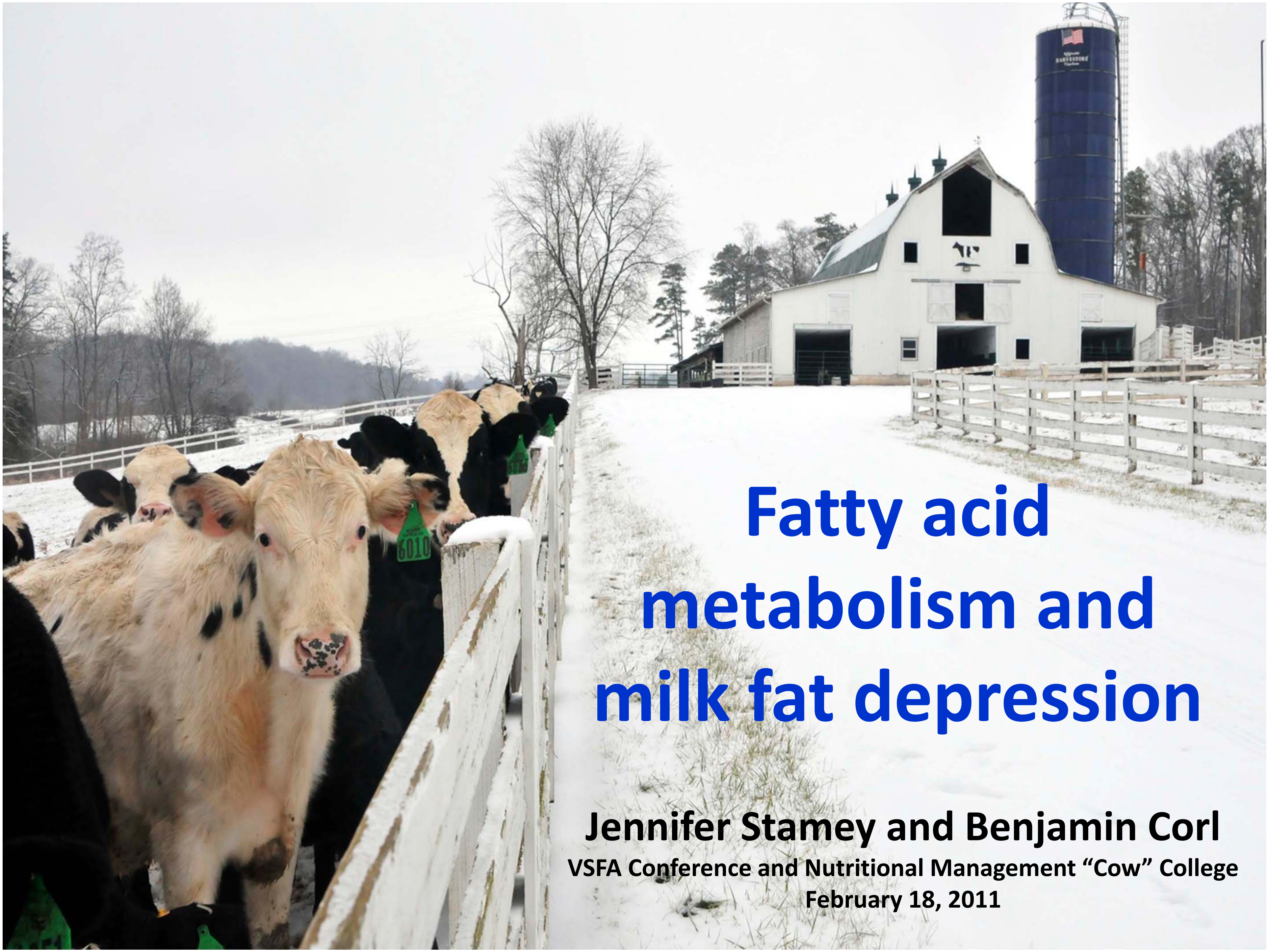


Fatty acid metabolism and milk fat depression

Jennifer Stamey and Benjamin Corl

VSFA Conference and Nutritional Management "Cow" College
February 18, 2011

Milk Fat

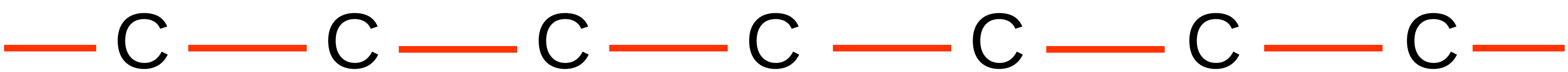
- Fat is the major energy component of milk
  - Economic value
  - Physical and manufacturing properties
- Milk fat content is markedly affected by diet
  - High grain
  - Vegetable oils
  - Marine oils

