The Weaning Transition in Dairy Calves: Why is it So Often So Traumatic?

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Weaning:
The “other” transition period

- Period preparing for and adapting to weaning
- Critical stage of heifer’s life with many stressors

Changes around weaning

- Diets
  - Removal of milk, total reliance on dry feed and free water, perhaps change from starter to grower
- Environment
  - Moving to different pen
- Social
  - Grouping with other calves
  - Removal of “surrogate mom” and suckling/milk feeding

Weaning distress compromises welfare

- Growth slumps
  - Attributable to lower nutrient intake and stress
- Adverse behavioral stress
  - Vocalization, decreased resting
- Increased disease susceptibility
  - Particularly respiratory and coccidiosis
  - Impaired immunity due to suboptimal nutrition and weaning stressors

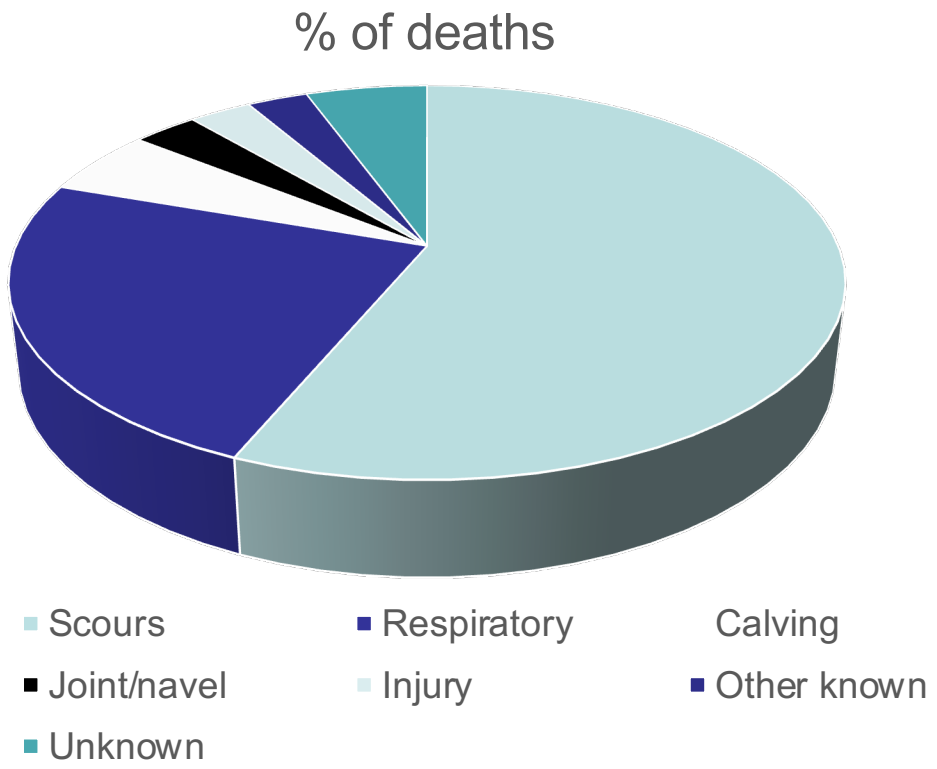
Photo courtesy of Jim Quigley

Producers are feeding more milk

- NAHMS (2014) data showed US average amount fed was 5.7 L/d, which would be ~740 g/d (1.6 lb/d) of milk solids (Urie et al., 2018)
- Contrasts with historical average of 1 to 1.25 lb solids/day
- Many farms feeding 6 to >8 L/d

Death loss has declined over same period

- Deaths in preweaned heifers declined from 11.0% of calves alive at 48 h of age in 1996 to 6.4% in 2014
- Related to greater milk intake early in life?
- Causes of death largely unchanged (scours and respiratory = 80% of deaths)



We are doing better with preweaned calves!

On average, fewer heifers die post-weaning

- NAHMS (2014) data show mean mortality of 2.7% of heifers born alive

But, there are too many trainwrecks at weaning

- Three large dairies (12,000 to 20,000 cows) reported death losses around weaning of 20 to 30% of calves (M. E. Van Amburgh, personal communication 2023)

Post-weaning performance lags pre-weaning

Variable	Holstein	Jersey
Birth weight, kg	43.0	35.1
Weaning weight, kg	91.4	70.1
ADG, kg/d	0.73	0.51
90-d weight, kg	104.0	86.2
ADG post-weaning, kg/d	0.60	0.76
Birth hip height, cm	82.8	75.8
Weaning hip height, cm	95.2	85.6
ADG height, cm/d	0.18	0.15
90-d height, cm	98.1	90.0
ADG height post-weaning, cm/d	0.14	0.18

Courtesy A. F. Kertz

Urie et al., 2018 (From NAHMS 2014 data)

Why do so many calves struggle at weaning?

Photo courtesy of Jim Quigley

Mother Nature's feeding program

- **Cows' milk:** 25 – 26% protein (dry solids basis)
- **Feeding rate:** > 2x the "conventional" feeding rate of milk replacers (1 – 1.5 kg solids vs. ~ 0.5 kg), spread over 6 – 12 meals per day
- **First solid feed:** High-quality fresh grass (high in sugars and easily fermented fiber)
- **Weaning:** gradually, at 6 to 10 mo vs. 4 to 8 wk

Empty body weight as proportion of live weight decreases from before to after weaning

- Empty body weight (EBW) is body weight minus GI tract fill
  - Milk only: EBW = 0.94 live BW
  - Milk plus starter: EBW = 0.93 live BW
  - Weaned calf: EBW = 0.85 live BW

So, gut fill is increasing during the weaning transition

NASEM, 2021

Impact of increasing gut fill on calf ADG postweaning

Variable	LMR + CCS	HMR + CCS	HMR + HCS	SEM
Overall ADG 5-10 wk, kg/d	0.89	0.83	0.92	0.12
5-wk digesta, kg	2.84	1.54	1.48	0.34
10-wk digesta, kg	10.29	9.54	11.32	0.94
ADG due to gut fill gain, kg/d	0.21	0.23	0.28	---
EBW gain 5-10 wk, kg/d	**0.49**	**0.47**	**0.68**	---

LMR + CCS = low milk replacer plus conventional calf starter; HMR + CCS = high milk replacer plus conventional calf starter; HMR + HCS = high milk replacer plus high-protein calf starter

Stamey Lanier et al., 2020

The GI tract grows allometrically during the weaning transition

Variable	LMR + CCS	HMR + CCS	HMR + HCS	SEM
Overall ADG 5-10 wk, kg/d	0.89	0.83	0.92	0.12
5-wk GIT, % of EBW	8.1	7.4	7.5	0.70
10-wk GIT, % of EBW	10.7	10.6	10.7	0.44
ADG due to GIT gain, kg/d	0.09	0.11	0.13	---
EBW gain 5-10 wk, kg/d	**0.49**	**0.47**	**0.68**	---

LMR + CCS = low milk replacer plus conventional calf starter; HMR + CCS = high milk replacer plus conventional calf starter; HMR + HCS = high milk replacer plus high-protein calf starter

