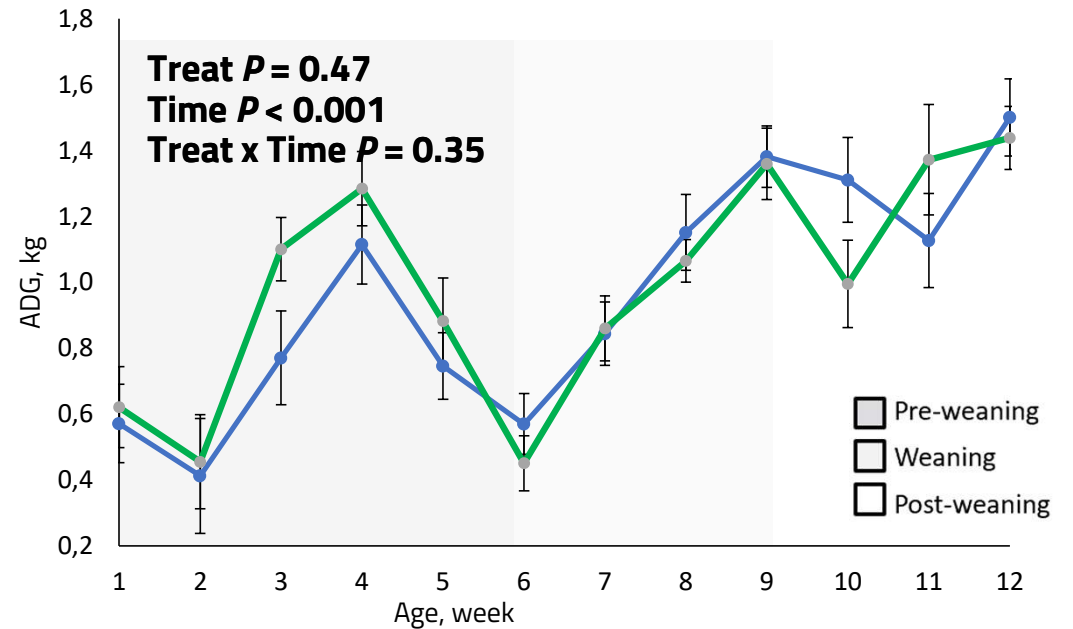
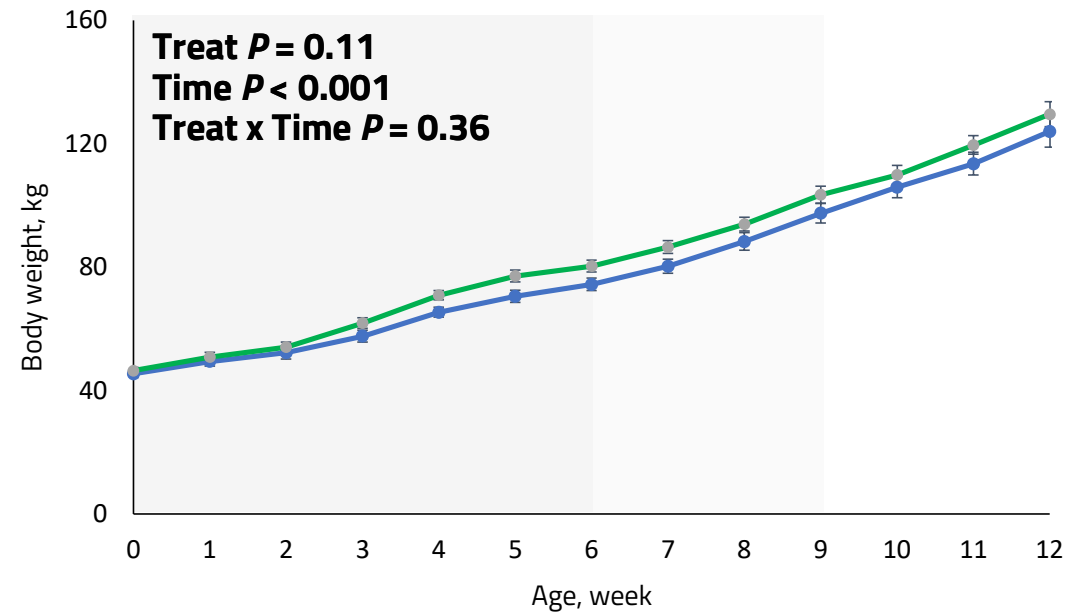
High Fat vs. High Lactose



- Up to 3L/d difference with no evident negative effect on solid feed
- Calves consuming MR based on energy density of the diets

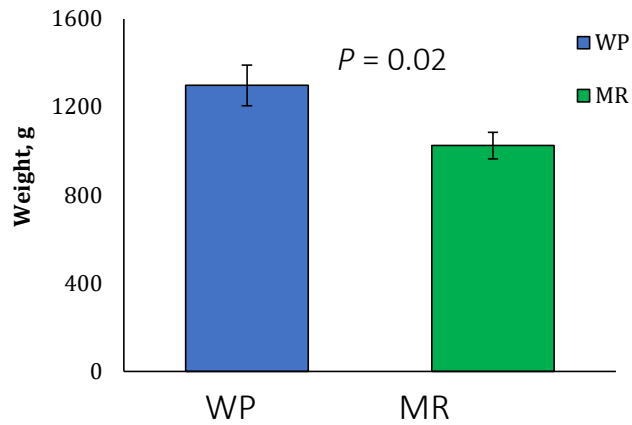
High Fat vs. High Lactose: Ad libitum

High Fat vs. High Lactose

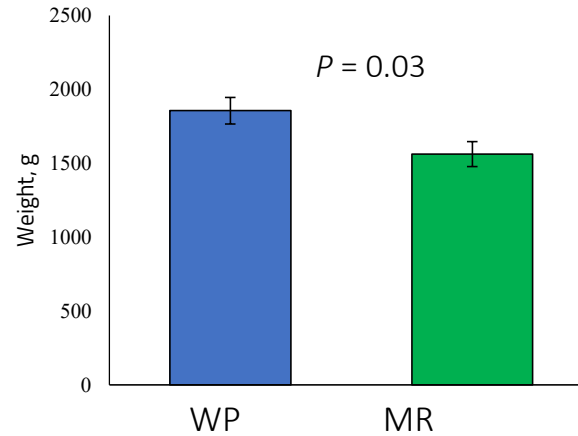


Whole Milk vs. Milk Replacer

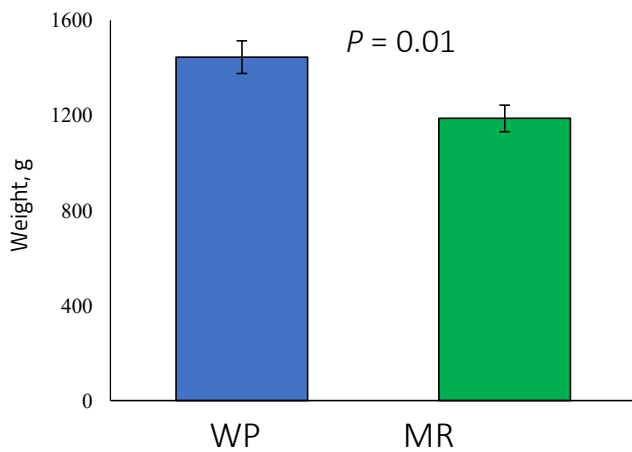
Forestomach Weight



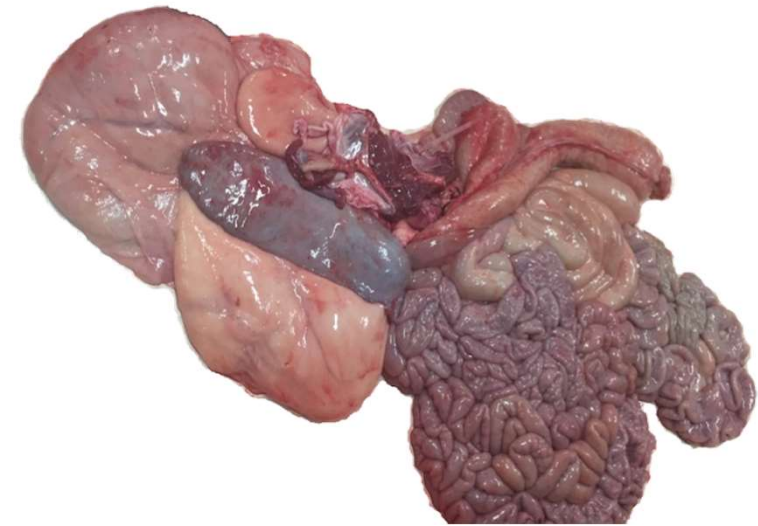
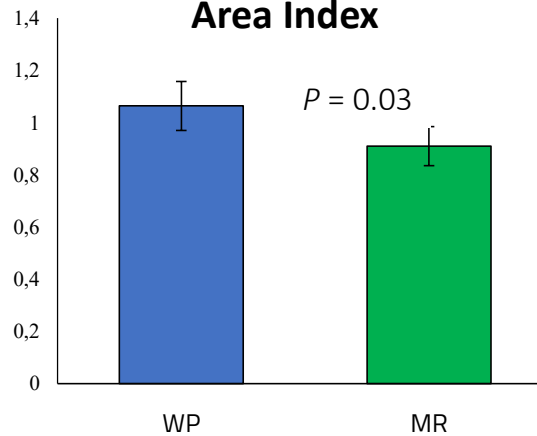
Small Intestine Weight



