Metabolic physiology of the dairy cow during the transition period under pasture based production systems

David A. Kenny[1] and Ainhoa Valldecabres[2]
Animal and Bioscience Research Department, [1]Teagasc Grange, Dunsany, Co. Meath, Ireland; [2]Teagasc Moorepark, Fermoy, Co. Cork, Ireland

Teagasc
Agriculture and Food Development Authority

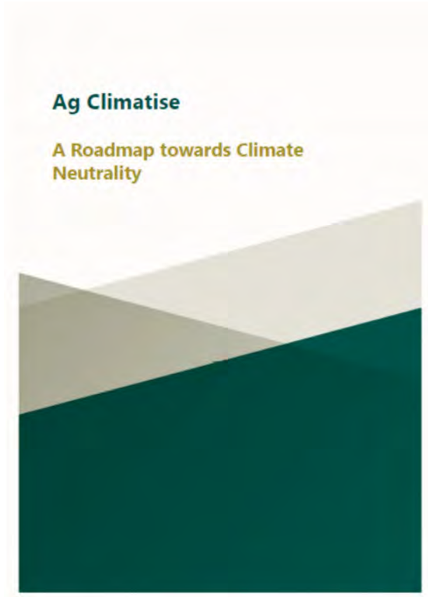
Overview

- Introduction to pasture based dairy production
- Dietary management of pasture based cows
- The transition period
- Metabolic regulation during transition period
- Implications of transition cow management for health and fertility
- Summary and conclusions

Irish Dairy Industry Statistics

- Fastest growing agri-food sector- growing by 50% since 2015
- 18,000 dairy farmers
- Irish milk production represented approximately 6% of total EU milk production in 2020.

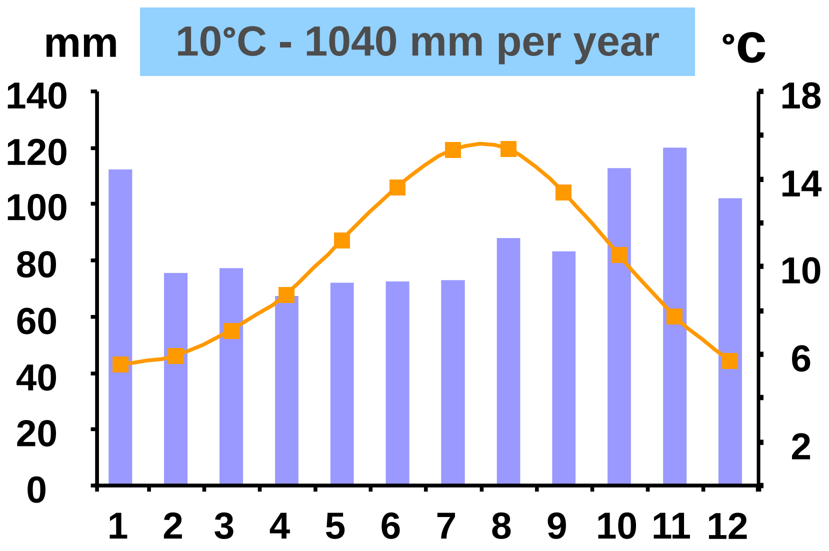
- In 2020 - 1.6 m dairy cows & total milk output at 7 billion litres
  - Average farm- 76 cows on 56 ha producing 363,692 litres
  - Average cow: 5,000 litres (4.14% fat & 3.48% protein).
  - 56 ha of grass - 150 kg N / ha – 1,000 kg Conc - 7 t grass used / ha

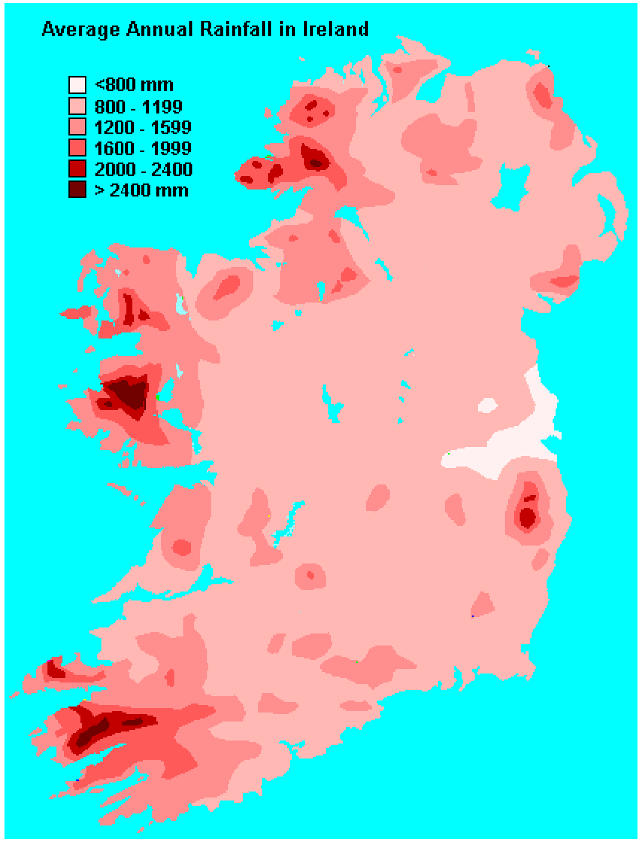


- System: Predominately seasonal spring calving pasture-based
- 20% of the country's total forage area
- 19 milk processors - 82% of milk processed by 6
- 85% of total production is exported: $^1/_3$ UK, $^1/_3$ EU, $^1/_3$ Other
- In 2020, Ireland exported dairy products to ~140 countries with a value > €5 billion

Low cost - grazed grass based systems

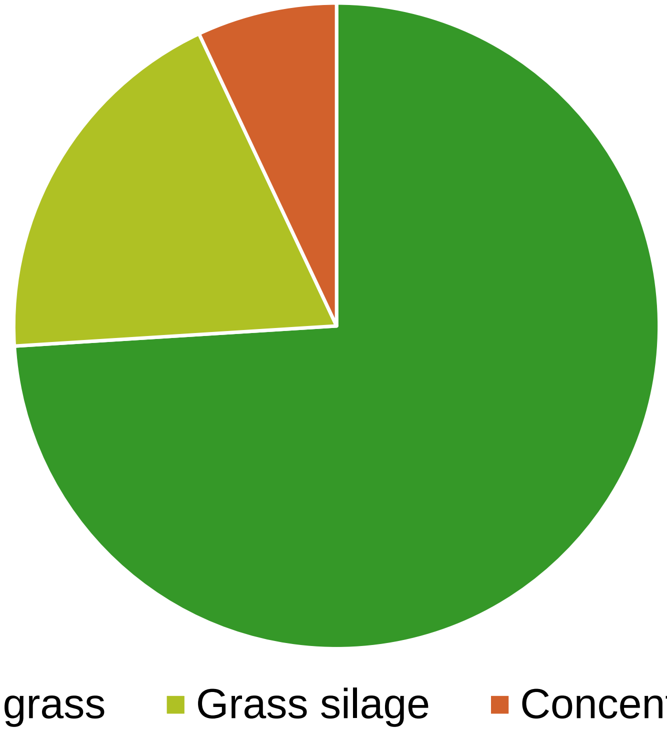
- Climate conditions favourable to grass growth
- Target: 10 - 15 t DM / ha





Annual feed budget for a spring calving cow

- 74% Grazed grass
- 19% Grass silage
- 7% Concentrates



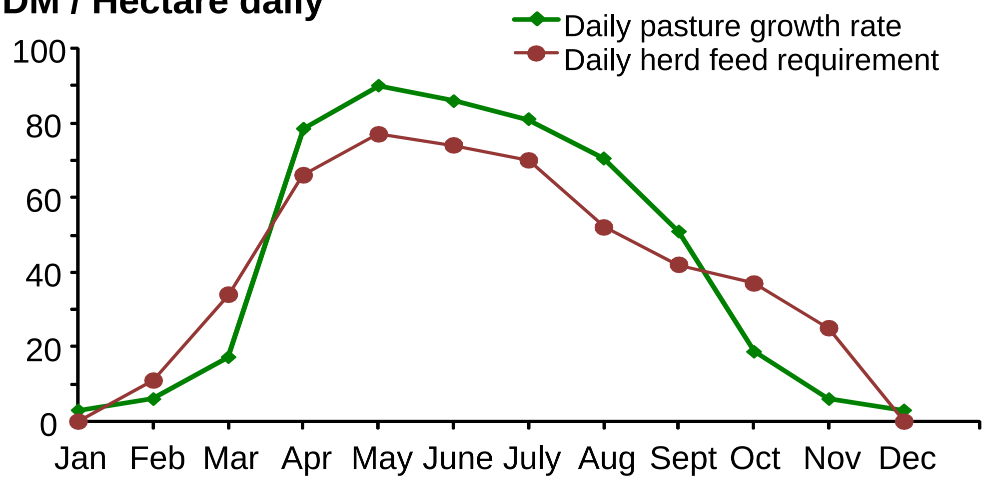
Target production: 400-450 kg milk solids per cow per year

Source: Teagasc Dairy Manual (2016)

First Principles of Pasture-based Systems…

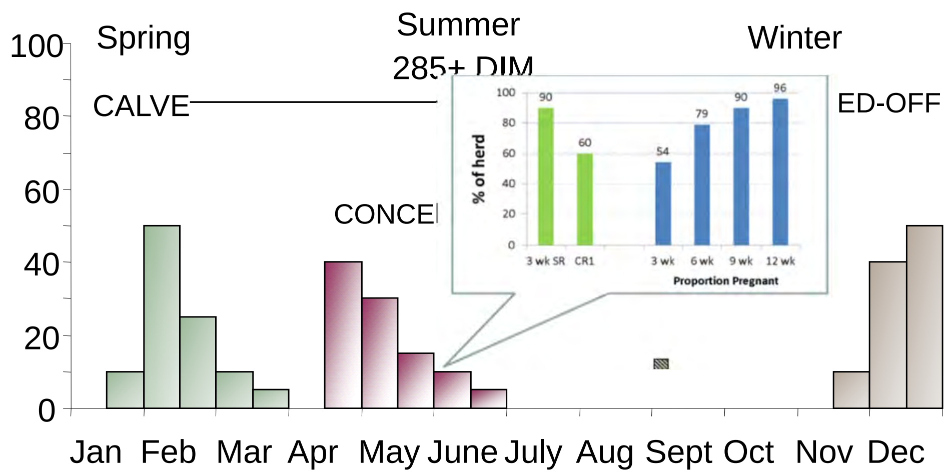
Alignment of Grass Supply & Animal Requirements

kg DM / Hectare daily



Compact calving, high fertility status dairy herd

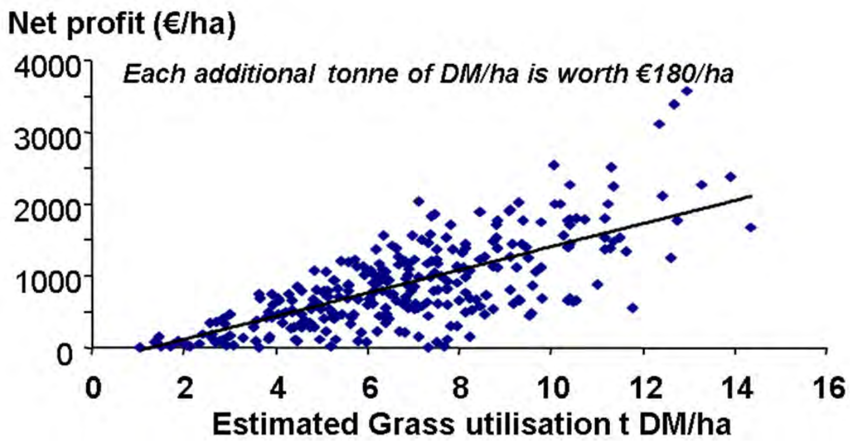
% of cows in the herd



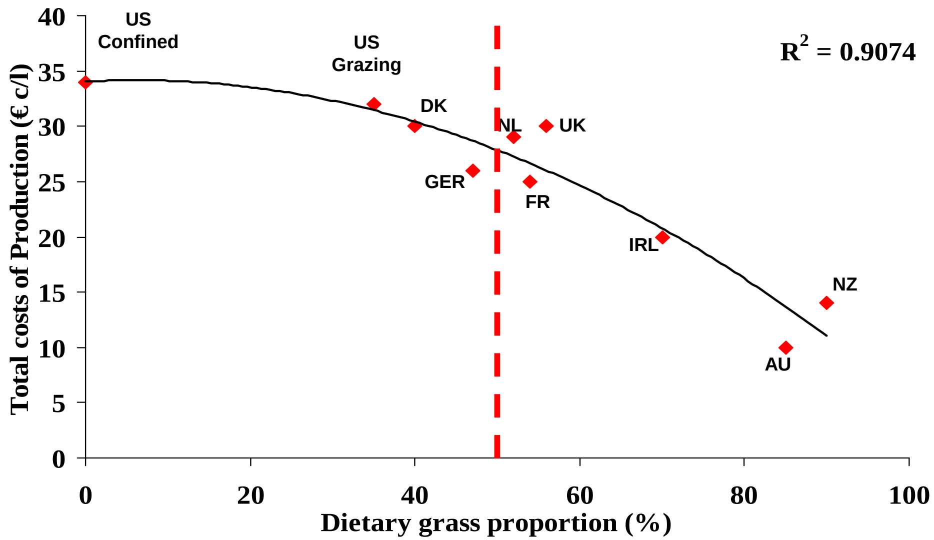
"Simplicity is the ultimate sophistication" – Leonardo da Vinci.

