Nutritional manipulation of the endocrine system in dairy cows: implications for health, fertility and milk fatty acids

Phil Garnsworthy
University of Nottingham
Phil.Garnsworthy@nottingham.ac.uk

Collaborators & Funding

- Nottingham
  - Bob Webb
  - Phil Garnsworthy
  - Kevin Sinclair
  - Tony Flint
  - George Mann
  - Ali Fouladi
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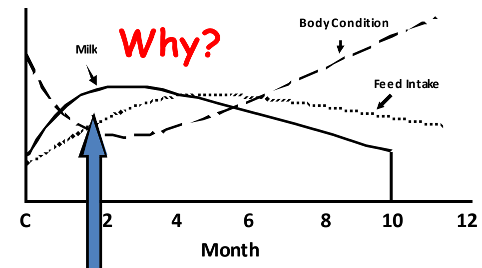
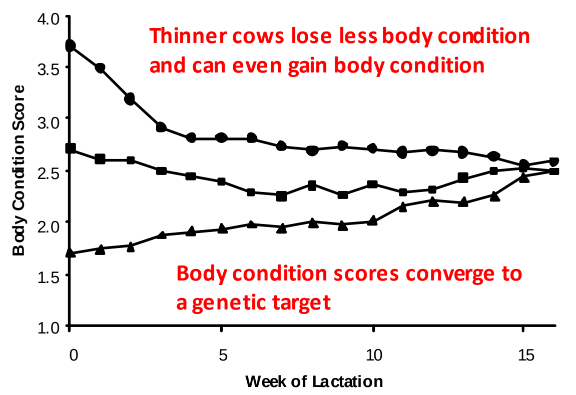
Long-term nutrition & metabolism

Negative Energy Balance and Manipulation of Body Condition

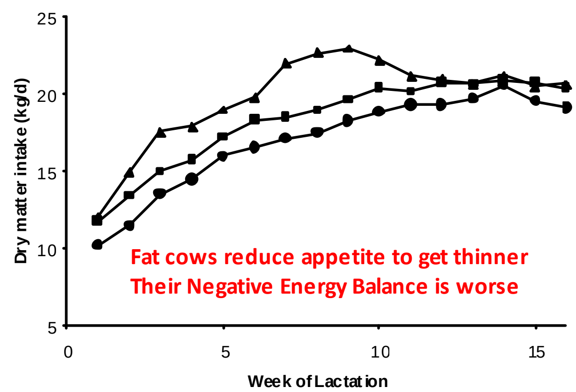
(homeorhesis)

Negative Energy Balance



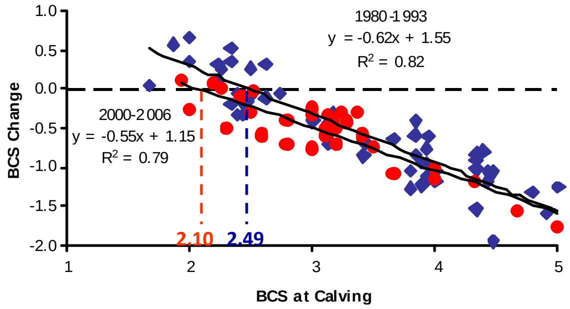


Garnsworthy and Topps, 1982



Garnsworthy and Topps, 1982

Effect of BCS at Calving on change in BCS (0-10 wks)

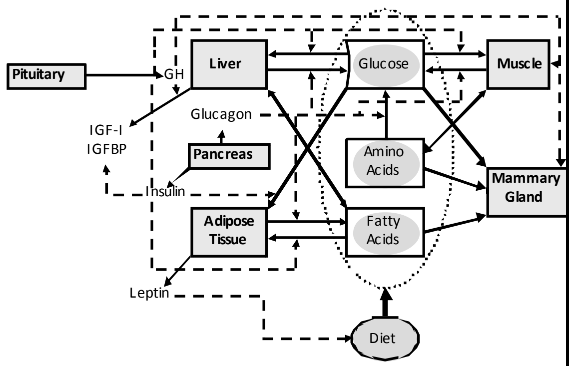


23 studies, 81 treatment groups, >5,000 cows — Garnsworthy, 2006

BCS @calving >3.0 or BCS-loss >1.0

- Delayed ovulation (Butler, 2004)
- Reduced pregnancy rate (Garnsworthy, 2006)
- Increased fatty liver (Treacher et al. 1986)
- Increased risk of ketosis (Gillund et al. 2001)
- Greater oxidative stress (Bernabucci et al. 2005)
- Poorer immune response (Lacetera et al. 2005)
- Low insulin status (Garnsworthy et al. 2008)

