Nutritional management of energy balance in cows during early lactation

K.J. Shingfield [1] and J. Vilkki [2]

MTT Agrifood Research Finland

[1] Animal Production Research
[2] Biotechnology and Food Research

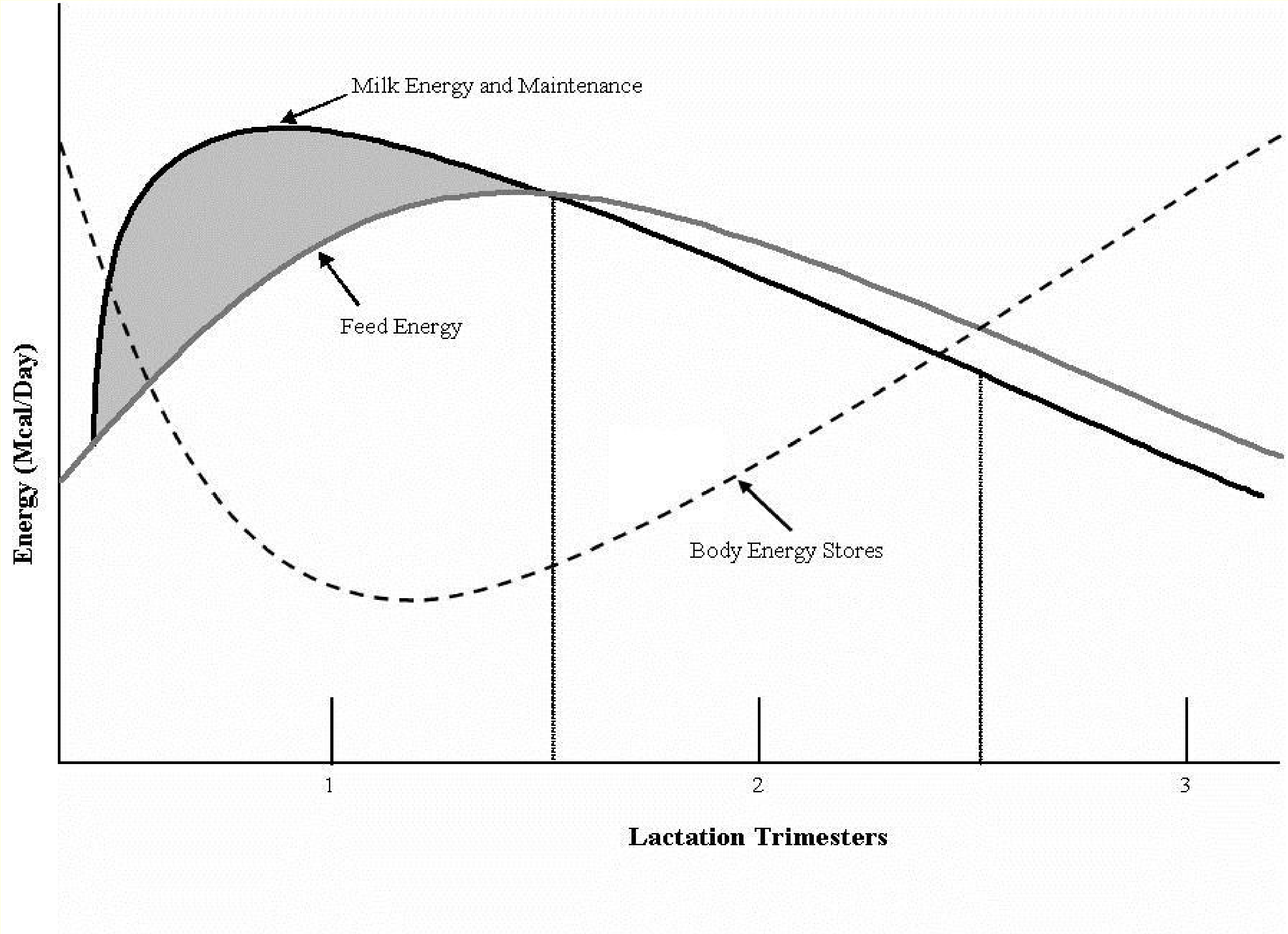
Overview

- Energy balance in early lactation
- Negative energy balance, metabolic health and fertility
- Challenges to improving energy balance in early lactation
- Potential to repartition energy in the lactating cows
- NUTRIREG research project