Economic Imperatives for Grassland Systems

- **High profitability grazing systems are based on high levels of pasture utilisation**



- **Curvilinear relationship between grass proportion in the diet and milk production cost**
- Reduced feed related costs
- Low fixed costs



Dillon et al. (2008)

Chemical composition pasture vs. TMR

- Dry matter (%): TMR > pasture
- Crude protein (CP): pasture > TMR
- Neutral detergent fiber (NDF): pasture > TMR
- Potassium (K): pasture > TMR
- Trace minerals: TMR > pasture

TABLE 2. Chemical composition and in vitro digestibility (IVDMD) of pasture and TMR during the intake period.

	Pasture	TMR
DM, %	17.0	58.2
	—— (% of DM) ——	
OM	90.6	92.6
CP	25.1	19.1
Soluble CP, % of CP	30.6	33.0
NDF	43.2	30.7
ADF	22.8	19.0
TNC[1]	19.3	28.8
NE_L, Mcal/kg	1.65	1.63
IVDMD	77.0	76.0
Ca	1.03	1.21
P	0.45	0.54
Mg	0.23	0.31
K	3.40	1.40
S	0.24	0.22
Na	0.03	0.43
Fe, ppm	175	245
Zn, ppm	34	80
Cu, ppm	9	19
Mn, ppm	60	81
Mo, ppm	3.5	1.6

[1]Total nonstructural carbohydrate.

Kolver and Muller (1998) J. Dairy Sci. 81 (5)1403-1411

Nutrient intake pasture vs. TMR

- Holstein cows fed grazed pasture (n = 8) or TMR (n = 8)
- Unsupplemented grazing Holsteins were:
  - Unable to achieve the same DMI as Holstein cows fed the TMR
  - Unable to achieve the same NE_L intake as Holstein cows fed the TMR

TABLE 3. Nutrient intake of cows consuming pasture or the TMR in confinement.

	Pasture	TMR	SE	$P <$
	(kg/d)			
DM[1]	19.0	23.4	0.6	0.01
OM	17.6	21.2	0.6	0.01
CP	4.9	4.7	0.2	NS[2]
NDF	8.5	7.6	0.4	NS
NE_L, Mcal/d	32.4	40.2	1.8	0.02
	(% of live weight)			
DM	3.39	3.93	0.12	0.01
OM	3.14	3.56	0.11	0.02
CP	0.85	0.75	0.03	0.02
NDF	1.47	1.21	0.04	0.01

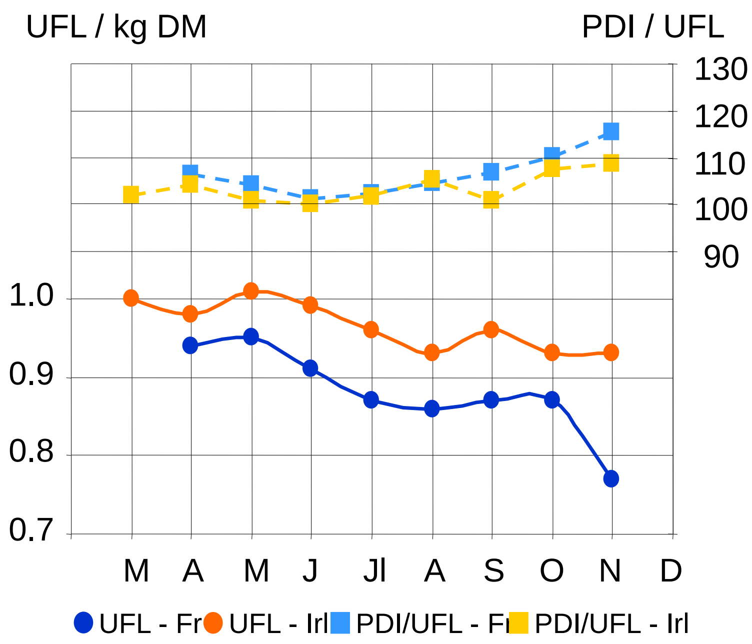
[1]Pasture DMI was estimated using a Cr_2O_3 marker; DMI of the TMR was calculated by weighing feed offered and orts.

[2]$P > 0.10$.

Kolver and Muller (1998) J. Dairy Sci. 81 (5)1403-1411

teagasc
Agriculture and Food Development Authority

How to increase DMI of grazing cows?



Well managed, grazed grass
is a natural TMR

But grazed grass is characterised
by a low DMI
due to the form and nature
of the forage offered

Average lactation performance

- 3 feeding and housing systems over a full lactation (n = 18 cows/group)
  - TMR: Cows housed indoors and offered a total mixed ration diet
  - Grass: Cows outdoors on a perennial ryegrass pasture
  - Clover: Cows outdoors on a perennial ryegrass/white clover pasture

O'Callaghan (2016) J. Dairy Sci. 99:9424–9440

teagasc
Agriculture and Food Development Authority

Average lactation performance

- Milk Yield: TMR > Clover > Grass
- Milk fat:
  - Content (%): Grass > TMR and Clover
  - Total (kg/d): TMR > Clover > Grass
- Milk protein:
  - Content (%): Grass and Clover > TMR
  - Total (kg/d): TMR > Clover > Grass

	Feeding system				
Item	TMR	Grass	Clover	SE	*P*-value
Milk yield (L/d)	27.71	20.98	24.59	0.14	<0.001
Milk solids (kg/d)	2.24	1.78	1.99	0.01	<0.001
Protein (kg/d)	0.94	0.76	0.87	0.01	<0.001
Fat (kg/d)	1.31	1.02	1.12	0.03	<0.001
Lactose (kg/d)	1.32	1.01	1.18	0.01	0.716
Live weight (kg)	591.51	532.11	550.45	13.15	<0.001

O'Callaghan (2016) J. Dairy Sci. 99:9424–9440

The transition period

- The ‘transition period’ is widely defined as the period from 3 weeks pre-calving until 3 weeks post-calving (Grummer, 1995)
- The period is characterised by marked changes in the endocrine status of the animal that are much more dramatic than at any other time in the lactation–gestation cycle
- The typical reduction in feed intake when nutrient demand for the developing conceptus and the impending lactogenesis are increasing is a particularly notable characteristic of the period
- The initiation of milk production has the direct effect of increasing calcium output from the cow at a time when calcium availability cannot readily be increased
- Reduced feed intake capacity at this time creates an imbalance of energy yielding inputs relative to energy outputs universally referred to as ‘negative energy balance’

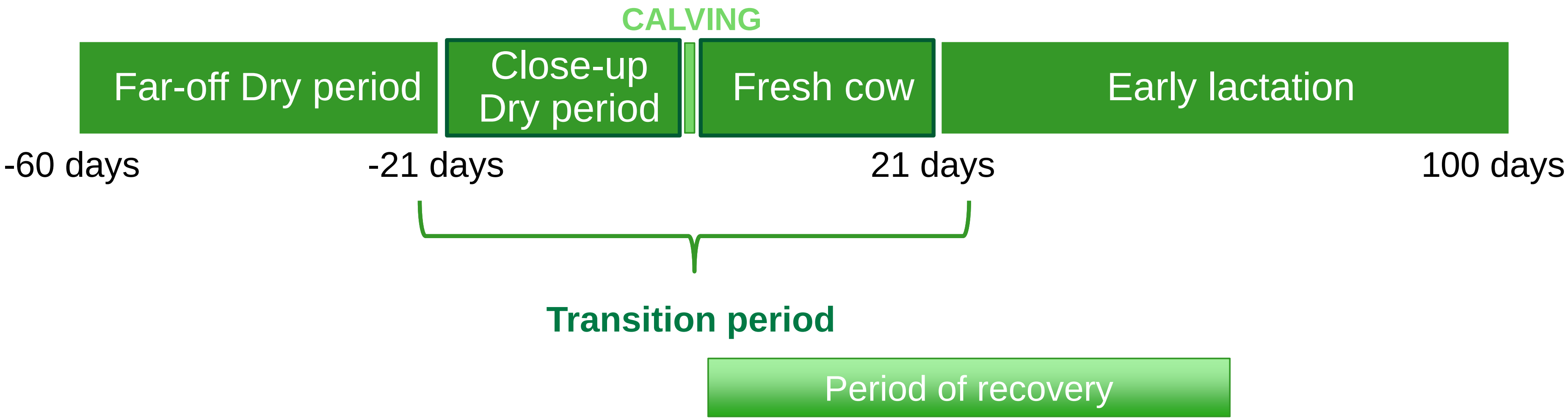
Mulligan and Doherty (2008)

Transition cows – pasture based system

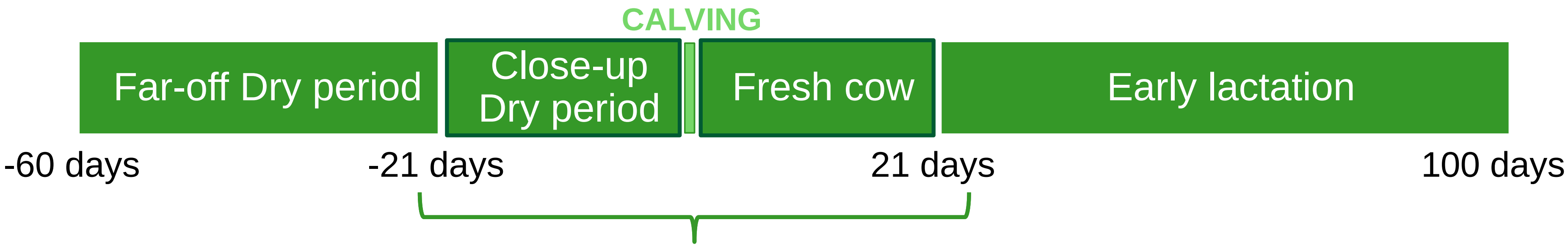
- Pasture-grazed transition dairy cows
  - Less dietary adjustment to undertake – easier adaptation to postcalving diet?
  - In general the diet is well balanced, with the exception of some minerals Protein quantity and quality is generally adequate
- The focus of transition cow nutrition, therefore, has been on energy nutrition and the prevention of metabolic diseases
- Revision of historical recommendations in relation to degree of precalving plane of nutrition and target BCS
- Increased precalving DMI is associated with a greater risk of milk fever at calving

Roche et al. (2017). Journal of Dairy Science Vol. 100 No. 12,

Transition period



- In seasonal calving pasture-based systems cows must recover from calving and become pregnant within 2 - 3 months to achieve a yearly calving interval



Transition period

- Physiological adaptations
  - Nutrient partitioning - Uncoupled somatotropic axis
  - Secretion of calciotropic hormones
- Metabolic challenges

  Energy, mineral and protein requirements increase faster than their availability (DMI, tissue mobilisation)

  - Negative balance
    - » Energy
    - » Mineral (Hypocalcemia, Hypomagnesemia)
    - » Protein?

