Origin of Conjugated Linoleic Acids

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“Functional Foods” and Health Promotion

“any food or food ingredient that may provide a health benefit beyond the traditional nutrients it contains”

Institute of Medicine, NAS 1994

Partial List of Health Effects of CLA

Biological Effect
Anticarcinogenic effects (*in vivo* and *in vitro*)
Antiatherogenic properties
Altered nutrient partitioning and lipid metabolism
Antidiabetic (type II) and reduced hyperglycemia
Immune modulation
Improved bone mineralization

Bauman et al., 2001

CLA Isomers in Ruminant Fat

- *cis/trans*, *trans/trans*, and *cis/cis* isomers for:

7,9	9,11	11,13
8,10	10,12	12,14

- many isomers identified in milk fat (n = 24) and beef fat (n = 14)
- *cis*-9, *trans*-11 in greatest abundance
- *trans*-7, *cis*-9 second in abundance
- *trans*-10, *cis*-12 increases under certain dietary situations

CLA Isomers in Supplement

- four isomers in typical animal supplement (*trans*-8,*cis*-10; *cis*-9,*trans*-11; *trans*-10,*cis*-12; *cis*-11,*trans*-13)
- two isomers in some human supplements (*cis*-9,*trans*-11; *trans*-10,*cis*-12)

Milk Fat CLA Isomers

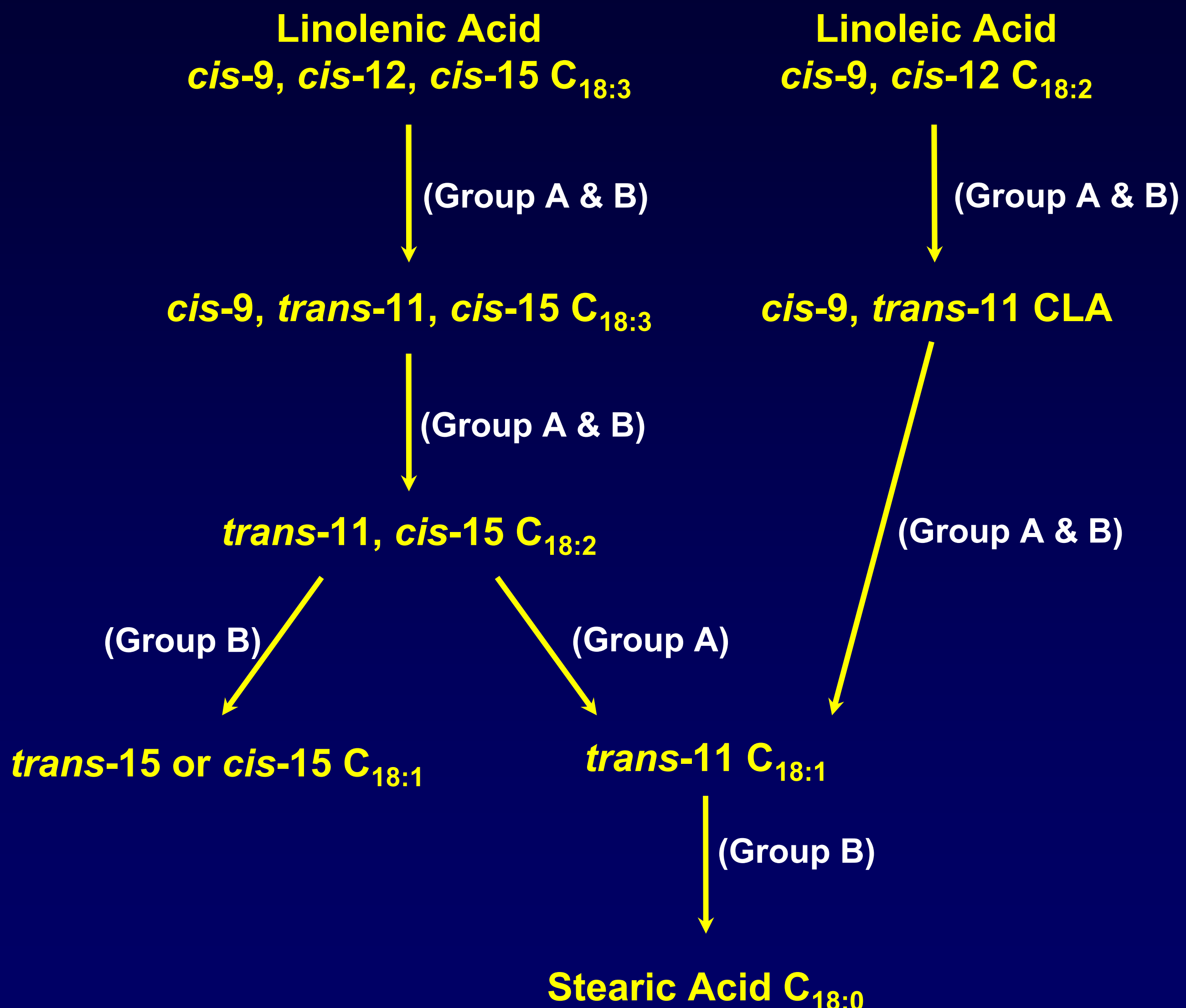
	(% total CLA)
• *cis*/*trans* isomers	
• 9,11	**76.5**
• 7,9	**6.7**
• 10,12	1.1
• 12,14	0.8
• 11,13	0.4
• 8,10	0.3
• *cis*, *cis* isomers	4.8
• *trans*, *trans* isomers	9.4