Hormonal control of metabolism

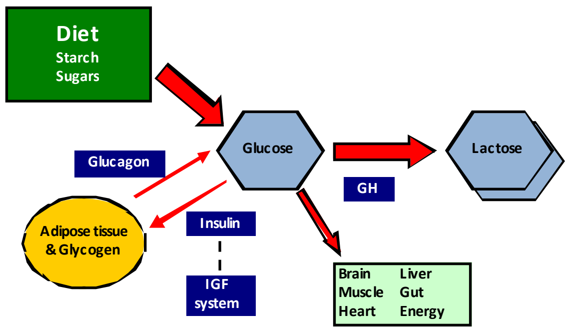


Garnsworthy et al. (2008) *Animal* 2, 1144-1152

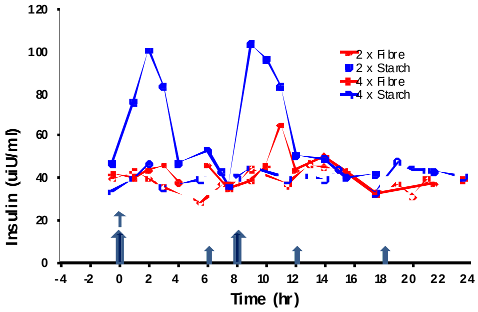
COMPONENTS OF THE IGF SYSTEM

Ligands	IGF-I and IGF-II
Binding Proteins	
• High affinity	IGFBP-1 to -6
• Low affinity	IGFBP-7 to -9 …
IGFBP Proteases	
Receptors	Type 1 IGF receptor
	Type 2 IGF receptor
	Insulin receptor

Glucose Homeostasis



Diurnal profiles - insulin



High versus Low Milk Yield

Growth Hormone and Insulin in dairy cows of Low or High genetic merit (15-60 days post-partum)

	GH ng/ml	Insulin ng/ml
Low merit	12.7	0.48
High merit	16.7	0.38

(Gutierrez *et al*., 1999; 2006)

Annual milk yield (l/yr): 5,000 Low merit; 7,000 high merit

Metabolic hormones, metabolites and milk yield for cows of Low or High genetic merit (15-35 days post-partum)

	GH ng/ml	Insulin ng/ml	IGF-I ng/ml	BOHB mmol/l	Milk Yield l/d
Low	7.0	0.18	166	0.7	30.2
High	10.2	0.13	115	1.0	31.9
	**	*	**	**	

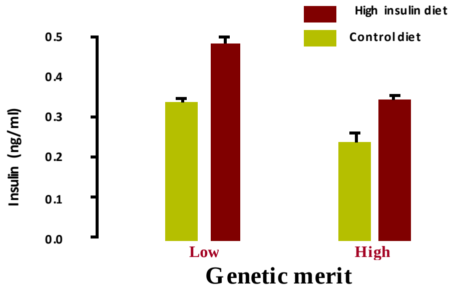
(Gutierrez *et al*., 1999; 2006)

Can we alter metabolic hormones by nutrition?

Insulin drivers

Diet	Rumen	Liver/Blood	Insulin effect
Starch	Propionate	Glucose	+++
Starch	bypass	Glucose	+++
Sugars	Butyrate	Butyrate	+/-
Amino acids	AA	AA/Glucose	++/(-)
Fatty acids	FA	FA	---/(+)

Insulin secretion in postpartum dairy cows (0 - 50 days)



Gong, Lee, Garnsworthy, and Webb (2002) *Reproduction*, **123**, 419-427.