Metabolic adaptation during transition

Adaptations to support nutrient partitioning for foetal growth and milk synthesis

- Uncoupling of the somatotropic axis (prepartum: ↓GHR expression, ↓IGF1, ↓insulin; postpartum: ↑GH)
- Low insulin + insulin resistance in muscle and adipose tissues
  - Glucose is spared for mammary gland lactose synthesis and energy source
- Upregulation of lipolytic pathways
  - Adipose-derived fatty acids are used for milk fat synthesis and ketogenesis

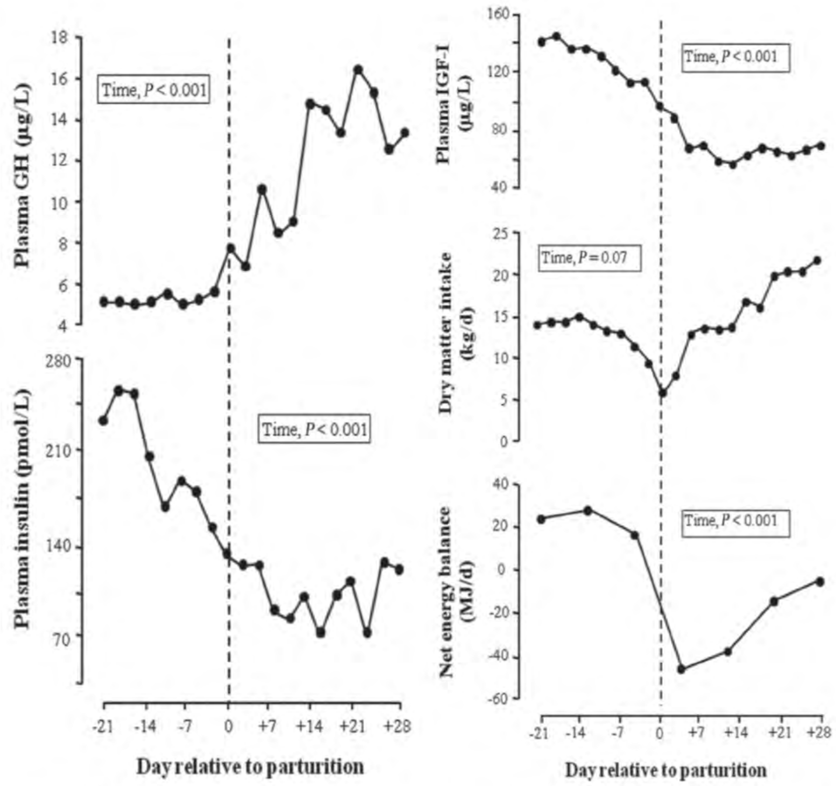
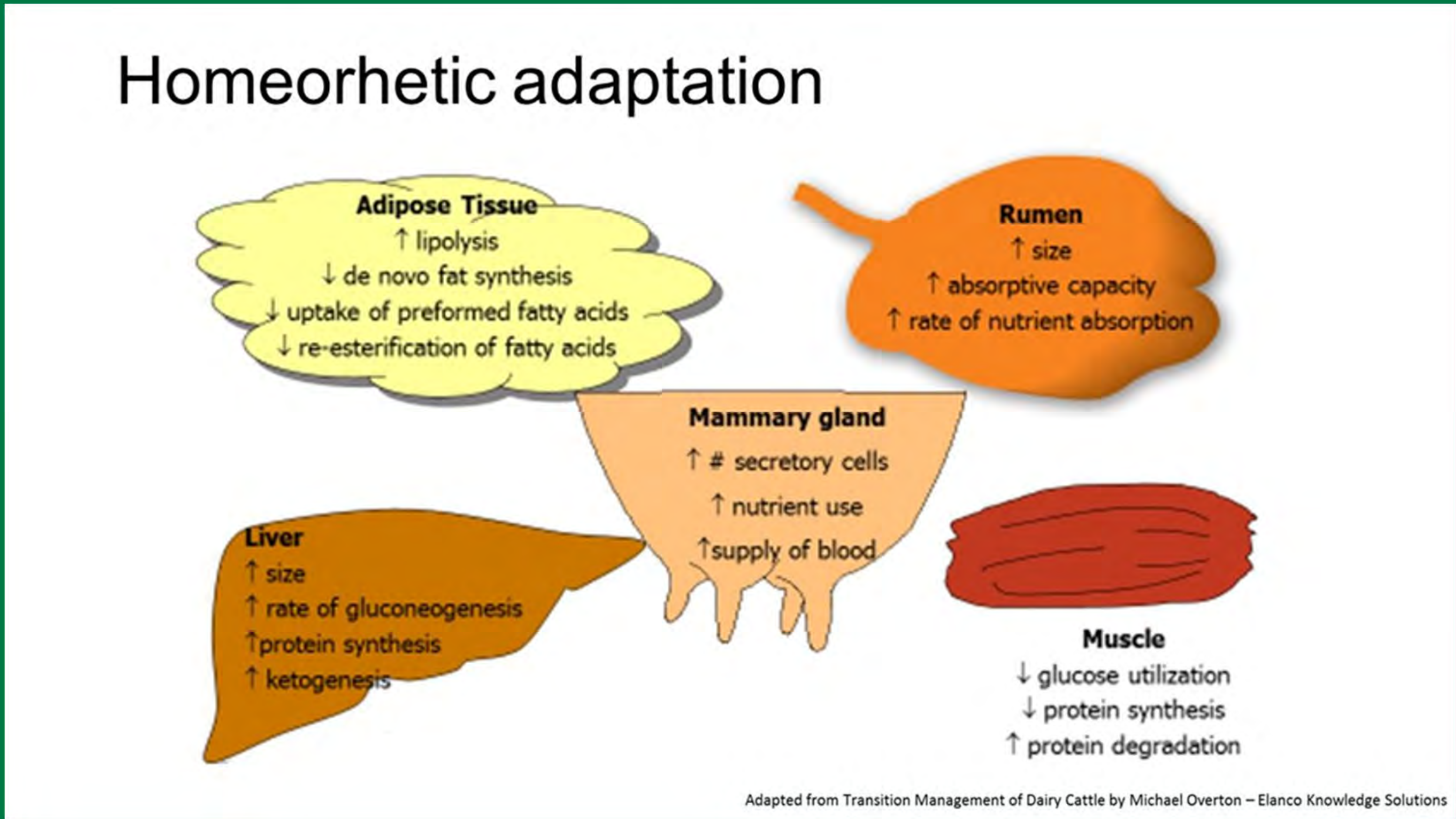
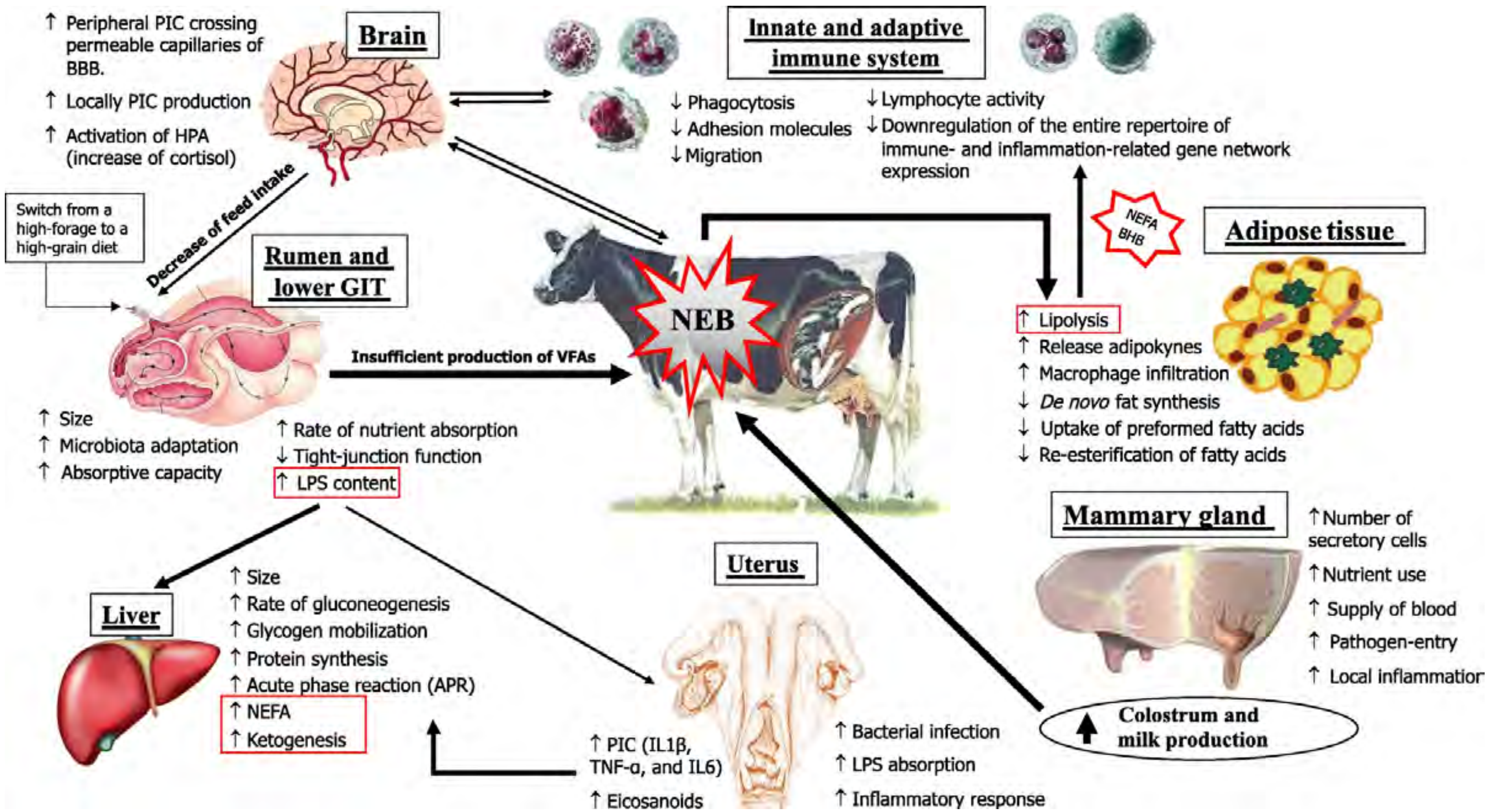


Figure 4. Temporal pattern of whole-animal energetics and key hormones responsible for nutrient partitioning in transitioning lactating Holstein cows. Reproduced from Rhoads et al. (2004) with permission of the American Society for Nutrition.

Source: Rhoads et al. (2004)

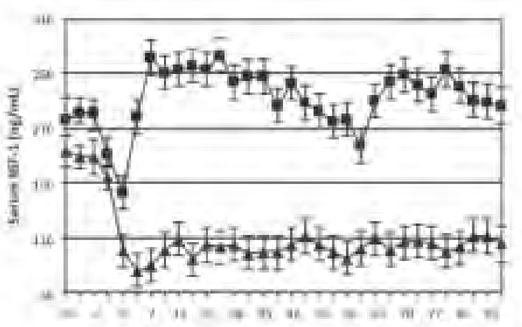
Physiological adaptations



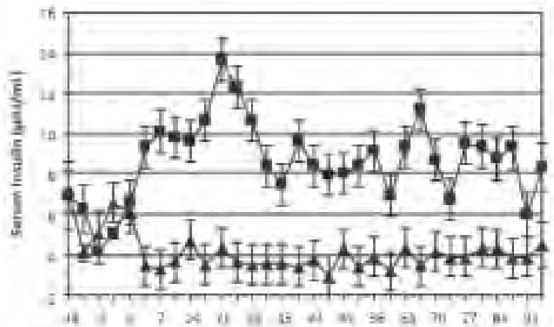


- Peripartal adaptations of key tissues such as liver, mammary gland, adipose, rumen, uterus, brain, as well as the immune system.
- Main factors that influence the functional response capacity of the key tissues involved in the homeorhetic adaptation during the transition period.

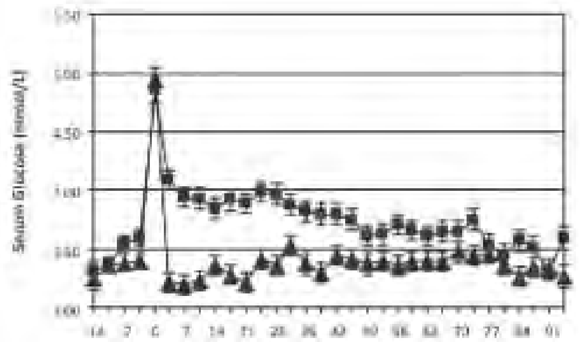
Source: Lopreiato et al. (2020). Journal of Animal Science and Biotechnology.