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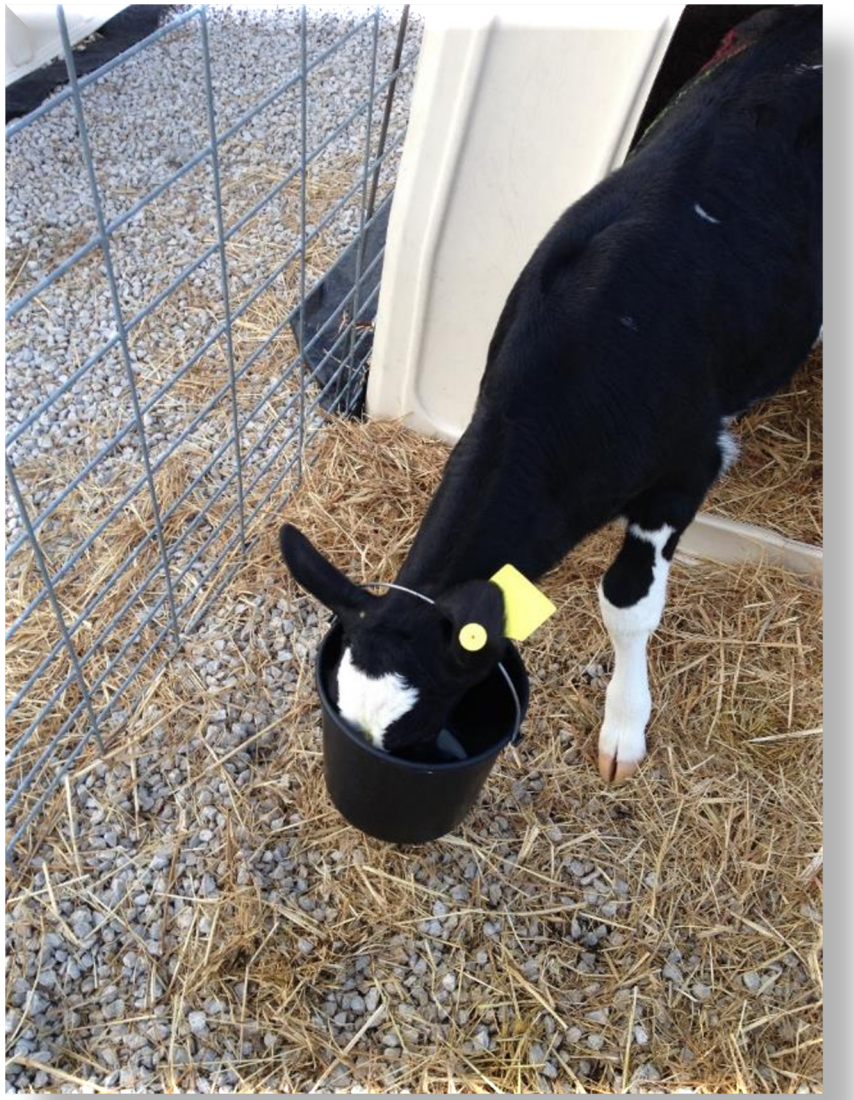
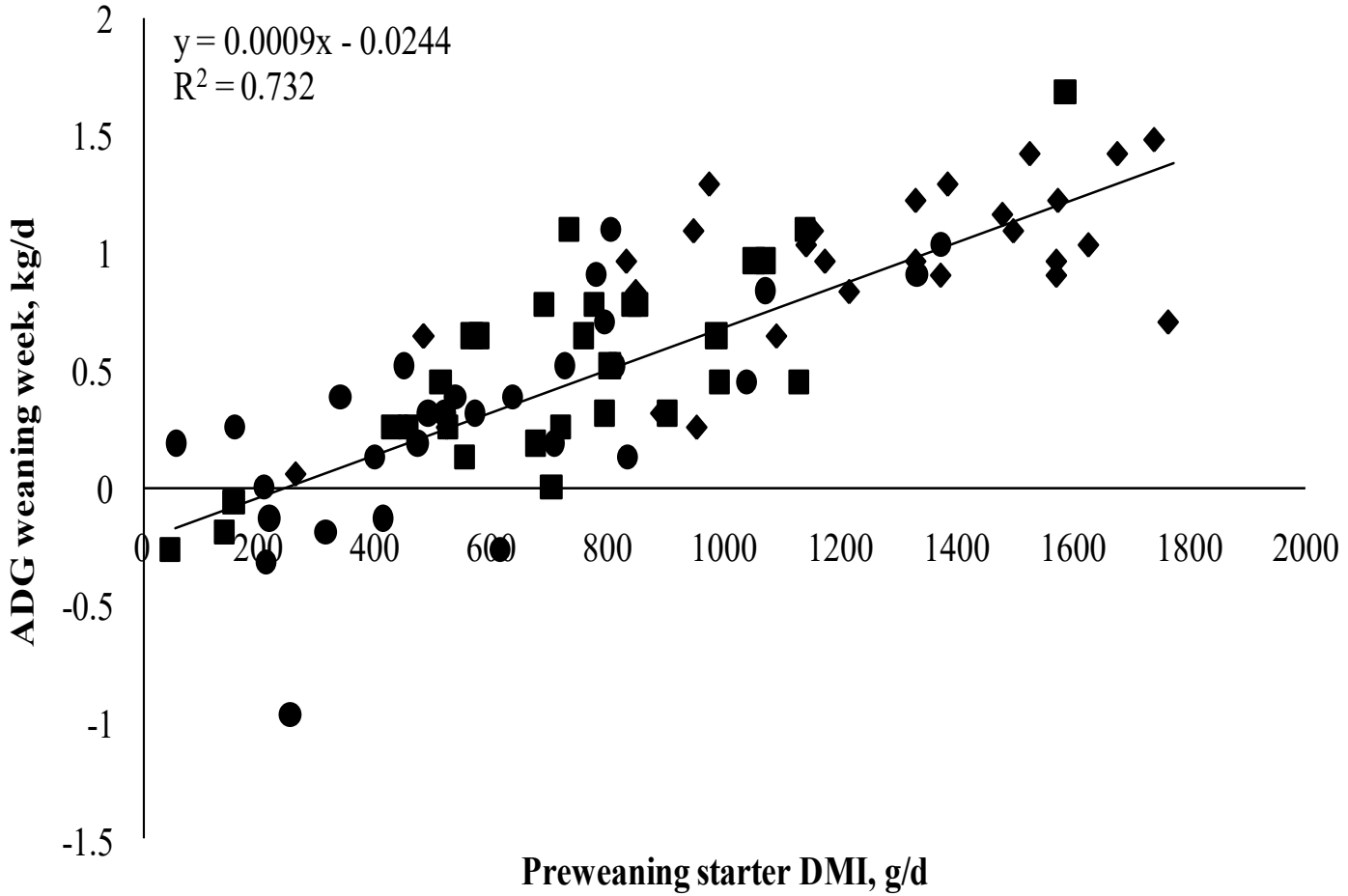


To avoid growth checks around weaning:

Must strive for starter intake and digestion pre-weaning

Pre-weaning starter intake determines post-weaning growth



Stamey et al., 2012

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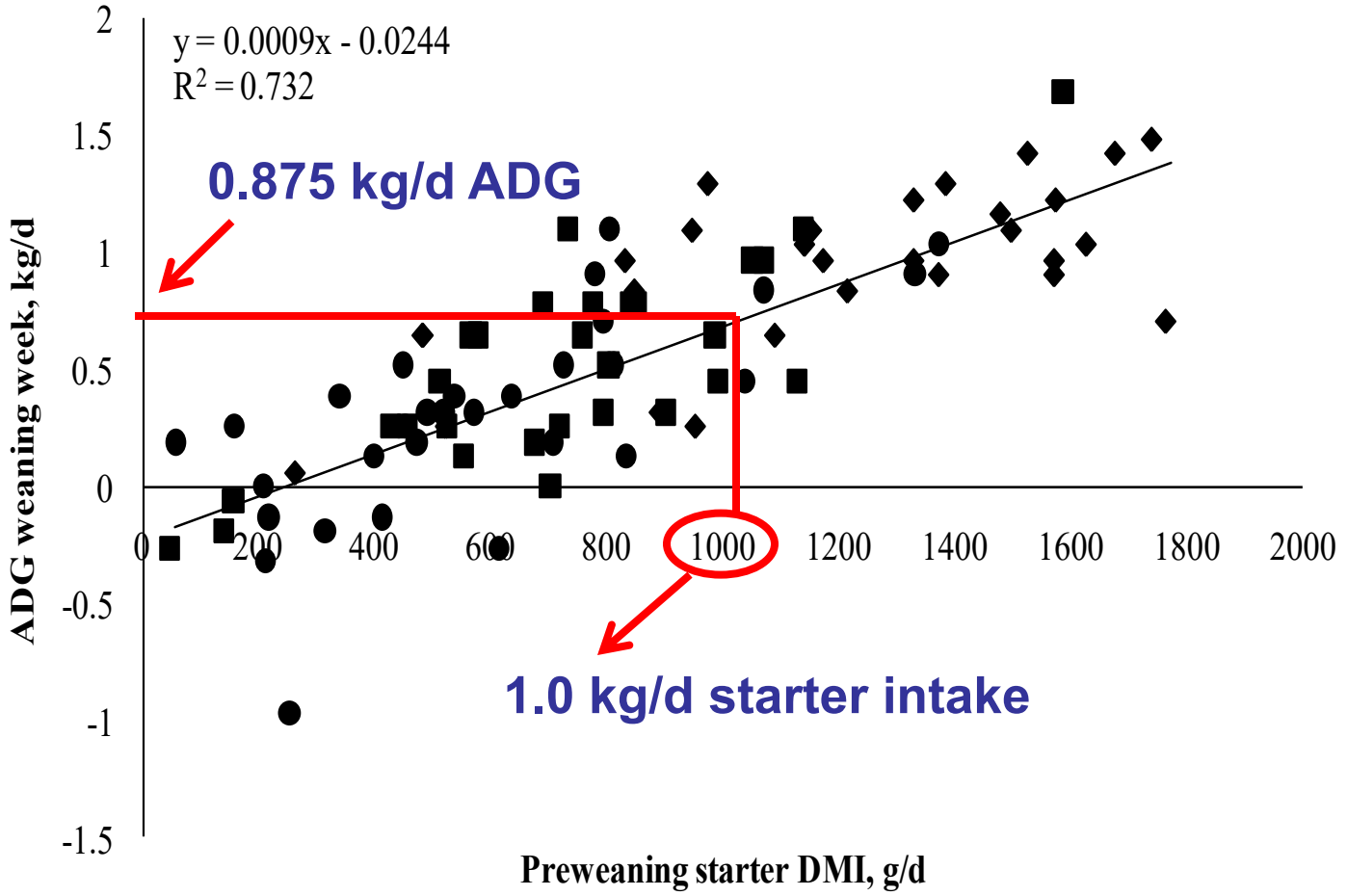


Stamey et al., 2012

Dry matter intake

- Calves < 65 kg (Holstein) consume ~2.25% of BW as milk solids if fed ad libitum
- Calves > 65 kg consume ~2.5% of BW as milk solids
- Calves < 8 wk fed limited amounts of milk and ad libitum starter consumed 1.93 ± 0.33% of BW as total DM (219 treatment means from 64 studies)
- Weaned calves > 8 wk consumed 3.06 ± 0.31% of BW as DM (79 treatment means from 27 studies)

NASEM, 2021

Maintenance energy in weaned calves

- NEm = 0.097 Mcal/kg $EBW^{0.75}$
- Maintenance ME = 0.138 Mcal/kg $EBW^{0.75}$ or 0.117 Mcal/kg $BW^{0.75}$
  - Greater than NRC (2001) but lower than in other systems and in Beef NASEM (2016)
- ***For 85-kg calf, need about 1 kg/d of starter just for maintenance***

NASEM, 2021

Effects of environmental temperature on maintenance energy requirement

	Increase in maintenance energy, kcal of NEm/d		Increase in maintenance energy, %	
Temperature, °C (°F)	< 3 wk old	> 3 wk old	< 3 wk old	> 3 wk old
40 (104)	524	524	28	**30**
35 (95)	349	349	19	**20**
0 (32)	698	349	38	**18**
-10 (14)	1048	698	56	**35**

- 110-lb calf gaining 1.4 lb/d under thermoneutral conditions would gain only 1.1 lb/d at 104°F