Fatty Acids

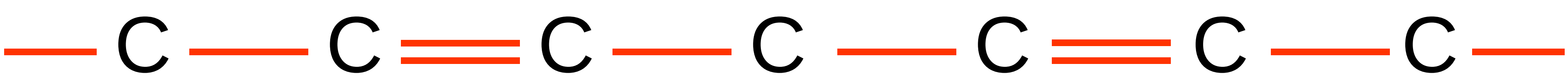
- Long carbon chains that contain a methyl group (CH_3) at one end and a carboxyl group (COOH) at the other
- Fatty acids make lipids energy rich
- Characterized by:
  - Number of carbons
    - Chain length
  - Number of double bonds
    - Degree of unsaturation
  - Location and orientation of these bonds
    - Non-conjugated, conjugated, *cis*, *trans*

Nomenclature and Structure

Saturated – single bonds

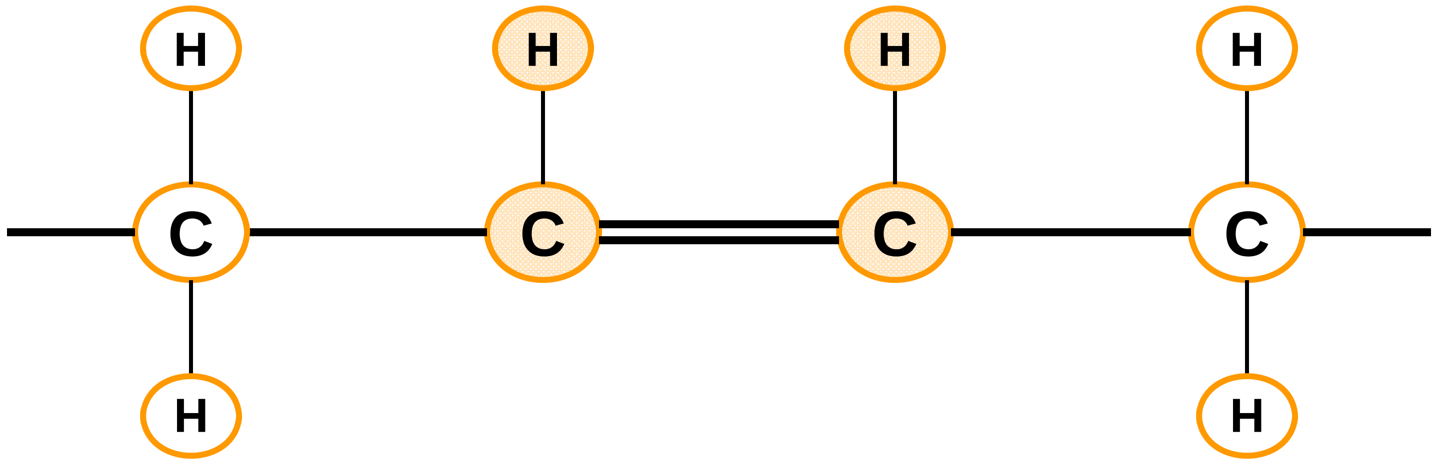


Unsaturated – double bonds