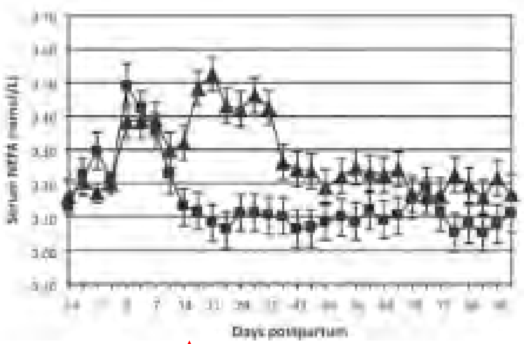
↓ IGF-1



↓ Insulin



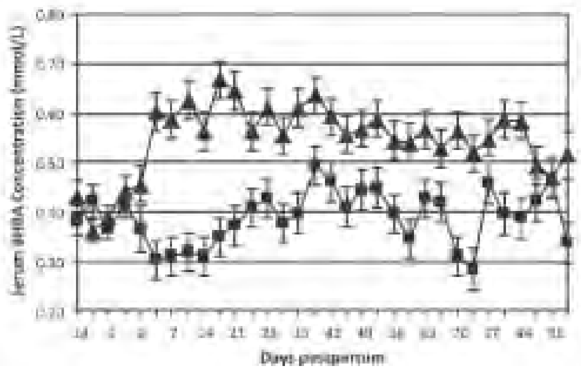
↓ Glucose



↑ NEFA

■ Non-lactating

▲ Lactating



↑ BHBA

Maillo et al., 2012

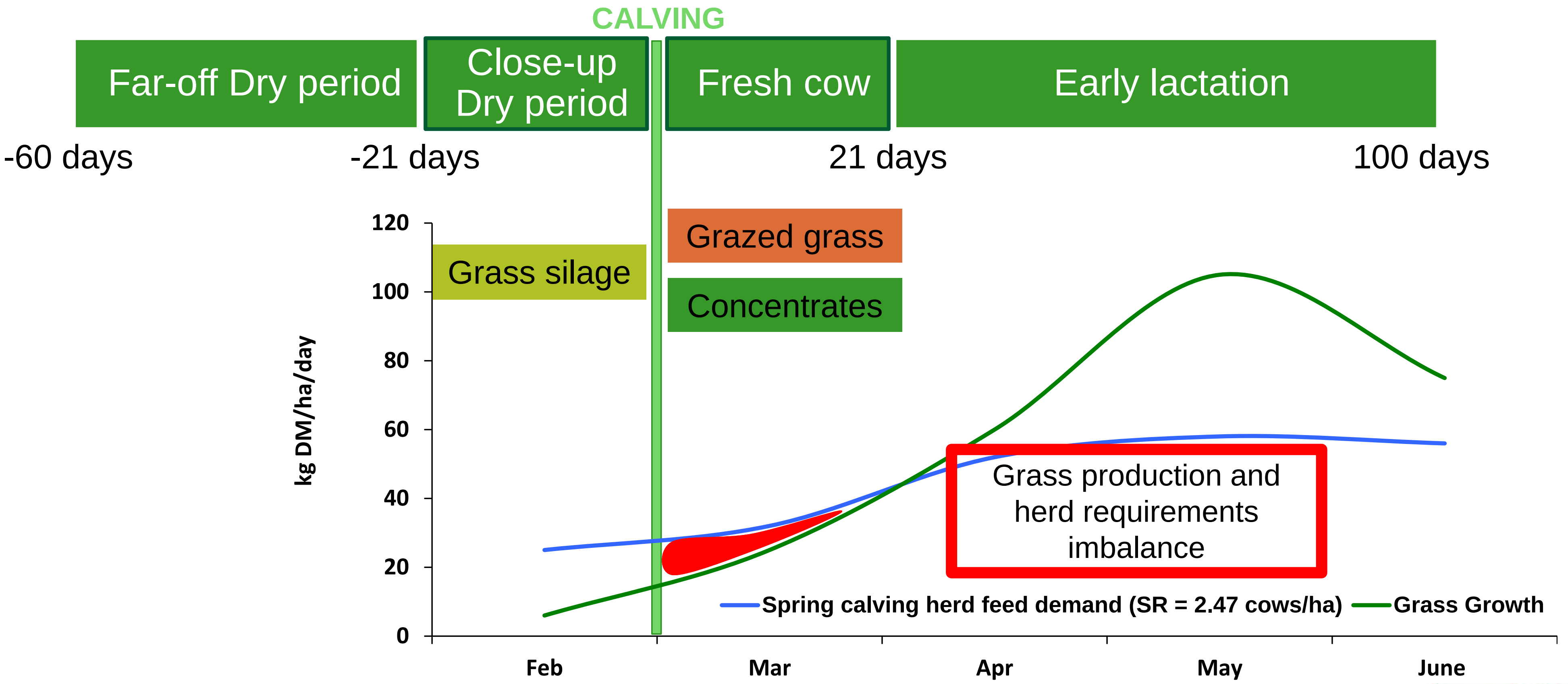
Forde et al., 2015

Challenges for the grazing transition cow

- Theoretically less because
  - Lower output (i.e., lower energy required for lactation)
- Reportedly similar
  - At 0 d postpartum:
    - Clinical hypocalcemia (≤1.4 mmol/L): 6%
    - Subclinical hypocalcemia (Ca ≤2.15 mmol/L): 60%
  - At 7 d postpartum:
    - Hyperlipidemia (NEFA ≥1.0 mmol/L): 43%
    - Hyperketonemia (BHB ≥1.2 mmol/L): 16%
- Potentially because limitations on DMI

Spaans et al. (2022) J. Dairy Sci. 105

Transition period: Feeding management



Grass growth figure source: Elodie Ruelle

Odds for grazing cows

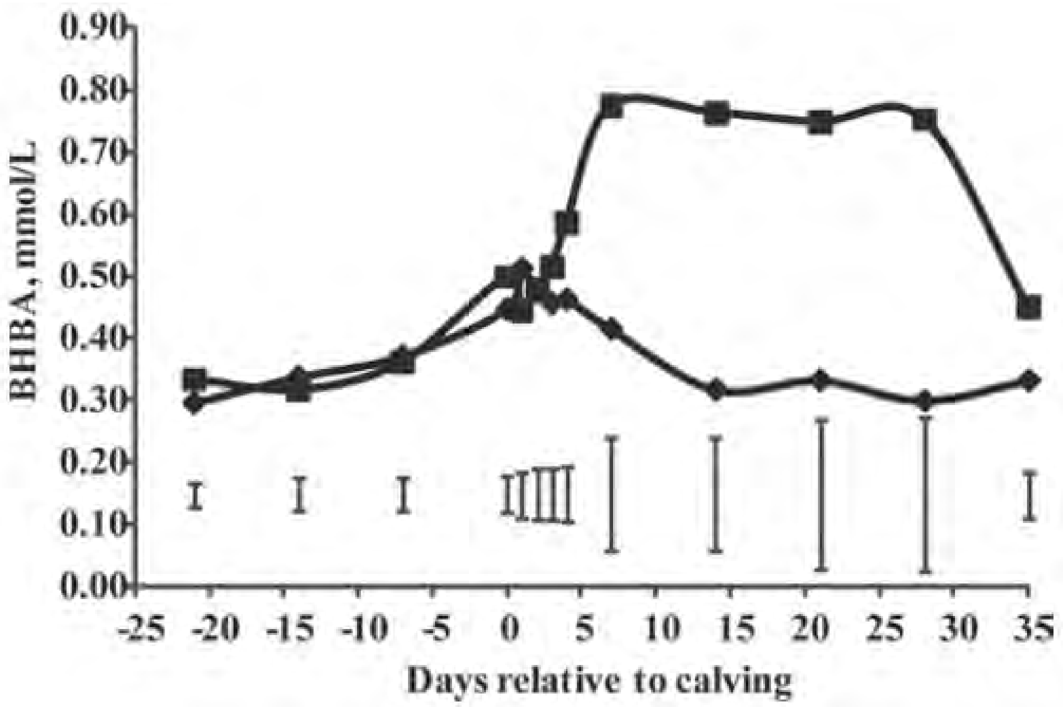
- Dataset of 69,161 unique individual cows (UK) from commercial dairies
- Access to grazed grass was associated with:
  - ↑ Prevalence of elevated β-hydroxybutyrate (BHB) and/or non-esterified fatty acids (NEFA) values in dry and lactating cows
- Access to fresh grass was associated with an exacerbated negative energy balance

		Dry cows (BHB ≥ 0.8 mmol/L and/or NEFA ≥ 0.5 mmol/L)				Lactating cows (BHB ≥ 1.0 mmol/L and/or NEFA ≥ 0.7 mmol/L)			
		Number	Prevalence (95% CI)	P value	Odds ratio (95% CI)	Number	Prevalence (95% CI)	P value	Odds ratio (95% CI)
Fresh grass	N	19,687	32.6% (31.4-33.8)	<0.001	ref	37,273	36.1% (35.2-37.1)	<0.001	ref
	Y	3,530	39.0% (36.9-41.1)		1.32 (1.21-1.44)	8,592	42.9% (41.5-44.4)		1.33 (1.26-1.41)

Macrae et al. (2019) The Vet Journal. 250: 15–23

Pre- and postpartum NFC concentration

- Isoenergetic diets differing in non-fiber carbohydrate (NFC) concentration pre- and postpartum.
  - ■Low NFC (pasture and pasture silage; n = 34)
  - ◆High NFC (pasture, pasture silage, and a grain-based concentrate; n = 34)
- Higher BHB is expected in pasture-fed cows given the diet particularities and associated reduced propionate production
- High BHB and NEFA concentrations indicate metabolically induced NEB



Roche et al. (2010) J. Dairy Sci. 93 :3671–3683

teagasc
Agriculture and Food Development Authority

Summary of metabolic analytes of pasture based transition dairy cows

- 2,610 cow lactations over 20 yr of transition cow research in New Zealand.
- ~28 d precalving to 35 d postcalving
- range of genetics, milk production potentials, and pasture-based farm management systems

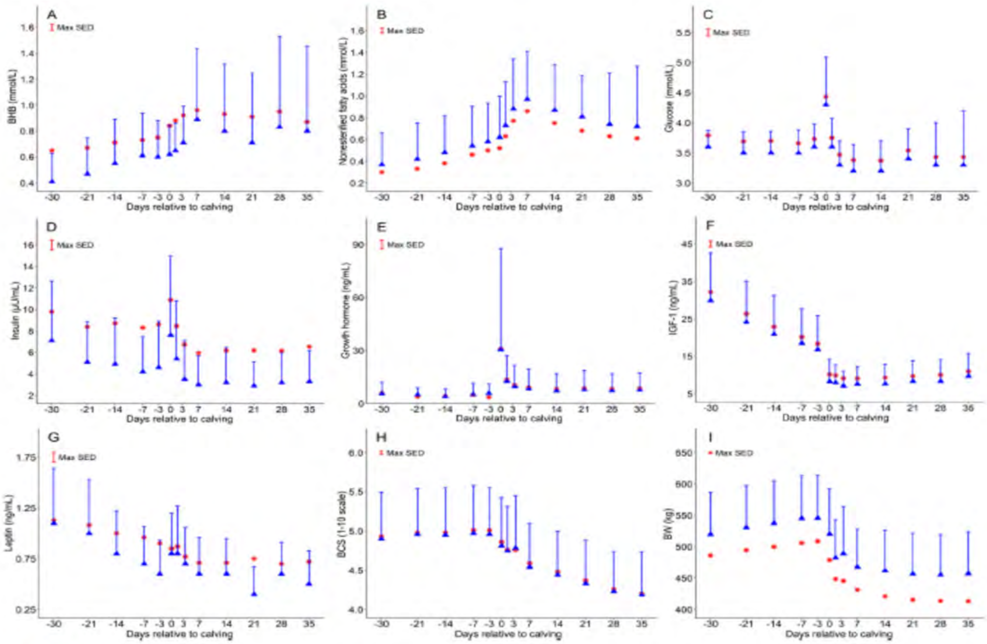
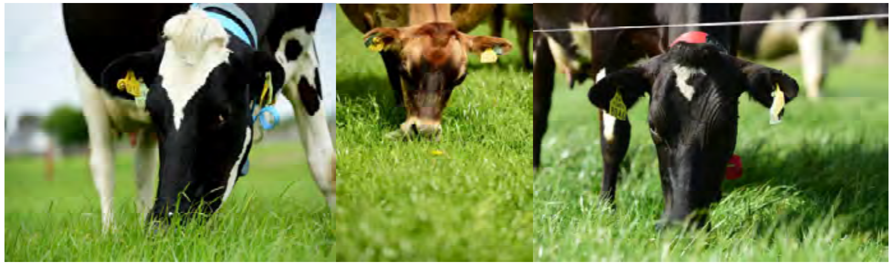


Figure 1. Mean (blue triangles) and upper SD, LSM (red circles), and maximum standard error of the difference (Max SED) for concentrations of energy indicator analytes. (A) β-Hydroxybutyrate (mmol/L), (B) nonesterified fatty acids (mmol/L), (C) glucose (mmol/L), (D) insulin (μU/mL), (E) growth hormone (ng/mL), (F) IGF-1 (ng/mL), (G) leptin (ng/mL), and animal health measures (H) BCS (1–10 scale) and (I) BW (kg) for the population of grazing dairy cows in the collated database with selected grouped time points by days relative to calving (d 0). Least squares means for repeated measures model, where variable = breed + parity group + calving season day + grouped day relative to calving (random effect: treatment within experiment; repeated variable = animal number); breed: Holstein-Friesian (≥12/16ths Holstein-Friesian genetics), Holstein-Friesian × Jersey crossbred, and Jersey (≥12/16ths Jersey genetics); parity: group 1 = parity 1 animals, group 2.5 = parity 2 and 3 animals, group 5 = parity 4 to 6 animals, group 7 = parity 7+ animals; calving season day: number of days between June 1 and calving date in the year of calving. d −30 = 30 d ± 5 d precalving; d −21, −14, −7 = 21, 14, 7 d ± 3 d precalving; d −3 = d 3 ± 1 d precalving; d 0 = d 1 precalving and day of calving; d 1.5 = d 1 and 2 postcalving; d 3.5 = d 3 and 4 postcalving; d 7, 14, 21, 28, 35 = 7, 14, 21, 28, and 35 d ± 3 d postcalving.