Jejunum

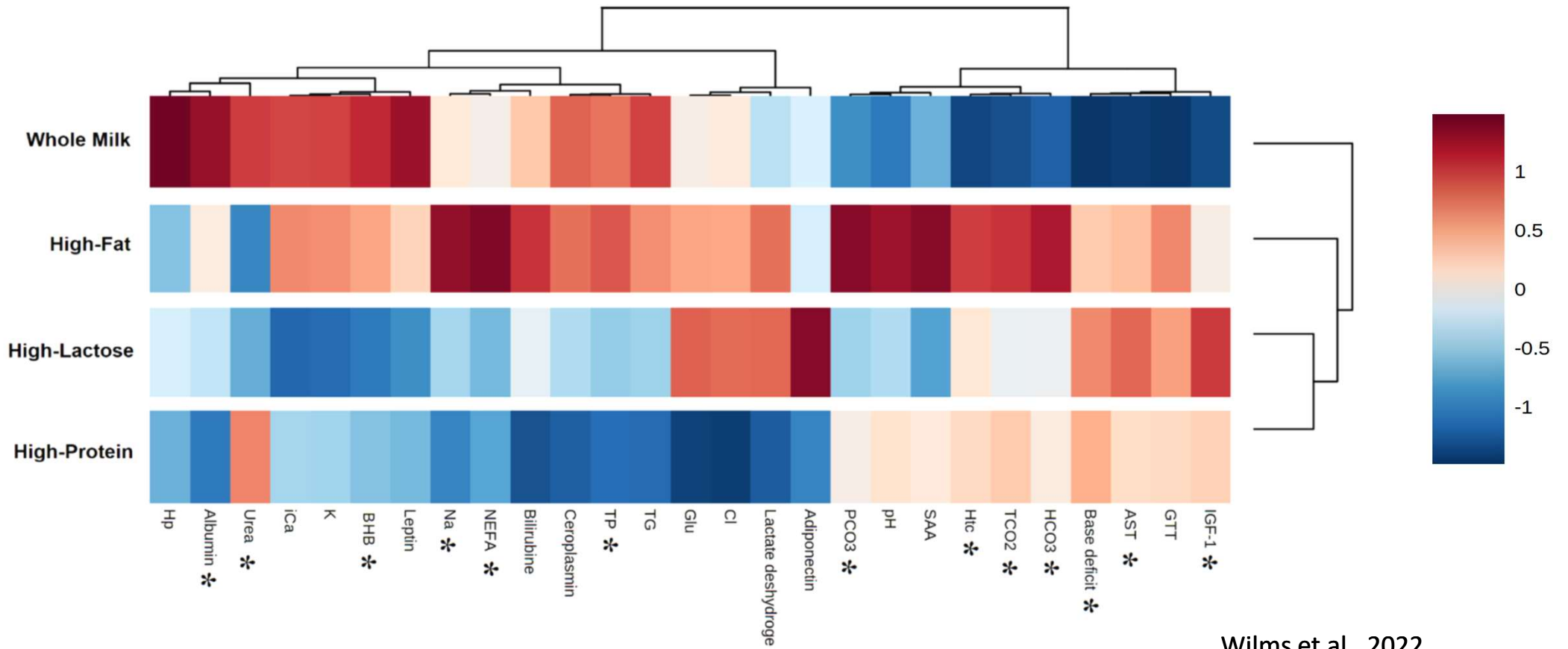


Distal Jejunum Surface Area Index



Mellors et al., 2022

Minimal differences in growth but large differences in metabolic fingerprint



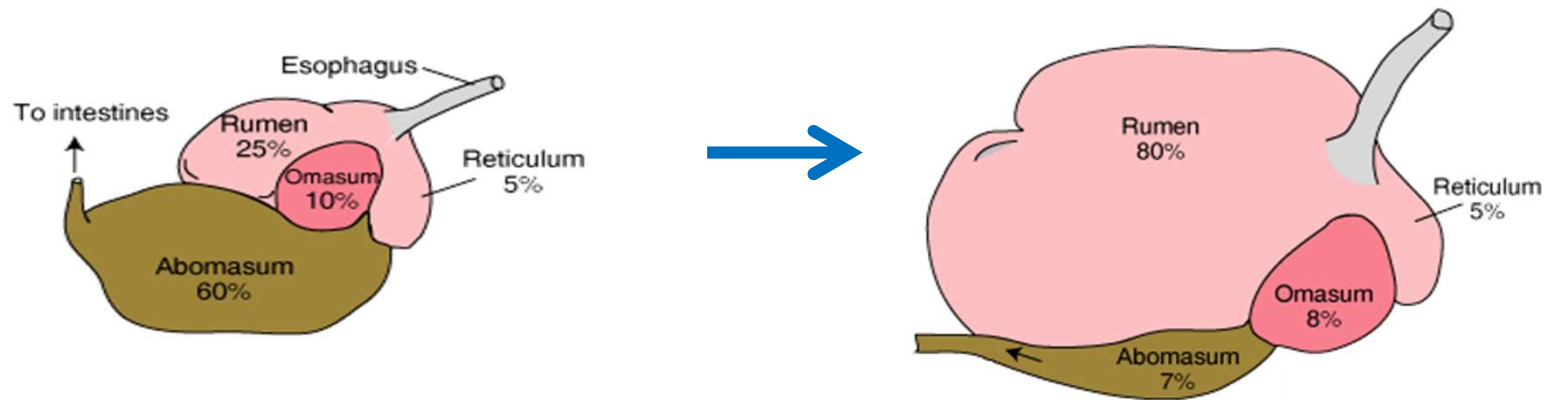
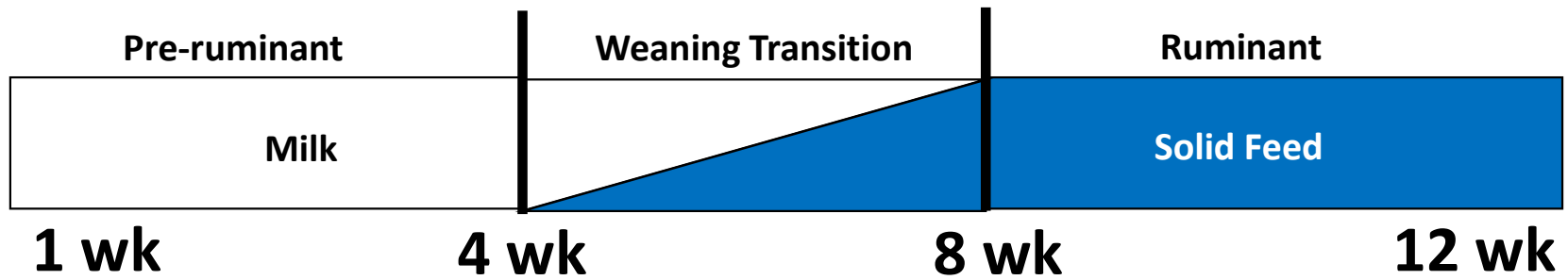
Wilms et al., 2022