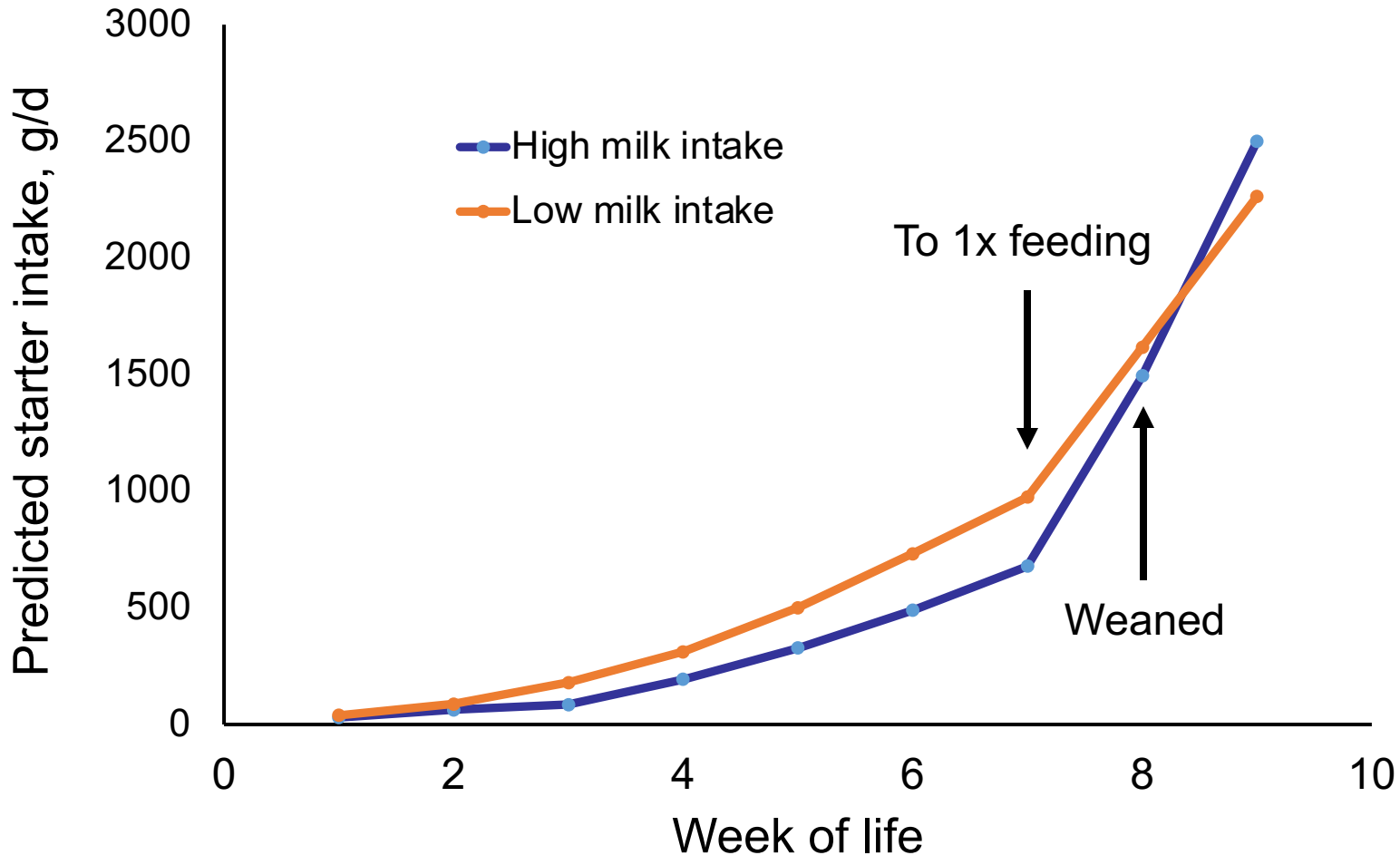
Prediction equations for starter intake

- Equation developed for calves in temperate conditions:

$$\text{Starter DMI (g/d)} = -652.525 + (\text{BW} \times 14.734) + (\text{MeiLD} \times 18.896) + (\text{Fpstarter} \times 73.303) + (\text{Fpstarter}^2 \times 13.496) - (29.614 \times \text{Fpstarter} \times \text{MEiLD})$$

- RMSE of 262 g/d, CCC of 0.71

Higher amounts of milk feeding result in lower starter DMI



Calculated from NASEM, 2021

Starter intake drives rumen development

What are we trying to develop?

- Size/volume of rumen (driven by *feed*)
- Musculature of rumen (driven by *bulk*)
- Absorptive epithelium (*papillae*; driven by *VFA*)
- Microbial population (driven by *feeds;* produces VFA and depends on epithelium for acid absorption)

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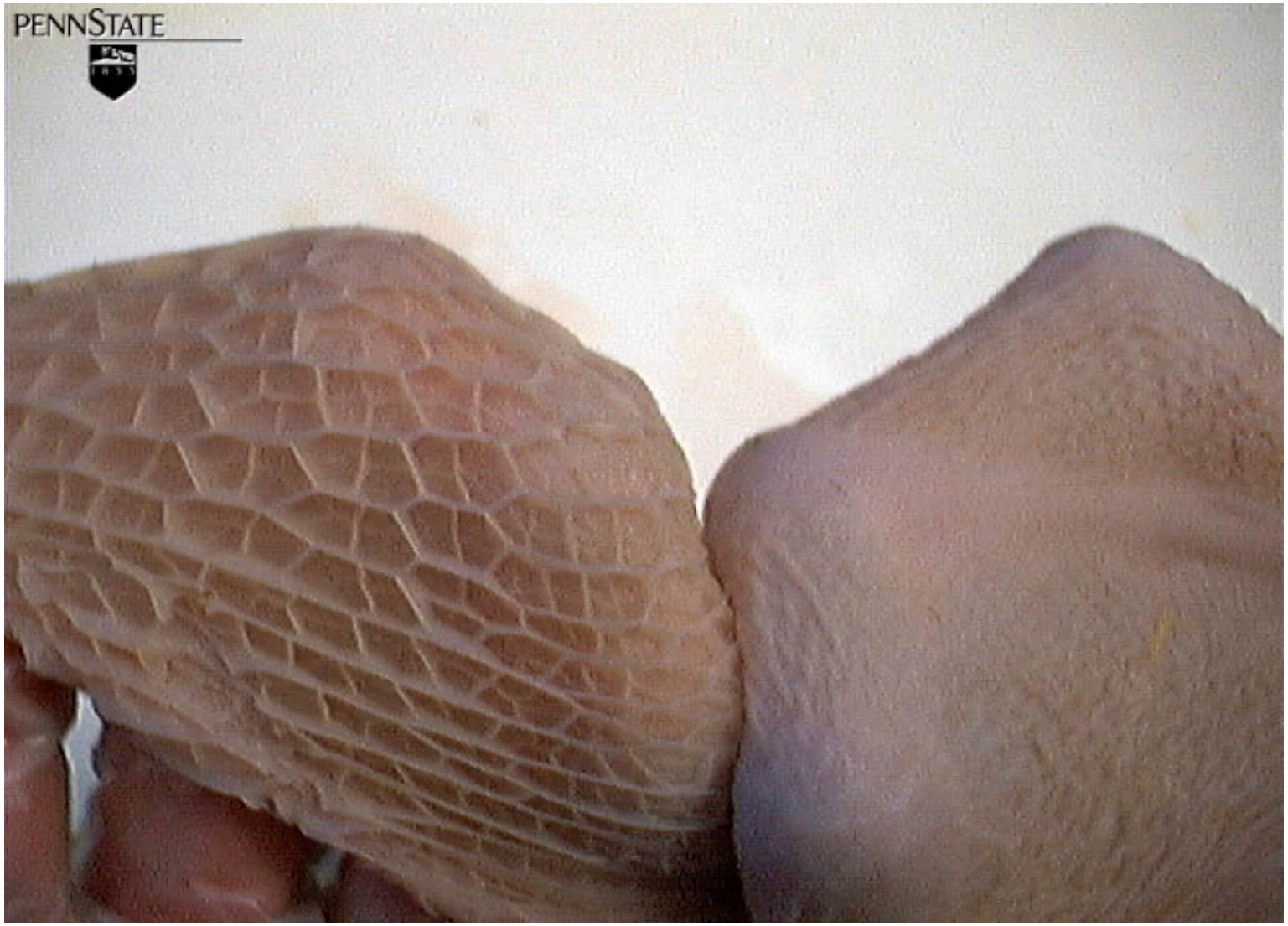
Effects of diet on rumen development

- Milk and hay do little to develop rumen epithelium (papillae)
- Starter grain (starch) or fresh grass (sugars) are key to development of rumen papillae via VFA production
- Papillae development can occur by 3-4 wk of age with good starter management
- Process takes ~3 wk no matter when start

Reticulum and rumen lining of 6-week-old calf fed milk only



http://www.das.psu.edu/dairynutrition/calves/rumen/

Reticulum and rumen lining of 6-week-old calf fed milk and grain

http://www.das.psu.edu/dairynutrition/calves/rumen/

Insufficient rumen development (starter intake) before weaning decreases nutrient digestibility after weaning

	Milk feeding program			
Nutrient	Low	High	Difference, %	*P*
Apparent digestibility, %				
DM	77.4	71.8	**- 7.2**	0.009
CP	77.1	71.6	**- 7.1**	0.01
NDF	34.7	20.3	**- 41.5**	0.02
Energy	75.6	69.8	**- 7.7**	0.007

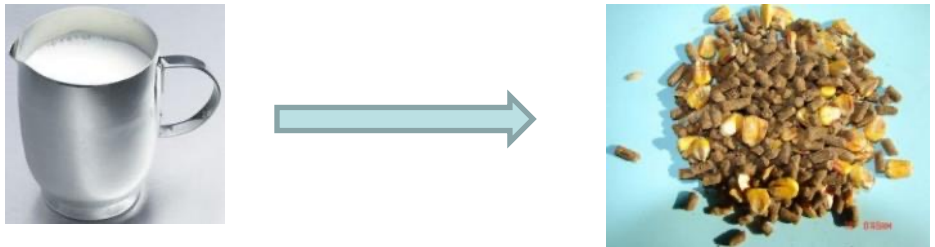
Terré et al., 2007

ME obtained from solid feed is lower when rumen is under-developed

- Actual ME obtained from digestion may be lower than calculated value if rumen is not fully developed (Quigley et al., 2018, 2019)
- Common in calves fed large amounts of milk
- In NASEM (2021) users have option to use discounted (10%) ME value for calves consuming large amounts of milk (>1.5% of BW as solids)

Approaching weaning…

- Tissue requirements for energy and amino acids do not change.
- Efficiency of use of ME from VFA and milk endproducts is not greatly different.
- Large differences in digestibility; ME of starter is ~ 60 to 70% of ME in milk replacer so growth will be ~2/3 of that on equal DM from milk replacer.