Bauman et al. 2000

Lipid Metabolism in the Rumen

- microbial hydrolysis of dietary triglycerides
- microbial biohydrogenation of free fatty acids
- passage from rumen as free fatty acids (~85%) or as microbial phospholipids (~15%)

Pathways for Rumen Biohydrogenation



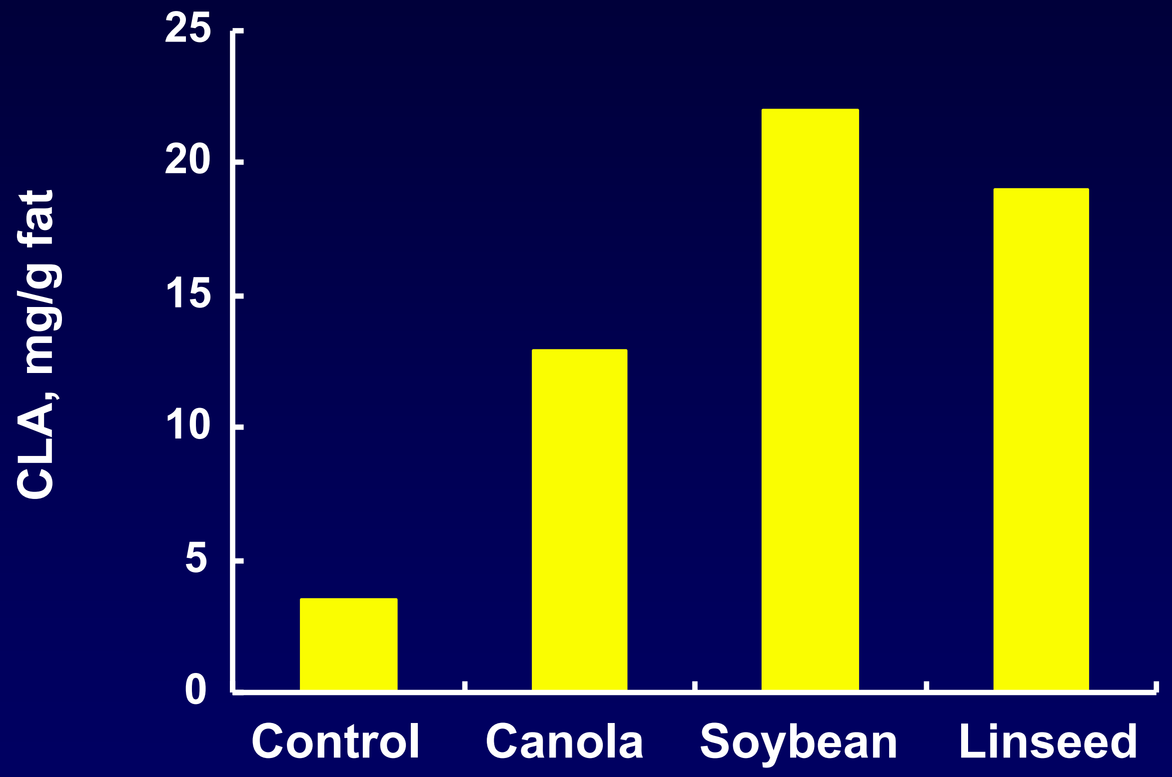
Griinari and Bauman, 1999

Dietary Factors Which Affect CLA in Milk Fat

Dietary Factor	Effect on CLA Content of Milk Fat
Lipid Substrate	
Unsaturated vs saturated fat	Increased by addition of unsaturated fat
Type of plant oil	Greatest with oils high in C18:2
Level of plant oil	Dose dependent increase
Ca salts of plant oils	Increased as with free oils
Fat in animal byproducts	Minimal effect
High oil plant feeds	
high oil corn	Minimal effect
soybeans	Heat processing will increase
rapeseed vs soybean	Similar effect
Modifiers of Biohydrogenation	
Forage:concentrate ratio	Increased with high ratio
Non structural carbohydrate level	Minor effect (possible oil x NSC interaction)
Restricted feeding	Increased with restricted
Fish oils	Greater increase than with plant oils
Monensin -ionophore	Variable effect
Dietary buffers	Little effect
Combination	
Pasture vs conserved forages	Higher on pasture
Growth stage of forage	Increased with less mature forage

