Bovine Milk Fats: A Look at Organic Milk

Gillian Butler, Nafferton Ecological Farming Group, Newcastle University

March 29, 2012

http://www.extension.org/organic_production

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Bovine Milk Fats: A Look at Organic Milk

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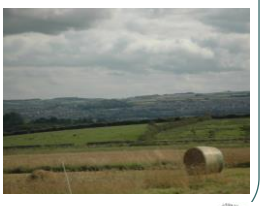
Newcastle University

Research supported by EU funding

Outline

1. Who am I
2. Newcastle University & Nafferton Ecological Farming Group
3. Background to milk fat
4. Variation in milk fatty acids
5. Farm survey in UK
6. Farm survey in Europe
7. Winter feeding trial
8. *Processing dairy products*
9. *CLA isomers in milk*
10. Where do we go from here?



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2 What do we do at NEFG?

- Nafferton Ecological Farming Group
- Newcastle University, School of Agriculture Food & Rural Development
- Research & communication
  - Consumers
  - Producers / farmers
  - Students, including school children
  - The science community
  - Funders!

Find us: www.nefg-organic.org

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Nafferton Farm

http://maps.google.co.uk/

- 300 ha arable & dairy farm, Tyne Valley, northern England
- Run as 2 parallel units since 2001
- Organic v conventional management
- 80 - 85 cows each in parallel dairy herd

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Past projects

- Organic potatoes & late blight (EU)
- Organic red meat production (UK)
- Quality & safety in organic and low input food; QLIF (EU)
- Lupins as home produced protein (UK)
- Better organic bread – BOB (UK)

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Current projects

- NUE – CROPS (EU)
- N-TOOLBOX (EU) (http://www.n-toolbox.eu)
- Low Input Breeds (EU) (http://www.lowinputbreeds.org/)
  - Breeding and management of organic and *low-input* livestock
- Tillman (UK/EU) www.tilman-org.net
- ProPIG (UK/EU)
  - Welfare, health & environmental impact of European organic pigs

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Other activities

- Involvement with industry
- Disseminate research findings
- MSc in Organic Farming & Food Production; in northern European & Mediterranean conditions

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3 Fats and Fatty acids - intro

- Dietary fat crucial to health +ve and –ve
- Minimum 15-20% energy intake; sufficient energy, fat soluble vitamins & antioxidants, **essential fatty acids**, taste & sensory characteristics of food
- Dairy products important source, especially in children (36% total)
- Fatty acids (FA) named according to:
  - number of carbon atoms: C4 – C24 (mostly even number)
  - degree of **saturation** (single v double bonds between carbon atoms)
  - number, position (and orientation (cis or trans)) of double bonds
    - 0 = saturated (**SFA**) eg Palmitic acid C16:0
    - 1 = monounsaturated (**MUFA**) eg Oleic acid C18:1 c9
    - 2+= polyunsaturated (**PUFA**) eg Linoleic acid C18:2 c9,12
- Balance of FA in milk varies - but dominated by saturated fats (SFA)

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Fats and Fatty acids in human nutrition

FAO report of expert consultation

http://www.who.int/nutrition/publications/nutrientrequirements/fatsandfattyacids_humannutrition/en/index.html

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Saturated fats

- Typically 60-70 % milk fat
- Rumen microbes 'saturate' or ***hydrogenate*** PUFA → SFA
- Increase LDL-cholesterol and risk of cardiovascular disease (CVD)
- Hence reduction in milk fat consumption
- C12:0, **C14:0** & C16:0 considered main culprits (others including C18:0 thought to be neutral/positive)
- Short chain SFA (C< = 16) produced in udder and longer chain FA originate from diet or mobilisation of body fat
- High content of SFA leads to high melting point – hard butter
- Growing evidence that dairy consumption offers *protection* against CVD[5]

[5] Kliem & Givens Annu. Rev. Food Sci. Technol. 2011.2:21-36

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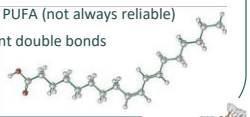
Unsaturated fat