Starter dry matter intake (DMI) required to support various rates of gain in weaned calves

BW (kg)	ADG (g/d)	Starter required (kg/d)
60	600	1.68
60	800	1.96
80	600	1.95
80	800	2.24

Based on starter containing 3.16 Mcal ME/kg DM

Calculated from NASEM, 2021

Starter dry matter intake (DMI) required to support various rates of gain in weaned calves

BW (kg)	ADG (g/d)	Starter required (kg/d)

Because of differences in energy content of starter and its use by calves, we need 1.4 to 1.7 times more starter than milk replacer for same amount of body weight gain

Based on starter containing 3.1 Mcal ME/kg DM

Calculated from NASEM, 2021

Factors contributing to poor weaning performance

- Weaning too early
- Weaning from high amounts of milk not gradual enough
- Too much forage
- Poor starter quality or composition (too high in starch, poor palatability, particle size issues)
- Poor water management
- Stacking stressors at weaning

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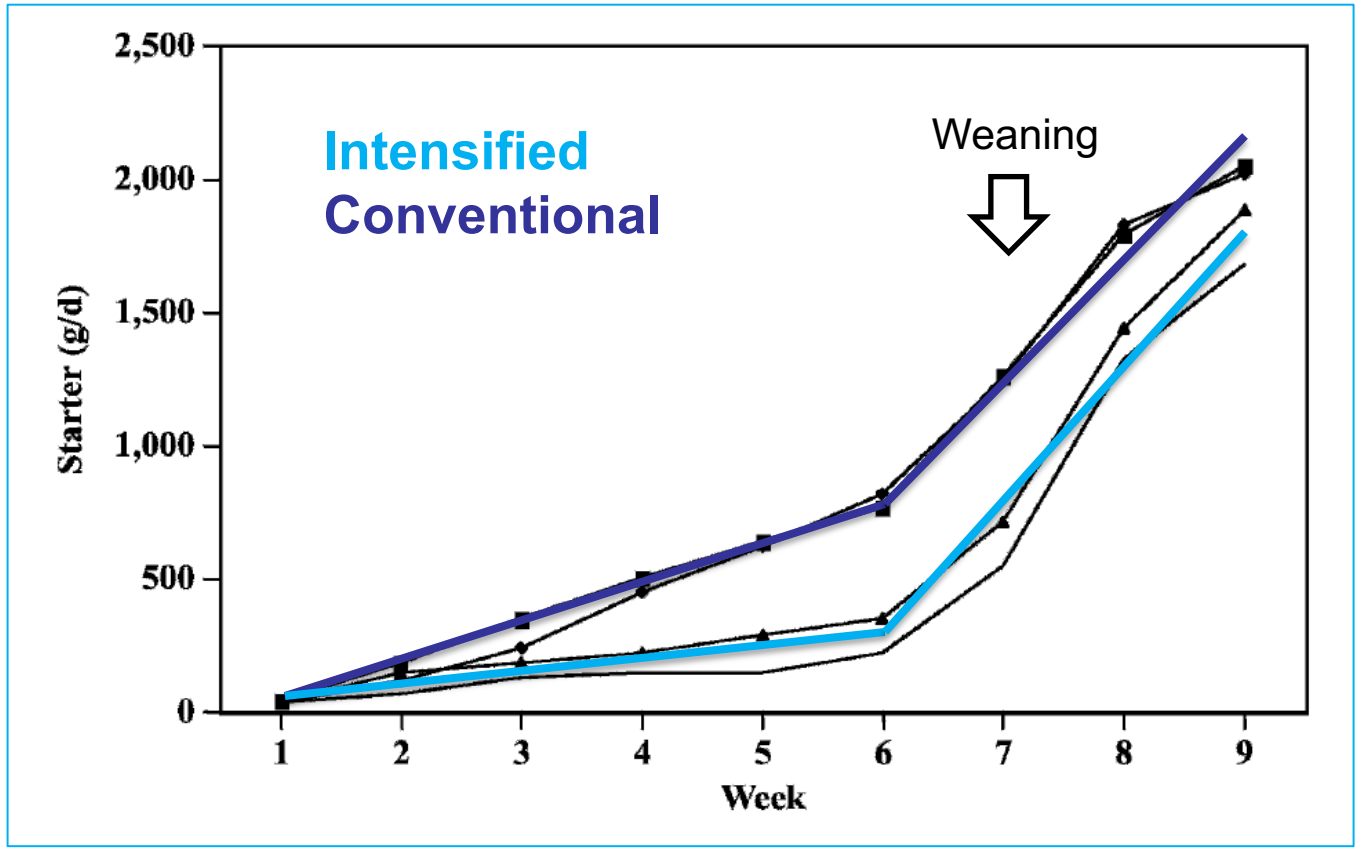
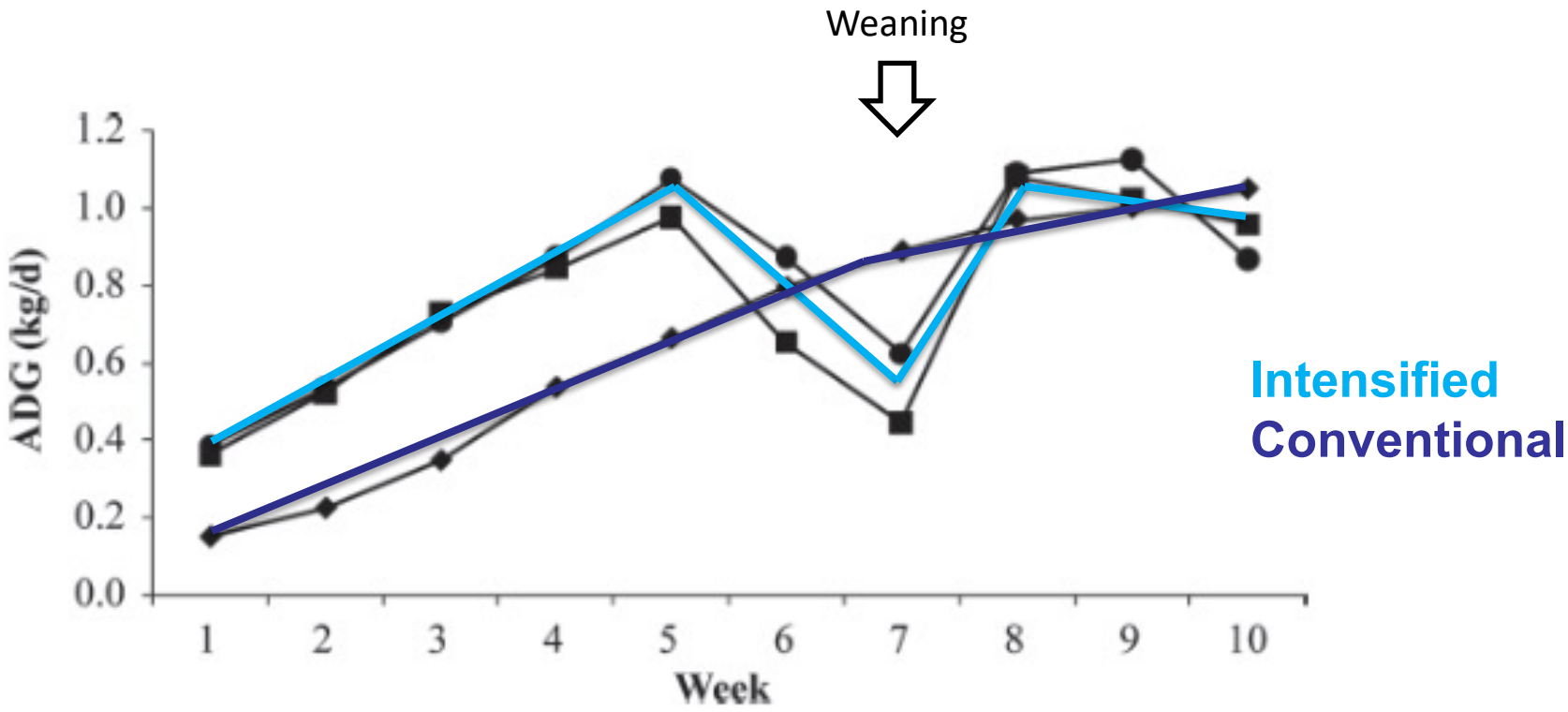
Higher rates of milk feeding decrease preweaning starter intake