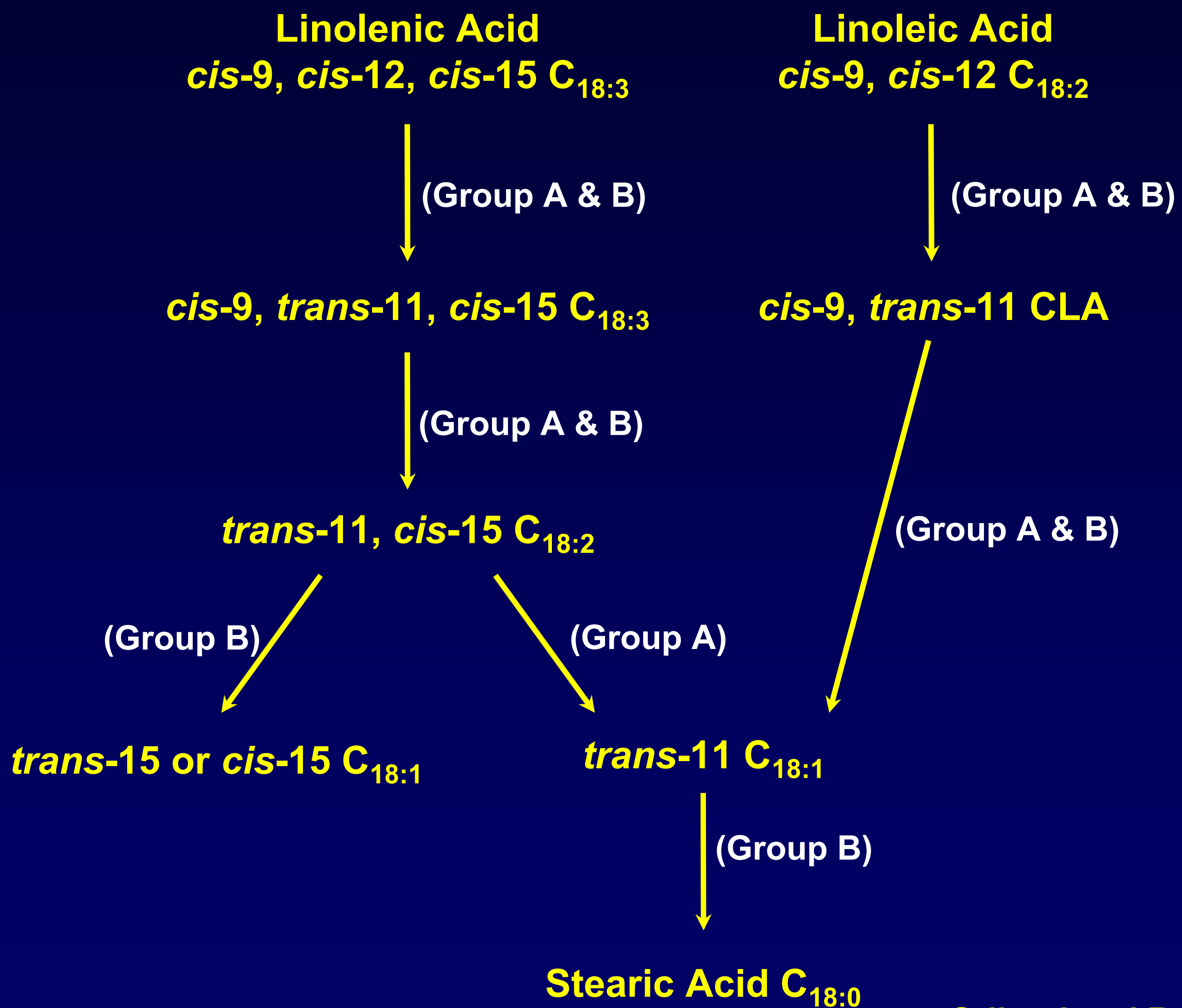
Bauman et al. 2001

Effects of Feeding Plant Oils on Milk Fat CLA



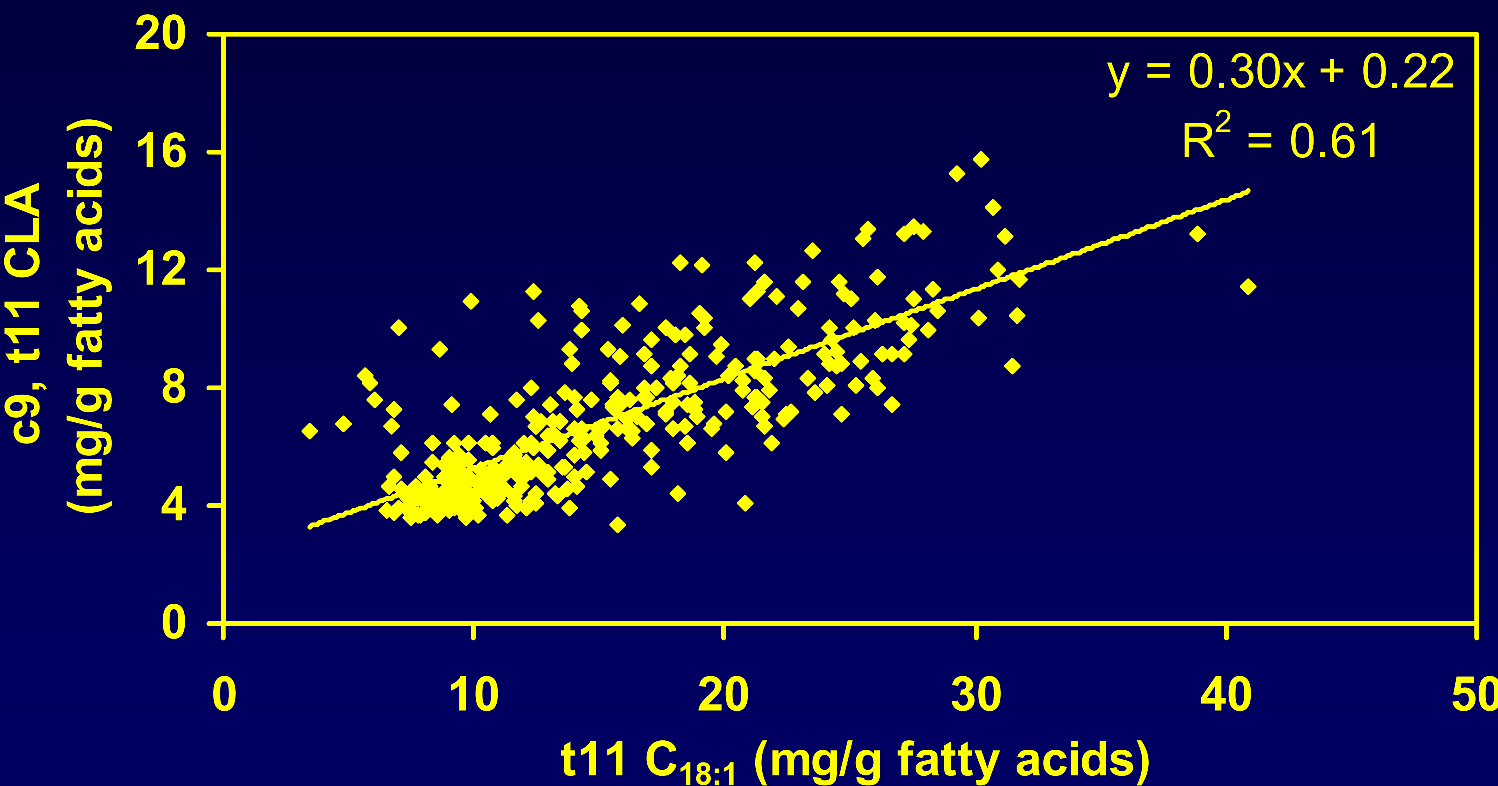
Chouinard et al. 2001

Pathways for Rumen Biohydrogenation



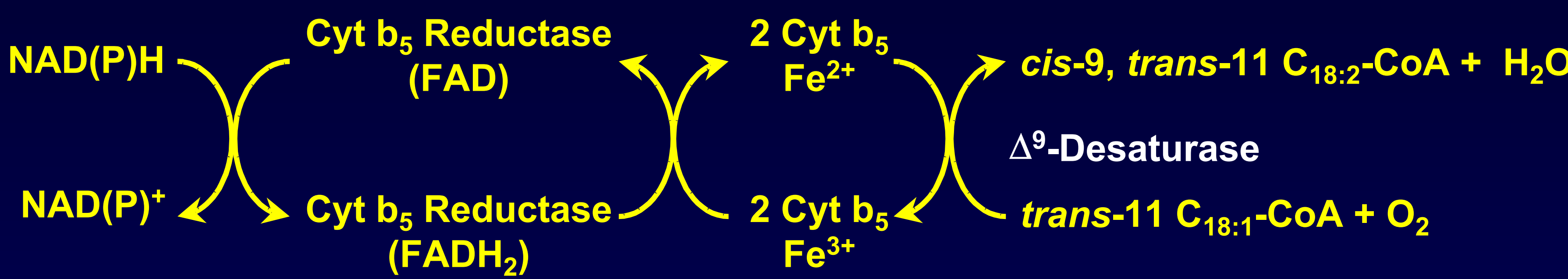