Proportion of cows that ovulated within 50 days of calving

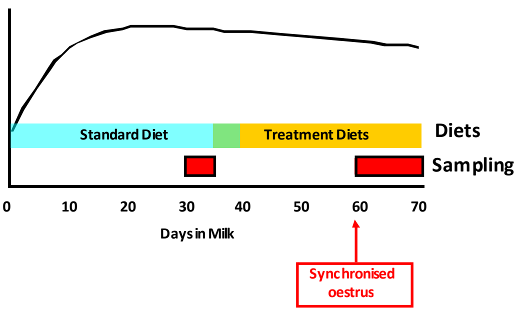
	Control diet	High insulin diet
High genetic merit	50%	80%
Low genetic merit	60%	100%

Gong, Lee, Garnsworthy, and Webb (2002) *Reproduction*, **123**, 419-427.

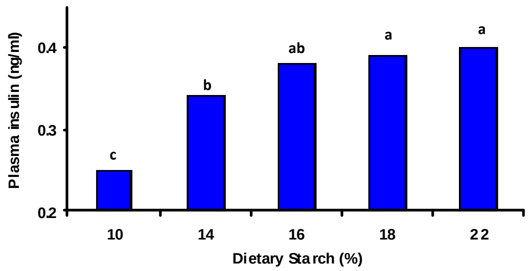
Diet effects on insulin (Nottingham University Studies)

- 162 Cows (Holstein, 8-10,000 L/cow/yr)
- 6 Experiments
- 26 Dietary treatments
  - Starch, Fibre, Fat, Amino acids
  - Forage & Concentrate type
  - Protected fat source

Nottingham experiments to test diet effects on insulin

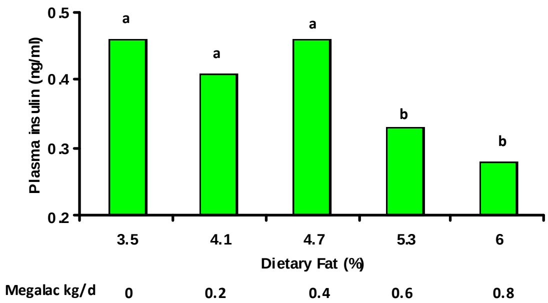


Effect of dietary starch content on plasma insulin



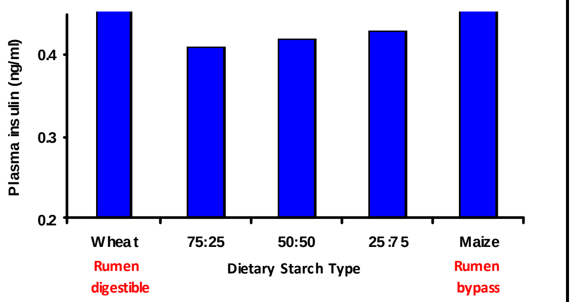
Garnsworthy et al. 2008 *J Dairy Sci* **91**:3814-3823.

Effect of dietary fat content on plasma insulin



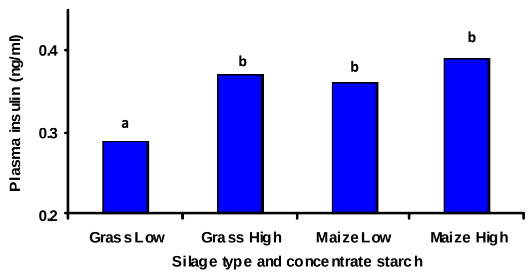
Garnsworthy et al. 2008 *J Dairy Sci* **91**:3824-3833.

No effect of concentrate starch type on plasma insulin



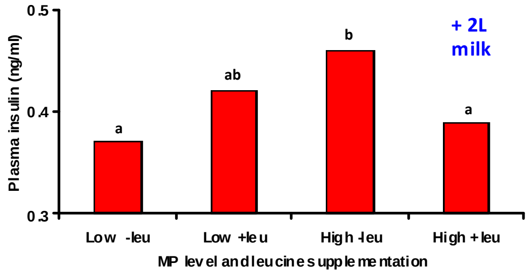
Garnsworthy et al. (2009) *Livestock Science* 125:161–168.

Effect of grass versus maize silage and concentrates of high or low starch content on plasma insulin



Garnsworthy et al. (2009) *Livestock Science* 125:161–168.