Spaans et al. (2022). J. Dairy Sci. 105:2669–2698

Metabolic adaptation: Breed effects

- Dairy systems in which pasture environments are core to production are dependent on cows achieving high DMI per unit of BW, with high milk solids (MLKS) production per unit of intake
- Production efficiency (NEI/kg MLKS) greater for Jersey and F_1 hybrid compared with HF
- Hybrid vigor evident for milk yield, milk lactose content, SCM, MLKS, net energy for lactation, BW, BCS, and net energy intake per MLKS
- When expressed per unit of BW, ruminating time was greater for the JE cows and they tended to have more ruminating mastications compared with HF cows
- Generally F_1 cows tended to be similar to the mid-parent mean, but had increased biting rate, lower grazing duration per bout, and a tendency to achieve a high intake per bite compared with the average of the parent breeds



Prendiville et al. (2009, 2010)

Metabolic adaptation: Breed effects

- 10 Pure HF, 10 pure Jersey and 10HF x JE F1 dairy cows
- Liver and duodenal tissue
- Candidate gene approach (n = 32 genes)

➢ A heterotic effect was observed in hepatic expression of AMKPB1, IGF1R, LEPR, POMC in the F1 genotype, possibly mediating improved feed efficiency in cross-bred cows

➢ Key genes involved in energy homeostasis and appetite behaviour were differentially expressed due to cow genotype in a tissue-dependent fashion.

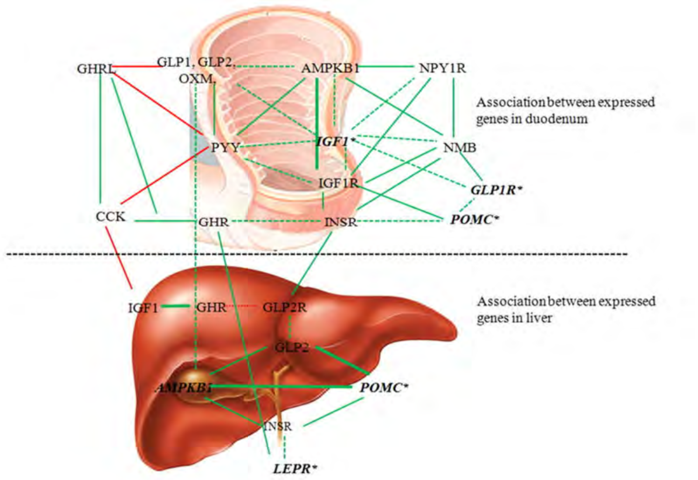
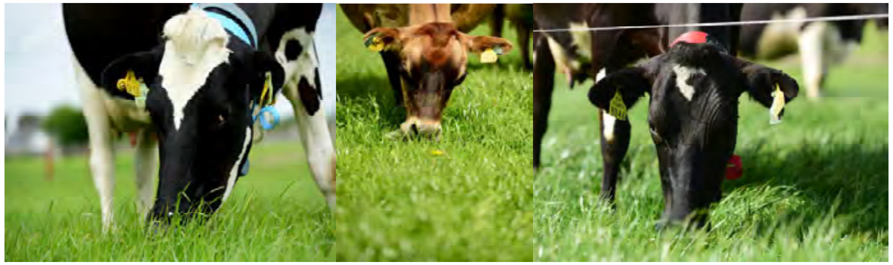


Fig. 2. A schematic representation of the correlations between gene expression within the duodenum and liver and across both tissue. Red line, negative association; green line, positive association; continuous thick line, $P < 0.001$; continuous thin line, $P < 0.01$; dashed line, $P < 0.05$. *Significantly differentially expressed ($P < 0.05$).



Prendivville et al. (2009, 2010); Alam et al. (2012)

eagasc
Agriculture and Food Development Authority

Metabolic adaptation: Within breed (NZ v NA)

- 10 New Zealand (NZ) and 10 North American Holstein Friesian (HP)
- Higher plasma IGF-1 concentration for NZ cows days 29-100 postpartum
- Lower degree of uncoupling in NZ
- Subsequent glucose tolerance, epinephrine and insulin challenges did not reveal any significant physiological basis for differences in partitioning
- Differences likely reflect the BCS profile of the strains within the study

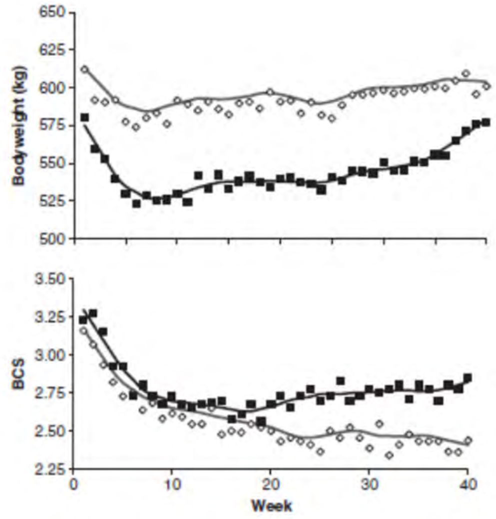


Figure 4 Effect of strain of Holstein Friesian on body condition score (BCS) and body weight (◇ = North American Holstein Friesian; ■ = New Zealand Holstein Friesian). The *P* values for the effects of strain, week and interaction between strain and week on weekly BCS were 0.16, <0.001 and 0.009, respectively. The s.e.d. was 0.08 BCS units. The *P* values for the effects of strain, week and interaction between strain and week on weekly body weight were 0.02, <0.001 and 0.57, respectively. The s.e.d. was 15.5 kg. Figures are presented with LOESS-smoothed lines for illustrative purposes.

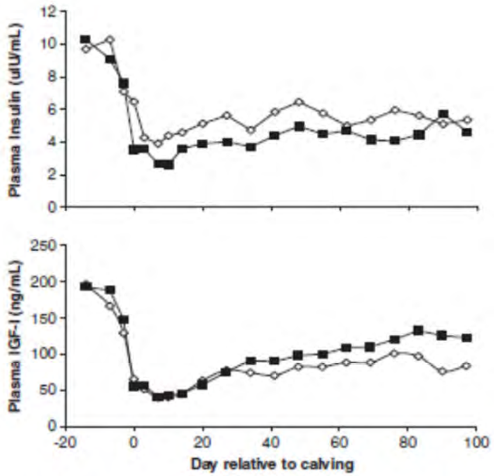


Figure 5 Effect of strain of Holstein Friesian on plasma insulin and IGF-I concentrations (◇ = North American Holstein Friesian; ■ = New Zealand Holstein Friesian). The *P* values for the effect of strain on insulin concentration were 0.01 and 0.06 for the transition period (2 week *pre partum* to day 28 *post partum*) and post-transition period (day 29 to day 100 *post partum*), respectively. The *P* values for the effect of strain on IGF-I concentration were 0.71 and 0.04 for the transition and post-transition periods, respectively. There were no significant strain-by-time interactions observed for either insulin or IGF-I across the entire experimental period ($P > 0.05$).

Patton J et al. (2008) Animal. 2(6):969-78; Patton J et al. (2009) Animal. 3(2)251–260; S.T. Butler

HF strain differences in uncoupling of somatotropic axis in hepatic tissue

Table 3. Real-time reverse transcription-PCR analysis for independent strain and time effects[1]

Gene[2]	Strain[3] NAHF	Strain[3] NZHF	*P*-value	Days postpartum 35	Days postpartum 140	*P*-value
IGF-1	0.32 (0.23–0.44)	0.51 (0.37–0.72)	<0.05	0.32 (0.22–0.47)	0.51 (0.34–0.76)	0.15
IGF-1R	0.004 (0.004–.005)	0.005 (0.004–0.006)	0.30	0.004 (0.004–0.005)	0.006 (0.005–0.008)	<0.001
GHRtot	0.51 (0.37–.071)	0.47 (0.33–0.66)	0.71	0.6 (0.42–0.88)	0.4 (0.27–0.58)	0.15
GHR1A	0.03 (0.02–0.04)	0.03 (0.02–0.04)	0.65	0.04 (0.03–0.05)	0.02 (0.02–0.03)	<0.05
IGFBP-ALS	0.06 (0.04–0.09)	0.1 (0.07–0.14)	0.06	0.06 (0.04–0.09)	0.1 (0.07–0.16)	0.11
IGF-2	15.0 (11.9–18.9)	14.6 (11.5–18.5)	0.85	14.9 (11.7–18.9)	14.7 (11.5–18.8)	0.95
IGF-2R	0.14 (0.13–0.16)	0.14 (0.13–0.16)	0.97	0.16 (0.15–0.18)	0.13 (0.12–0.14)	<0.01
IGFBP-1	4.3 (2.8–6.8)	4.3 (2.7–6.8)	0.98	7.7 (4.9–12.3)	2.4 (1.5–3.8)	<0.01
IGFBP-2	3.4 (2.6–4.4)	3.1 (2.3–4.1)	0.62	5.5 (4.0–7.5)	1.9 (1.4–2.6)	<0.001
IGFBP-3	0.48 (0.37–0.62)	0.5 (0.39—0.65)	0.82	0.64 (0.49—0.84)	0.38 (0.29—0.5)	<0.05
IGFBP-4	0.25 (0.21–0.30)	0.24 (0.2–0.29)	0.85	0.25 (0.2–0.3)	0.24 (0.2–0.3)	0.93
IGFBP-5	0.23 (0.2–0.27)	0.23 (0.2–0.27)	0.98	0.2 (0.18–0.25)	0.25 (0.21–0.3)	0.21
IGFBP-6	0.003 (0.002–0.004)	0.003 (0.003–0.004)	0.79	0.003 (0.003–0.005)	0.004 (0.003–0.0005)	0.20
ERα	0.41 (0.37–0.47)	0.46 (0.41–0.53)	0.22	0.36 (0.31–0.4)	0.54 (0.47–0.61)	<0.001
INSR	0.03 (0.03–0.04)	0.02 (0.02–0.03)	0.18	0.031 (0.03–0.04)	0.025 (0.02–0.03)	<0.01
HNF-4α	0.3 (0.26–0.35)	0.32 (0.27–0.37)	0.56	0.47 (0.4–0.54)	0.2 (0.18–0.24)	<0.001
SOCS-3	0.5 (0.41–0.6)	0.8 (0.66–0.98)	<0.01	0.4 (0.33–0.49)	0.99 (0.8–1.23)	<0.001
JAK2	0.0004 (0.0002–0.0005)	0.0005 (0.0003–0.0007)	0.28	0.0005 (0.0003–0.0007)	0.0004 (0.0002–0.0006)	0.45
STAT5b	0.1 (0.095–0.11)	0.1 (0.09–0.11)	0.51	0.11 (0.1–0.12)	0.1 (0.09–1.1)	0.29

[1]Real-time reverse transcription-PCR values are back-transformed least squares means, followed by the 95% confidence limits in parentheses, and are expressed in picograms per microgram of reverse-transcribed RNA.