Griinari and Bauman, 1999

Relationship Between *cis*-9, *trans*-11 CLA and *trans*-11 $C_{18:1}$ in milk fat

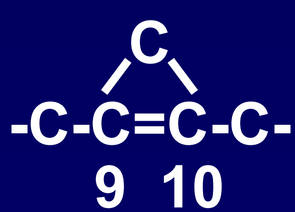


Peterson et al., 2002

Δ^9-Desaturase



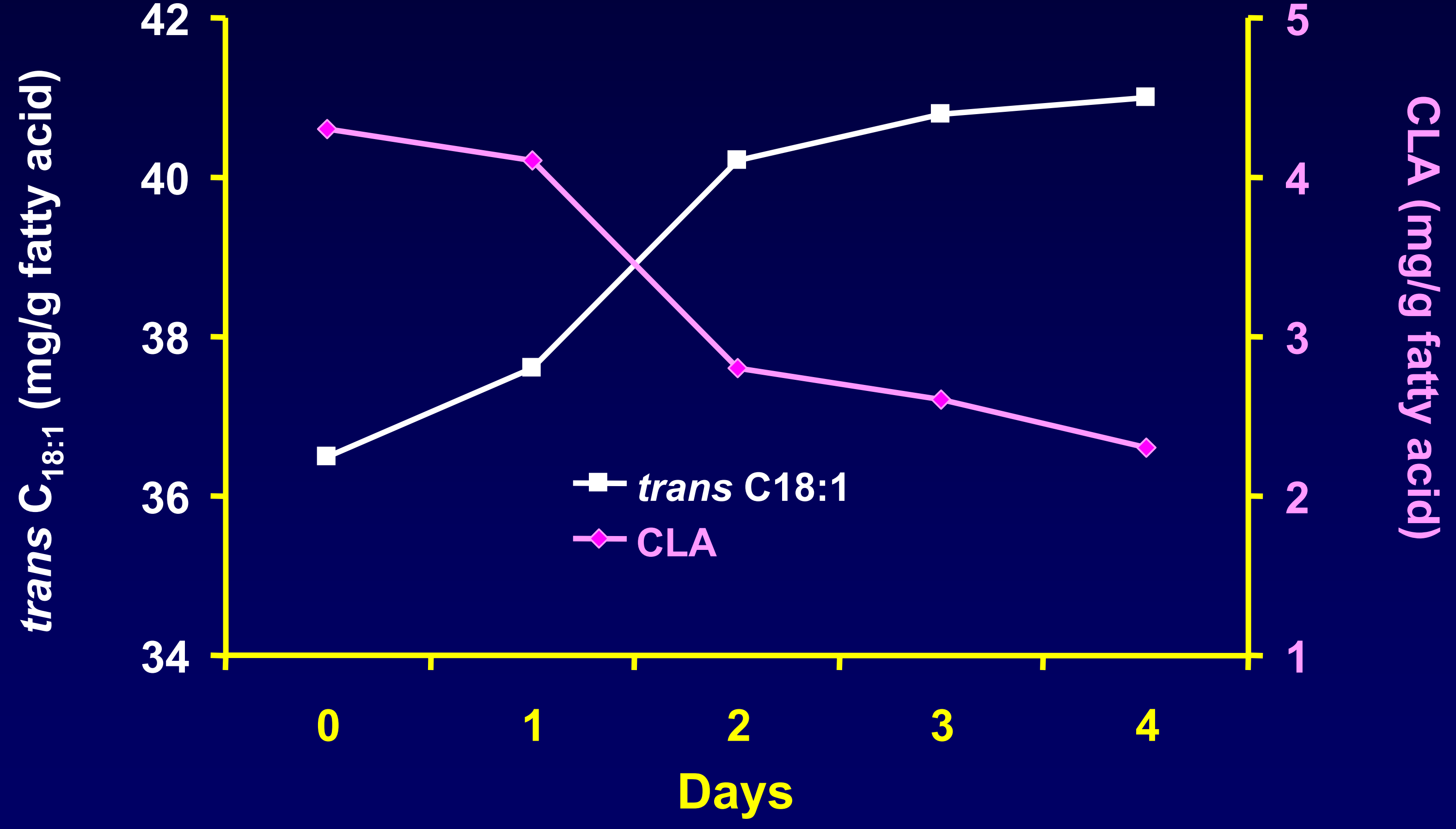
Sterculic Acid (cyclopropene fatty acid)