- 30-40% of milk fat (25-35% MUFA & 5-8% PUFA)
- PUFA mostly classified: omega 3 (**n-3**) or omega 6 (**n-6**) ; 'last' double bond location
- Ideally n6:n-3 ratio 2-4:1 but western diets dominated by n-6
- Essential fatty acids:
  - linoleic acid (LA) = C18:2 c9,12 (n-6)
  - alpha linolenic (α-LA) = C18:3 c9,12,15 (n-3)
  - converted to longer chain n-3 and n-6 PUFA (not always reliable)
- Conjugated linoleic acid (CLA) with adjacent double bonds
  20-30 isomers, many in milk
  – dominated by C18:2 c9t11 (**CLA9**)



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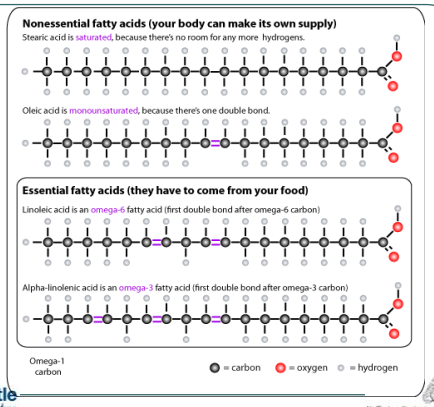

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http://www.gorillaprotein.com/Fatty_acids.html

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Beneficial Fatty acids & milk

- **CLA** only found in **ruminant** products – milk and meat
- Synthesised from vaccenic acid (**VA** C18:1 t11) – in udder and in us
- **n-3 FA** high in oily fish but (grass fed) meat and milk significant source if low consumption of marine fish
- α-LA converted to **EPA**, **DPA** & **DHA** but in competition with **n-6**
- CLA, αLA, n-3, n-6, VA & OA all found **in milk**
- Many positive effects on **health**
  - Protection against cardiovascular disease
  - Prevention of many types of cancer
  - Action against hypertension and behavioural disturbances
  - Anti-inflammatory function and immunological function
  - Development of brain, visual function and cognition
  - Anti-obesity, anti-diabetic, asthma treatment .....

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Antioxidants

- Milk also a valuable source of fat soluble vitamins & antioxidants
- Vitamin E in butter higher than most fruit and veg
- Carotenoid content of butter higher than many fruits
- 3 important functions
  - Improve health of dairy cows (reduced mastitis and improved fertility)
  - Prolong *shelf life* of unsaturated fats (prone to oxidation)
  - protection against cell damage; cancer & heart disease in humans

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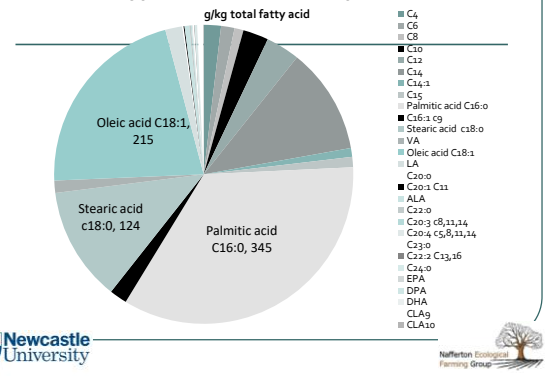
4 Typical milk fat composition



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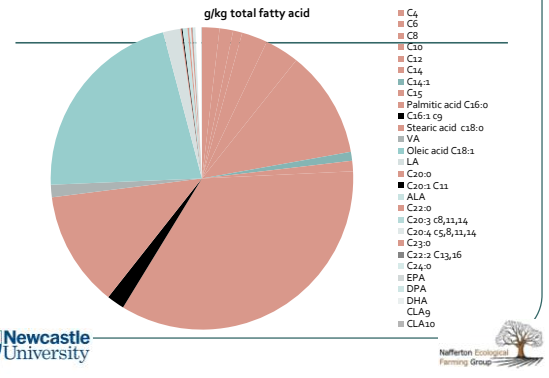
Saturated fatty acids (SFA)



