The role of energy balance in transition and early lactation cow health

Dr Finbar Mulligan
School of Veterinary Medicine
University College Dublin

Agricultural Science Association
Lyons Farm
October 14th 2015
Energy balance in transition and early lactation cow health

• Background

• Teaching

• Research

• Herd investigation and monitoring
  • Work with nutritionists and vets

• With often see interesting cases as part of herd work
• The role of energy balance in transition and early lactation cow health

• Some recent developments in control strategies
Issues related to energy balance

Difficult calving
Retained placenta
Uterine infections
Lameness
Ketosis
Fatty liver
Milk fever
Displaced abomasum
Mastitis
Infertility
Poor production
Total disease incidence was the sum of mastitis, ketosis, digestive disorders and laminitis from national records for the Danish dairy herd for cows that calved in 1998 ($n=93,347$ Danish Agricultural Advisory Centre).
• Nutrient requirements are well defined

• Complicating factors
  • Milk price often determines energy allowance on Irish farms
  • Advice to feed least cost diet regardless of energy requirements
  • Intensive selection for milk production
  • Genetic diversity within herds
  • Feed availability and quality
  • Environmental factors
  • Climatic factors
Classical early lactation negative energy balance

Source: Wattiaux Babcock Institute

Figure 1: Energy balance of dairy cows in early lactation

9 Linden Dr., Madison, WI 53706 USA, phone: 608-265-4169, babcock@calshp.cals.wisc.edu

Finbar Mulligan
• Are all states of negative energy balance the same??

• Pre-calving negative energy balance

• Post-calving NEB fat cow
• Post-calving NEB thin cow?
Energy balance in transition and early lactation cow health

- The amount of negative energy balance in total (total calorie deficit in early lactation)
- The severity of negative energy balance (calorie deficit at nadir)
- The duration of negative energy balance
- All are variable
• Important energy balance issues pre-partum
  • Level of energy feeding in the dry period
  • Negative shift in energy balance in the last month
  • Long-term energy over-supply or under-supply
Energy balance in transition and early lactation cow health

• Level of energy feeding in the dry period

• Does the level of energy feeding in the dry period have a conditioning effect on the pattern of energy balance change experienced in the transition period?
Energy balance in transition and early lactation cow health

• Controlled energy feeding in the dry period

• Feeding ≤ 100% of energy requirements in dry cow period

• Recommendations as low as 85%

• Reports of better metabolic status in early lactation
  • Cardoso et al., 2013; Roche et al., 2013; Beever et al., 2006
Energy balance in transition and early lactation cow health

- Controlled energy feeding in the dry period
- Effect of feeding controlled energy (CE) or high energy (HE) in the far off dry period
Controlled energy feeding prepartum
Cardoso et al 2013 JDS 96:5859-5871 (wk 1-4)

HE = high energy; CE = controlled energy
FO= far-off dry period; CU = close-up dry period
HE = high energy; CE = controlled energy
FO = far-off dry period; CU = close-up dry period
Cows fed controlled energy in the dry period had a shorter interval between parturition and conception.
## Controlled energy feeding

- Keogh et al 2009
- High and low feed allowance in dry period

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEFA (mmol/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepartum</td>
<td>0.28</td>
<td>0.30</td>
</tr>
<tr>
<td>Calving</td>
<td>0.41</td>
<td>0.40</td>
</tr>
<tr>
<td>Postpartum</td>
<td>0.43</td>
<td>0.32*</td>
</tr>
<tr>
<td>BHB (mmol/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepartum</td>
<td>0.38</td>
<td>0.41</td>
</tr>
<tr>
<td>Calving</td>
<td>0.38</td>
<td>0.35</td>
</tr>
<tr>
<td>Postpartum</td>
<td>0.63</td>
<td>0.54</td>
</tr>
<tr>
<td>Glucose (mmol/l)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepartum</td>
<td>3.69</td>
<td>3.50*</td>
</tr>
<tr>
<td>Calving</td>
<td>3.96</td>
<td>3.62</td>
</tr>
<tr>
<td>Postpartum</td>
<td>3.34</td>
<td>3.27</td>
</tr>
</tbody>
</table>
Controlled energy feeding