sterculia nut
41% oil
sterculic oil
62% cyclopropenoic acids

Sterculia foetida

trans $C_{18:1}$ and CLA during Sterculic Oil Infusion



Corl et al., 1998

Desaturase Pairs (*cis*-9 double bond)

trans-11 $C_{18:1}$ / *cis*-9, *trans*-11 CLA

$C_{18:0}$ / $C_{18:1}$ (stearic / oleic)

$C_{16:0}$ / $C_{16:1}$ (palmitic / palmitoleic)

$C_{14:0}$ / $C_{14:1}$ (myristic / myristoleic)

Importance of Endogenous Synthesis

Diet	Control Milk fat CLA (mg/g)	Endogenous Synthesis of *c*9, *t*11 CLA[a]	Reference
Total Mixed Ration	4.2	64%	Griinari et al., 2000
Total Mixed Ration + PHVO[b]	6.5 > 7.6	78%	Corl et al., 2001
Pasture	15.5	>90%	Kay et al., 2002

[a]Estimated by use of sterculic oil as a source of cyclopropene fatty acids to block Δ^9-desaturase.

[b]Partially hydrogenated vegetable oil.

Endogenous Synthesis of CLA

Rumen

Linoleic Acid
cis-9, *cis*-12 $C_{18:2}$

↓

cis-9, *trans*-11 CLA → (Tissues)

↓

trans-11 $C_{18:1}$ (Vaccenic Acid) → (Tissues)