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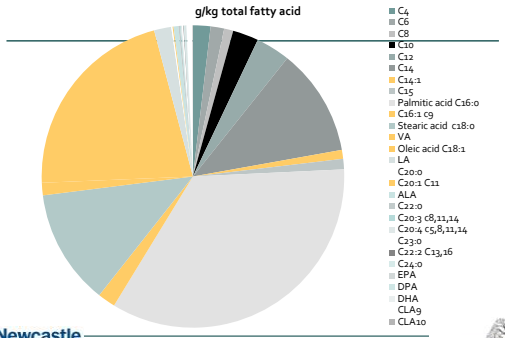
Monounsaturated fatty acids (MUFA)



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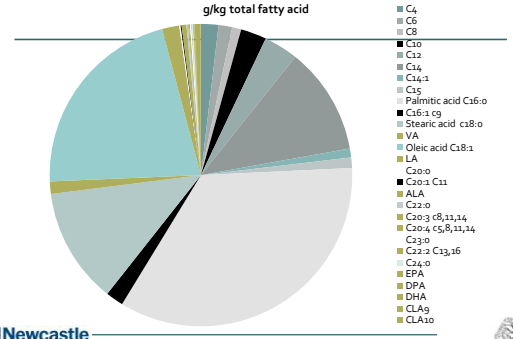
Polyunsaturated fatty acids (PUFA)



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Research into milk fat

- Most research striving to: ↓SFA and ↑PUFA (especially n-3 & CLA)
- Balance of '*good*' & '*bad*' fats in milk is highly variable
- Largely depends on dairy **diets** although genetics also involved (within and between breed differences)
- High PUFA intake by cows → high(er) PUFA content of milk – but not very efficient; **80-90% 'lost'** in rumen
- Fresh forage (**grazing**) diets, especially with **clover**, ↑ milk unsaturated fatty acids particularly α-LA, other n-3 and CLA
- Alternative approach – feeding oilseeds/vegetable oils but outcome dependant on oilseeds used (PA, OA, LA or α-LA)
- Maize & soya (oil) based diets ↑ n-6 in milk, clover and grass favours n-3

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What influences milk fat quality?

- Study considering milk from retail outlets in NE England
- Full fat milk
- 22 *Brands :* 10 organic & 12 *conventional*
- Purchased on 4 occasions
  - August 2006 & January 2007 (year 1)
  - August 2007 & January 2008 (year 2)
- Excluded fortified or Jersey brands
- Looking at fatty acid profiles

Butler G, Stergiadis S, Seal C, Eyre M, Leifert C. Fat composition of organic and conventional retail milk in northeast England *Journal of Dairy Science* 2011, **94**(1), 24-36.

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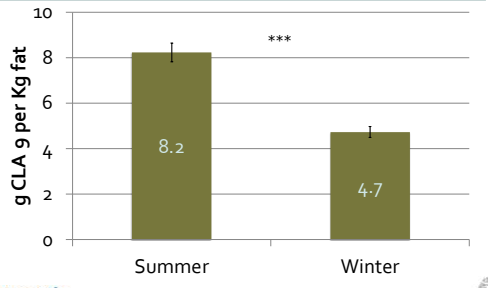
CLA9 & season



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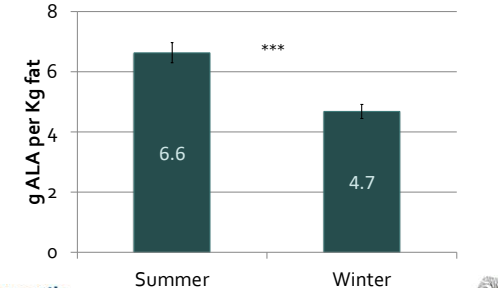
α-LA & season