Outline

1. Opportunities
2. Neonatal
3. Preweaning
4. Weaning

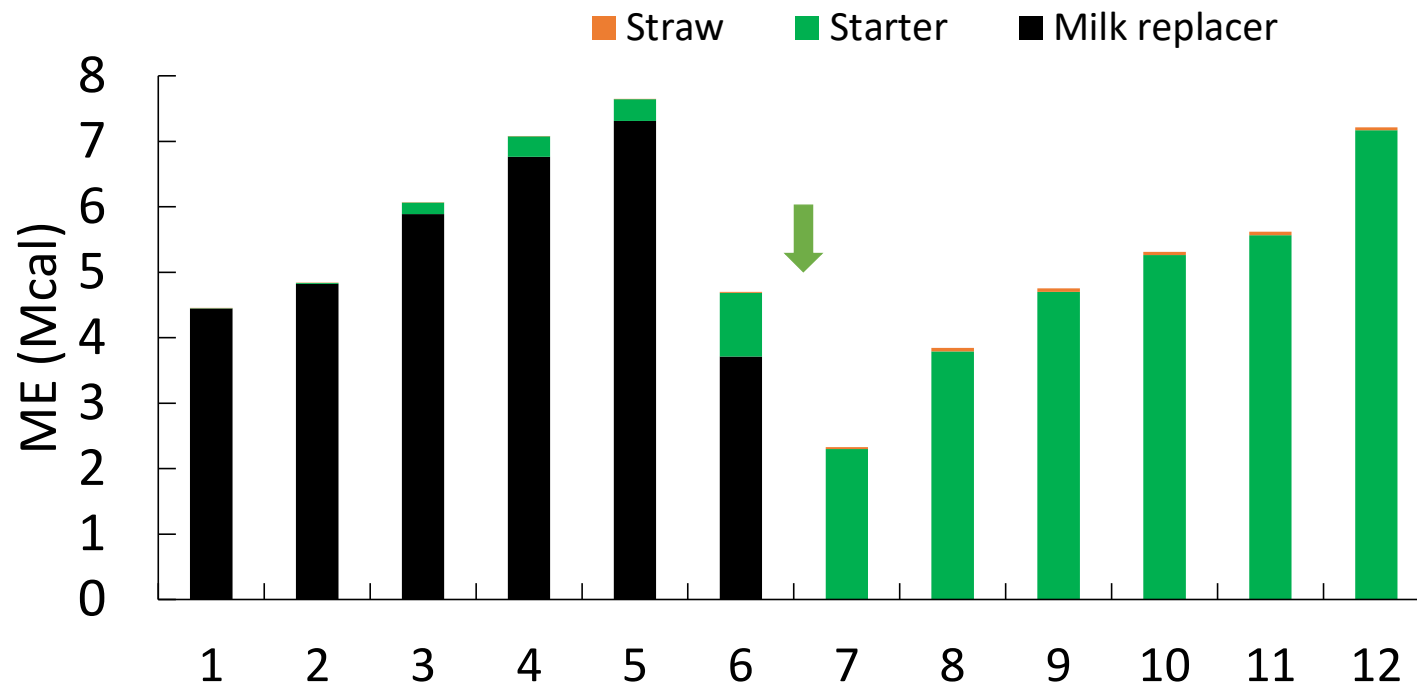


Pre and Post-Weaning



Week

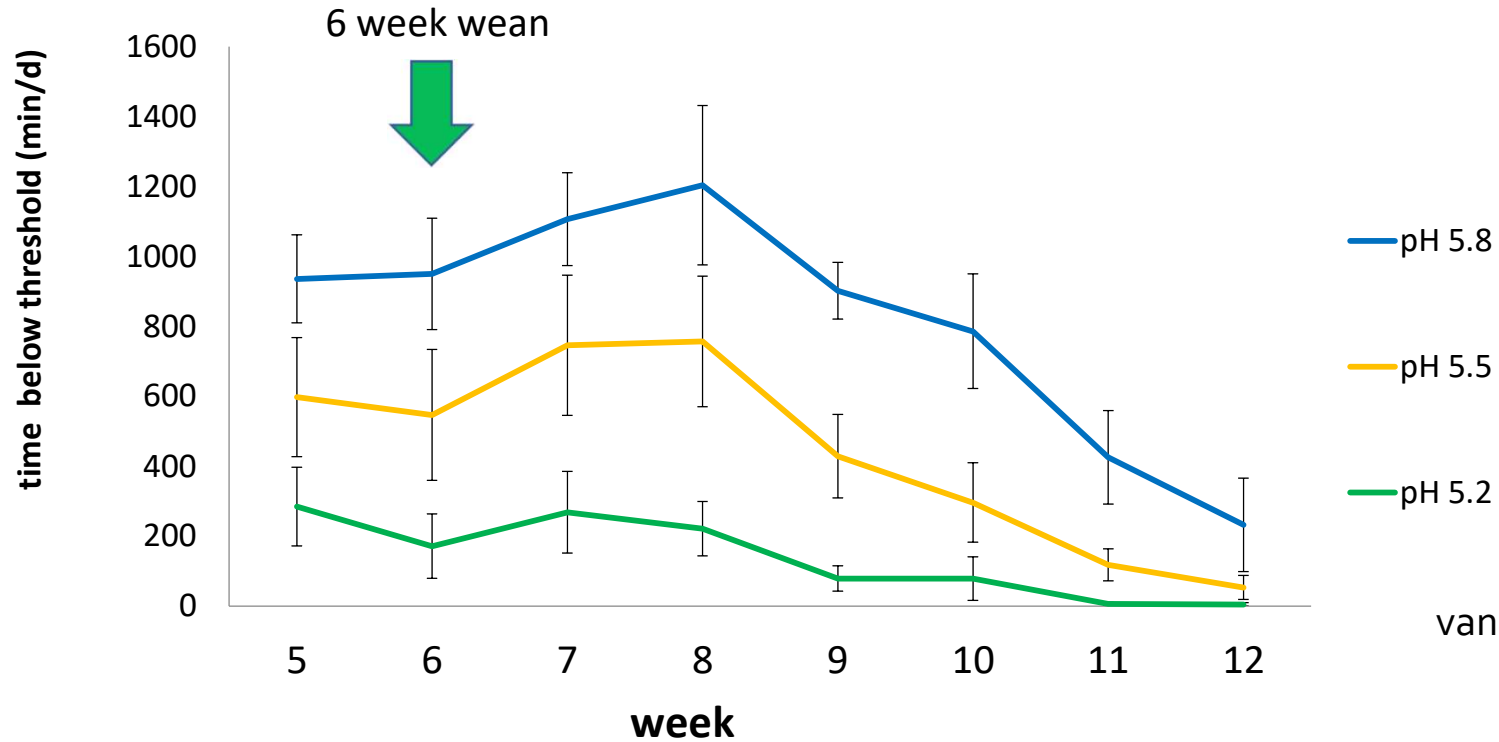
Total Metabolizable Energy



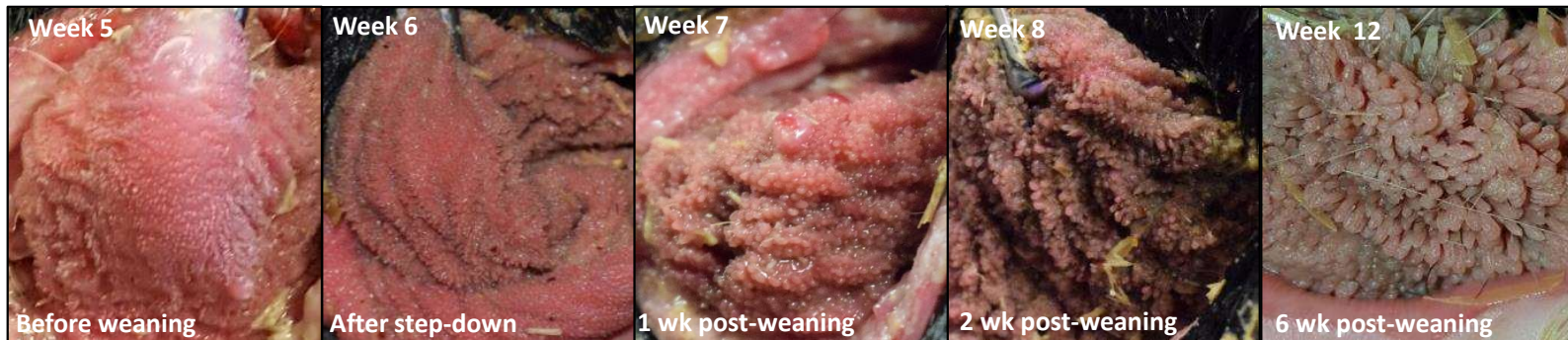
Week

van Niekerk et al., 2021

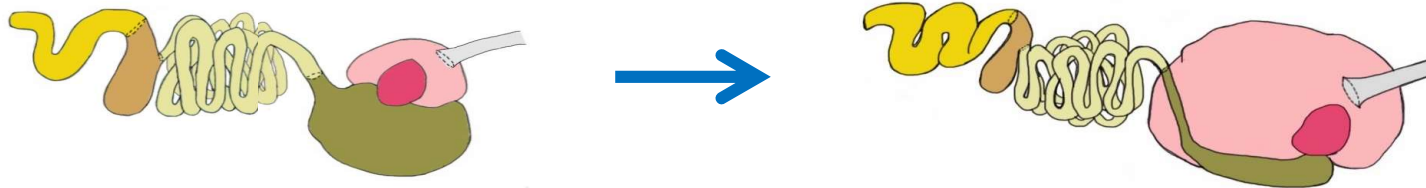
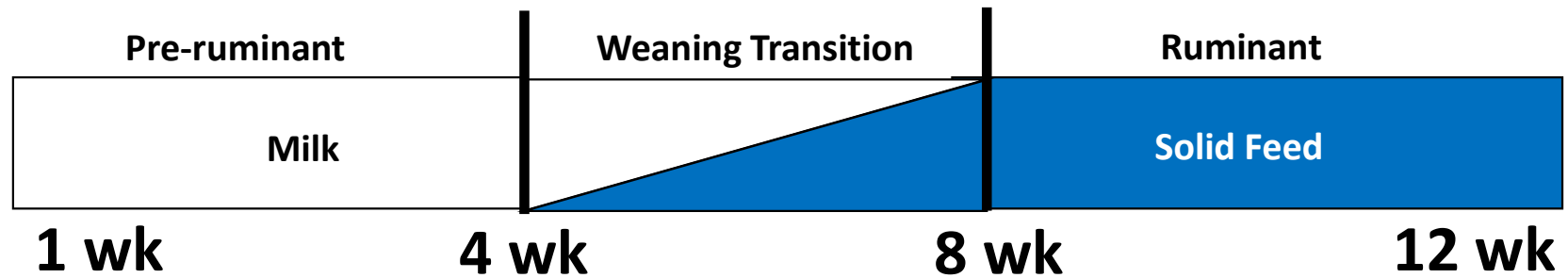
Ruminal pH During Weaning



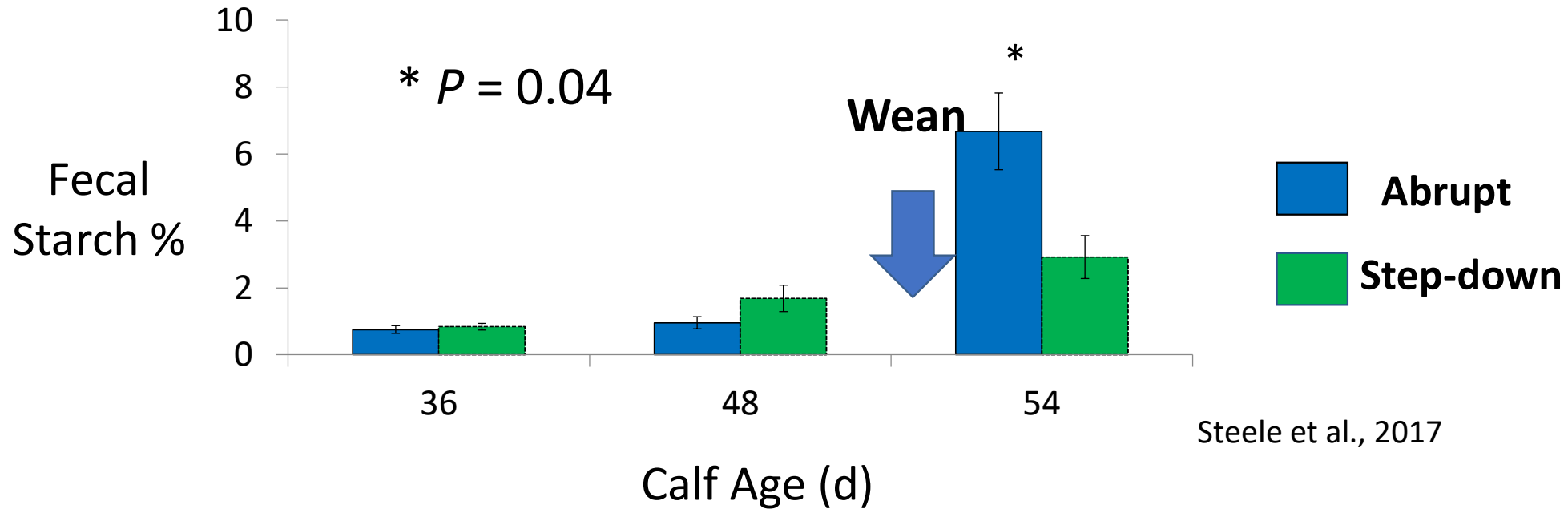
van Niekerk et al., 2021



Pre and Post-Weaning



Abrupt Weaning – Fecal Starch



Starter Chemical Composition

| Authors | % DM | | | |
|------------------------|------|-------|-------------|-------------------|
| | NDF | Sugar | Starch | Sol. Fiber (*cal) |
| Hill et al., 2008 | 38.4 | 5.2 | 15.6 | 5.7 |
| | 15.4 | 5.1 | 43.5 | 11.1 |
| Chapman et al., 2016 | 15 | 6.1 | 40.4 | 11.3 |
| Hill et al., | | | | - |
| | | | | 11.1 |
| Suarez-M | | | | - |
| | | | | - |
| Rosenberg | | | | - |
| Dennis et | | | | 10.3 |
| Quigley et | | | | 7.5 |
| Gelsinger et al., 2019 | 15.1 | 5.0 | 47.2 | - |
| | 25.3 | 6.2 | 35.3 | 3.4 |
| Benetton et al., 2019 | 18.3 | - | 37.3 | - |
| Hu et al., 2019 | 14.5 | 6.0 | 43.9 | 4.0 |