↓

Stearic Acid
$C_{18:0}$

Tissues

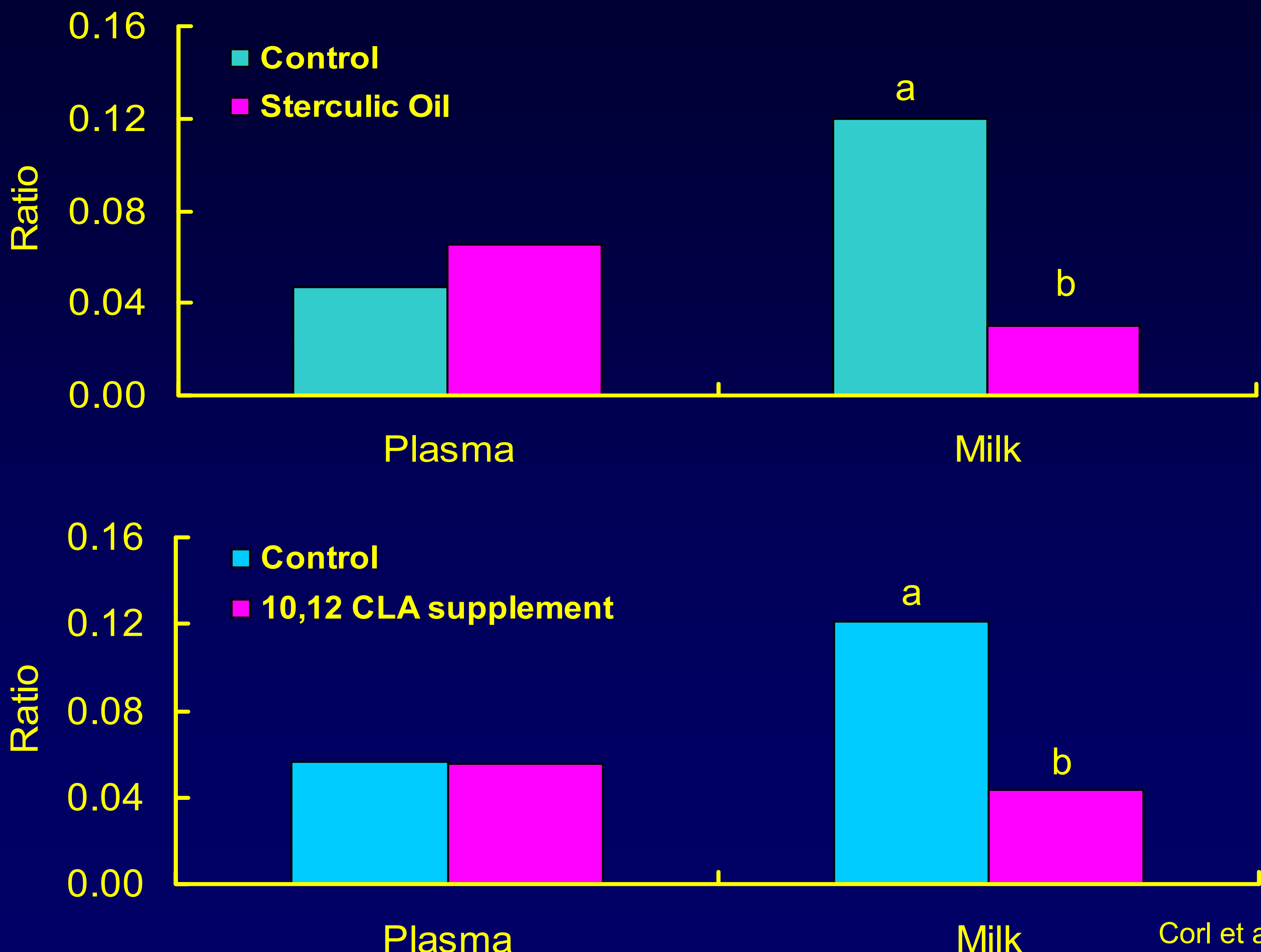
cis-9, *trans*-11 CLA

↑ Δ^9-desaturase

trans-11 $C_{18:1}$

Bauman et al., 2000

Source of *trans*-7, *cis*-9 CLA



Corl et al., 2002

Source of CLA Isomers in Milk Fat

cis-9, *trans*-11
- endogenous synthesis (major)
- rumen origin (minor)

trans-7, *cis*-9
- endogenous synthesis

other *cis/trans*, *trans/trans*, and *cis/cis* isomers
- rumen origin

Rumen Biohydrogenation

linoleic acid
(*cis*-9, *cis*-12 $C_{18:2}$)

↓

conjugated linoleic acid
(*cis*-9, *trans*-11 CLA)

↓

***trans*-11 $C_{18:1}$**

↓

stearic acid ($C_{18:0}$)

---

linoleic acid →

conjugated linoleic acid
***trans*-10, *cis*-12 CLA**

↓

***trans*-10 $C_{18:1}$**

↓

stearic acid ($C_{18:0}$)

Griinari and Bauman, 1999

Δ^9-Desaturase

- Physical Characteristics
- Regulation
  - Endocrine
  - Dietary
  - Physiological State
- Methods of Regulation
  - Transcriptional
  - Microsomal Protease

cis-9, *trans*-11 CLA Endogenous Synthesis

- mice - Santora et al. 2000
- rats - Ip et al. 1999
- humans - Salminen et al. 1998
  - Adlof et al. 2000
  - Turpeinen et al. 2001

Relative Risk of Coronary Heart Disease in Women[1]

	Relative Risk in Quintile				
Trans Isomer Source	1	2	3	4	5
Vegetable fats	1.00	1.43	1.11	1.39	1.78
Animal fats	1.00	0.76	0.69	0.55	0.59

[1]Nurses health study - 69,181 women

Willet et al., Lancet 341:581

Transfer of Dietary CLA Isomers to Milk Fat in Dairy Cows[1]

CLA Isomer	Series 1[a]	Series 2[b]
	percent ± S.E.	
trans-8, *cis*-10	25 ± 6	23 ± 3
cis-9, *trans*-11	34 ± 8	23 ± 6
trans-10, *cis-12*	21 ± 5	11 ± 2
cis-11, *trans*-13	28 ± 4	26 ± 5

[1]Supplement contains CLA isomers as unesterified fatty acids and was abomasally infused to avoid modifications by rumen bacteria.