• Keogh et al 2009
• High and low feed allowance in dry period

<table>
<thead>
<tr>
<th></th>
<th>High</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield (kg/d)</td>
<td>28.8</td>
<td>27.2</td>
</tr>
<tr>
<td>Milk fat%</td>
<td>4.43</td>
<td>4.25*</td>
</tr>
<tr>
<td>Milk prot%</td>
<td>3.31</td>
<td>3.28*</td>
</tr>
<tr>
<td>Milk fat yield</td>
<td>1.19</td>
<td>1.08*</td>
</tr>
<tr>
<td>Milk prot yield</td>
<td>0.94</td>
<td>0.88</td>
</tr>
<tr>
<td>Milk fat and prot yield (kg/d)</td>
<td>2.23</td>
<td>2.05*</td>
</tr>
<tr>
<td>Solids corrected yield (kg/d)</td>
<td>27.32</td>
<td>25.13*</td>
</tr>
</tbody>
</table>
Controlled energy feeding

Should cows with low BCS at dry-off be placed on controlled energy dry cow regimes?
Energy balance in transition and early lactation cow health

• Negative shift in energy balance in the last month pre-partum!
Energy balance in transition and early lactation cow health

- 32% of dairy cows have raised NEFA prepartum
- They are twice as likely to be culled within 30 days of calving

- Ospina et al., 2010
Energy balance in transition and early lactation cow health

• Dry-cow negative energy balance

• Controlled energy diets
• Marginal under feeding especially in far-off dry period may benefit health production and reproduction (Cardosso et al., 2013)

• Vs

• Acute onset of adipose mobilisation in the close-up dry period
• (associated with many transition cow problems)
Energy balance in transition and early lactation cow health

Figure 1. Consequences of negative energy balance and related disorders pre-calving.
Energy balance in transition and early lactation cow health

• Suppression of the immune system (Ingvartsen and Moyes 2013)
  • Retained foetal membranes
  • Uterine infection
  • Mammary infection
Energy balance in transition and early lactation cow health

• Suppression of the immune system
  • Low glucose
  • High BHB
  • Negative energy balance (calculated)
  • Low glutamine
  • High NEFA (Hammon et al., 2006)
  • Related to immune suppression
  • (Ingvartsen and Moyes 2013)
Energy balance in transition and early lactation cow health

• Suppression of the immune system
  • Low glucose (negative energy balance)

  • Glucose required by phagocytic cells for proliferation, survival and differentiation
  • The preferred metabolic fuel for activated PMNs, macrophages, lymphocytes
Energy balance in transition and early lactation cow health

- Suppression of the immune system
- High BHB (subclinical ketosis)
  - Innate immunity
  - BHB in vitro: Chemotactic capabilities and respiratory burst activity of bovine blood PMN are reduced (Effect in sheep also demonstrated)
- Specific immunity
- BHB in vitro: Inhibitied IgM secretion of bovine lymphocytes
  - Ingvartsen and Moyes (2013)
Energy balance in transition and early lactation cow health

Figure 1. Neutrophil function (iodination: △) and lymphocyte function (blastogenesis: ●) are impaired during the weeks immediately before and after parturition. Values are expressed as percent-
Energy balance in transition and early lactation cow health

Immune function suppression around parturition

Hammon et al., 2006

![Graph showing immune function suppression around parturition](image)

- **Highest feed dry matter intake**
- **Lowest feed dry matter intake**

Finbar Mulligan
Energy balance in transition and early lactation cow health

- Dry cow NEFA dairy cows Kilkenny
- Herd with 80% RFM
Energy balance in transition and early lactation cow health

- The consequences long-term energy deficit or surplus

- High BCS (Adipose stored internally in other depots)
- Low BCS
Energy balance in transition and early lactation cow health
• Effect of prolonged chronic negative energy balance:
• The Thin Cow!!
Energy balance in transition and early lactation cow health

Data from Buckley et al., (2003)

<table>
<thead>
<tr>
<th>BCS at 1st service</th>
<th>Pregnant at d 42 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;2.5</td>
<td>50</td>
</tr>
<tr>
<td>2.75</td>
<td>57</td>
</tr>
<tr>
<td>≥3.0</td>
<td>66</td>
</tr>
</tbody>
</table>
Energy balance in transition and early lactation cow health

- Correlation between BCS and digital cushion thickness (Bicalho et al., 2009)

- Low BCS and BCS loss related to lameness (Lean et al., 2013)
Energy balance in transition and early lactation cow health

• Roche and Berry (2006)
  • Greater risk for milk fever in thin cows in comparison to cows with optimal BCS.

• Heuer et al. (1999) and Hoedemaker et al. (2009) greater risk of uterine infection in thin cows.
Energy balance and metabolic status in the critical period

Finbar Mulligan
Energy balance in transition and early lactation cow health

- BCS = 2.8 (n = 96),
- BCS = 3.6 (n = 516),
- BCS = 4.4 (n = 79)

(Day relative to calving)

Finbar Mulligan

(Hayirli et al., 2002)
Energy balance in transition and early lactation cow health

Alibrahim et al., 2010

* = P<0.05, ** = P<0.01

PC, entire post-calving period

* = P<0.05, ** = P<0.01

PC, entire post-calving period
Energy balance in transition and early lactation cow health

Alibrahim et al., 2010

• ** = P<0.01, *** = P<0.001

PC, entire post-calving period
Energy balance in transition and early lactation cow health

Effect of calving BCS on insulin status in early lactation.