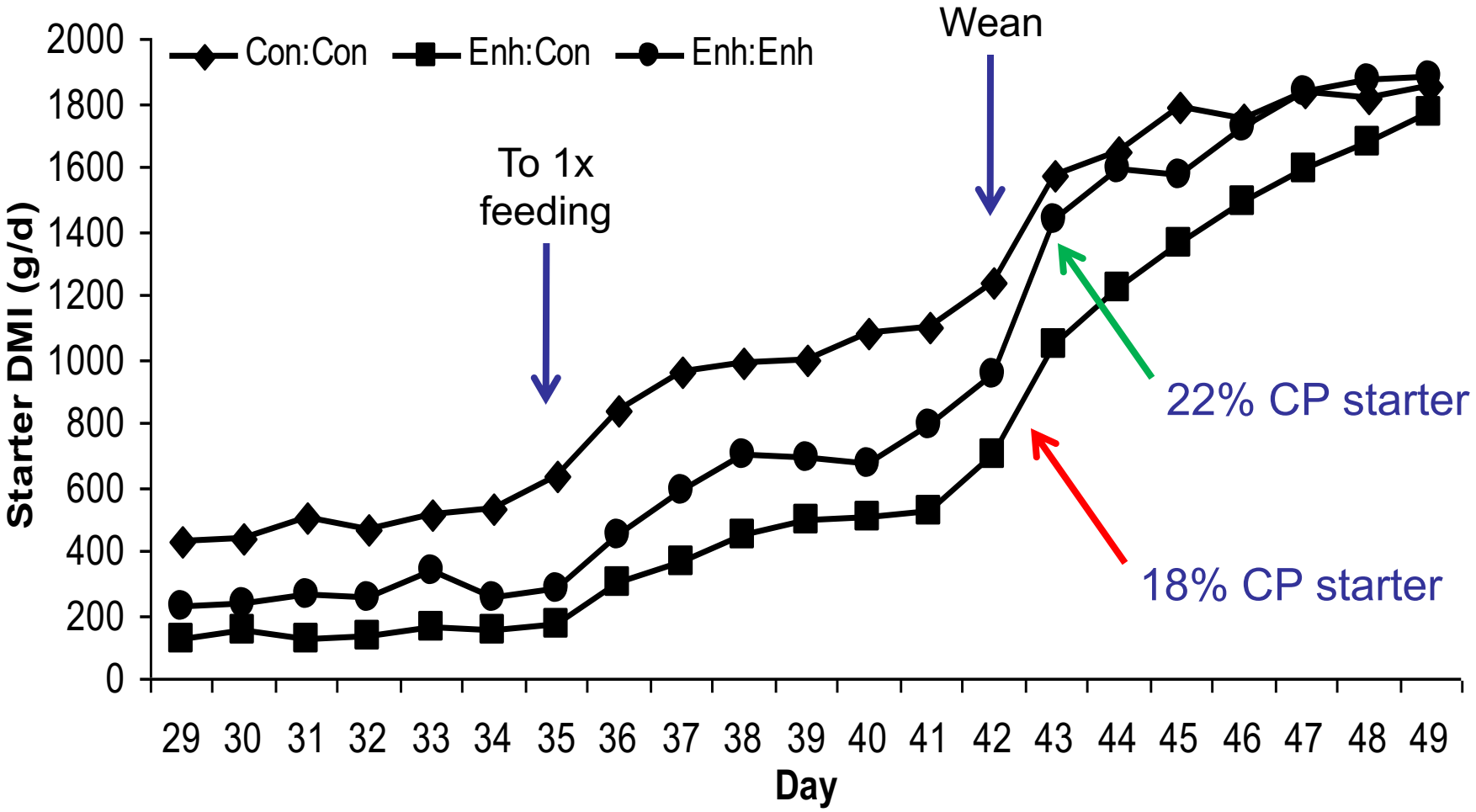
Cowles et al., 2006

Weaning slump has been common with increased milk feeding



Stamey et al., 2012

Daily starter intake around weaning



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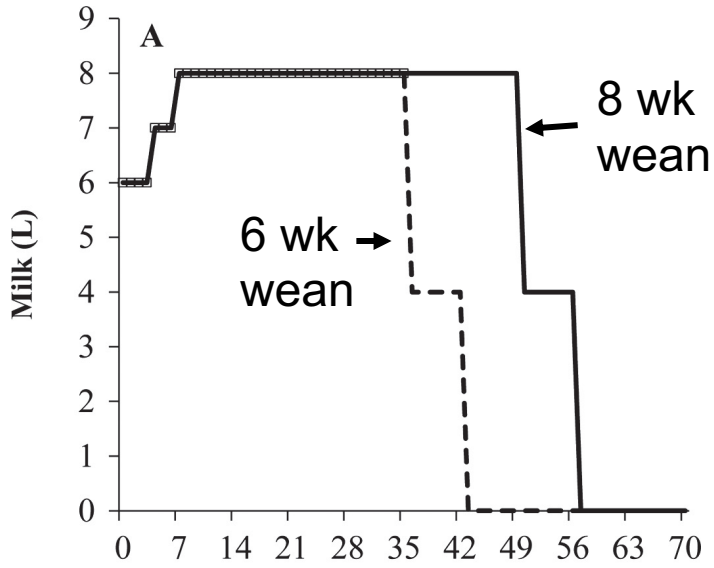
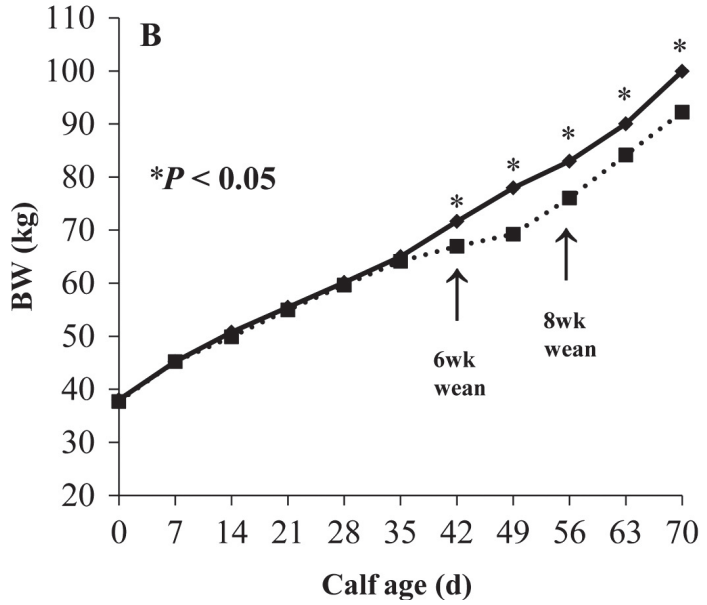
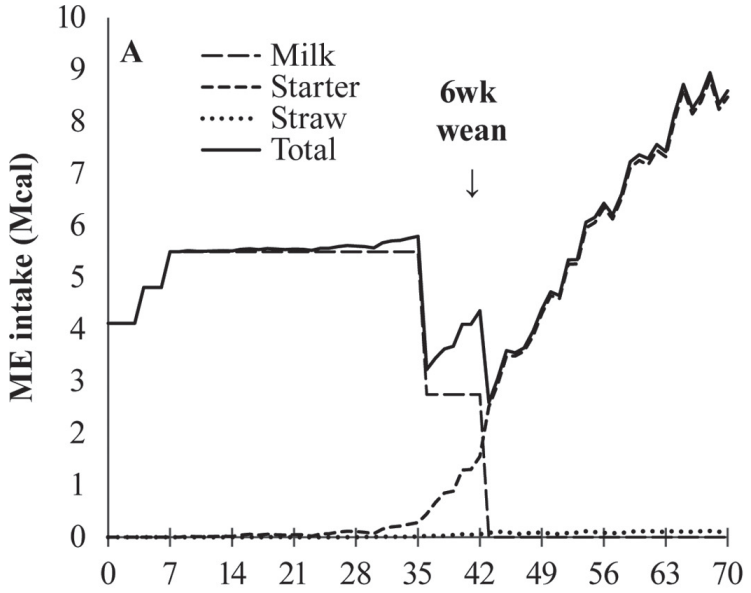
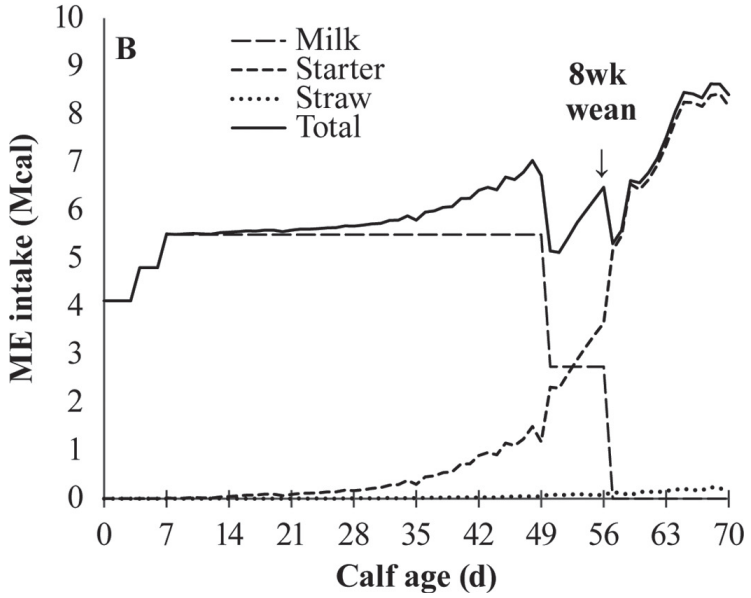