Mean starch content : 37.8%

Mean NDF content: 19.2%

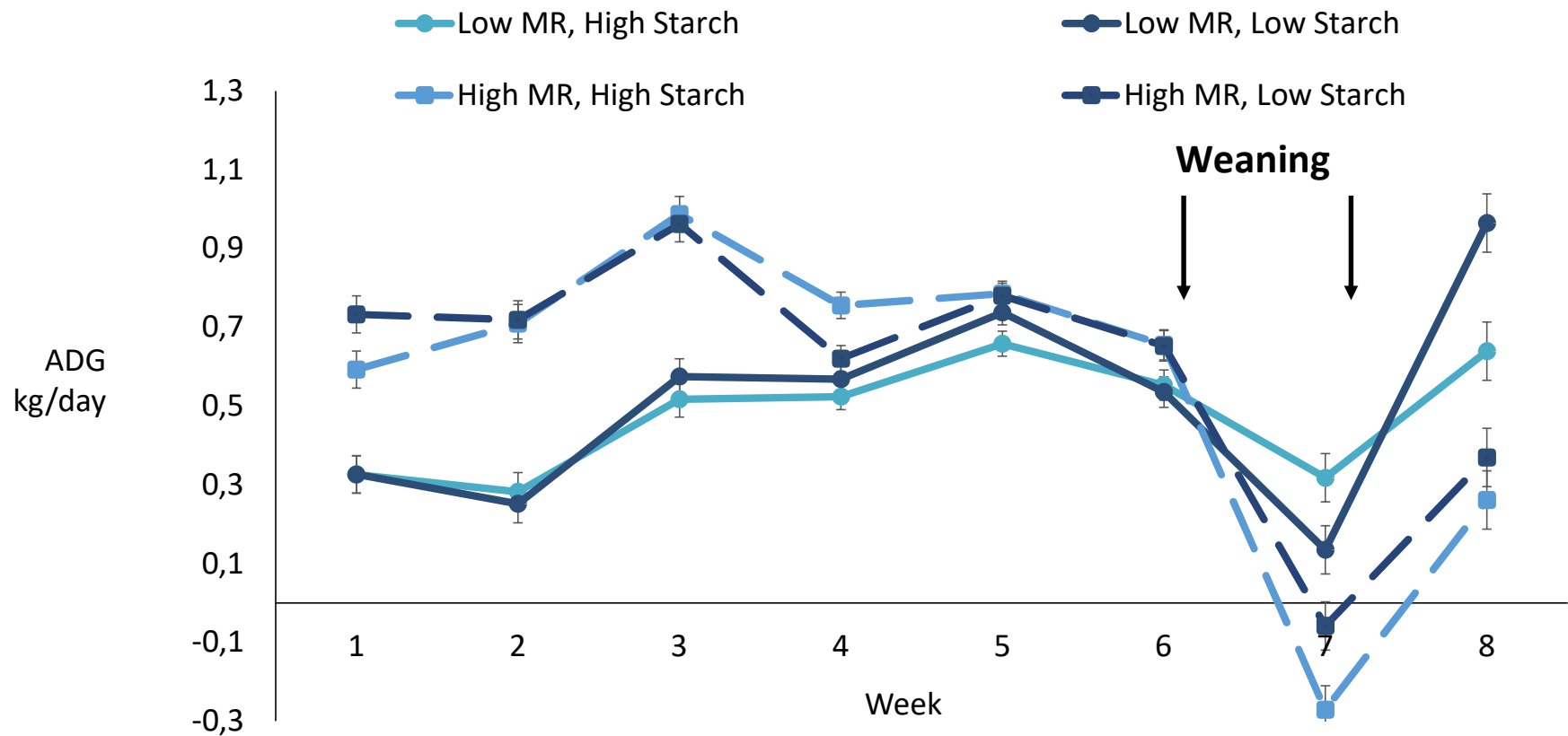
What about starter composition?

- Why do starters range from 10-50% starch?
- Induces ruminal acidosis and possibly hindgut acidosis
- Should starter composition be tailored for milk feeding program?

Hindgut acidosis?

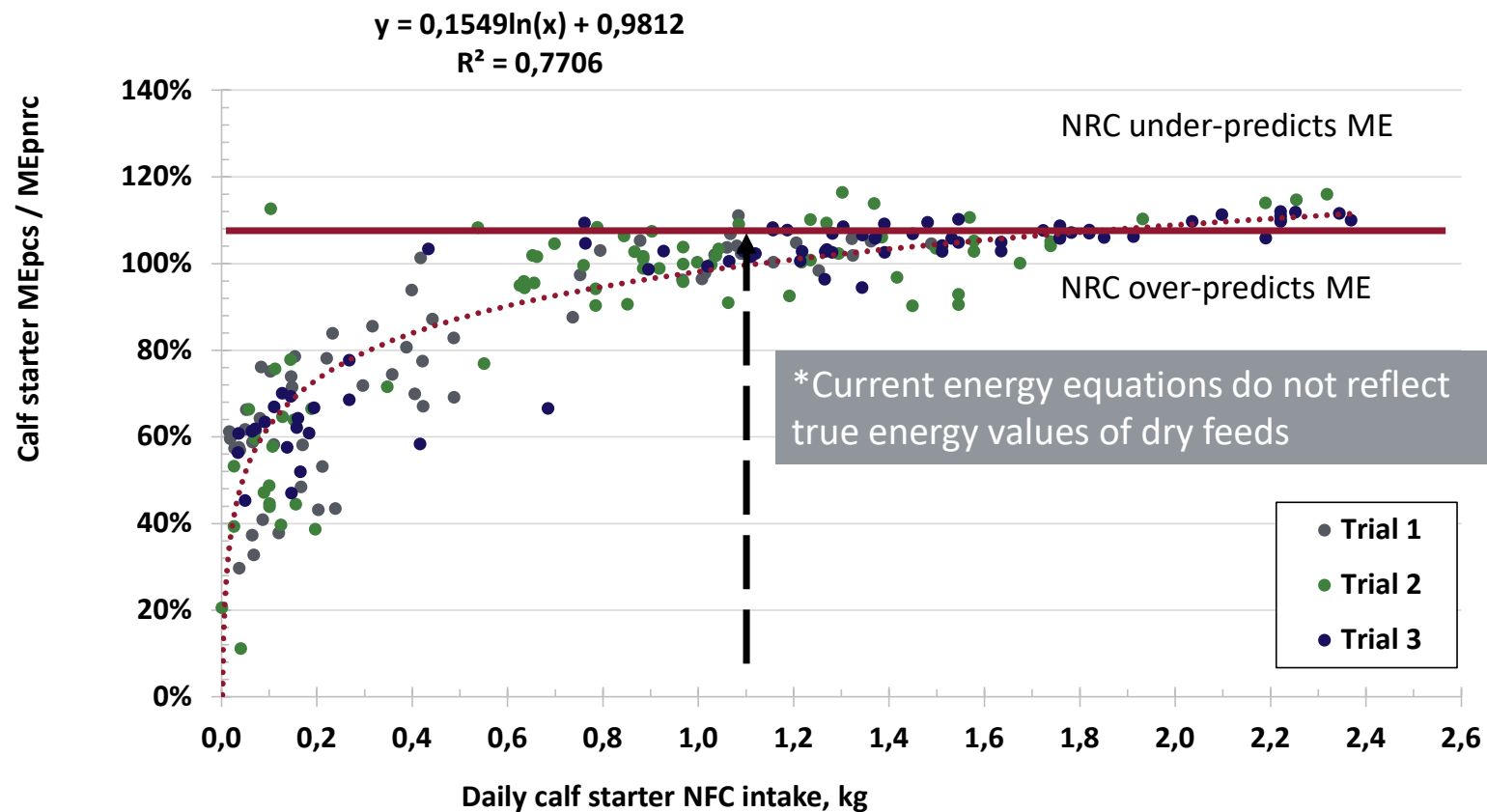


Matching Milk and Solid Feed



Yohe et al., 2021

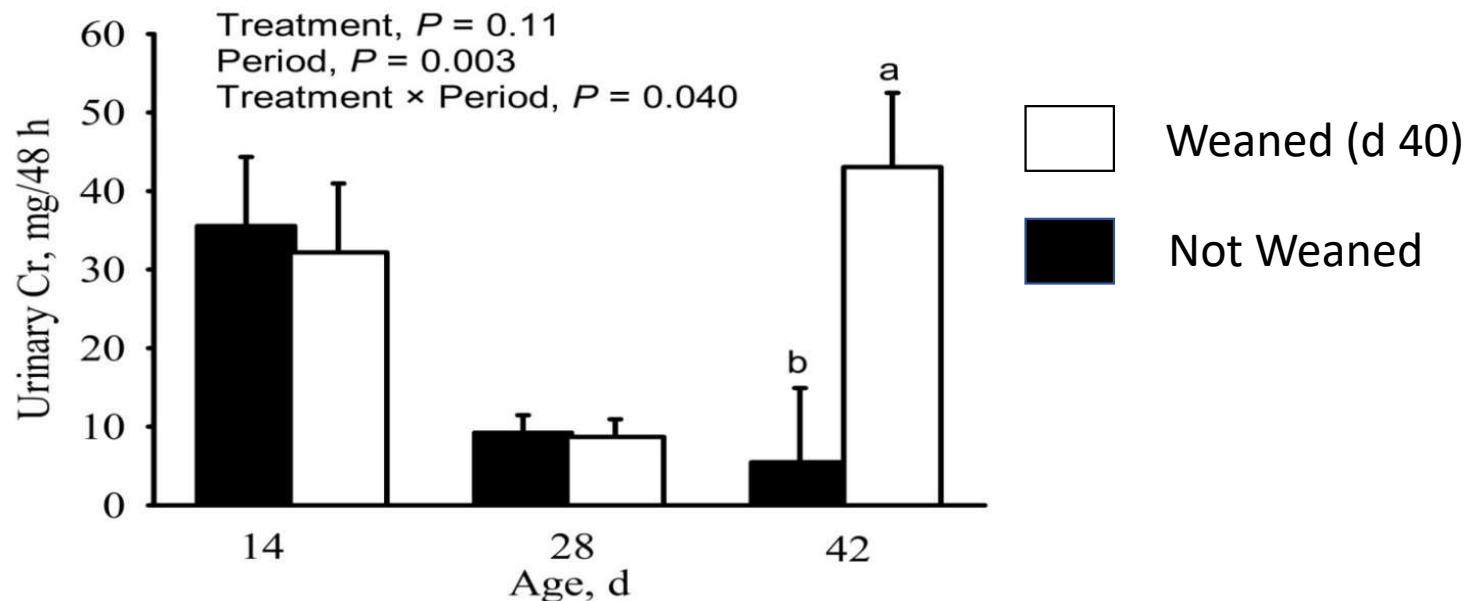
Intake Impacts Energy Value of Calf Starters