Importance of prepartum-postpartum transition

- Interval 21 d prepartum to 21 d postpartum is critical to health, production and fertility in high genetic merit cows
- Most infectious diseases and metabolic disorders occur during the periparturient period
- Disorders include milk fever, ketosis, retained faetal membranes, metritis and displaced abomasum
- Immunosuppression also increases the susceptibility to mastitus

Energy balance of cows during early lactation



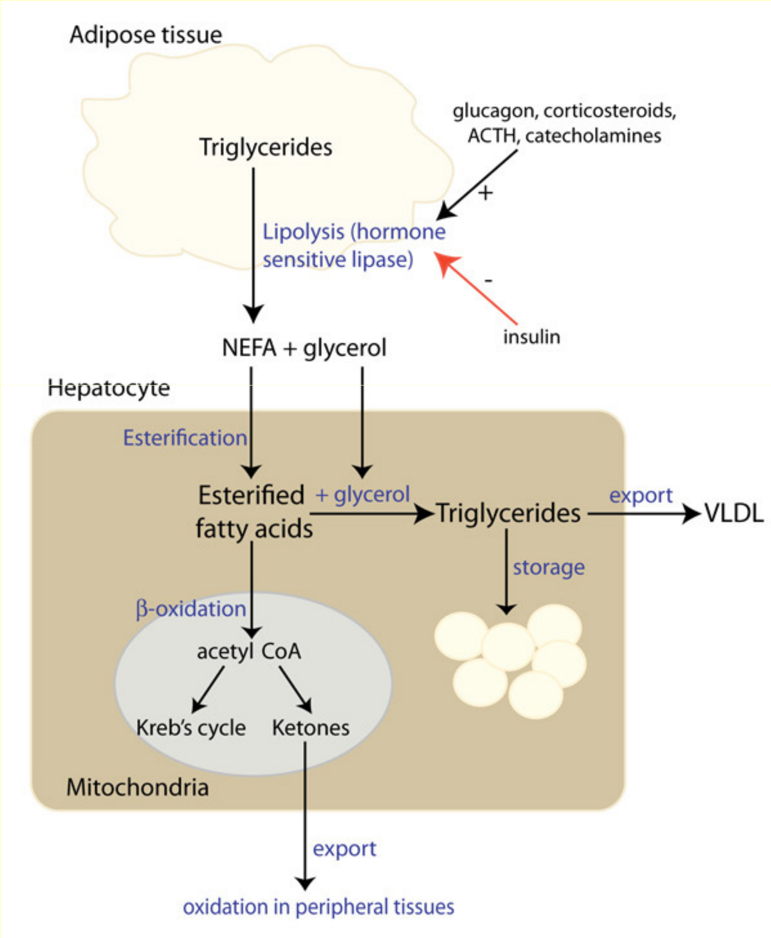
Kutches, 1983

Association between energy balance and reproductive performance

- **Period of negative energy balance coincides with first service and an energy deficiency or live weight loss increases in first service interval and/or lowered conception rates**
- **Onset of postpartum ovulation thought to be delayed 0.67 d per MJ of negative energy balance experienced during the first 20 d postpartum**

Butler, 1989

Association between energy balance and ketosis



- **Mobilised fatty acids used to synthesise acetone, acetacetate, β-OH-butyrate**
- **Excessive loss of body fat stores results in higher circulating concentrations of ketone bodies**
- **Prolonged and extensive negative energy balance increases the risk of subclinical or clinical ketosis**

Leslie et al., 2000

Can we alleviate negative energy balance during early lactation by increasing energy intake?

Energy content of ruminant feedstuffs

	Energy content (MJ/kg DM)		
	GE	ME	NE lactation
Grass	18.7	11.2	6.9
Grass silage	20.9	11.0	6.8
Barley grain	18.5	13.3	8.1
Fat prills	39.0	33.0	26.4
Tallow	39.3	30.5	24.4

Garnsworthy, 1997

Expected benefits to dietary fat supplements

Fats generally included in the diet to increase energy density and caloric intake:-

- Support higher milk production or growth rates
- Improve energy balance during early lactation or in periods of restricted feed availability and thereby lower mobilisation of body reserves

Fat supplements have variable effects on energy balance and live weight during early lactation