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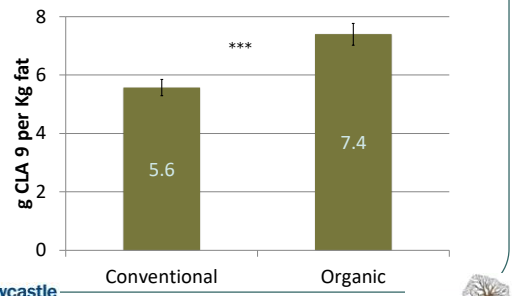
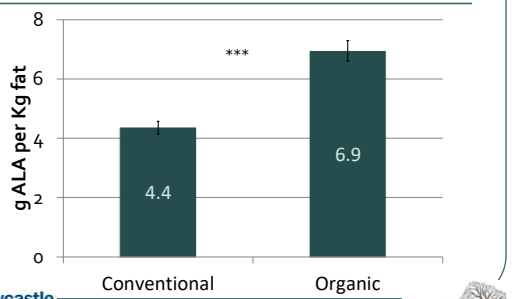
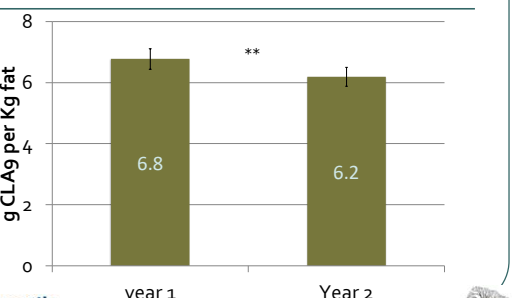
CLA9 & management



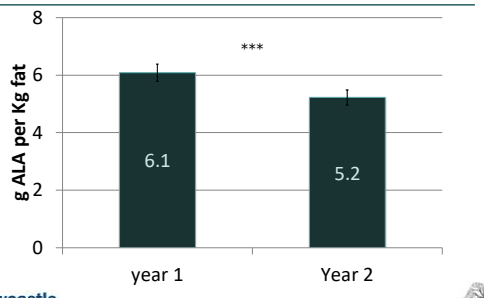
α LA & management



CLA9 & year



α-LA & year



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5 Experimental work UK

Nafferton Ecological Farming Group monitored milk from 25 farms in the UK

- 2 production systems in **North East England**
  1. High input conventional
  2. Low Input organic certified
- 3 production systems in **Wales** (south west UK)
  1. High input conventional
  2. Low Input organic certified (block calving)
  3. Low Input non-certified (block calving)
- Milk and management records – 5 times in 1 year : summer and winter
- Assessed fatty acids and antioxidants

Butler G, Nielsen JH, Slots T, Seal C, Eyre MD, Sanderson R, Leifert C. Fatty acid and fat-soluble antioxidant concentrations in milk from high- and low-input conventional and organic systems: Seasonal variation. *Journal of the Science of Food and Agriculture* 2008, **88**(8), 1431-1441

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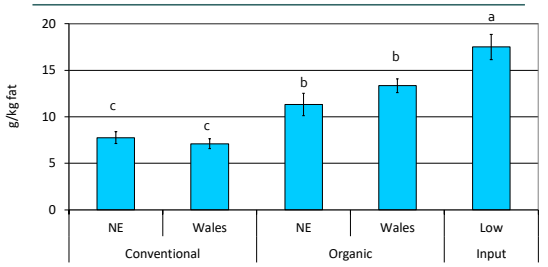
Conjugated Linoleic acid (CLA9)



p <0 .0001

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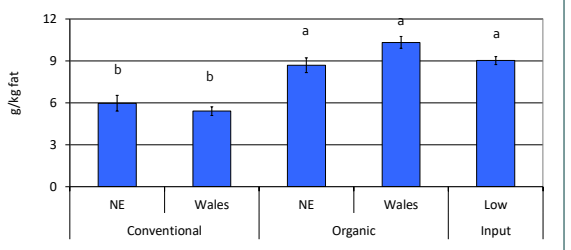
Alpha linolenic acid



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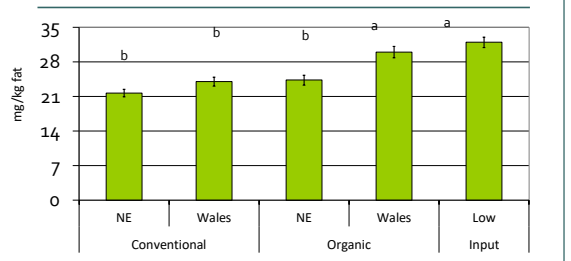
Alpha Tocopherol (Vitamin E)