Barrier Function at Weaning

- Starter feeding in calves decreased the expression of tight junctions

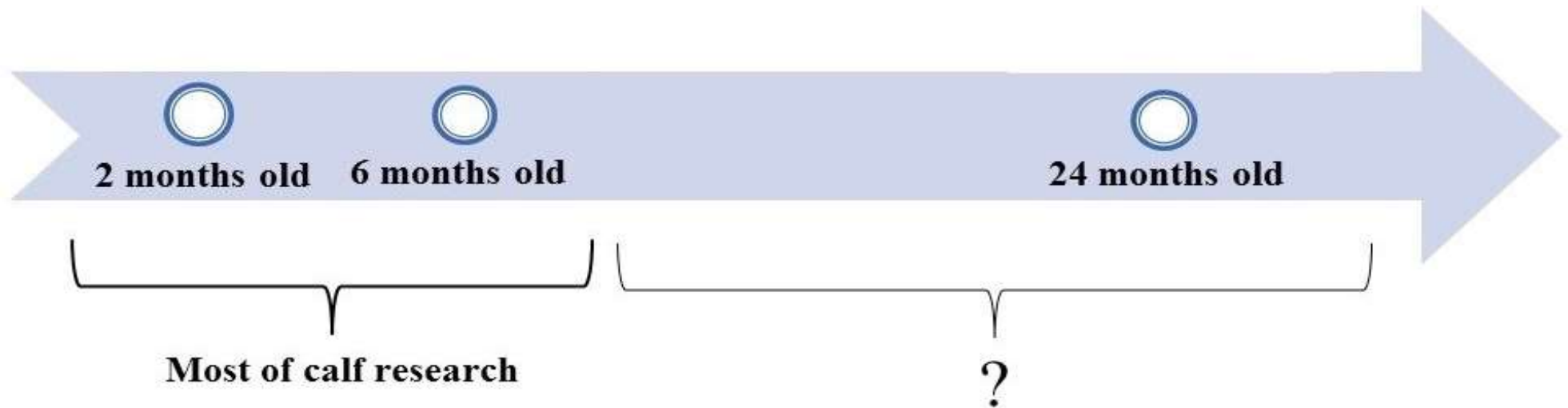
Malmuthuge et al., 2012



Wood et al., 2015

Post-Weaning and Beyond

- An area that has not been studied
- Need to integrate pre and post weaning planes of nutrition with lifetime performance



Review

1. Opportunities

- Gut health challenges are major issues on calf farms that can be improved

2. Neonatal

- Feeding more colostrum and extending colostrum feeding after the first day of life can improve gut health

3. Preweaning

- Calves can consume large meals of milk and milk replacer composition is an important factor

4. Weaning

- Delayed and gradual weaning is essential and large variation in starter composition exists



A close-up, front-facing view of a black, textured microphone head. The microphone is positioned in the lower center of the frame. The background is a large, out-of-focus crowd of people, likely at a concert or event, with many hands raised in the air. The scene is illuminated with vibrant purple and blue stage lights, creating a bokeh effect with bright, glowing spots. A semi-transparent white rectangular box is centered in the upper half of the image, containing the text "Questions?".

Questions?

Practical Translation and Discussion



Colostrum Basics

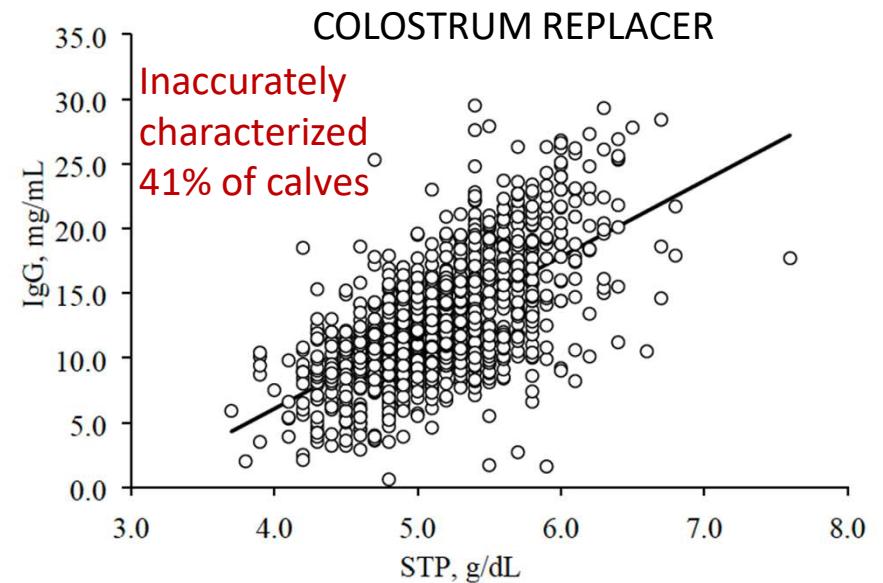
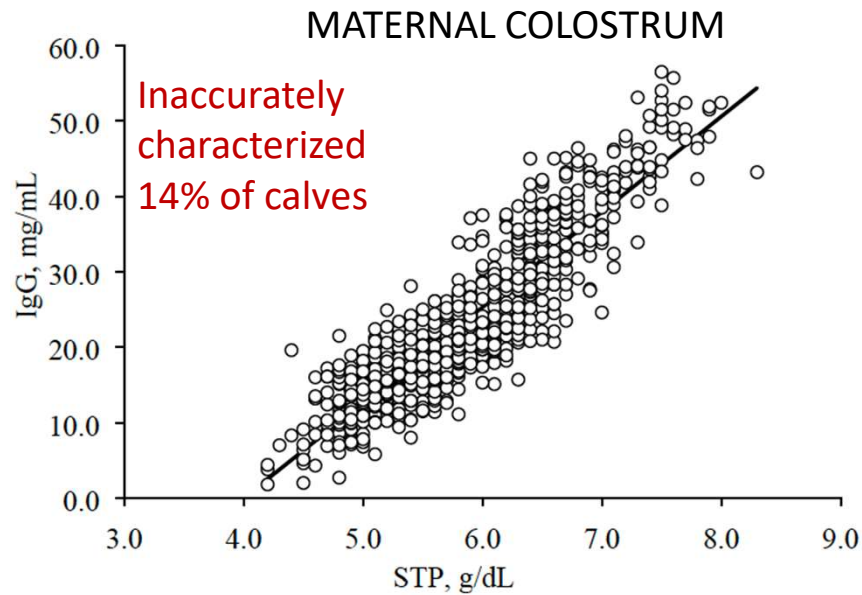


Fischer-Tlustos et al., 2021

Assessing Passive Transfer of Immunity on Farm

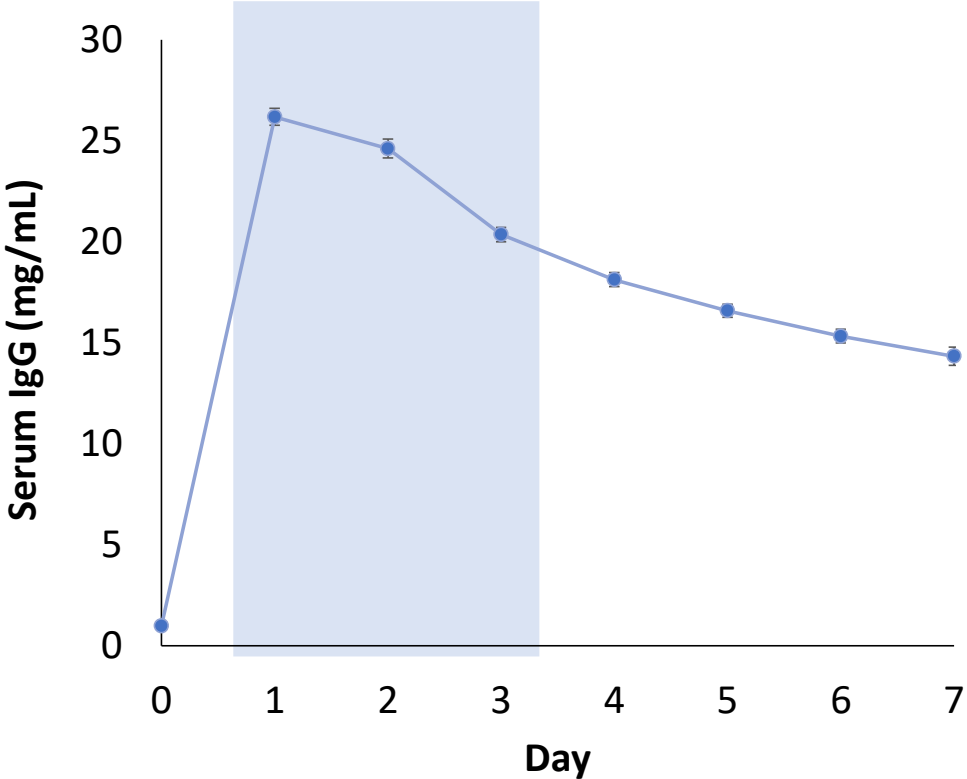


Serum total protein (STP): >5.2 g/dl = passive transfer



STP is not an accurate tool to predict passive transfer status in CR-fed calves

Assessing Passive Transfer of Immunity on Farm



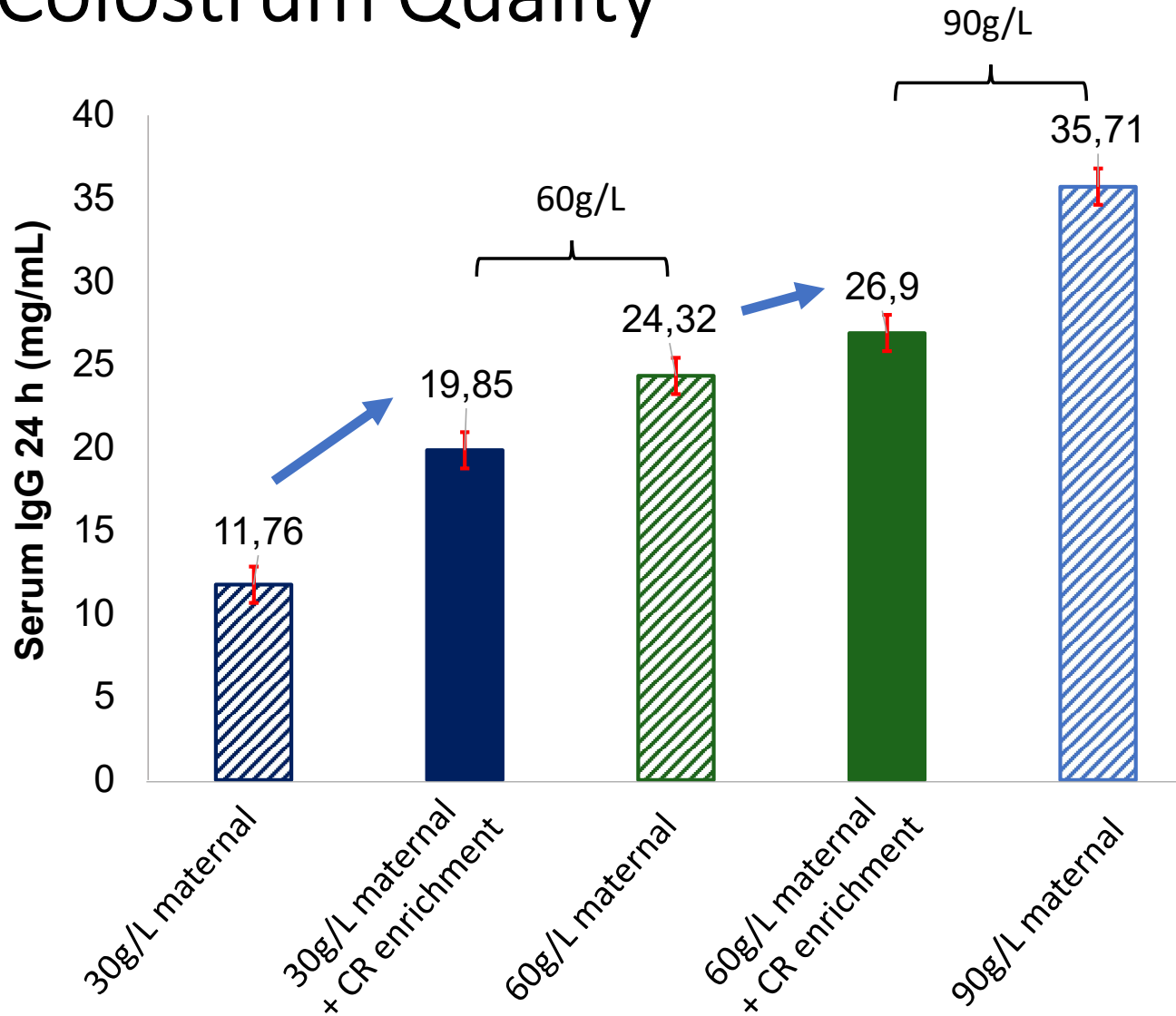
| TPI category | Serum IgG category (g/L) | Equivalent TP (g/dL) | Equivalent Brix % |
|--------------|--------------------------|----------------------|-------------------|
| Excellent | ≥25.0 | ≥6.2 | ≥9.4 |
| Good | 18.0–24.9 | 5.8–6.1 | 8.9–9.3 |
| Fair | 10.0–17.9 | 5.1–5.7 | 8.1–8.8 |
| Poor | <10.0 | <5.1 | <8.1 |