Fat source	Week of lactation	Change in energy balance (Mcal NEL/d)	Change in live weight (g/d)
Ca Salts of palm oil	2 - 6	+4.1	+72
Ca Salts of palm oil	1 – 11	-1.9	-14
Ca Salts of palm oil	1 – 11	-0.7	-261
Saponified rapeseed	2 – 6	+3.5	+465
Extruded rapeseed	2 – 6	+3.1	+358
Soyabean oil	1 – 7	+1.0	-45

Chilliard, 1993

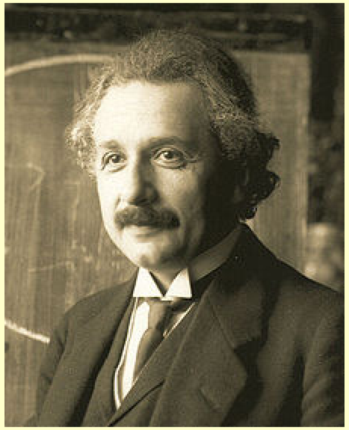
More creative and imaginative solutions required to meet these multifaceted challenges

"Doubt is not an agreeable condition, but certainty is an absurd one."

François-Marie Arouet "Voltaire"

"The significant challenges we face cannot be resolved at the same level of thinking we were at when we created them."

Albert Einstein



Can we alleviate negative energy balance during early lactation by lowering energy secretion in milk?

Decreasing fat to lower milk energy content

- **Controlled decreases in milk energy secretion could be used to improve energy balance during early lactation**
- ***Trans*-10, *cis*-12 CLA inhibits milk fat synthesis**
- **Formulate diets that induce milk fat depression**

Effect of rumen protected CLA on energy metabolism during early to mid-lactation

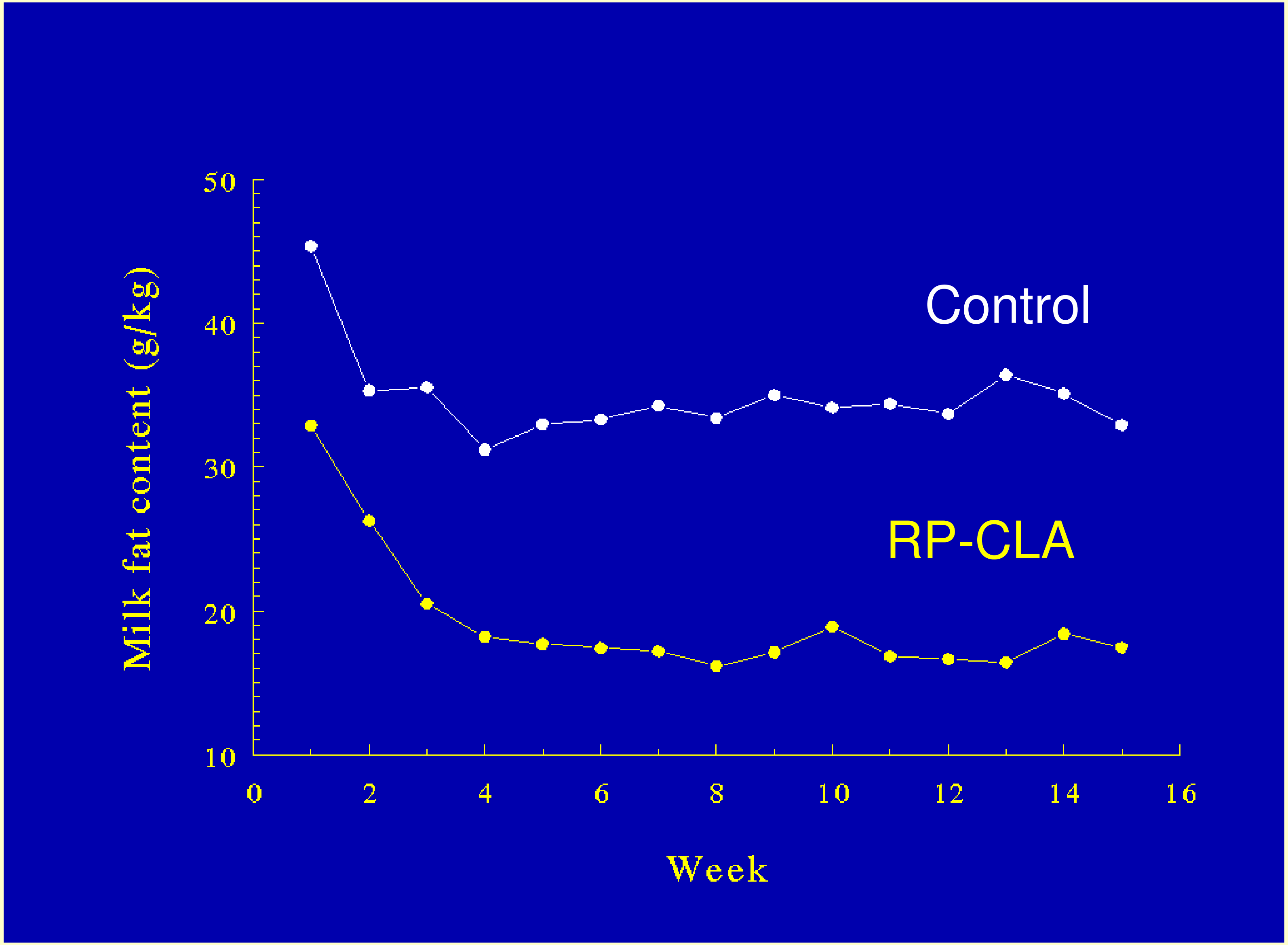
- 12 cows used in a repeated measures randomized block design recruited 21 d pre-partum
- Treatments consisted of control or the same diet + 110 g/d of rumen protected CLA (RP-CLA)
- Estimates of energy balance performed during weeks 3, 7, 11 and 15 of lactation based on total excreta collection and gaseous exchange measured in open-circuit respiration chambers