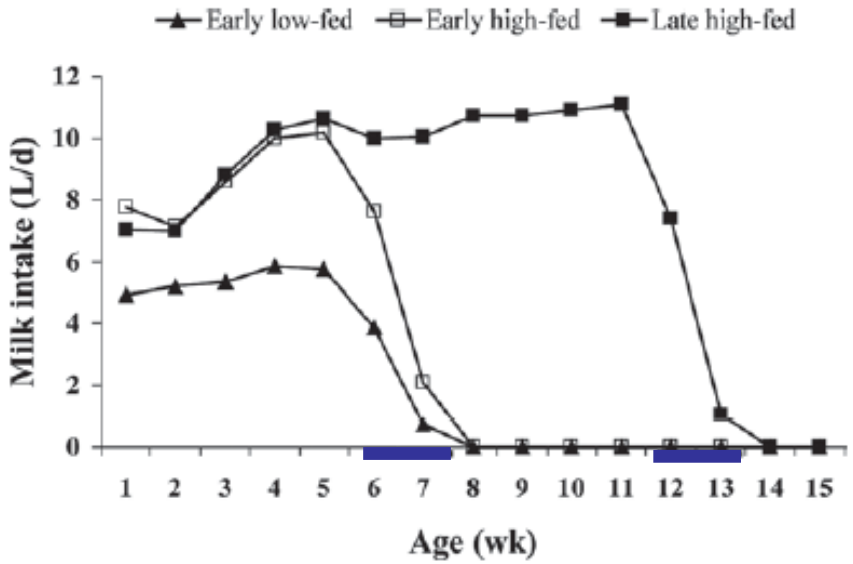


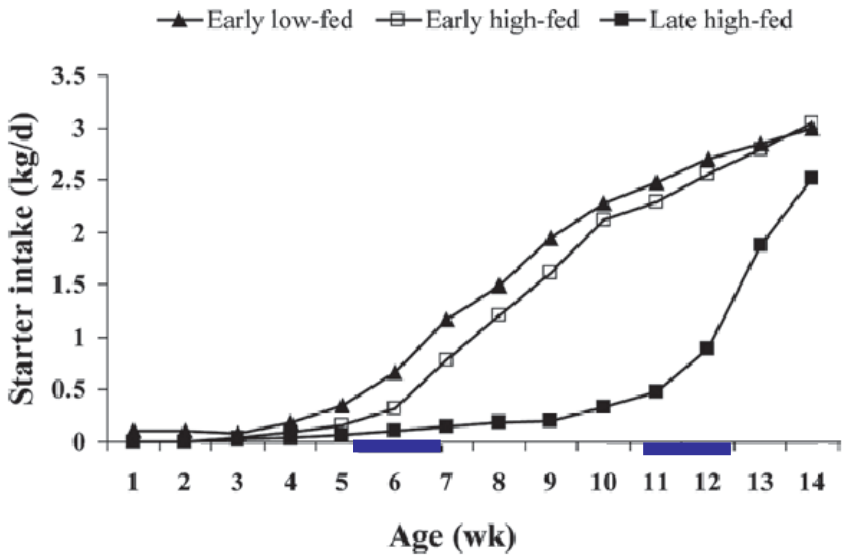


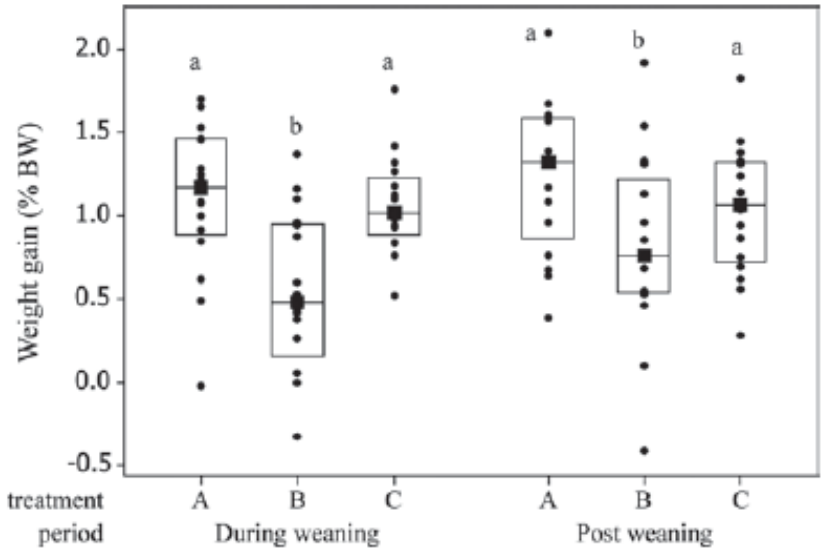
Weaning at 8 wk instead of 6 wk decreases the energy deficit at weaning

Eckert et al., 2015

Older age at weaning improves success





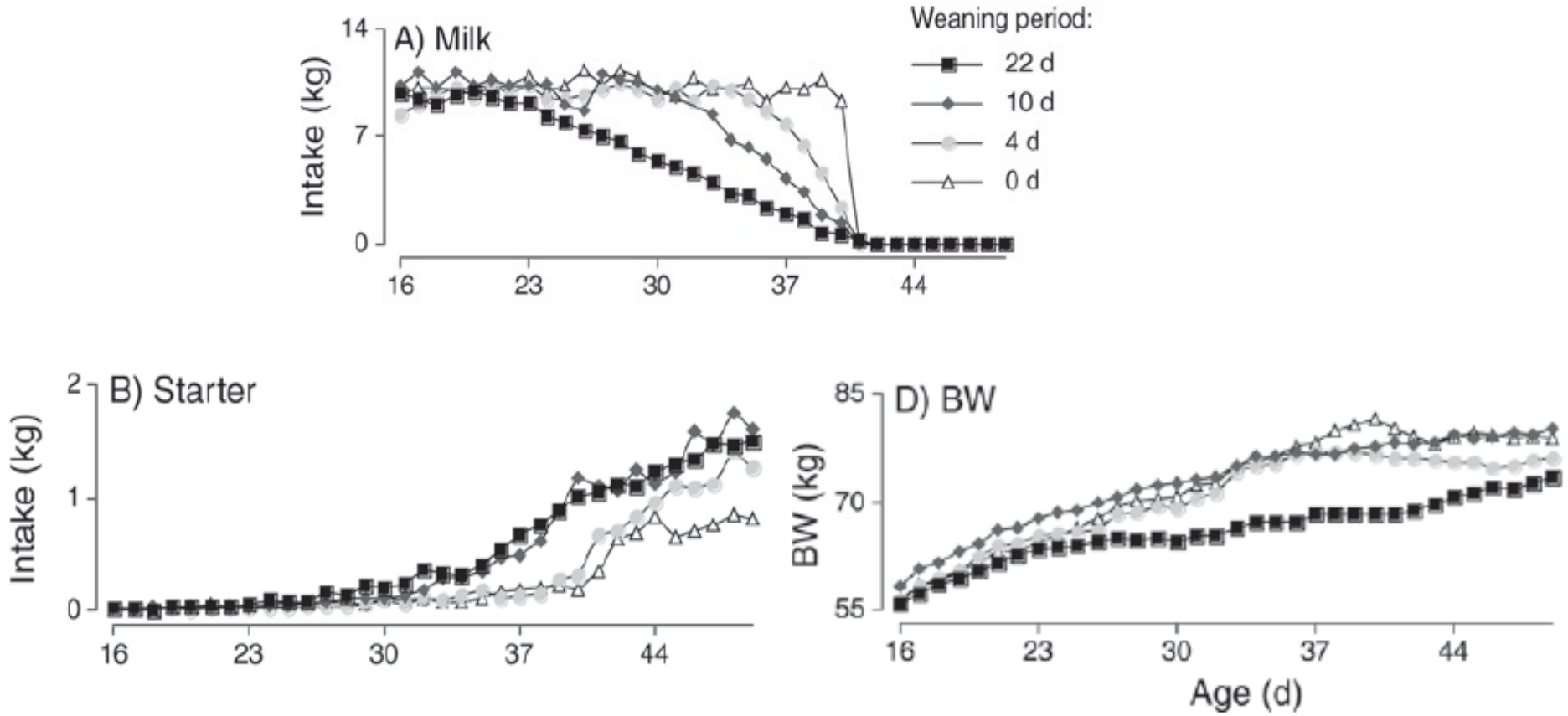


de Passilé et al., 2011

Factors contributing to poor weaning performance

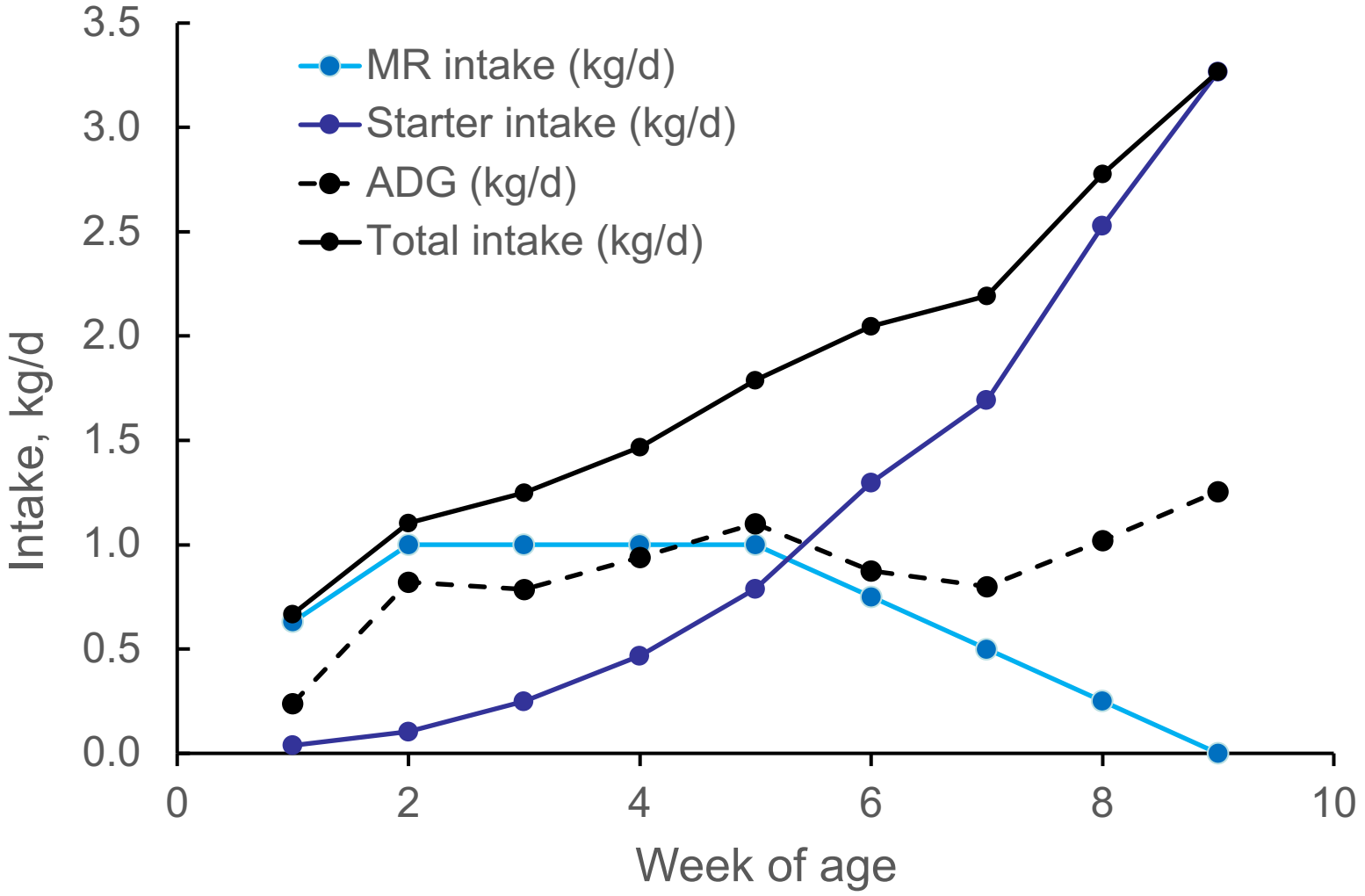
- Weaning too early
- **Weaning from high amounts of milk not gradual enough**
- Too much forage
- Poor starter quality or composition (too high in starch, poor palatability, particle size issues)
- Poor water management
- Stacking stressors at weaning