Effect of Metabolisable Protein and Leucine on plasma insulin



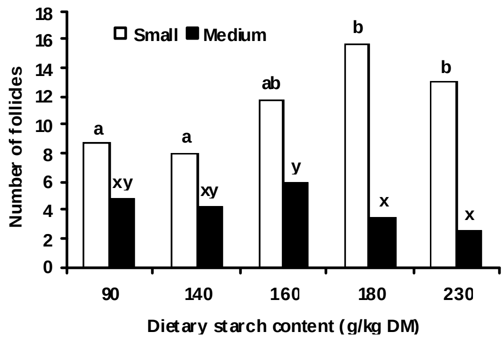
Garnsworthy et al. 2008 *J Dairy Sci* **91**:4190-4197.

Glucagon

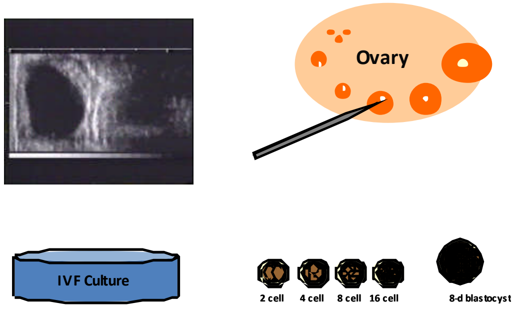
- Stimulates gluconeogenesis
- Moderate correlations with insulin (r=0.3-0.6)
- Rumen digestible starch (propionate) ++
- Rumen bypass starch (glucose) – –
- High protein diets (excess AA) +++
- Sometimes elevated in high-yielding cows with high insulin [insulin resistant?]

Implications for fertility

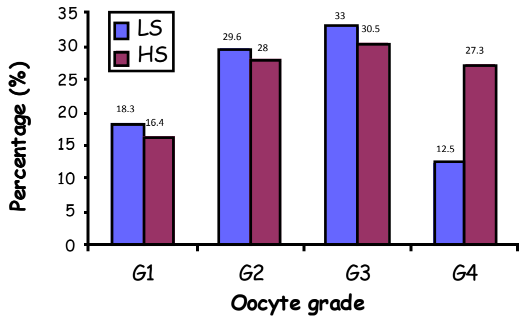
Effect of dietary starch content on ovarian follicles



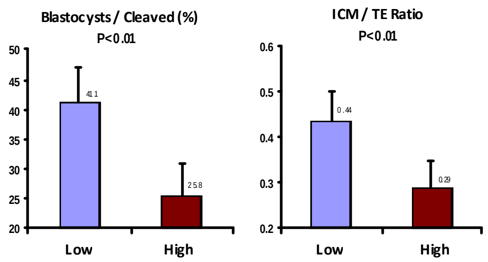
Ultrasound-guided ovum pickup (OPU)



High Starch diet produced more poor quality oocytes



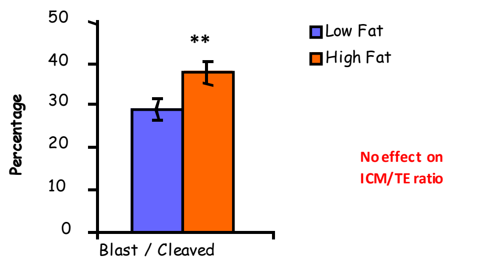
High Insulin reduces oocyte quality in dairy cows



56 OPU, 243 oocytes

Fouladi et al. (2005)

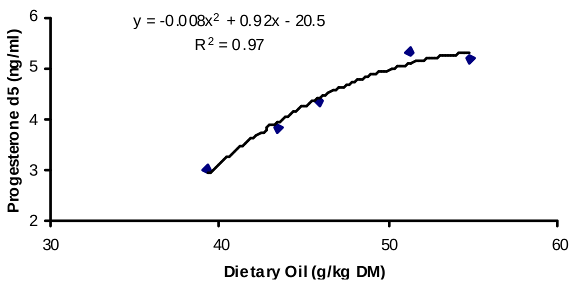
High Fat produces better oocytes in dairy cows



Fouladi-Nashta et al. 2007

144 OPU, 1051 oocytes

Effect of dietary fat concentration on Progesterone at Day 5 of the Oestrous Cycle



Garnsworthy et al. 2008

Fertility and Insulin - Summary

Early resumption of oestrous cycles

High insulin

Good follicular recruitment

High insulin

Good quality oocyte

Low insulin – High fat

Establishment of pregnancy (High Day-5 P4)

Low insulin – High fat

A conundrum!