[2]IGF-1R = IGF-1 receptor; GHRtot = growth hormone receptor; GHR1A = growth hormone receptor 1A variant; IGFBP-ALS = IGF-binding protein acid-labile subunit; IGF-2R = IGF-2 receptor; IGFBP-1 to IGFBP-6 = IGF binding protein-1 to IGF binding protein-6; ERα = estrogen receptor α; INSR = insulin receptor type A; HNF-4α = hepatocyte nuclear factor-4α; SOCS-3 = suppressor of cytokine signaling-3; JAK2 = Janus-activated kinase 2; STAT5b = signal transducer and activator of transcription 5b.

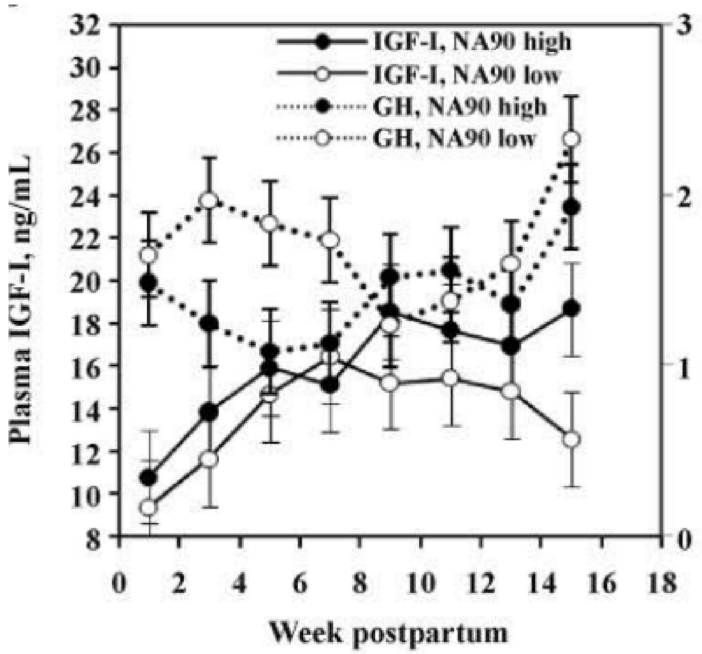
[3]NAHF = North American Holstein-Friesian; NZHF = New Zealand Holstein-Friesian.

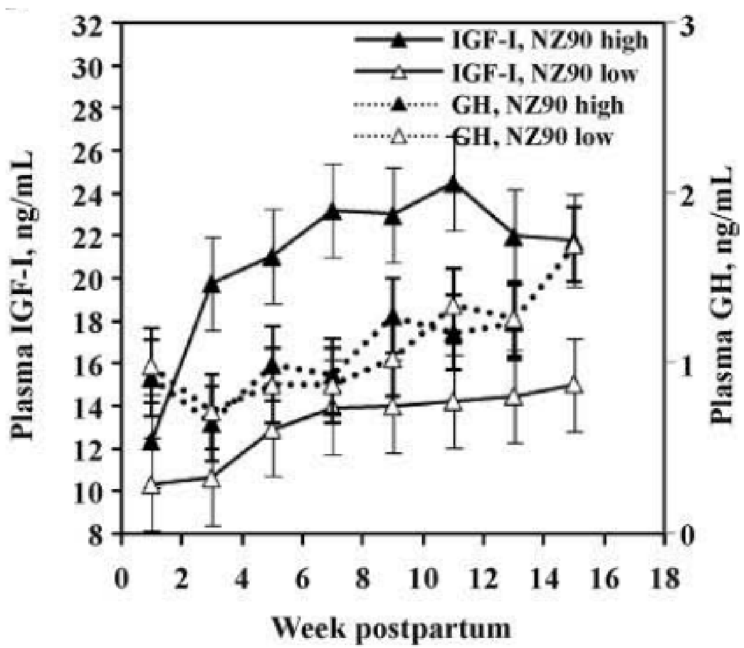
- Abundance of insulin-like growth factor (IGF)-1 mRNA was greater in the NZ strain, concomitant with a tendency for increased expression of acid-labile subunit mRNA.
- Across strains, mRNA abundance of IGFBP-1, IGFBP-2, and GHR1A decreased from d 35 to 140 postpartum, whereas expression of IGF-1 and acid labile subunit tended to increase.

McCarthy et al. (2009). Journal of Dairy Science Vol. 92 No. 10

Nutrient partitioning: genotype*diet

- North America (NA; n = 74) and New Zealand (NZ; n = 81) genetic strains at high and low feed allowances commensurate with their genetic milk yield potential
- Additional feed allowance failed to change blood IGF-I concentrations in NA cows but increased IGF-I concentrations in NZ cows

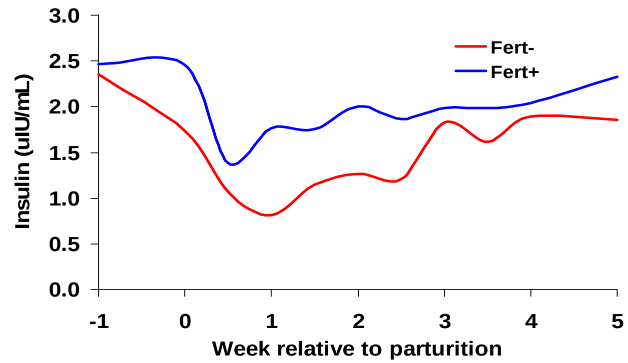


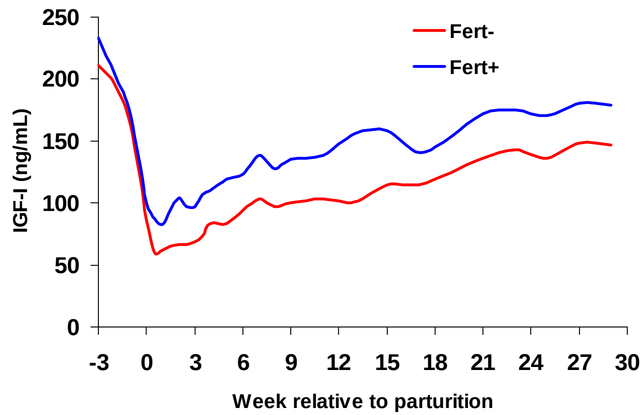


Lucy et al. (2009) J. Dairy Sci. 92:526–539

Metabolic adaptaton: Genetics (Fert genotype)

- Cows with similar genetic merit for milk production and divergent genetic merit for fertility (bottom 10% and top 20%)
- Higher plasma insulin and IGF-1 concentration for high fertility genetic merit (Fert +)
- Faster “recoupling” of the somatotropic axis in Fert+ cows





Cummins et al. (); S.T. Butler

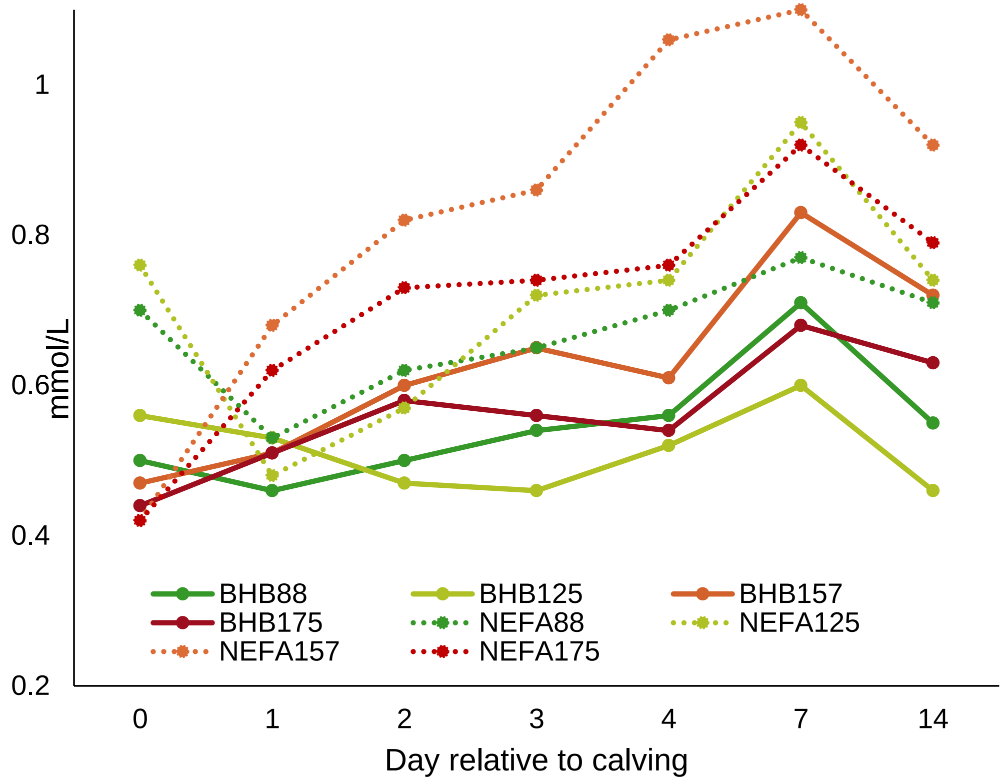
Control of DMI during peripartum period

- Cow level factors
  - BCS
  - Genetics
  - Pregnancy
- Feed factors
  - Energy density
  - DM content
  - Protein content
  - Digestibility
- Management

teagasc
Agriculture and Food Development Authority

Pre-calving feed allowance

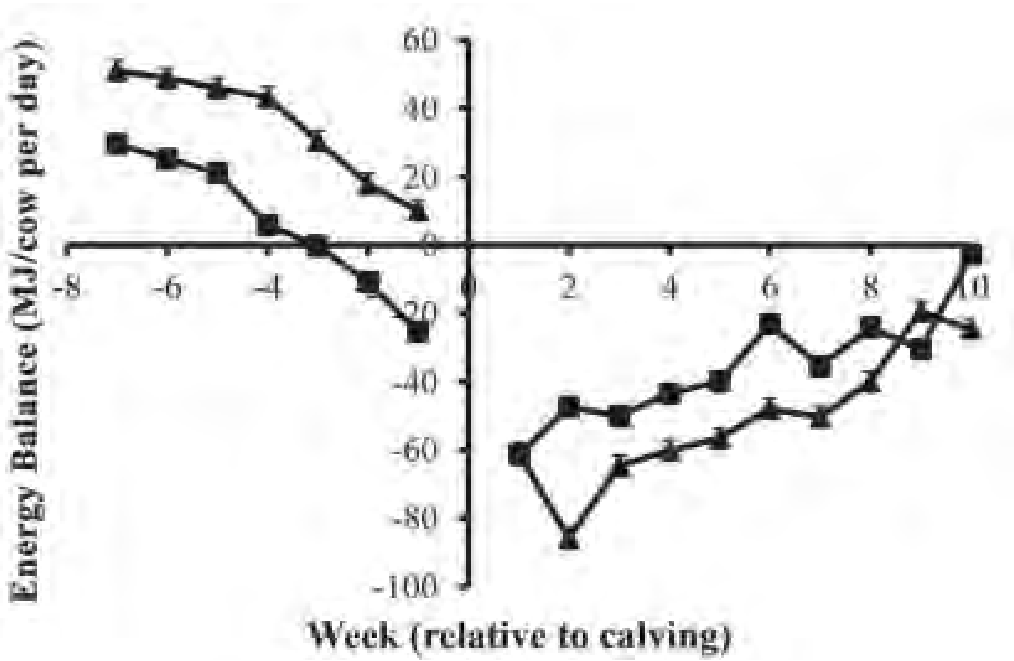
- 4 precalving fresh pasture feed allowance scenarios (n = 13 cows/group):
  - 88% calculated ME requirements
  - 125% calculated ME requirements
  - 157% calculated ME requirements
  - 175% calculated ME requirements
- Negative energy balance postpartum increased with precalving feeding level
- Plasma Ca concentration at calving tended to decline as precalving feed allowance increased
- Effect on milk production was small, and other than milk fat, was confined to wk 1 postcalving



Adapted from Roche te al. (2005) J. Dairy Sci. 88:677–689

Pre-partum ME (low BCS cows)