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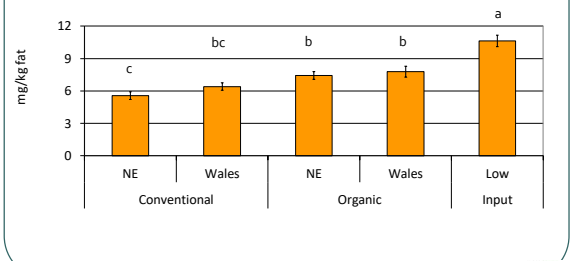
Carotenoids (precursor of vitamin A)



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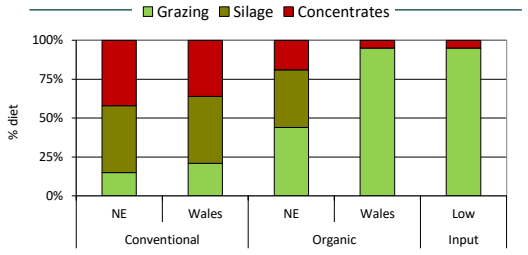
What cows ate



Organic and low input cows ate more 'forage' especially grass

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6 European study

- Initial farm study repeated
  - Sweden, Denmark & Italy
- 5 *systems* compared in each country, including 2 organic or *low input* (1/4 in Sweden)
- Bulk milk samples and management information collected throughout the year
- Fatty acid & fat soluble antioxidant profiles determined

*Butler G, Nielsen JH, Larsen MK, Rehberger B, Stergiadis S, Canever A, Leifert C. The effects of dairy management and processing on quality characteristics of milk and dairy products. NJAS Wageningen Journal of Life Sciences 2011, **58**(3-4), 97-102*

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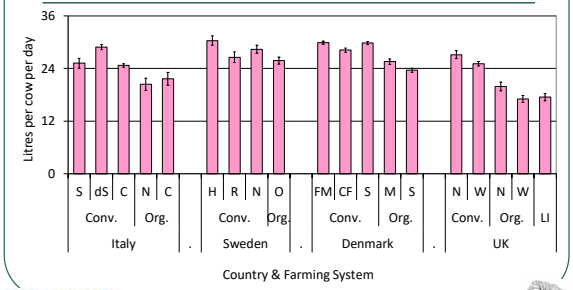
Milk yield