Lombard et al., 2020

Sample calves for passive transfer on days 1-3 after birth – after day 4 is too late

Cantor et al., 2022

Colostrum Quality

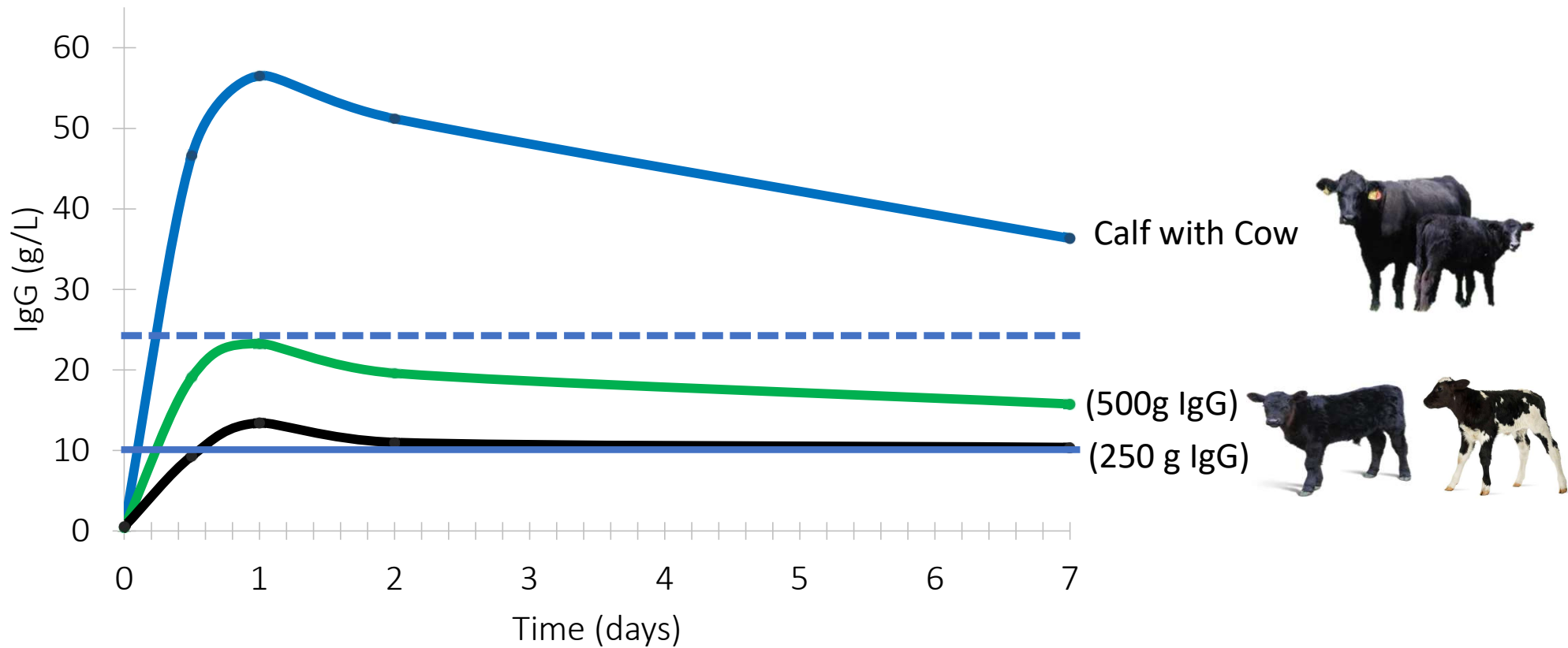


GOOD QUALITY COLOSTRUM

60 g of IgG/L
200 g of IgG total

Enriching low-quality colostrum with CR may be a feasible strategy to ensure passive transfer

Calf IgG Concentrations



Milk Basics

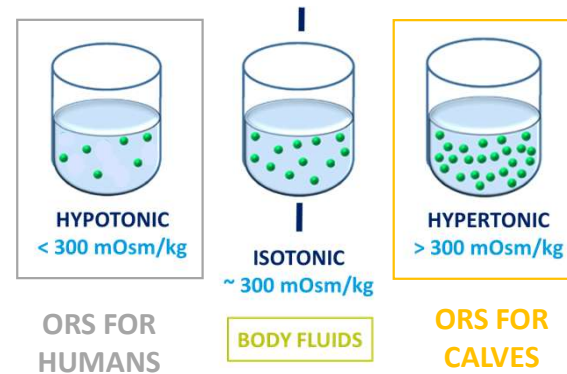


Van Niekerk et al., 2021



Conflicting Recommendations Regarding ORS Tonicity

| Item | WHO ORS | ORS for calves |
|-----------------------|---------|----------------|
| Glucose, mM | 75 | 100 - 260 |
| Na ⁺ , mM | 75 | 90 - 130 |
| Cl ⁻ , mM | 65 | 40 - 80 |
| Osmolality, mOsm/kg | 245 | 400 - 600 |
| Alkalizing agents, mM | 20 | > 50 |
| SID, mEq/L | 30 | > 60 |
| Glu:Na ratio | 1.0 | 1.1 - 3.1 |



Smith, Vet Clin Food Anim, 2009; Smith and Berchtold, Vet Clin Food Anim, 2014.

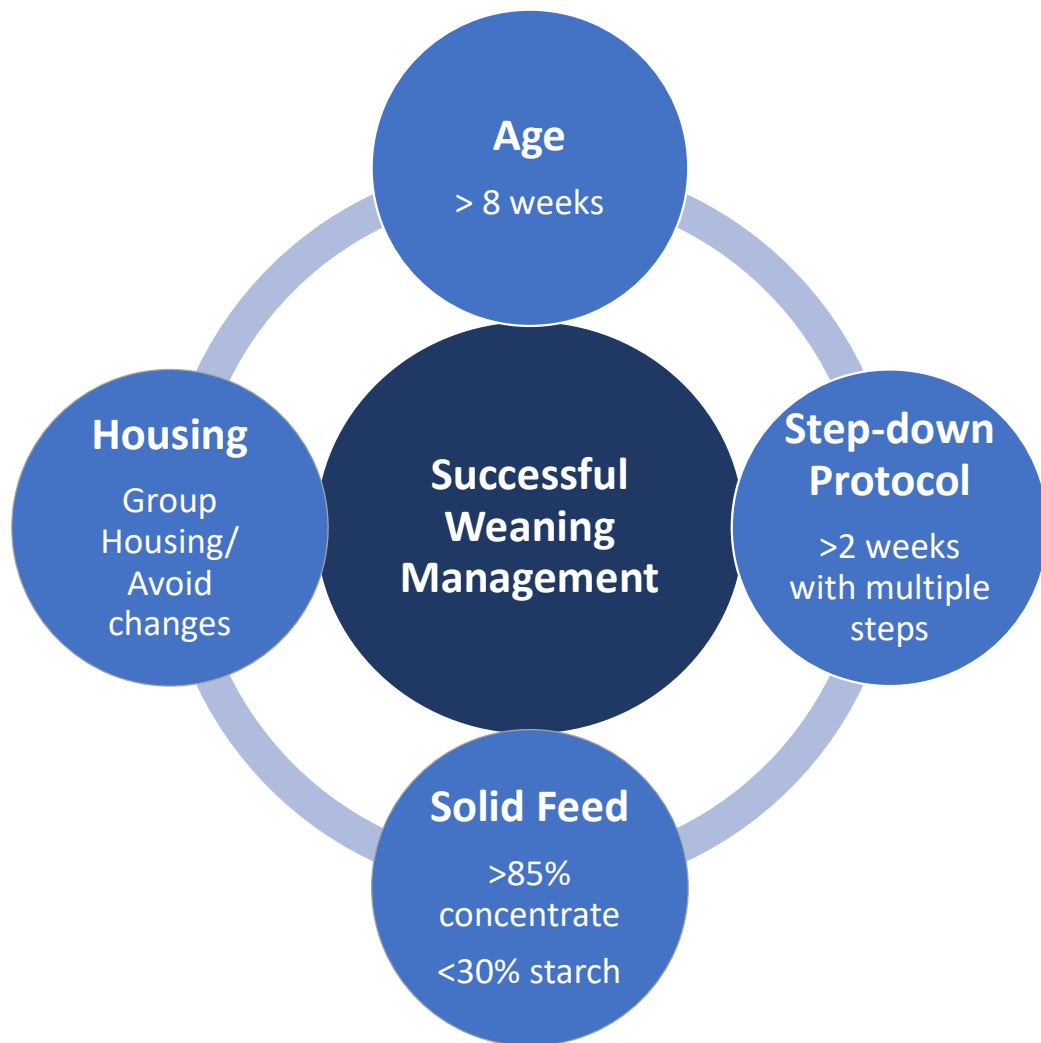
Feeding Scheme is Key

| TIME | FEEDING SCHEME | MEAL SIZE |
|-------|-----------------|-----------|
| 7:00 | Milk / CMR | 2.5 L |
| 12:00 | OES water-based | 2.0 L |
| 17:00 | Milk / CMR | 2.5 L |
| 22:00 | OES water-based | 2.0 L |