Slower weaning improves starter intake



Sweeney et al., 2010

Gradual weaning leads to sustained gains



Henrichs et al., 2021

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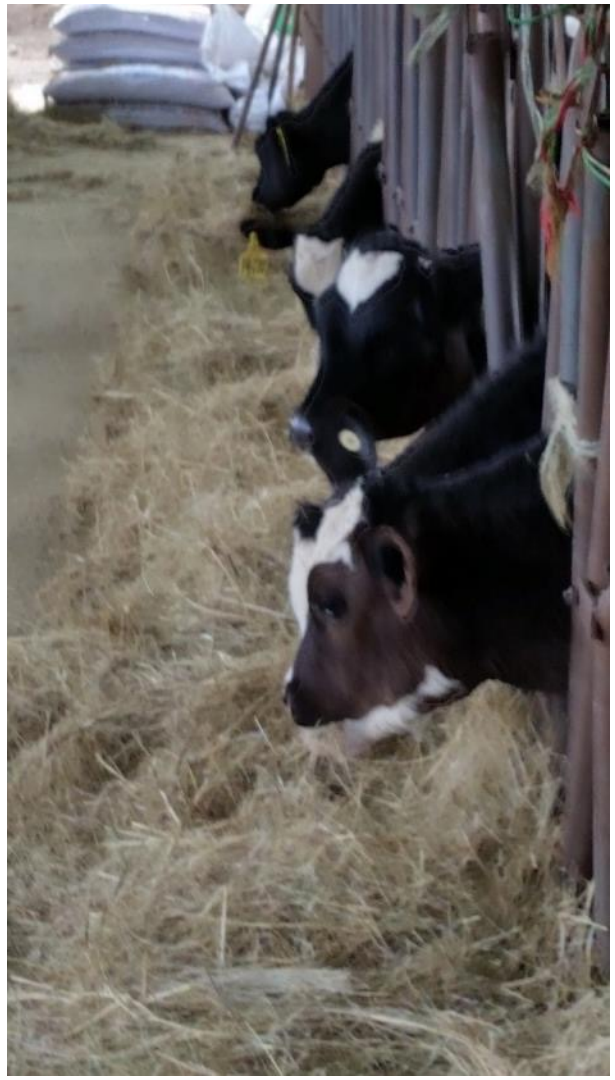
Ad libitum forage can harm the weaning transition

Calves fed ad libitum hay and limited concentrate do not grow well and are in poor health after weaning



Photos courtesy of Jim Quigley

Rumen pH in young rumen is very low, with or without hay in the diet

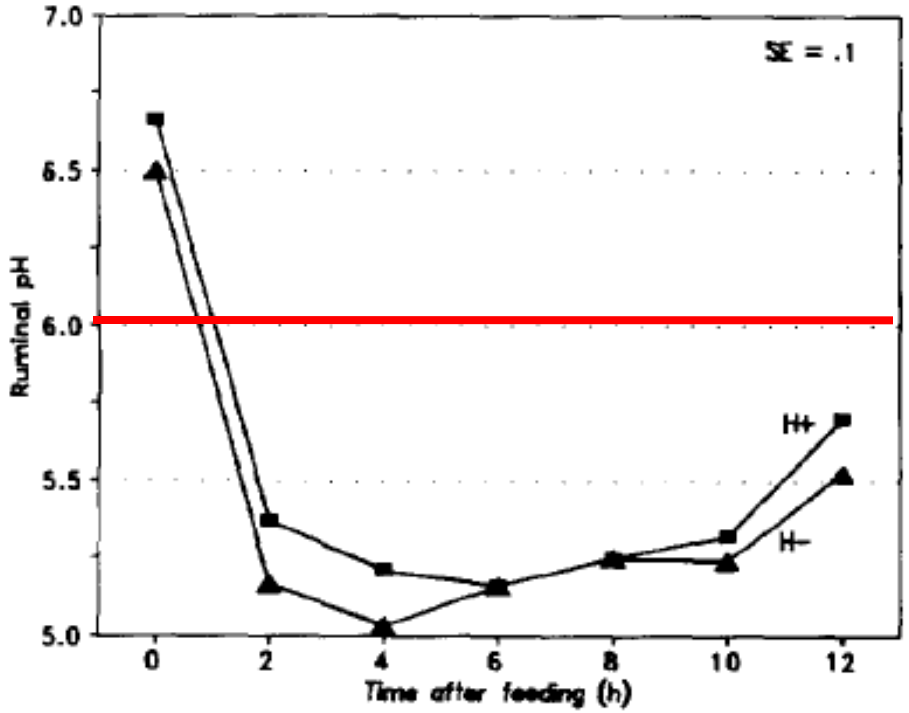
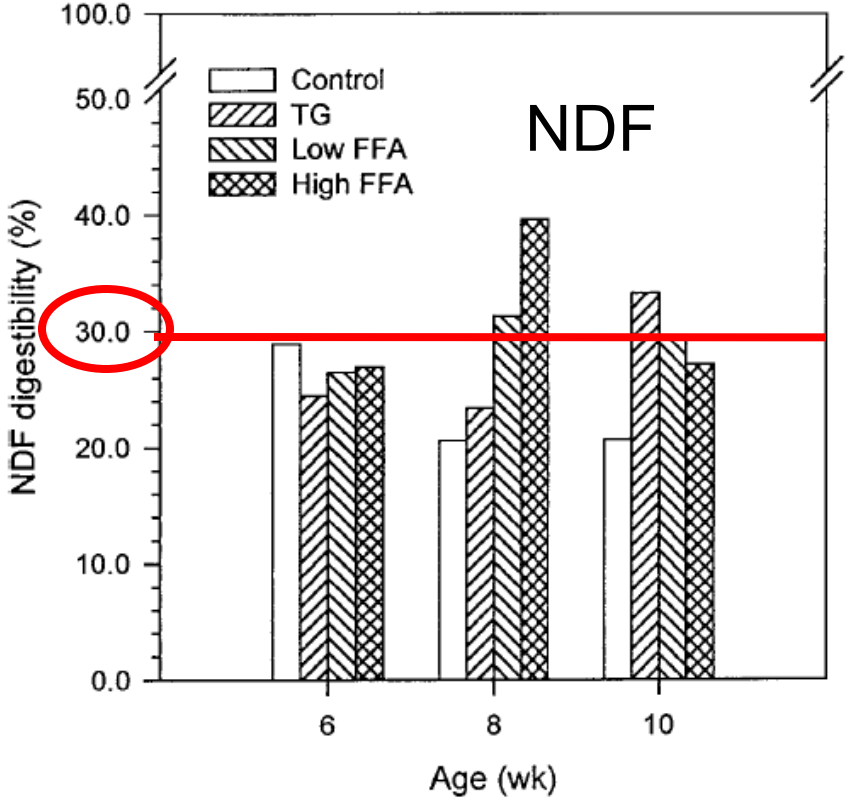


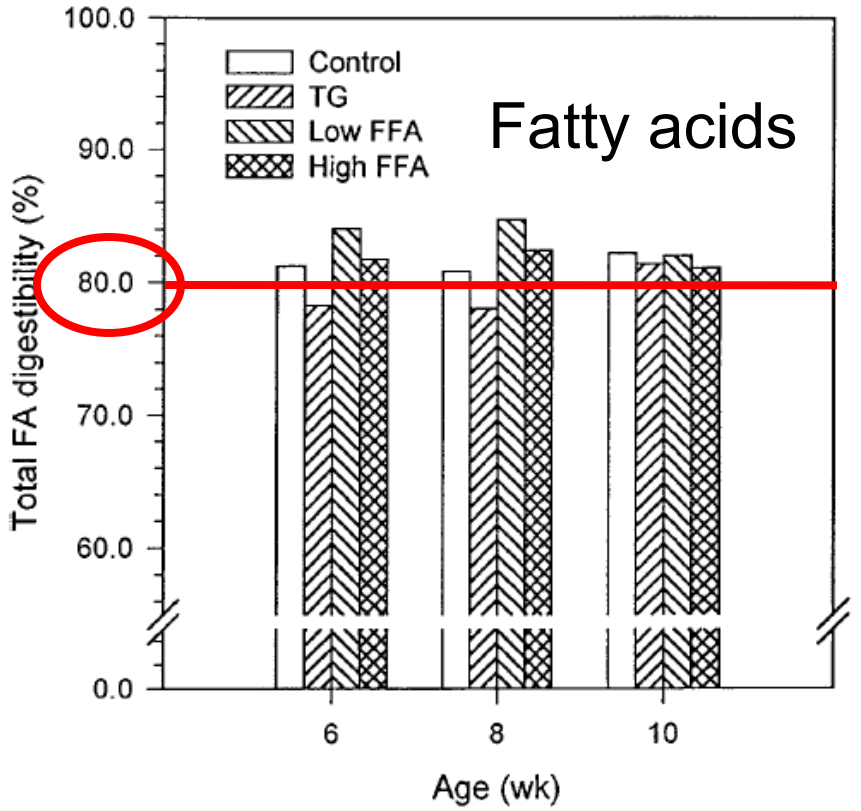
Figure 1. Ruminal pH with time after feeding in calves fed starter (4.5 kg/d) with (H+) or without (H–) alfalfa hay for ad libitum consumption.

Sustained rumen pH >6.0 is needed to establish functional populations of cellulose-digesting bacteria

Quigley et al., 1992

Digestibility of NDF is very low in young calves





Starter contained 25% alfalfa meal and 8% wheat bran.
No forage fed.

Spanski et al., 1996

Peformance of calves fed varying amounts of grain and hay

Variable	Diet 1	2	3	4	5
Grain DMI, kg/d	0.40	0.76	1.04	1.34	1.37
Hay DMI, kg/d	0.63	0.34	0.26	0.23	0.06
GIT contents, kg	13.8	12.8	12.8	11.9	11.3
ADG, kg/d	0.32	0.42	0.47	0.60	0.59
EBG, kg/d	0.14	0.24	0.31	0.43	0.43
% of ADG due to gut & fill	73.4	55.5	48.7	37.9	38.6

Calves were fed 3.0 kg/d milk from 0 to 5 wk.