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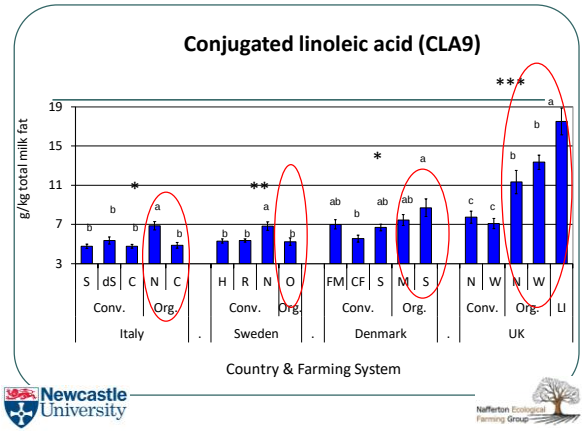
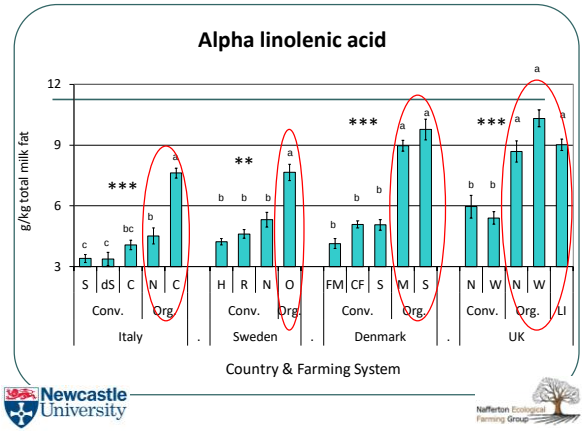
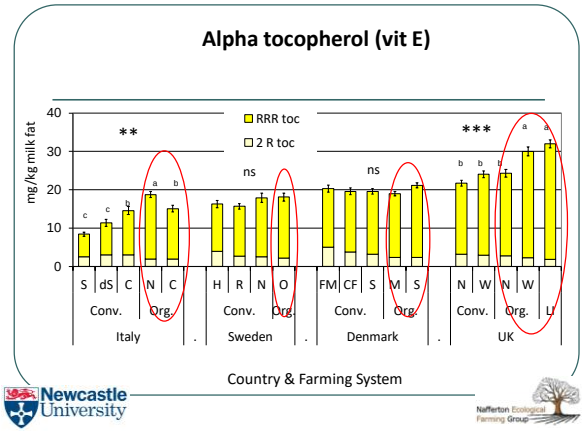
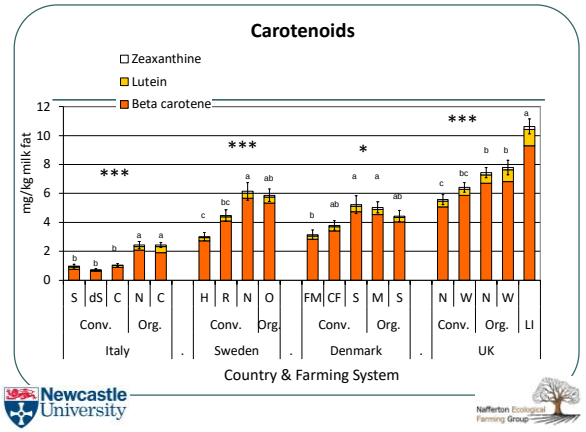

Conjugated linoleic acid (CLA9)
g/kg total milk fat
19
15
11
7
3
S dS C N C H R N O FM CF S M S N W N W
Conv. Org. Conv. Org. Conv. Org. Conv. Org. LI
Italy Sweden Denmark UK
Country & Farming System


Alpha linolenic acid
g/kg total milk fat
12
9
6
3
S dS C N C H R N O FM CF S M S N W N W
Conv. Org. Conv. Org. Conv. Org. Conv. Org. LI
Italy Sweden Denmark UK
Country & Farming System


Alpha tocopherol (vit E)
mg/kg milk fat
RRR toc
2 R toc
40
30
20
10
0
S dS C N C H R N O FM CF S M S N W N W
Conv. Org. Conv. Org. Conv. Org. Conv. Org. LI
Italy Sweden Denmark UK
Country & Farming System


Carotenoids
Zeaxanthine
Lutein
Beta carotene
mg/kg milk fat
***
***
*
***
S dS C N C H R N O FM CF S M S N W N W
Conv. Org. Conv. Org. Conv. Org. Conv. Org. LI
Italy Sweden Denmark UK
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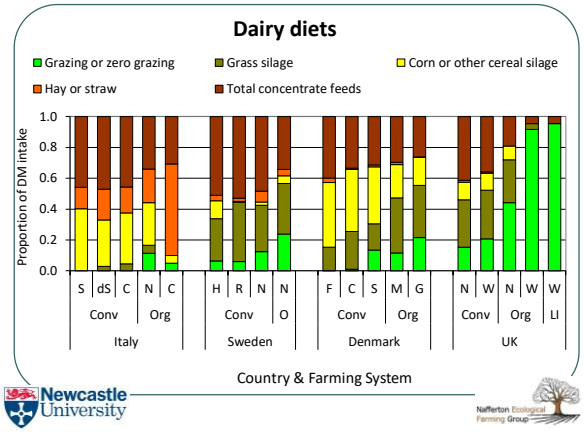
Dairy diets
Grazing or zero grazing
Grass silage
Corn or other cereal silage
Hay or straw
Total concentrate feeds
Proportion of DM intake
S dS C N C H R N N F C S M G N W N W W
Conv Org Conv O Conv Org Conv Org LI
Italy Sweden Denmark UK
Country & Farming System
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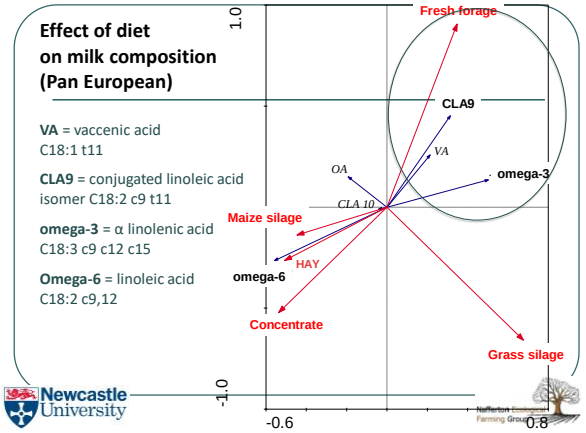
Effect of diet on milk composition (Pan European)
VA = vaccenic acid C18:1 t11
CLA9 = conjugated linoleic acid isomer C18:2 c9 t11
omega-3 = α linolenic acid C18:3 c9 c12 c15
Omega-6 = linoleic acid C18:2 c9,12
Fresh forage
CLA9
VA
OA
omega-3
CLA 10
Maize silage
HAY
omega-6
Concentrate
Grass silage
1.0
-1.0
-0.6
0.8
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Effect of diet on milk composition (Pan European)