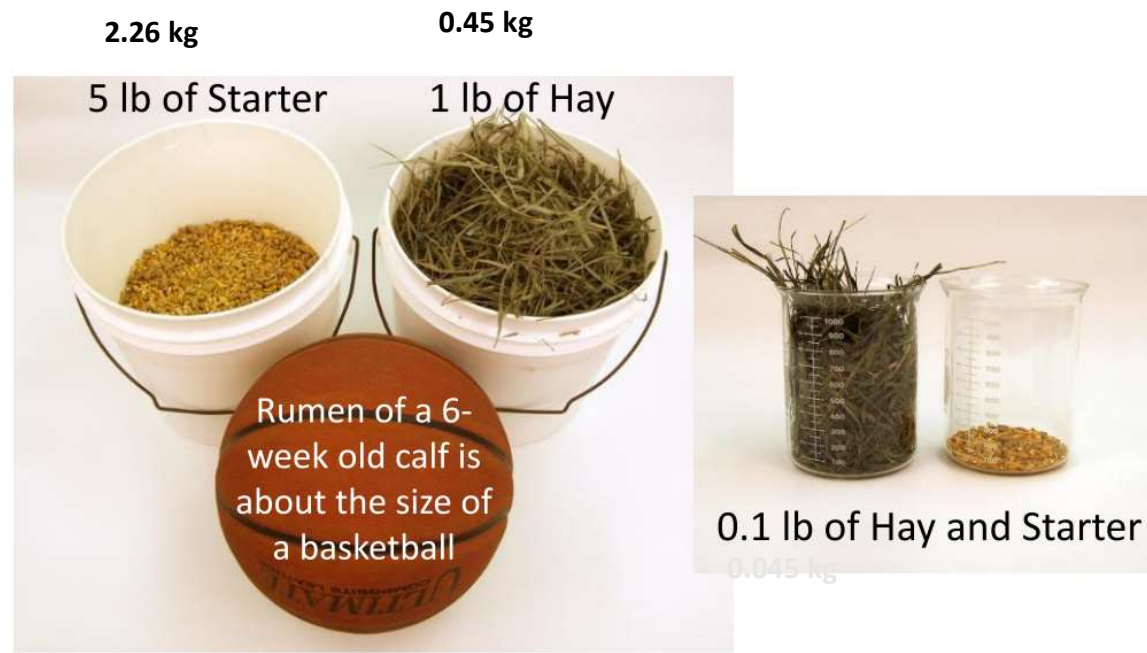
- Sustain usual milk daily allowance and provide free water access
- Reduce meal size and increase feeding frequency
- OES offered until disappearance of dehydration signs / diarrhea (no more than 3 days ideally)

Weaning Basics



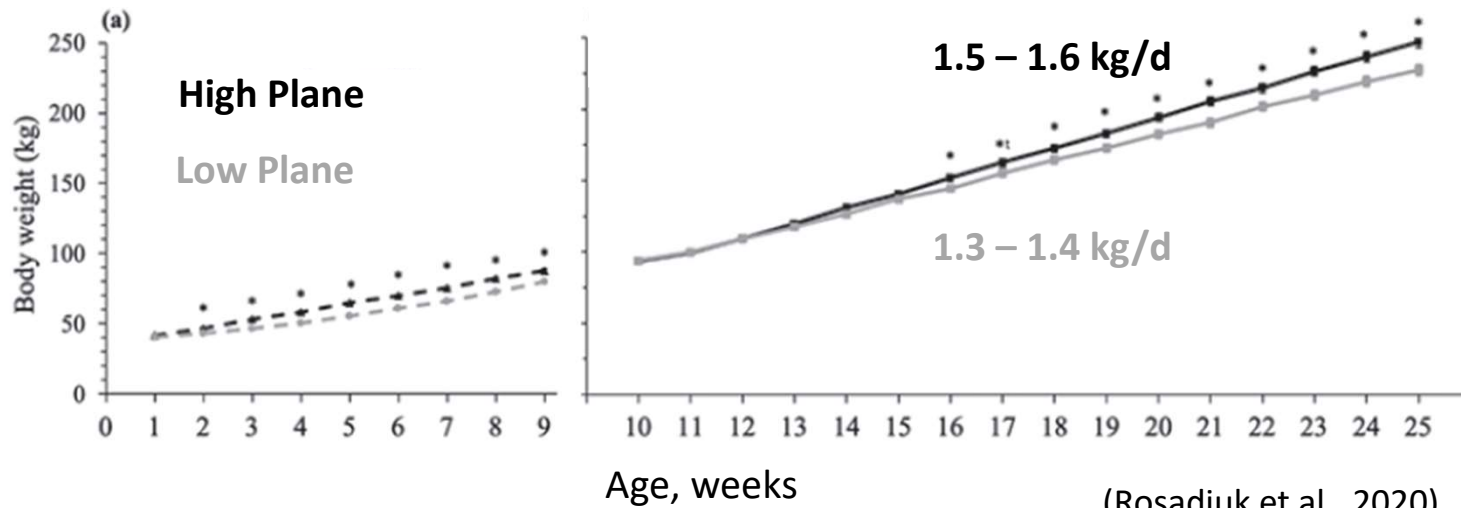
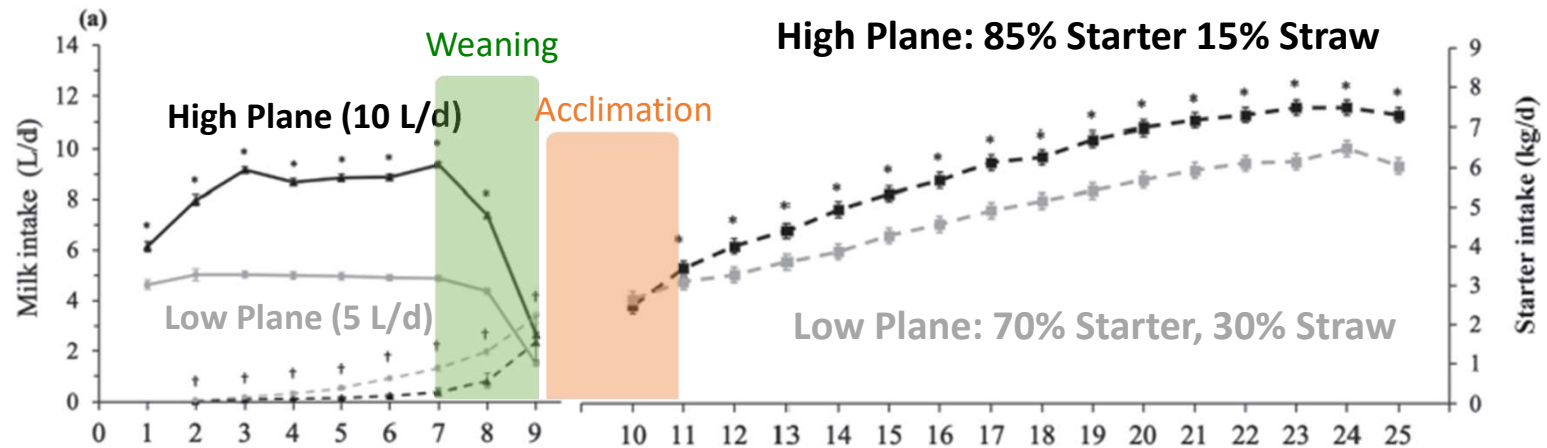
Van Niekerk et al., 2021

Are we assuming that calves are consuming more forage than what they are?