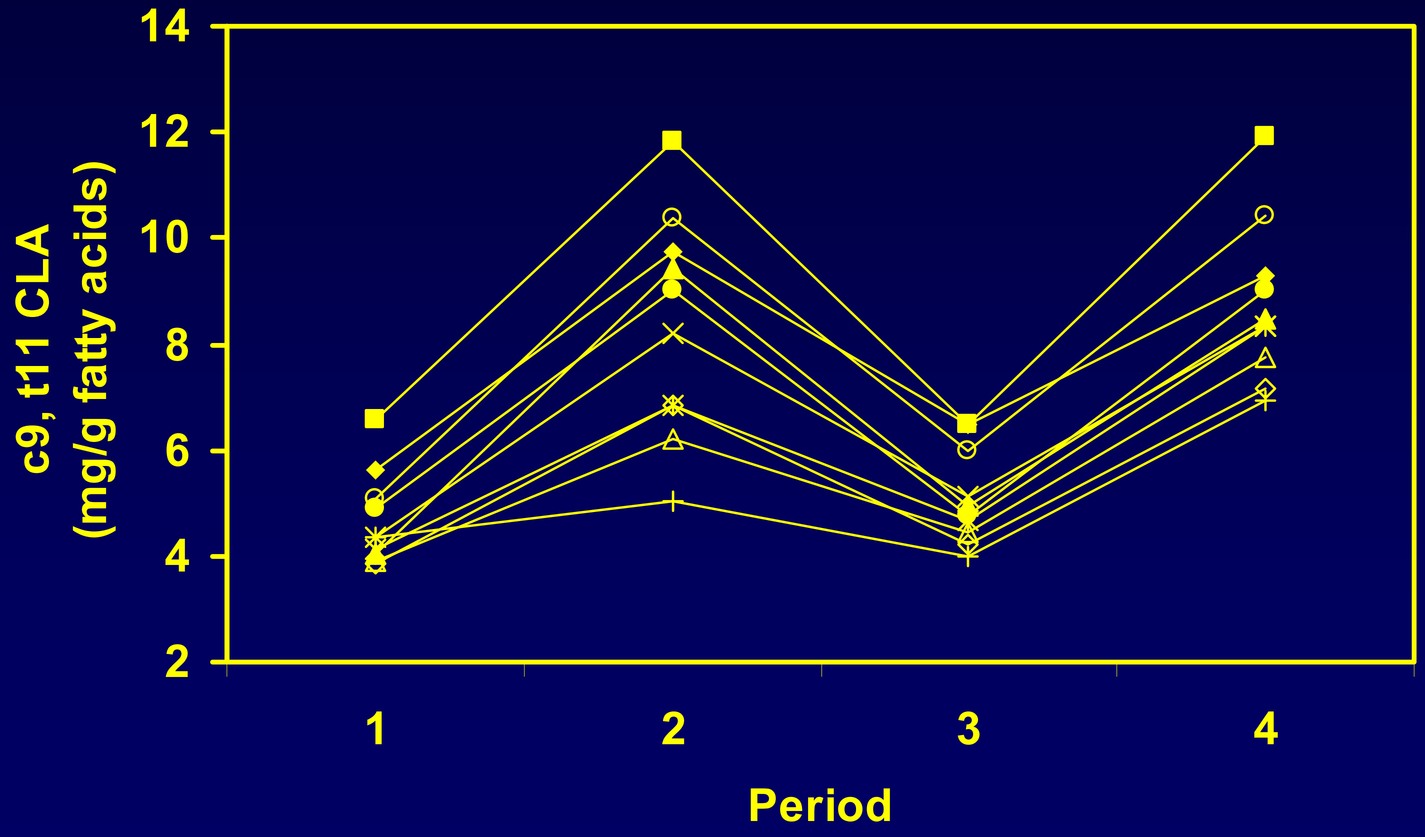
[a]Chouinard et al., J. Dairy Sci. 82:2737.

[b]Chouinard et al. J. Nut. 129:1579.

Milk Fat Content of CLA

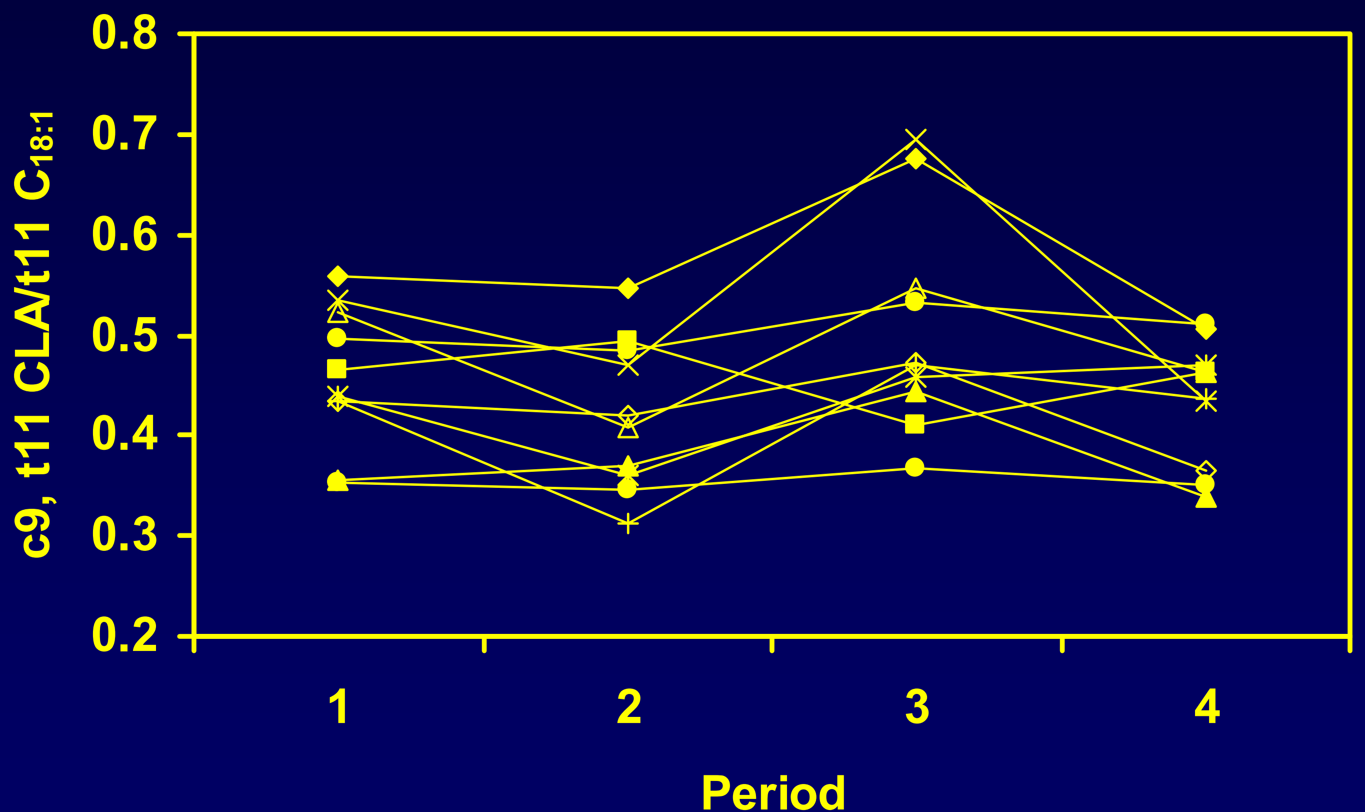
Large variation among individuals, even when physiological and environmental factors are similar