Stobo et al., 1966

Postweaning performance of calves fed starter without or with chopped hay

Trial and variable	Diet			
	C	G	H1	H2
Trial 1				
ADG, kg/d	0.91	0.74	1.22	1.02
Gain:Feed	0.52	0.42	0.66	0.58
Trial 2				
ADG, kg/d	0.78	0.72	0.85	0.82
Gain:Feed	0.50	0.50	0.51	0.57

C = coarse starter, G = ground starter, H1 = C + 7.5% chopped hay, H2 = C + 15% chopped hay.

Bromegrass hay sieved to 8 to 19 mm length

Trial 1: C vs. G; C vs. H1 + H2; H1 vs H2 significant.

Trial 2: all non-significant (P > 0.10)

Coverdale et al., 2004

Forage inclusion in starters increased DMI and body growth

Variable	CON	AM10%	AM20%	CC	SE
Preweaning DMI, kg	9.9^{b}	15.7^{a}	14.5^{ab}	9.5^{b}	1.9
Postweaning DMI, kg	33.8^{b}	38.1^{ab}	42.3^{a}	33.5^{b}	1.9
Postweaning gain:feed	0.47	0.44	0.49	0.44	0.05
Digesta, kg	3.2^{b}	3.7^{ab}	4.7^{a}	2.9^{b}	0.3
Carcass-adjusted BW gain, kg	25.7^{b}	34.4^{a}	35.5^{a}	25.2^{b}	2.9

CON = steam flaked corn, AM = alfalfa meal in pellet, CC = all cracked corn

Benschop and Cant, 2009

Forage to concentrate ratio selected by calves given free choice of both

Forage	F:C	ADG (kg)
None	---	0.72^{c}
Alfalfa hay	14:86	0.76^{bc}
Oat hay	8:92	0.93^{a}
Barley straw	5:95	0.88^{a}
Rye-grass hay	4:96	0.84^{ab}
Corn silage	5:95	0.82^{ab}

Conducted in Spain. Hay or straw chopped. Gain:feed was not different among diets.

From Castells et al., 2012

Calves will choose high-quality alfalfa hay over starter concentrates

Photo by J. K. Drackley

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Forage	F:C	ADG (kg)
None	---	0.72^{c}
Rye-grass hay	4:96	0.84^{ab}
Corn silage	5:95	0.82^{ab}

For 1.5-kg total DM intake, forage intake would be only **75 g/d** for barley straw vs. **210** g/d for alfalfa hay.

Conducted in Spain. Hay or straw chopped. Gain:feed was not different among diets.

From Castells et al., 2012

Summary of forage recommendations

- Do not feed free choice alfalfa hay.
  - decreases starter intake, very palatable but low digestibility (high lignin)
- Small amounts of chopped grass hays or straw (<100 g/d or 5% of total “TMR”) will *increase* starter consumption and feed efficiency.
- Limit amount of alfalfa hay offered through at least 6 months so that calves consume all programmed concentrates.

A good solution

Photo by J. K. Drackley

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- Weaning from high amounts of milk not gradual enough
- Too much forage
- **Poor starter quality or composition (too high in starch, poor palatability, particle size issues)**
- Poor water management
- Stacking stressors at weaning

Characteristics of starter formulation important for protein supply

- Palatable ingredients
- Sufficient fiber (>15% NDF, particle size)
- Not dusty or too many fines
- Protein for rumen and post-ruminal digestion; adequate total protein content
- Avoid whole oilseeds and high fat content; corn byproducts less palatable

Effects of starter physical form and forage

Pazoki et al., 2017

Effects on rumen epithelium

Pazoki et al., 2017

Digestible fiber and sugars vs. starch

- Typically starch content of starters has been 34 – 40% of DM
- Recent concern has been that this contributes to very low rumen pH in transitioning calves (<5 for much of day)
- Trend in industry is toward lower starch and higher digestible fiber and sugars
  - Data are limited

Example of a low-starch, high sugar starter

Ingredient	% of DM
Pellet	
Bypass soybean meal	19.78
Wheat midds	19.29
Canola meal	6.59
Dextrose	3.30
Dried whey	5.94
Blood meal	3.96
Rumen protected Met	0.73
Minerals, vitamins, additives	3.82
Flaked corn	20.11
Beet pulp shreds	13.19
Molasses	3.29

Molano et al., 2021

Example of a low-starch, high sugar starter

Chemical component	% of DM
CP	25.50
Crude fat	2.96
aNDFom	25.10
Starch	17.80
Sugars	14.10
Ash	8.18
ME, Mcal/kg	2.50

Molano et al., 2021

Factors contributing to poor weaning performance

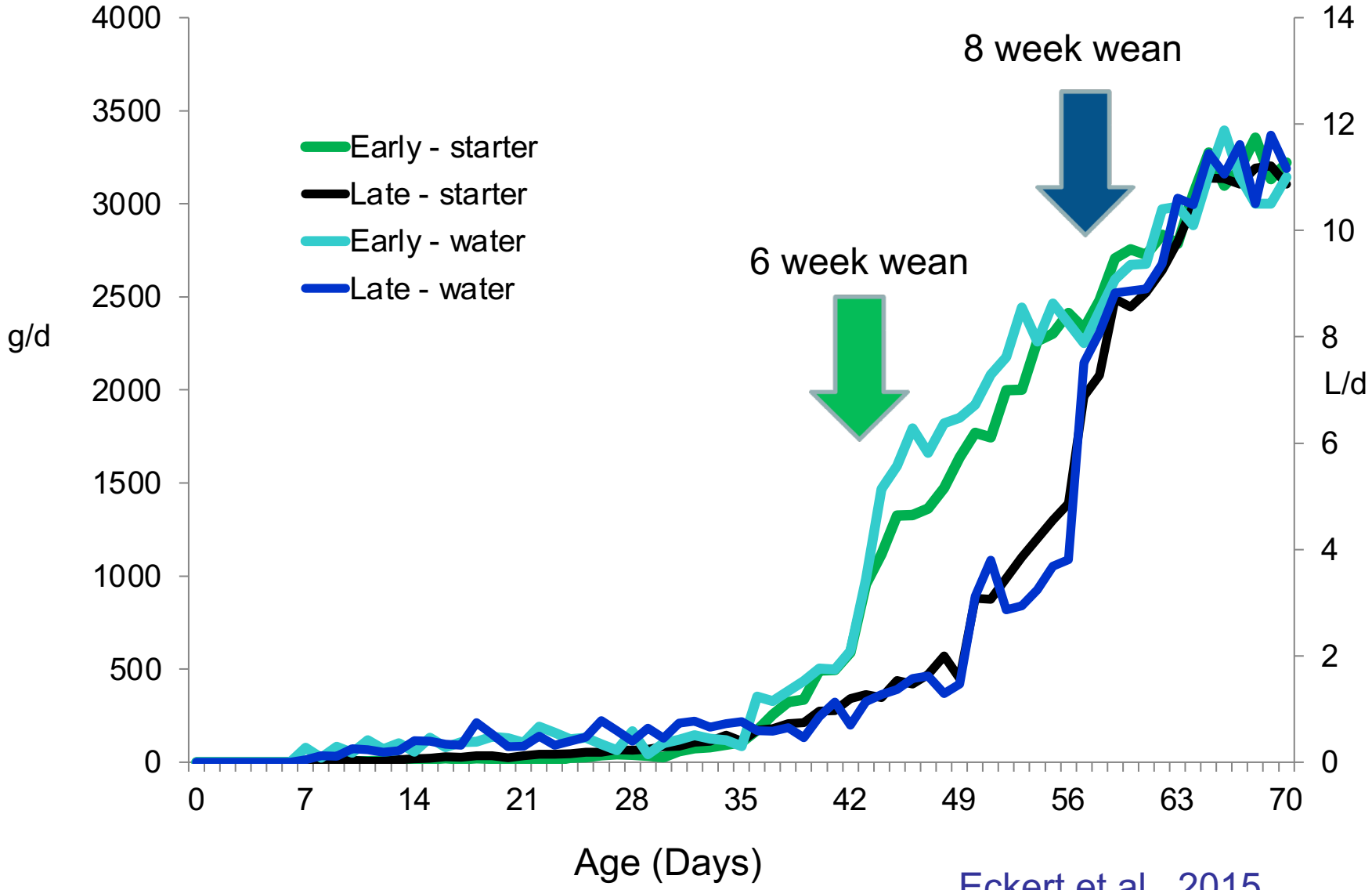
- Weaning too early
- Weaning from high amounts of milk not gradual enough
- Too much forage
- Poor starter quality or composition (too high in starch, poor palatability, particle size issues)
- **Poor water management**
- Stacking stressors at weaning

Water: the most important, and most neglected, nutrient

Milk-fed calves need free water

- Milk or MR bypasses rumen, whether fed by nipple or bucket
- Need supplemental water to enter rumen and support microbial environment
- For 1 kg starter intake, need 4 L water intake
  - Inadequate water = less starter intake
  - **= *Decreased growth***

Water and starter intake patterns are almost identical!



Courtesy M. Steele, University of Alberta

Eckert et al., 2015

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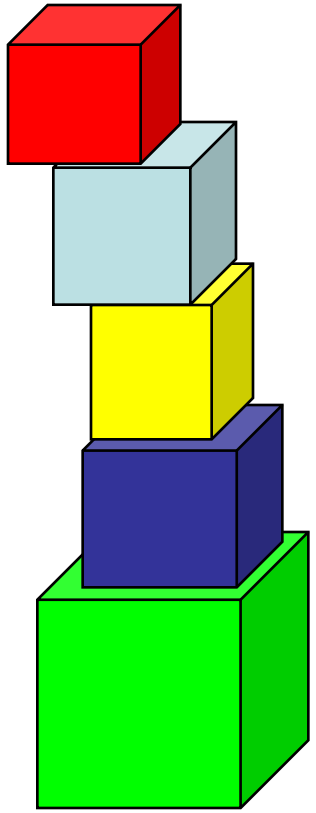
Avoid “stacking” stressors at weaning



Vaccination

Dehorning

Environmental stress

Social stress

Nutritional stress

- Do not move calves or change diet for 1 wk post-weaning.
- Do not combine weaning with other management tasks such as vaccination and dehorning.

Summary
To avoid traumatic weanings:

- Don’t wean too early
- Wean gradually
- Don’t feed too much forage
- Feed a high quality starter
- Provide fresh water
- Don’t stack stressors around weaning

Thank you!

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