Alibrahim et al., 2010

Fig. 2. Effect of BCS (■ 3.25 and ♦ 4.00) at calving on serum insulin concentration during the periparturient period.
Effect of calving BCS on peripheral Oestradiol concentration 2 days before ovulation of the first dominant follicle post-partum

Alibrahim et al., 2010

Energy balance in transition and early lactation cow health

P=0.06

Finbar Mulligan
Energy balance in transition and early lactation cow health

Alibrahim et al., 2010

BCS and BW loss for BCS 3.25 and 4.0 at calving

<table>
<thead>
<tr>
<th>Calving BCS</th>
<th>BCS loss</th>
<th>BW loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.25</td>
<td>0.64</td>
<td>43.30</td>
</tr>
<tr>
<td>4.00</td>
<td>1.12</td>
<td>55.52</td>
</tr>
<tr>
<td>P</td>
<td>0.001</td>
<td>0.065</td>
</tr>
</tbody>
</table>

Finbar Mulligan
Energy balance in transition and early lactation cow health

Important energy balance issues post-partum
• McArt et al. (2013) herds with more than 15-20% elevated NEFAs or BHBs in early lactation have higher rates of subsequent negative events including reduced reproduction and reduced milk yield.

• Ospina et al. (2013) cows with a serum BHB of 1.2mmol/l or greater in the first week after calving were eight times more likely to develop a DA.
Reduced fertility

Physiological basis for NEB effects on fertility

• Reduced LH pulse frequency
• Reduced circulating concentrations of insulin and IGF-1
• Reduced production of oestradiol by ovarian follicles
• Smaller CL formation
• Deleterious effects of high NEFA, high BHB and low glucose on oocyte development
• Oocytes that develop in negative energy balance are less viable several months later

Roche et al., 2000; Boland and Lonergan, 2003; Leroy et al., 2005
# A Model for Poor Fertility in Dairy Cows

SW Walsh, EJ Williams, ACO Evans
University College Dublin, Ireland


<table>
<thead>
<tr>
<th>EVENT</th>
<th>TIME (DAYS)</th>
<th>ISSUE</th>
<th>INCIDENCE</th>
<th>REASON(S)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>COWS</td>
<td>HEIFERS</td>
</tr>
<tr>
<td>Parturition</td>
<td>0</td>
<td>UTERINE CONTAMINATION</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>UNCOUPLING OF ↑GH &amp; ↓IGF-I</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>METRIS</td>
<td>≤40%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>SEVERE BCS LOSS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>ENDOMETRITIS</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>CULLING</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>40</td>
<td>FAILURE TO RESUME CYCLICITY</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>Move to positive energy balance</td>
<td>45</td>
<td>FAILURE TO RESOLVE UTERINE INFLAMMATION</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>Start of breeding season</td>
<td>60</td>
<td>CULLING</td>
<td>3%</td>
<td></td>
</tr>
</tbody>
</table>

- Negative energy balance
- Low appetite & intake
- High BCS precalving
- Genetic selection
- Endocrine status
- Inappropriate immune response
- Type of pathogen
- Death or disease
- Low LH, Oestradiol, IGF-I
- Metritis
- Metritis / Endometritis
- See above
<table>
<thead>
<tr>
<th>Oestrus Ovulation</th>
<th>0</th>
<th>SHORT, LOW INTENSITY OESTRUS</th>
<th>5H</th>
<th>14H</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>FAILURE TO OVULATE</td>
<td>10%</td>
<td>1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>FERTILIZATION FAILURE</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>PREGNANCY RATE</td>
<td>85%</td>
<td>95%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maternal recognition of pregnancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Term / Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td>282/0</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Stress:**
- Lameness
- Low LH, Oestradiol

**Severe negative energy balance**
- Inappropriate lipid accumulation in oocyte
- Low P4 previous cycle
- Uterine pathology

**Chromosomal abnormalities**
- Low progesterone
- Poor CL / Follicle
- Liver metabolism

**Embryo chromatin (epigenetics), Poor placental function, Disease**

**Epigenetics, Disease**

**Dystocia, Twinning, Inbreeding**

**Disease**

**KEY:** ■ INDICATES SIGNIFICANT ISSUE TO BE RESOLVED
Figure 1 Diagrammatic representation of possible mechanisms by which embryo quality can be impaired in high-yielding dairy cows.