RRR = α-tocopherol 3R (natural) isomer

2RS = α-tocopherol synthetic isomer

B-CAR = β-carotene

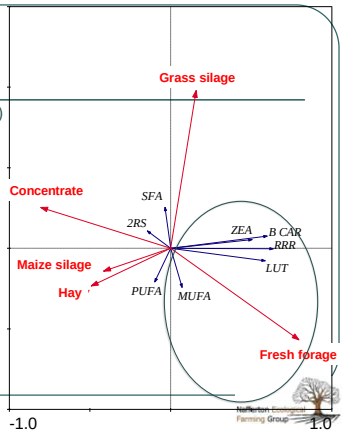
LUT = Lutein

ZEA = Zeaxanthin

SFA = saturated fatty acids

MUFA = mono-unsaturated fatty acids

PUFA = polyunsaturated fatty acids



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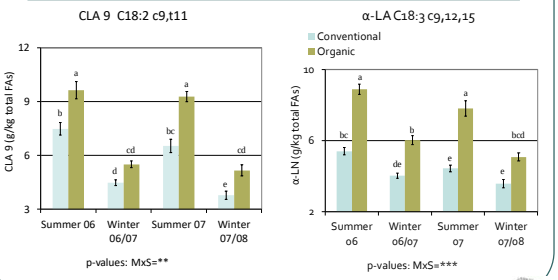
Seasonal variation – UK retail milk



Butler et al 2011 J Dai Sci

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7 Improving milk fat on winter diets

- Fresh herbage improves fatty acid profile in milk
- Limitation to herbage production (cold or dry)
- Milk quality poorer on silage, especially maize/corn
- Oilseeds can raise PUFA in milk (also reduces methane)
- Two parallel herds at Nafferton (conventional & organic) ; 3 diets:
  - Control
  - Linseed (high in α LA)
  - Rapeseed (high in oleic acid – 18:1 c9)

Stergiadis S, Leifert C, Seal C, Eyre MD, Butler G. Impact of dietary linseed and rapeseed supplementation on milk fatty acid composition from housed cows under organic and conventional management systems. In: British Society of Animal Science - Advances in Animal Biosciences - Healthy food from healthy animals. 2012, Nottingham, UK

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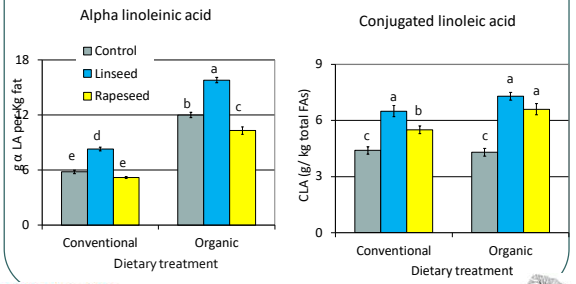
Supplementation trial - Results



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10 Conclusions & *questions*?