Shingfield et al., 2004

Mean effects of rumen protected CLA on animal performance

	Control	RP-CLA	SEM	*P*
DMI (kg/d)	22.2	24.6	0.77	< 0.10
Yield				
Milk (kg/d)	40.3	47.4	1.84	< 0.05
Fat (g/d)	1395	901	66.7	< 0.001
Protein (g/d	1254	1422	42.7	< 0.05
Lactose (g/d)	1873	2186	77.5	< 0.05
Concentration				
Fat (g/kg)	34.9	19.2	1.11	< 0.001
Protein (g/kg)	31.3	30.1	0.36	< 0.05
Lactose (g/kg)	46.4	46.1	0.24	

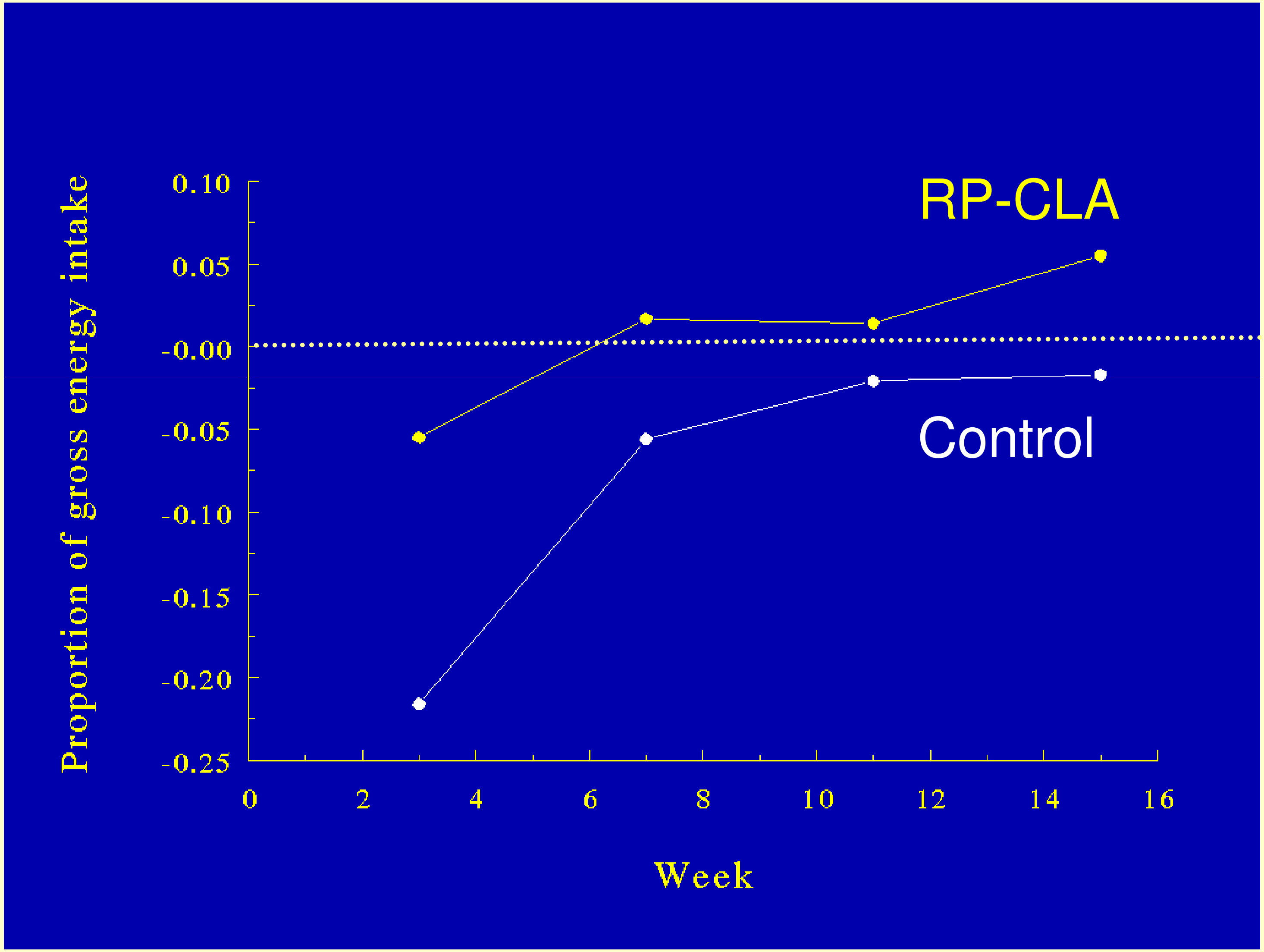
Temporal changes in milk fat content



Mean effects of rumen protected CLA on the intake and partitioning of gross energy

	Control	RP-CLA	SEM	*P*
GE intake (MJ/d)	389	434	20.2	
Partition of GE				
Heat	0.408	0.392	0.0126	
Methane	0.063	0.060	0.0028	
Feces	0.278	0.274	0.0034	
Urine	0.029	0.025	0.0013	0.051
Milk	0.299	0.241	0.0221	0.010
Retained	-0.078	0.008	0.0331	0.010

Temporal changes in the partitioning of gross energy intake towards body tissues



The Journal of Nutrition
Nutrient Physiology, Metabolism, and Nutrient-Nutrient Interactions

Expression of Enzymes and Key Regulators of Lipid Synthesis Is Upregulated in Adipose Tissue during CLA-Induced Milk Fat Depression in Dairy Cows[1–3]

Kevin J. Harvatine, James W. Perfield II,[4] and Dale E. Bauman*

Department of Animal Science, Cornell University, Ithaca, NY 14853

Treatments were control and 4-d abomasal infusion of *trans*-10, *cis*-12 CLA (7.5 g/d).

Adipose tissue expression of lipid synthesis enzymes, including lipoprotein lipase, FA synthase, stearoyl-CoA desaturase, and FA binding protein 4, and the transcription factors sterol-response element binding protein 1, thyroid hormone responsive spot 14 and PPARγ were examined

Milk fat depression to *trans*-10, *cis*-12 CLA associated with the upregulation of genes involved in adipogenesis