Leroy et al., 2008
Energy balance in transition and early lactation cow health

Fig. 2. Average (±S.E.M.) glucose concentrations (mM) in serum and follicular fluid of nine high-yielding dairy cows during the experimental period.
Control of early-lactation negative energy balance
Energy balance in transition and early lactation cow health

• Dietary control of energy balance
• High protein diets V Low protein diets
• High starch (glucogenic diets)
Energy balance in transition and early lactation cow health

- Dietary protein and energy balance
  - High levels of RDP make negative energy balance worse
  - High levels of metabolisable protein in the diet seem to push milk yield and make energy balance worse
  - Option to reduce dietary protein and increase energy consumption
Energy balance in transition and early lactation cow health

**Short communication:** Effect of dietary manipulation of crude protein content and nonfibrous-to-fibrous-carbohydrate ratio on energy balance in early-lactation dairy cows

S. J. Whelan, F. J. Mulligan, V. Gath, B. Flynn, and K. M. Pierce

*School of Agriculture and Food Science, University College Dublin, Lyons Research Farm, Newcastle, Dublin, Ireland
†School of Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland

**ABSTRACT**

Disparities between nutrient intake and demand often result in a state of negative energy balance (EB) in the early-lactation dairy cow. Reducing dietary crude protein (CP) content and providing glucogenic nutrients may overcome this issue. This study evaluates whether or not offering a diet lower in CP and higher in nonfiber carbohydrates (LP-NFC) can improve EB and the metabolic status of the early-lactation dairy cow compared with a diet higher in CP and fibrous carbohydrates (HP-FC). Twenty Holstein-Friesian dairy cows were allocated to treatment groups for 52 days. EB was calculated by adjusting the nitrogen balance, and the metabolic status of the cows was determined by analyzing body condition score, milk fat, and protein concentrations. The results showed that the LP-NFC diet improved EB and reduced the risk of metabolic disorders, thereby improving the reproductive performance of the cows.

**Key words:** [AU2: Please provide up to 5 key words/phrases.]

Short Communication

Increases in the genetic potential for milk production have created technical challenges for nutritionists and metabolic challenges for the early-lactation dairy cow. In particular, disparities between energy intake and that required for production can result in a state of negative energy balance (EB) and a metabolic status that predisposes the cow to reduced reproductive performance.
Whelan et al 2014, Dietary effect on energy balance

High CP low starch TMR (HP-LS)
- 15% CP
- 6% Starch

Low CP high starch TMR (LP-HS)
- 12% CP
- 28% Starch

Diets were iso-energetic (1.05 UFL/ kg DM)
**Energy balance in transition and early lactation cow health**

- Data for indoor diets
- High Protein Low Starch (HPLS) or
- Low Protein High Starch (LPHS)

<table>
<thead>
<tr>
<th>Diet</th>
<th>HPLS</th>
<th>LPHS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk yield kg/hd/d</td>
<td>31.6</td>
<td>29.2*</td>
</tr>
<tr>
<td>Fat kg/hd/d</td>
<td>1.29</td>
<td>1.19*</td>
</tr>
<tr>
<td>Prot kg/hd/d</td>
<td>0.92</td>
<td>0.85*</td>
</tr>
<tr>
<td>Fat%</td>
<td>4.01</td>
<td>3.88</td>
</tr>
<tr>
<td>Prot%</td>
<td>2.92</td>
<td>2.93</td>
</tr>
</tbody>
</table>

*, Indicates significant effect
Influence of High Protein Low Starch and Low Protein High Starch on Energy balance in Weeks 1-9 of lactation, Indoor diets
UCD Lyons Research Farm, Whelan et al., 2014

Energy Balance (UFL d⁻¹)

Week of Lactation

HP-LS  LP-HS
### 305d Lactation Yield

**Whelan et al 2014**

<table>
<thead>
<tr>
<th></th>
<th>HP-LS</th>
<th>LP-HS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fat (Kg)</td>
<td>349</td>
<td>334</td>
</tr>
<tr>
<td>Protein (Kg)</td>
<td>255</td>
<td>261</td>
</tr>
</tbody>
</table>
Energy balance in transition and early lactation cow health

• Conclusion

• Many different states of negative energy balance

• Conditioning in the far-off dry period large influence on pattern of energy balance change in periparturient period
Energy balance in transition and early lactation cow health

• Conclusion

• Managed controlled energy V excessive mobilisation in the last month

• Some adipose is needed, thin cows are not acceptable
Energy balance in transition and early lactation cow health

• Conclusion

• Diet used postpartum can influence energy balance change pattern experienced in lactation
Thank you for your attention!!