- Evidence that fat profile in organic milk is likely to be less detrimental to health compared with conventional products – *(needs proof)*
- BUT not consistent & greater seasonal variation in organic dairy products - reflecting forage utilisation
- Milk profiles optimised by maximising grazing intake, especially clover
- Maybe consider linseed/flaxseed in conserved forage diets *(sustainability?)*
- *Genetic improvements - suitable breeds/crosses for LowInput & organic dairy production and scope to select for milk fat quality?*
- Early evidence shows organic dairy products do have health benefits – 2 studies Netherlands (Higher CLA in breast milk and lower incidence of childhood eczema with organic dairy)[$]
- It we can't resist cream or butter - better to opt for organic

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[$] Rist *et al Br J Nutr* **97**:735–743 & Kummeling *et al Br J Nutr* **99**:598–605.

Cheers!

I gratefully acknowledge funding from the European Community under the Sixth and Seventh Framework Programmes:

QUALITYLOWINPUTFOOD FP6-CT-2003- 506358

&

LowInputBreeds, FP7 - KBBE 222 632

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8 Processing & storage of healthy milk fat

- Assessing processing procedures for dairy products
  - Fermentation of cream and churning to butter
- Feeding oilseeds to *enrich* milk fat (increase PUFAs)
- Assessing stability and sensory quality of raw material and end products
  - 8 weeks @ 8° C
  - Challenged with; UV light, heating and oxidation
  - Using GC-O and sensory methods to characterise aroma
  - GC/MS/O detecting oxidation rates

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Results – i) processing

- Significant differences in total CLA content between cream from convention and organic milk
- Butter from fermented cream (both conventional and organic) no significant change in CLA content

Origin	n =	CLA cream g/Kg fat	CLA butter g/Kg fat	Difference g/kg fat
Conventional	7	13.5 $^{b\,x}$	13.1 $^{d\,x}$	0.4
Organic	5	15.4 $^{a\,y}$	14.8 $^{c\,y}$	0.6

$^{a,b\ \&\ c,d}$: different letters in columns: significant differences ($p < 0.005$)
^{x,y}: different letters in rows: significant differences ($p < 0.01$)

Bisig et al (2007) 2007*Lait* 87 (1) , pp. 1-19

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Results – ii) stability & storage

- Enriched butter elevated PUFA but also antioxidants
- Enriched butter more spreadable
- Both butters had similar:
  - flavour profiles after storage
  - odour compounds after storage
- Little change in fatty acid profiles during storage
- Levels of α tocopherol (antioxidant) declined with time

Mallia et al 2009 *Journal of Agricultural and Food Chemistry* 57 (16) , pp. 7464-7472

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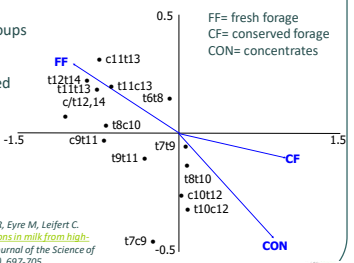
9 Detailed CLA profiles

- 14 known isomers, dominated by C18:2 c9t11 - CLA9
- Range in physiological functions in man and dairy cows – not all beneficial
- Mostly synthesised by rumen hydrogenation also desaturation in udder; CLA9 (largely) & C18:2 t7c9(totally)
- CLA isomer concentrations in milk from 3 management systems: (UK)
  - Conventional
  - Low input organic certified
  - Low input not certified

CLA isomers and management

- CLA isomers cluster into 3 groups
- CLA9 >80% total
- Only **some** isomers influenced by feeding system
- Link to fresh forage in diet



FF= fresh forage
CF= conserved forage
CON= concentrates

Butler G, Collomb M, Rehberger B, Sanderson R, Eyre M, Leifert C. *Conjugated linoleic acid isomer concentrations in milk from high- and low-input management dairy systems.* Journal of the Science of Food and Agriculture 2009, **89**(4), 697-705

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