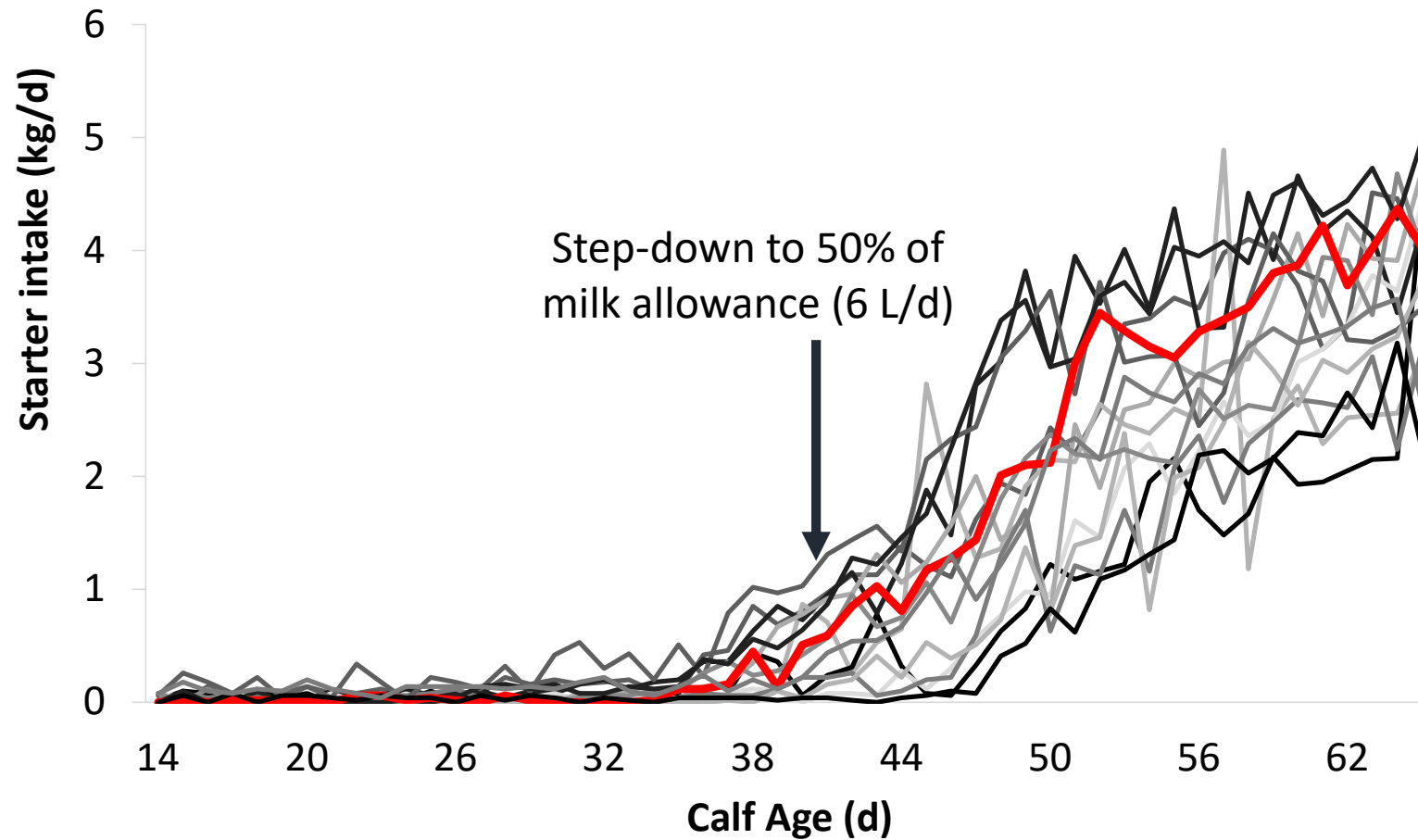


BW and ADG

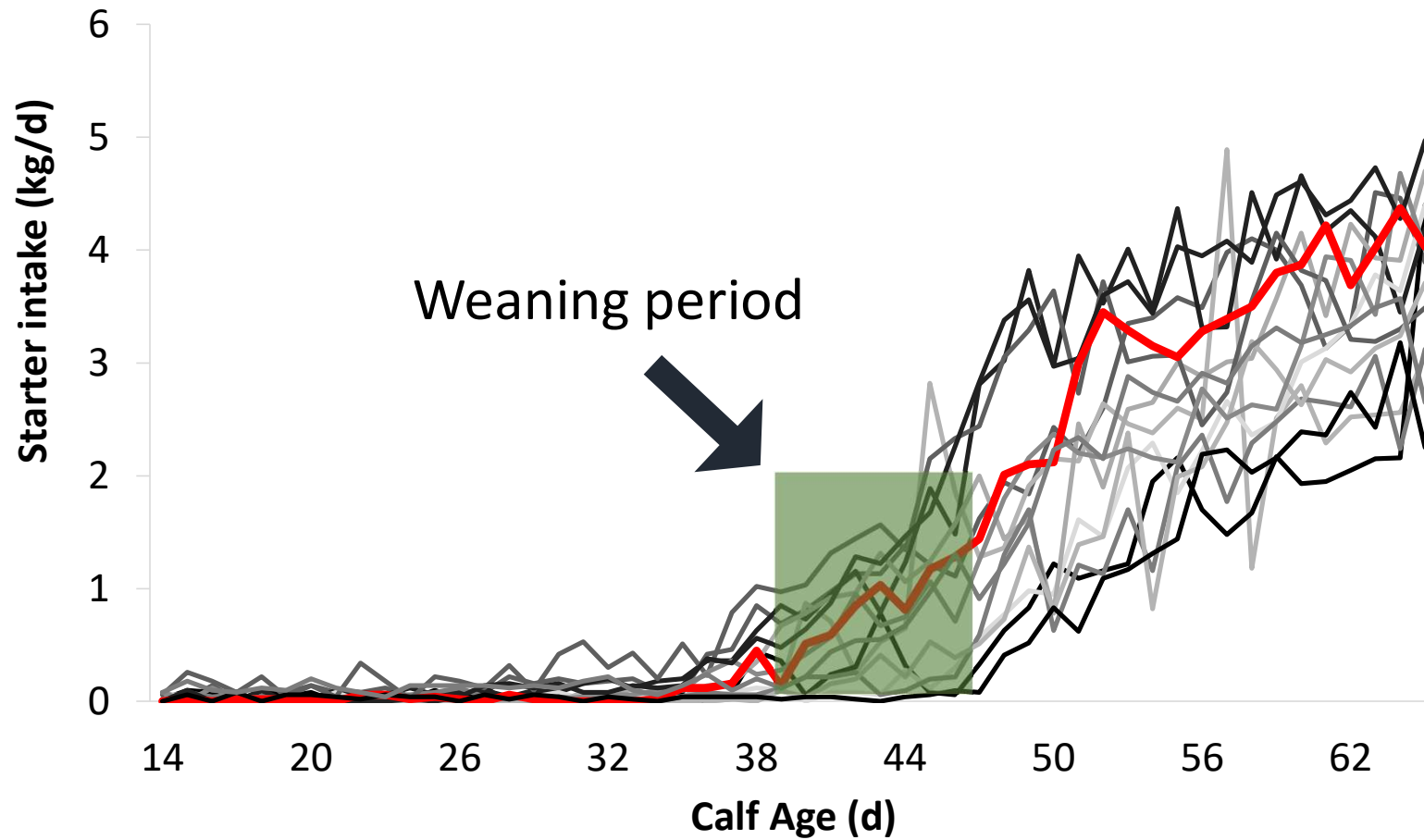


(Rosadiuk et al., 2020)

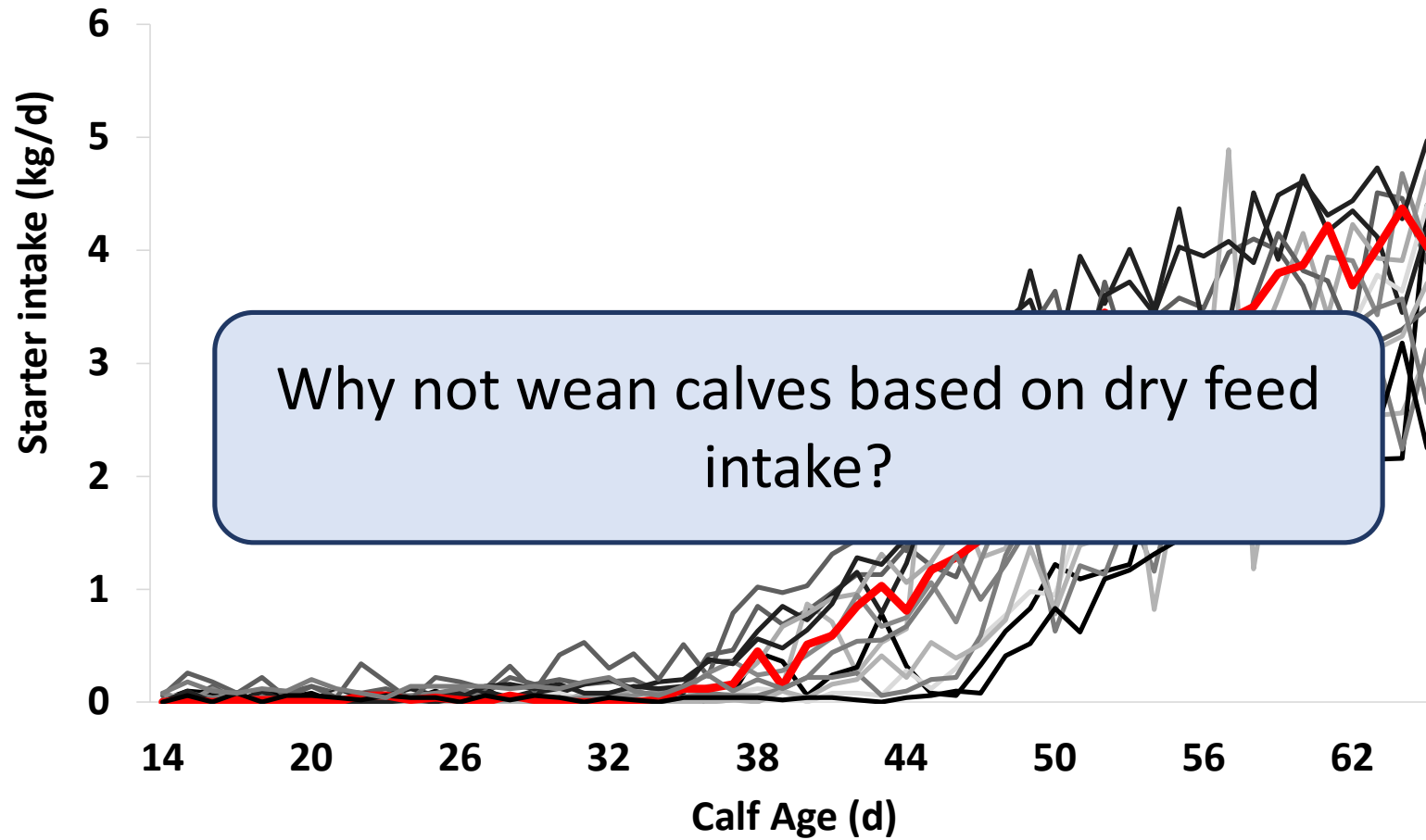
Starter intake by calf when fed 12 L/d milk



Variability in Grain Feed Intake



Variability in Grain Feed Intake

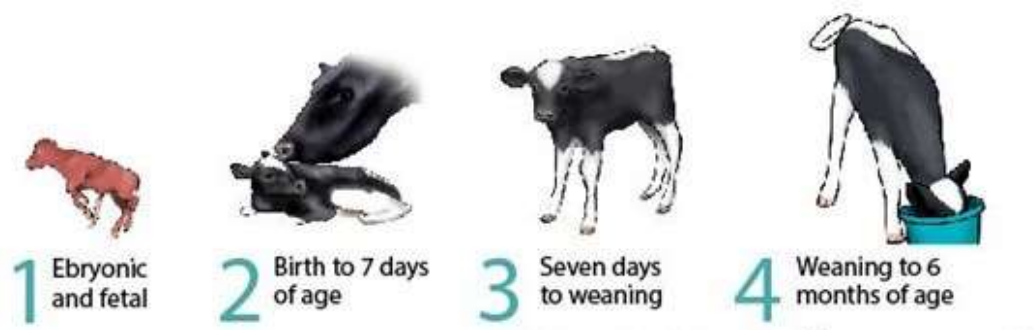


The future...



Phase Feeding and Precision Feeding Definitions

- **Phase feeding** is defined as changing the nutrient concentrations in a series of diets formulated to meet an animal's nutrient requirements more precisely at a particular stage of development or production
- **Precision feeding** aims to match nutrient supply precisely with the nutrient requirements of individual animals, based on real-time feedback from sensors



Zuidhof, 2019; Pomar & Remus, 2023

Individualized Calf Feeding



Pictures Courtesy of Trouw Nutrition

Guelph Calf Research Team



Many Thanks



NSERC
CRSNG



Ontario

Ministry of Agriculture,
Food and Rural Affairs



SCCL

SCIENCE • NATURE • CARE

We are colostrum



trouw nutrition

a Nutreco company



DAIRY 
at GUELPH

Mike Steele

masteele@uoguelph.ca



A close-up, front-facing view of a black, textured microphone head. The microphone is positioned in the lower center of the frame. The background is a large, dimly lit concert venue filled with a dense crowd of people. The audience is illuminated by vibrant purple and pink stage lights, creating a bokeh effect with bright spots of light. The overall atmosphere is that of a live performance or event.

Questions?