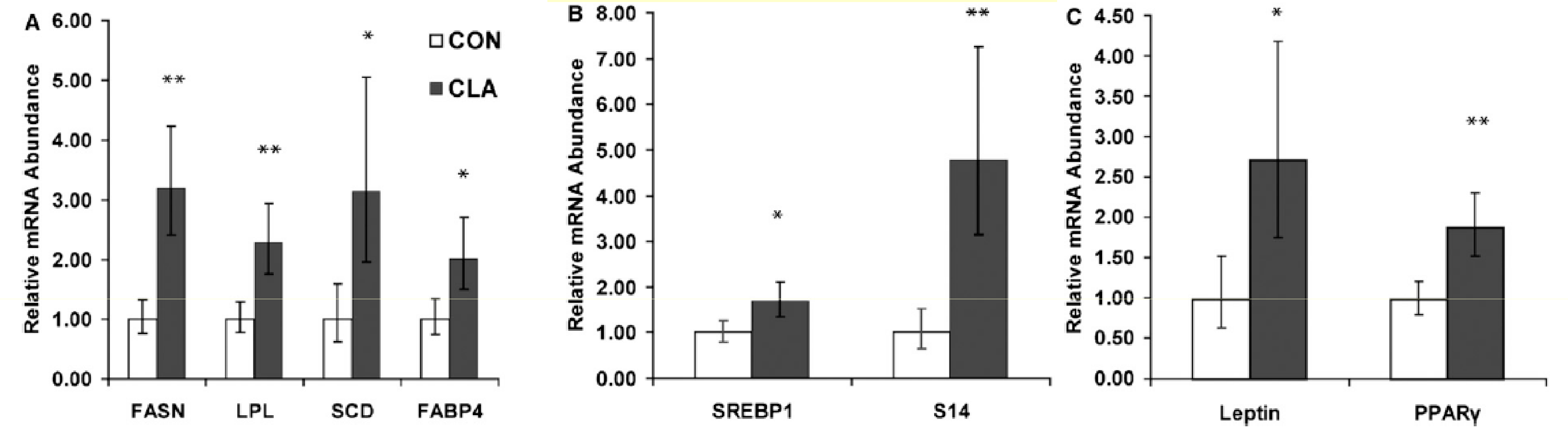


FIGURE 1 Effects of 4-d abomasal infusion of 7.5 g/d *trans*-10, *cis*-12 CLA on adipose tissue mRNA abundance for mRNA abundance of key proteins of lipid synthesis (*A*), key regulators of lipid synthesis (*B*), and of markers of adipose energy status (*C*) in lactating dairy cows. Values are means ± SE, $n = 12$ (CON) or 8 (CLA). Asterisks indicate different from control: $^{*}P < 0.05$, $^{**}P < 0.01$.

Harvatine et al., 2009

Diet-induced milk fat depression associated with Increased fat synthesis in adipose

J. Dairy Sci. 92:4290–4300
doi:10.3168/jds.2008-2000

Adipose tissue lipogenic gene networks due to lipid feeding and milk fat depression in lactating cows

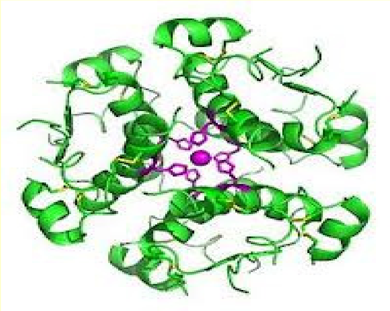
B. J. Thering, D. E. Graugnard, P. Piantoni, and J. J. Loor[1]
Mammalian NutriPhysioGenomics, Department of Animal Sciences and Division of Nutritional Sciences, University of Illinois, Urbana 61801

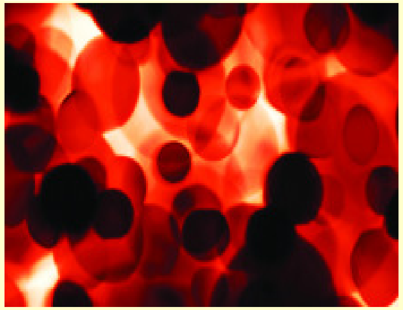
"Overall, our results suggest that long-term milk fat depression caused by feeding FSO provided additional energy as well as long-chain fatty acids that, coupled with upregulation of a subset of adipogenic genes in subcutaneous adipose tissue, might have resulted in greater tissue lipid deposition."

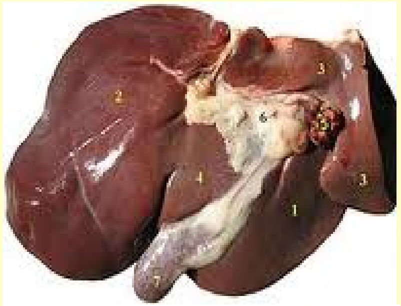
Thering et al., 2009

Summary

- Increasing amount of experimental evidence to support the concept that decreasing milk fat offers the opportunity to repartition energy towards body tissues during early lactation
- Data on the effects on reproductive performance are limited
- Need to explore opportunities to lower milk fat during early lactation for improving health and fertility as a means to improve the sustainability of Finnish milk production







Future approaches

- Study of the function of molecules, cells, organs or organisms in a living system
- Investigations at different physiological stages/environment/productivity
- Interrelated and co-ordinated nature of physiological responses make it difficult to establish cause and effect
- Physiological response; nutrient, metabolite or endocrine..?