Milk Fat Content Across Dietary Shifts



Peterson et al., 2002

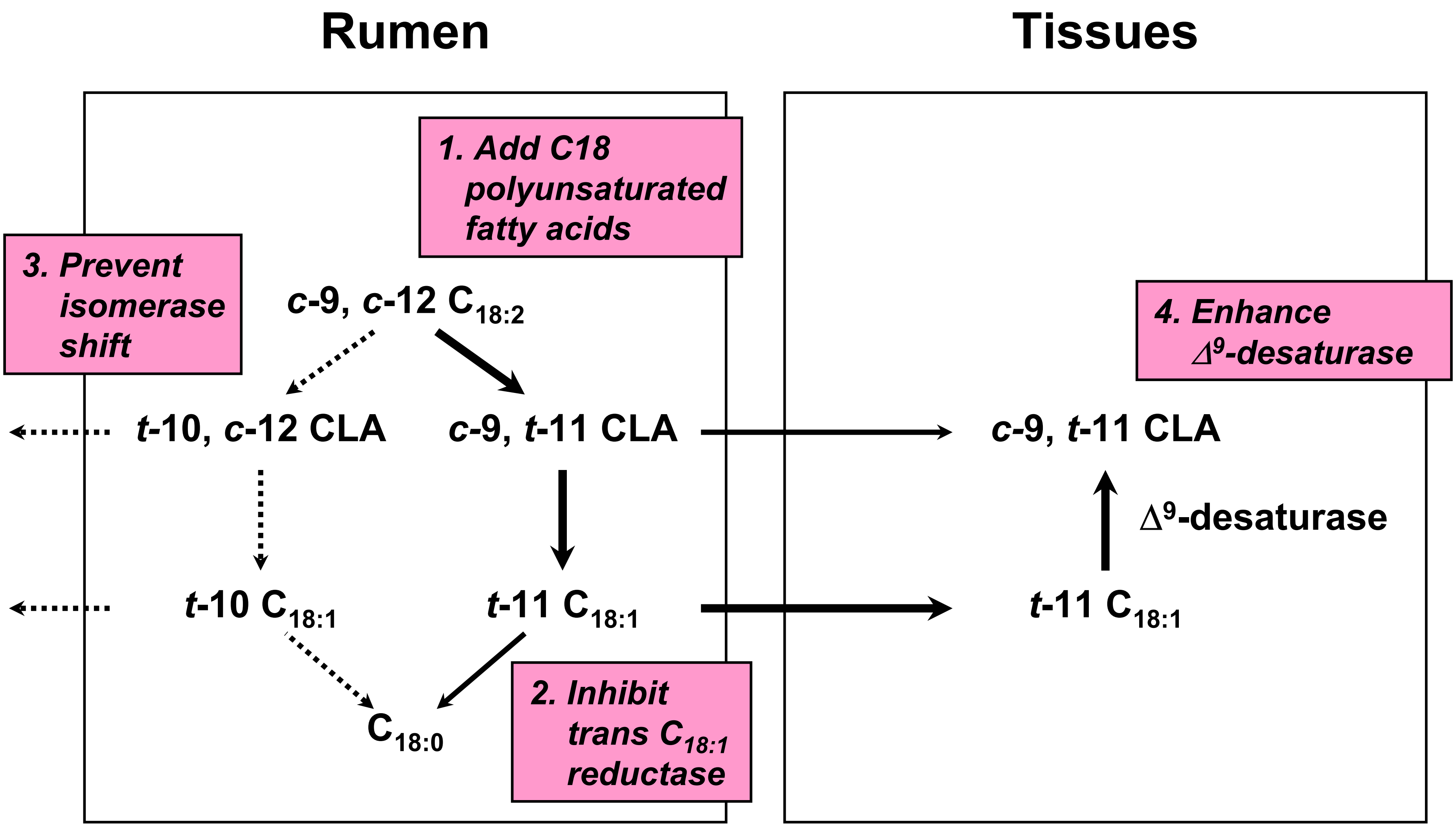
Desaturase Index in Milk Fat Across Dietary Shifts



Peterson et al., 2002

CONCLUSIONS

- *cis*-9, *trans*-11 CLA mainly from endogenous synthesis via Δ^9-desaturase with *trans*-11 $C_{18:1}$ as substrate
- *trans*-7, *cis*-9 almost exclusively from endogenous synthesis whereas other minor CLA isomers are of rumen origin
- enhancing CLA in foods derived from ruminants involves rumen production of *trans*-11 $C_{18:1}$ and tissue activity of Δ^9-desaturase



Griinari, 2002