- 2 feeding scenarios prepartum for low BCS cows (2.5)
  - ■Grass Silage (ME = 10.5 MJ/kg of DM; n = 26)
  - ▲Grass Silage + 3 kg concentrate/cow/d as a mixed ration (ME = 12.6 MJ/kg of DM; n = 27)
- Prepartum: ↑ DM intake, energy balance, and body weight (BW) and BCS gain
- Postpartum: ↑ BW and BCS loss, milk fat% and serum NEFA concentration. “No effect” on DM intake, energy balance, and milk yield



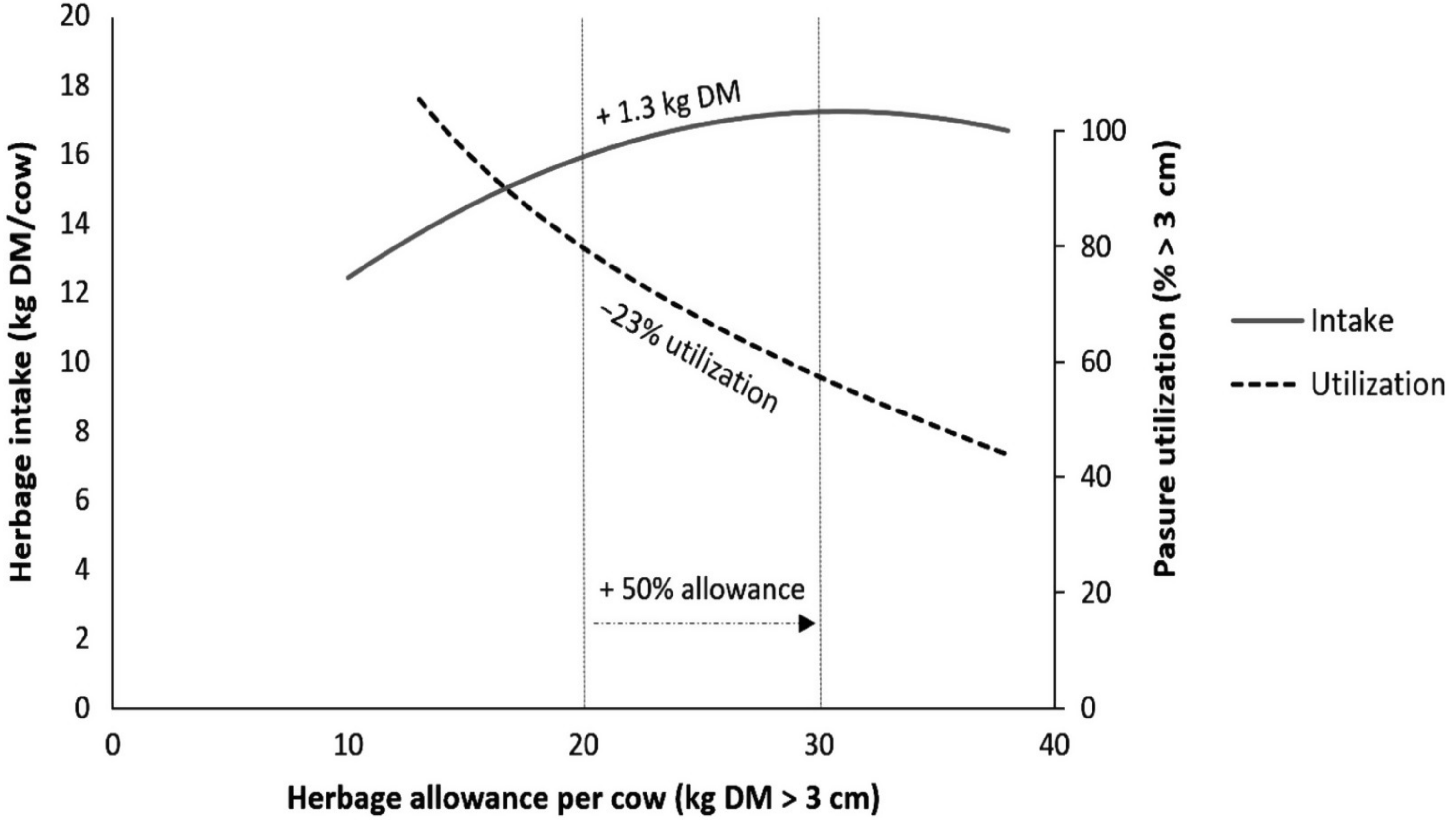
Little et al. (2016) J. Dairy Sci. 99:7102–7122

Interaction between pre-calving BCS and feeding level – NZ grazing studies

- Pre-calving BCS and pre-calving feeding level have both independent and interdependent effects on production and health characteristics of transition dairy cows
- Irrespective of pre-calving BCS, a controlled restriction pre-calving reduced NEFA release postpartum and increased plasma calcium concentrations, reducing the risk of milk fever
- Fatter cows produced more milk but had a greater BCS loss postpartum and both a greater level of liver fat infiltration and a greater risk of metabolic diseases associated with excessive hepatic lipidosis
- In comparison, thinner cows are at risk of an accentuated reduction in peri-partum immune competence if subjected to a feed restriction before calving, probably increasing the risk of infectious diseases
- It would appear from this data set that optimally conditioned cows will benefit from a short-term (2–3 wk) controlled feed restriction (75–90% of requirements), whereas cows in less-than-optimal condition should be fed to requirements before calving

Roche et al. (2015)

Herbage allowance *v* intake and utilisation



Grass and Forage Science, Volume: 75, Issue: 1, Pages: 1-17, First published: 02 December 2019, DOI: (10.1111/gfs.12458)

Metabolic adaptation: Post-calving pasture/feed allowance

- Pasture allowance (PA) in early lactation is widely acknowledged to influence animal performance; however, climatic factors can limit grass growth in early spring, resulting in potential feed deficits on farm
- Milk production, body weight, and production efficiency per cow decreased significantly as SR increased due to reduced herbage availability per cow and increased grazing severity (Coffey et al., 2017)
- Short-term restrictions (2 – 6 wks) of PA up to 25% of DMI (~2.7 UFL/d), for up to 6 weeks, can be used as a management strategy to cope with feed deficits in early lactation without impairing normal metabolic function of the early lactation dairy cow (Claffey et al., 2021)
- Existence of strong interactions between feeding system and genetic merit for milk production demonstrates that the optimum feeding system to support lactational demands will depend on the nutritional requirements of the prevailing cow type (Horan et al., 2005)

Lying behaviour and activity during the transition period – grazing dairy cows

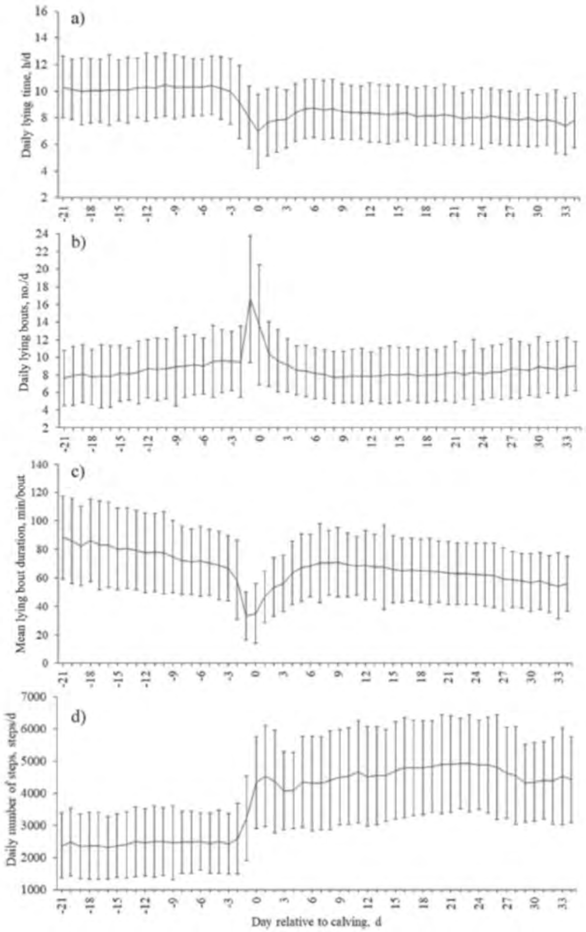


Figure 1. Daily lying time (h/d; a), daily lying bouts (no./d; b), mean lying bout duration (min/bout; c), and number of steps (steps/d; d) during the period −21 to 34 d relative to the day of calving (d 0). Vertical bars represent SD of the sample population.

Hendricks et al. (2019)

Agriculture and Food Development Authority

Rumen microbiome during the transition period

- The ruminal microbial community is dynamic and changes with diet, host, physiological status, and environment (Edwards et al., 2004).
- Zhu et al. (2017) concluded that the structure of the metabolically active bacterial and archaeal rumen communities changed over the transition period, likely in response to the dramatic changes in physiology and nutritional factors like dry matter intake and feed composition
- Sofyan et al. (2019) reported that transition to a high-concentrate diet reduced bacterial diversity in the rumen and the composition of rumen microbiota differed between LY and HY dairy cows during the transition period. The differences were associated with rumen fermentation products and predictive functional genes relating to nutrient metabolism

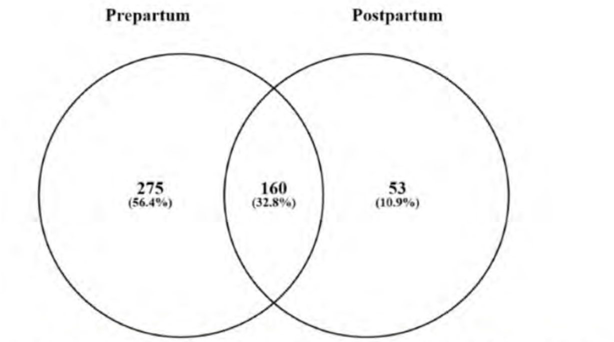
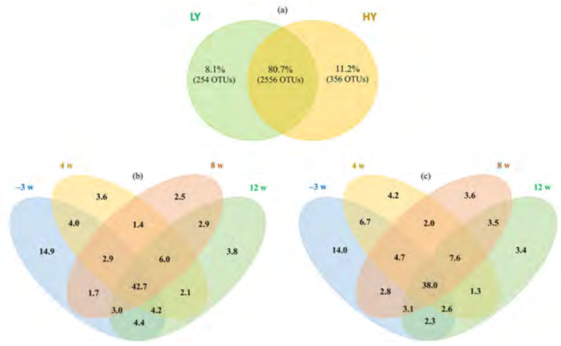


Fig 1. Distribution (Venn diagram) of OTUs among the 16S rRNA transcript amplicons. The OTUs identified in the 16S rRNA transcript amplicon library of all the prepartum (435) and postpartum samples (213) are included in the Venn diagram and grouped as OTUs either unique to or shared between the prepartum and postpartum microbiome.