Rapid and significant advances in molecular technologies and the 'omics concept

- **Rapid development in high throughput techniques**
- **Possible to characterise**
  - **-genome**
  - **-transcriptome**
  - **-proteome**
  - **-metabolome**
- **Generate quantitative data for discovery and dynamic modelling**

Regulation of lipogenesis and epigenesis in ruminants: A nutrigenomic and nutrigenetic based approach (NUTRIREG)

- **NUTRIREG is a major new initiative to establish an animal nutrigenomics research programme to expand the capacity of MTT to undertake fundamental bioscience research within the overall aim of improving the competitiveness and sustainability of Finnish livestock production**

- **Develop the infrastructure and resources for research on the role of nutrients on the genome, proteome and metabolome in ruminant livestock**

NUTRIREG: Research themes

- **Role of nutrients and dietary ingredients on the expression of genes and genes involved in the regulation of milk fat synthesis in lactating cows and potential to regulate energy partitioning**
- **Characterising the expression of gene networks in adipose, liver and the mammary glands to understand the inter-relation between nutrient use and tissue metabolism in lactating cows**

NUTRIREG: Research themes

- **Understanding the influence of diet and the host animal on microbial communities in the rumen and the association with enteric methanogenesis and nutrient digestion**
- **Influence of maternal nutrition on the regulation of epigenetic effects during embryo development based on the collection of bovine oocytes and transcriptome profiling of endometrium during early and established lactation**

Progress to date

- **Two detailed physiological experiments to examine the potential to lower milk fat content and associated changes in rumen microbiology, gene expression energy metabolism and milk fat composition in cows fed grass silage based diets**
- **Long-term experiment initiated to examine the potential to lower milk energy content on energy balance, expression of genes involved in energy metabolism, inflammation and reproductive function and fertility.**

Physiological experiments: Proof of concept

- **4 x 4 Latin square to examine the effects of forage:concentrate ratio (65:35 vs 35:65) and sunflower oil (0 vs 50 g/kg diet DM) in cows fed grass silage**

- **4 x 4 Latin square to examine the effects of dietary starch content and a mixture of unsaturated fatty acids (0 vs 30 g/kg diet DM) in cows fed grass silage (F:C; 55:45 vs 35:65)**

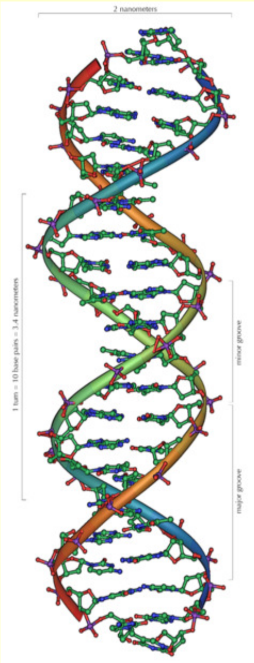
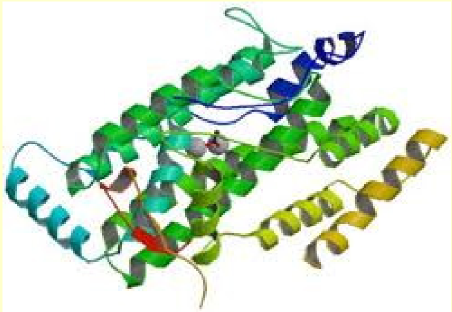
Large scale study: Research into practice

- Randomised block design for repeated measures
- 72 cows recruited 28 d prepartum to 126 d postpartum
- Treatments based on grass silage (F:C; 55:45)

  1) Control

  2) Control + RP CLA (9.4 and 14.1 g/d t10,c12/d)

  3) Diet formulated to induce MFD
- Measurements include animal performance, energy balance on d14, 42, 70 and 98, tissue biopsies, oocyte collection and reproductive performance



Thank you for your attention