Nottingham Pregnancy study

High insulin cycling diet (CD; 18% starch, 3.9% fat)

Low insulin mating diet (MD; 10% starch, 5.3% fat)

4 dietary treatments, 60 cows (n = 15)

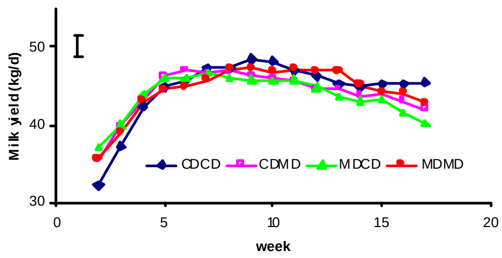
Diets changed after cows started to cycle (≈50 d)

Days 0 to 120 of lactation

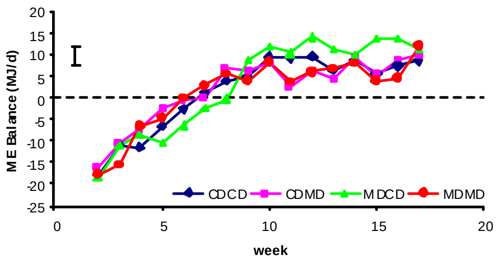
1. Worst for reproduction (MDCD)
2. Intermediate A (CDCD)
3. Intermediate B (MDMD)
4. Best for reproduction (CDMD)

Garnsworthy et al. (2009) *Reproduction* **137**, 759-768

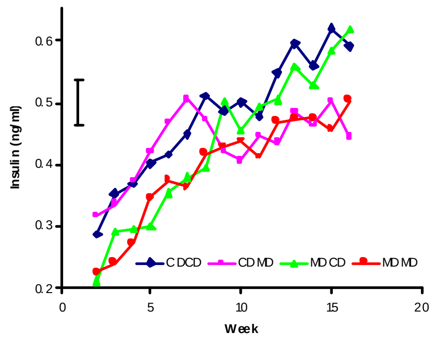
No treatment effect on milk yield



No treatment effect on energy balance



Significant interaction for insulin

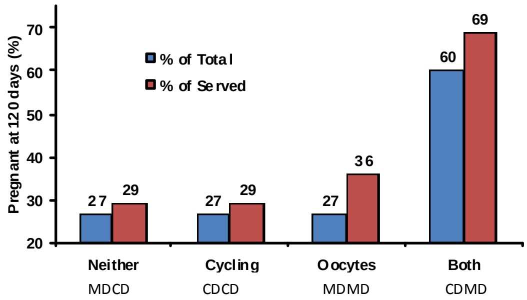


CDCD v MDMD P=0.02

No treatment effect on:

- Days to first progesterone rise (29 +/- 5.4)
- Days to first insemination (74 +/- 7.6)
- Proportion of cows served (87%)
- Days to conception (78 +/- 12.2)
  (for cows pregnant at 120 DIM)

Pregnancy rate at 120 days with diets designed to improve cycling or oocytes



J Dairy Sci 93:4292-4296 (2010)

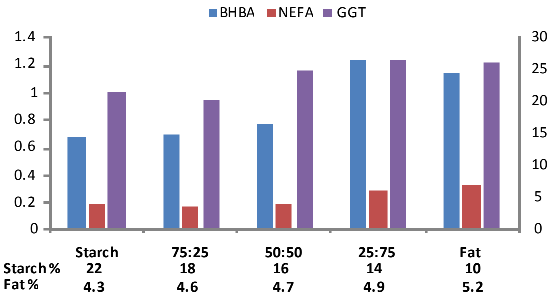
Short communication: **Effects of dietary nonstructural carbohydrates pre- and postpartum on reproduction of grazing dairy cows**

C. R. Burke,[1] J. K. Kay, C. V. C. Phyn, S. Meier, J. M. Lee, and J. R. Roche
DairyNZ Limited, Private Bag 3221, Hamilton 3240, New Zealand

- High starch supplement offered to grazing cows for 35 d postpartum, then grazing only
- No effect on energy balance
- Postpartum anoestrus interval 8 days shorter with starch (28.6 d) v control (36.5 d)
- 6-week pregnancy rate 17% greater with starch (93%) v control (77%)

Dietary manipulation of hormones – health implications

Insulin-changing diets and plasma health indicators



Garnsworthy et al. 2008 *J Dairy Sci* **91**:3814-3823.