Metagenomic profiles of the rumen microbiota during the transition period in low-yield and high-yield dairy cows



Zhu et al. (2017); Sofyan et al. (2019)

Metabolic management postpartum: Milking frequency

- Once a day milking may provide a tool to better manage the metabolism and energy balance of cows during early lactation or during periods of pasture deficit

- More suitable for dairy systems that are not based on milk production per cow (i.e. pasture based)

Agriculture and Food Development Authority

Metabolic effects of milking frequency

- Cows milked 1× have lower plasma NEFA concentrations and lesser BCS loss during early lactation (Patton et al., 2006; McNamara et al., 2008; Phyn et al., 2011)
- Plasma glucose and leptin concentrations are greater in cows milked 1× (Loiselle et al., 2009; Kay et al., 2013); indicating lower glucose requirements and greater adipose tissue stores compared with cows milked 2×
- Hepatic gene expression analysis suggest that the effect of MF on metabolism during early lactation is greatest during the first 3 wk of lactation (Grala et al., 2013)

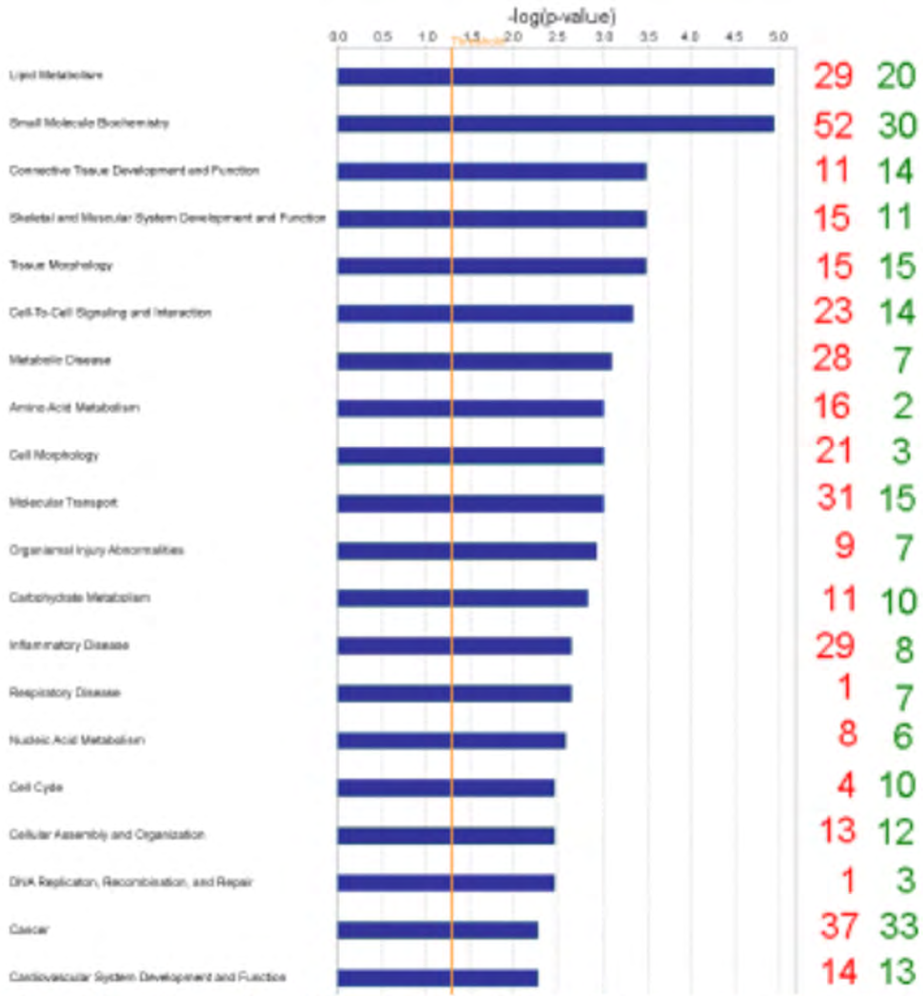
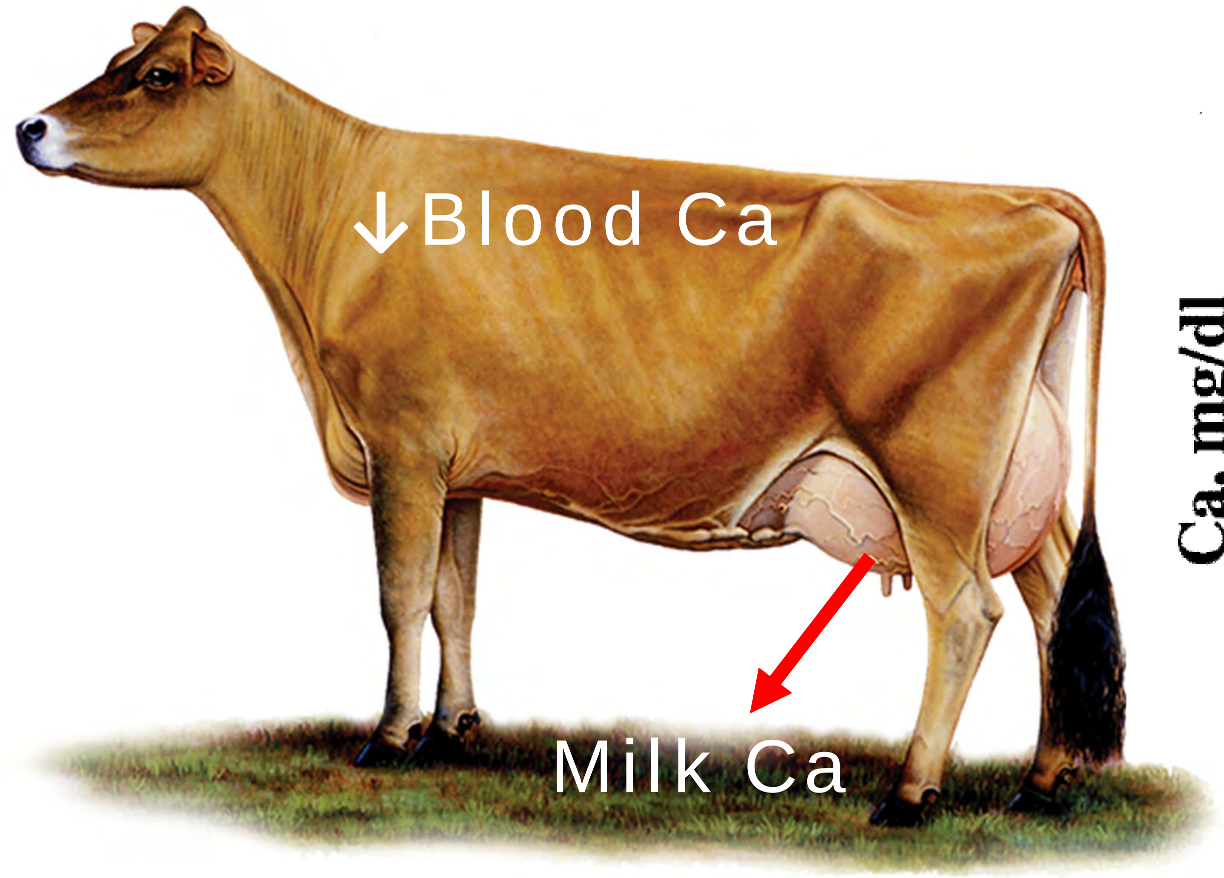
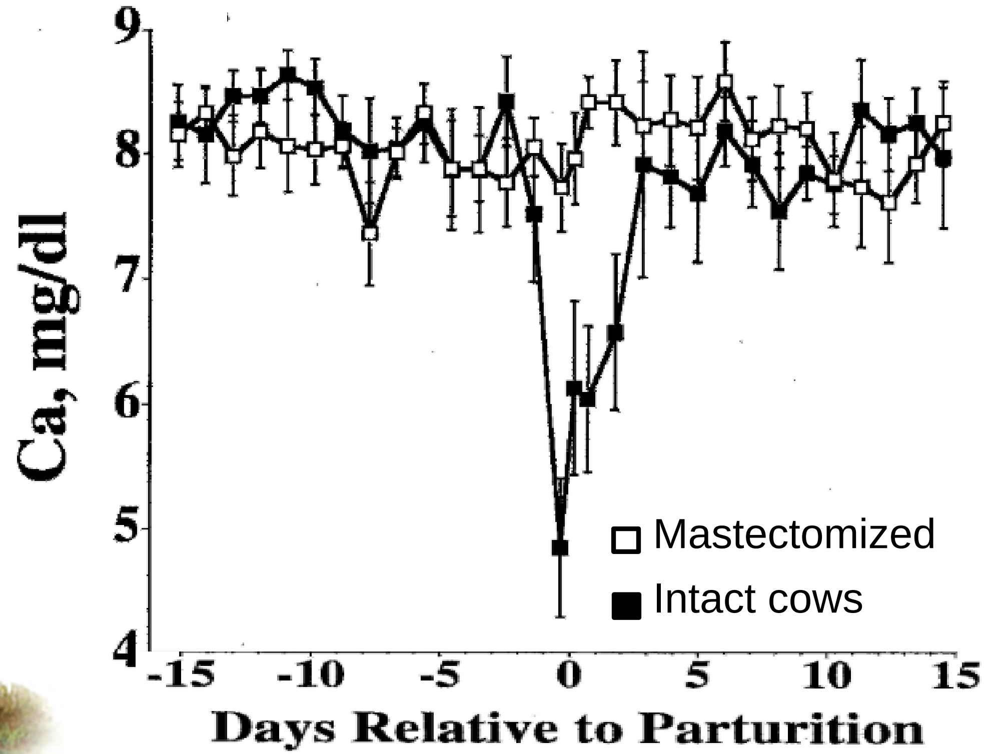


Fig. 1. Classification of differentially expressed genes (DEG) according to top 20 molecular and cellular functions, most significantly affected by energy balance (EB) using Ingenuity Pathways Analysis. The blue bars indicate the likelihood [−log (P-value)] that the specific molecular and cellular function category was affected by negative energy balance compared with others represented in the list of DEG. The number of up- and downregulated genes in each group is represented on the righthand side by red and green numbers, respectively. The cut-off (yellow line) is shown at $P < 0.05$ (1.301 log scale).

Hypocalcemia





Goff et al. (2002)

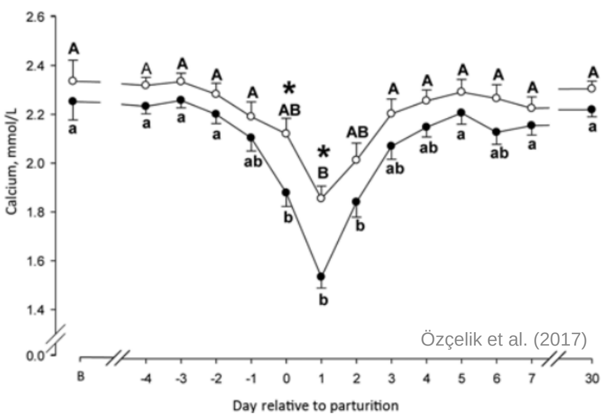
Mineral metabolism in pasture fed cows

High K intake

- **↑DCAD**
Induces a metabolic alkalosis, which ↓tissue sensitivity to parathyroid hormone (PTH), and therefore also bone resorption and active Ca absorption
- **↓Mg absorption**
↓PTH secretion and action on its receptors

High P intake

- **Slurry/P fertilizer**
↓1,25(OH)2 Vit D and active Ca absorption



○Daylight (12 h in-/outdoor; n = 20)
●Control (fulltime indoor; n = 20)

Low UV light exposure

- **Indoor housing**
Vitamin D_3 and derivative molecules synthesis, resulting on lower active Ca absorption

Energy balance in early lactation cow fertility

- Energy balance during early lactation is positively associated with conception rate to first insemination
- More positive EB was associated with a greater likelihood of earlier resumption of cyclicity and earlier conception
- No relationships were identified between level of milk production, either during early lactation or at the time of first insemination, and reproductive outcomes
- Relationships between DMI and measures of fertility were, however, similar to EB, indicating that DMI is the principal component mediating EB effects on reproductive function
- Assessing milk protein content and plasma IGF-I concentration during the early postpartum period may be useful as indicators of subsequent fertility

Patton et al. (2007).

BCS change post calving – cow fertility

Reproductive and productive responses of Holstein cows (n = 1,887) in two commercial herds in Wisconsin that lost, maintained or gained BCS from calving to 3 wk postpartum

Item	BCS change category: Lost	Maintained	Gained	*P*
% of cows	41.8	35.8	22.4	
Pregnant to AI at 40 d (%)	25.1	38.2	83.5	< 0.01
Pregnant to AI at 70 d (%)	22.8	36.0	78.3	< 0.01
Pregnancy loss (%)	9.1	5.8	6.2	0.34
BCS at calving	2.93	2.89	2.85	< 0.01
BCS at 21 DIM	2.64	2.89	3.10	< 0.01
Energy-corrected milk[a] (kg/d)	30.9	31.5	28.7	0.30

[a] Mean from calving to d 21 postcalving

Carvalho et al., 2014

Summary and conclusions

- The ability of cows to both milk and maintain sufficient body condition for reproduction is fundamental to pasture based seasonal production systems
- The transition period is characterised by marked changes in the intrinsic biochemical status of the animal that are much more dramatic than at any other time in the lactation–gestation cycle
- The metabolic responsiveness and adaptation to transition is dependent on complex interplay between the molecular physiology of key metabolic and neuroendocrine organs and is conditioned on inherent genetic predisposition and nutritional status well in advance of the transition period
- There is clear evidence of genotype x environment interaction in the adaptive potential of dairy cow breeds and genotypes to pasture based production systems
- The efficacy of nutrition of the cow prior to and during the transition period is key to regulation of voluntary feed intake postpartum which is the key driver of EB in pasture fed cows
- Greater understanding of the intrinsic biochemical control of the interaction between metabolic status pre- and postpartum, rumen microbiome and metagenome, together with genomically based selection programs will facilitate more optimum animals and nutritional regimens for health and welfare friendly, economically and environmentally sustainable and pasture based production systems

Thank you!