Glucogenic versus lipogenic diets

(multiparous cows)

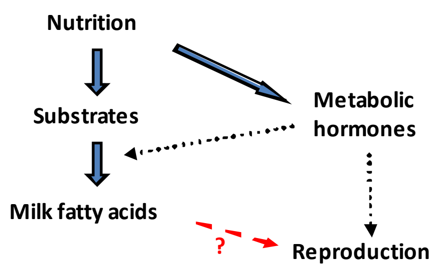
	Glucogenic	50:50	Lipogenic	SEM
Milk yield, kg/d	43.4	44.0	43.2	1.1
Energy balance, kJ/kJ$^{0.75}$.d	-33[a]	-125[b]	-89[ab]	21
Insulin, µIU/ml	4.19[a]	2.78[b]	2.88[b]	0.33
BHBA , mmol/l	0.64[a]	0.79[ab]	0.84[b]	0.05
NEFA, mmol/l	0.22[a]	0.31[b]	0.31[b]	0.02
Liver TAG, mg/g	25.7[a]	62.7[b]	58.6[b]	10.4
SCC, x10^3/ml	77[a]	65[a]	303[b]	26

Van Knegsel et al. (2007) J. Dairy Sci. 90:3397–3409

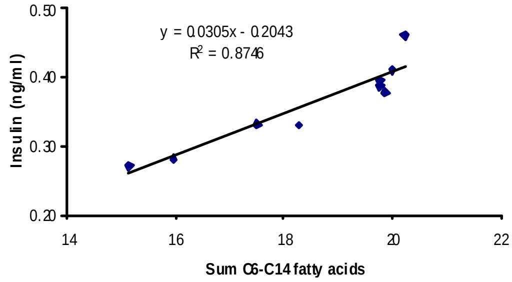
Implications for health - Summary

- Too few cows in experiments to analyse health incidence
- High insulin (glucogenic) diets reduce some indicators of metabolic disease risk:
  - Negative energy balance and BCS loss
  - Liver fat content
  - BOHB
  - NEFA

Can we use milk fatty acids to predict insulin and fertility?

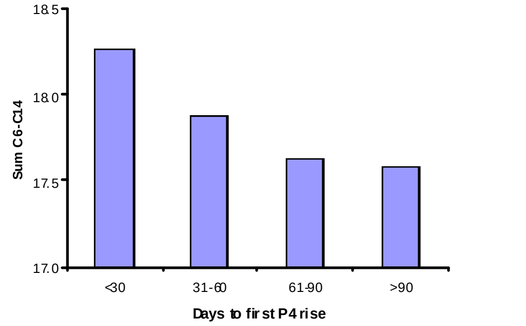


Milk short-chain fatty acids are related to insulin



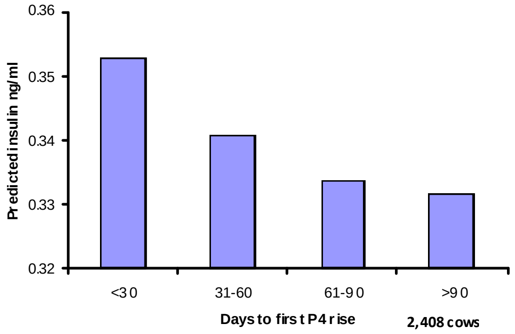
60 cows 10 diets

Milk short-chain fatty acids are related to progesterone rise



2,408 cows
commercial farms

Progesterone rise is related to insulin predicted by milk fatty acids



2,408 cows
commercial farms

Summary and Conclusions

- BCS at calving drives negative energy balance
- Hormones, especially insulin, can be altered by diet composition
- Insulin influences cyclicity (+) and oocytes (-)
- Low insulin suggests more health problems
- Milk fatty acids might indicate insulin status
- For best results – feed right diet at right time

Thank you for your attention