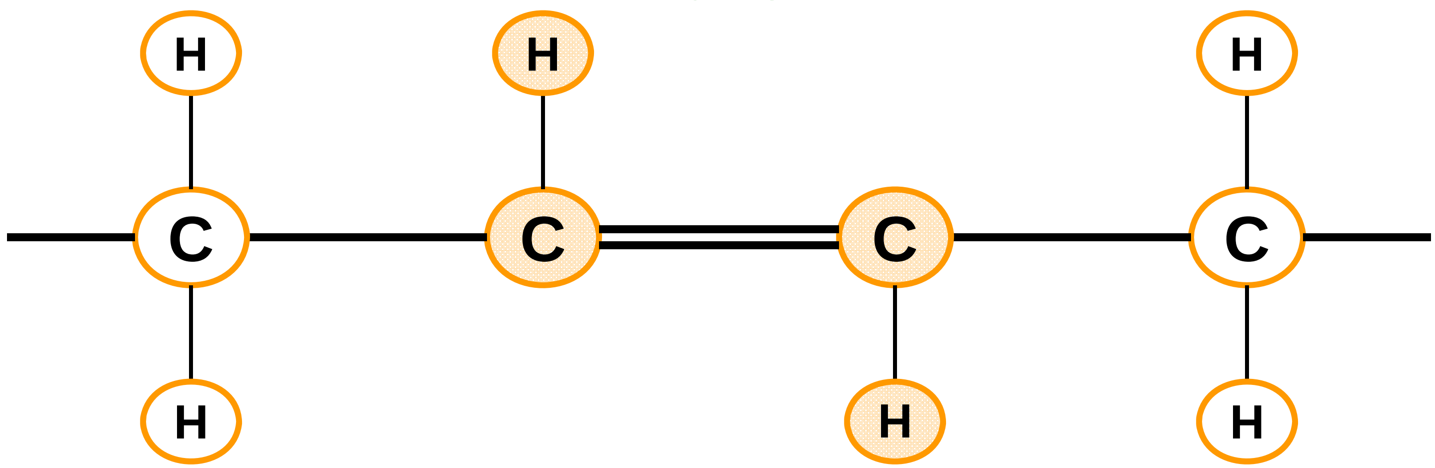


Nomenclature and Structure

cis

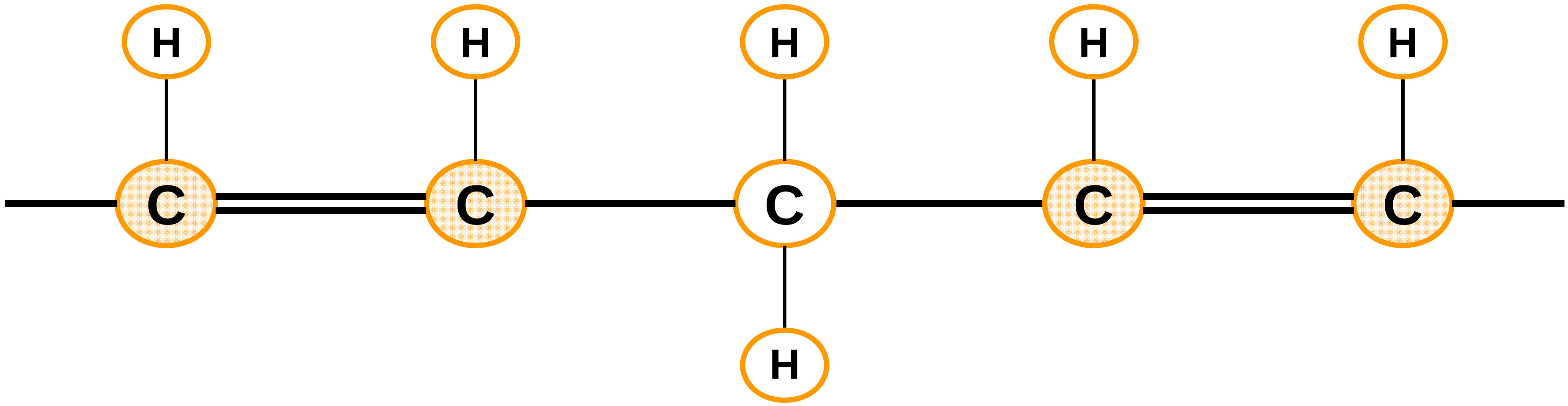


trans

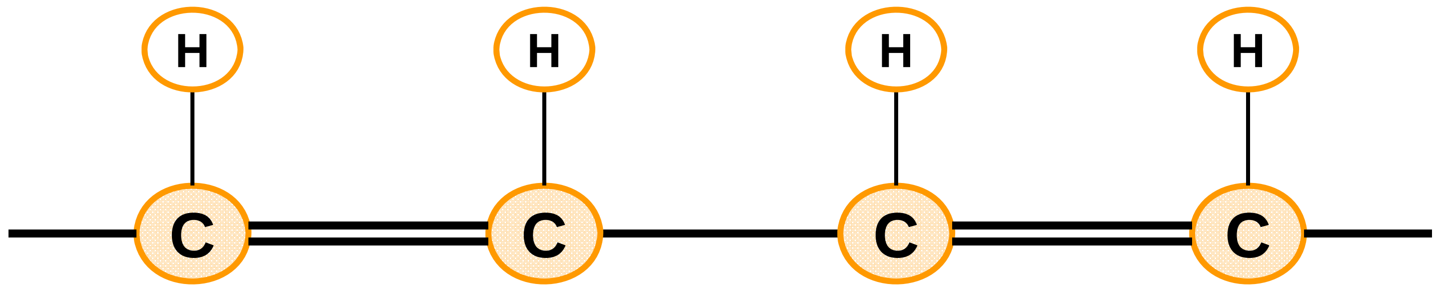


Nomenclature and Structure

non-conjugated



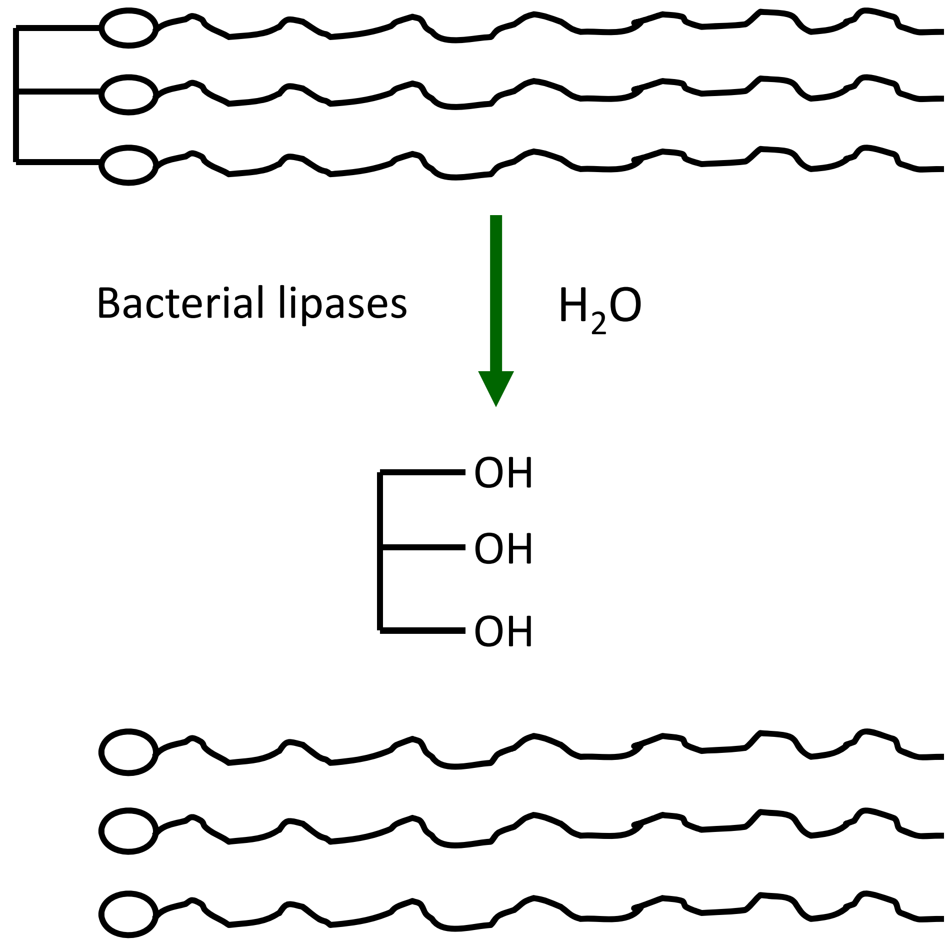
conjugated



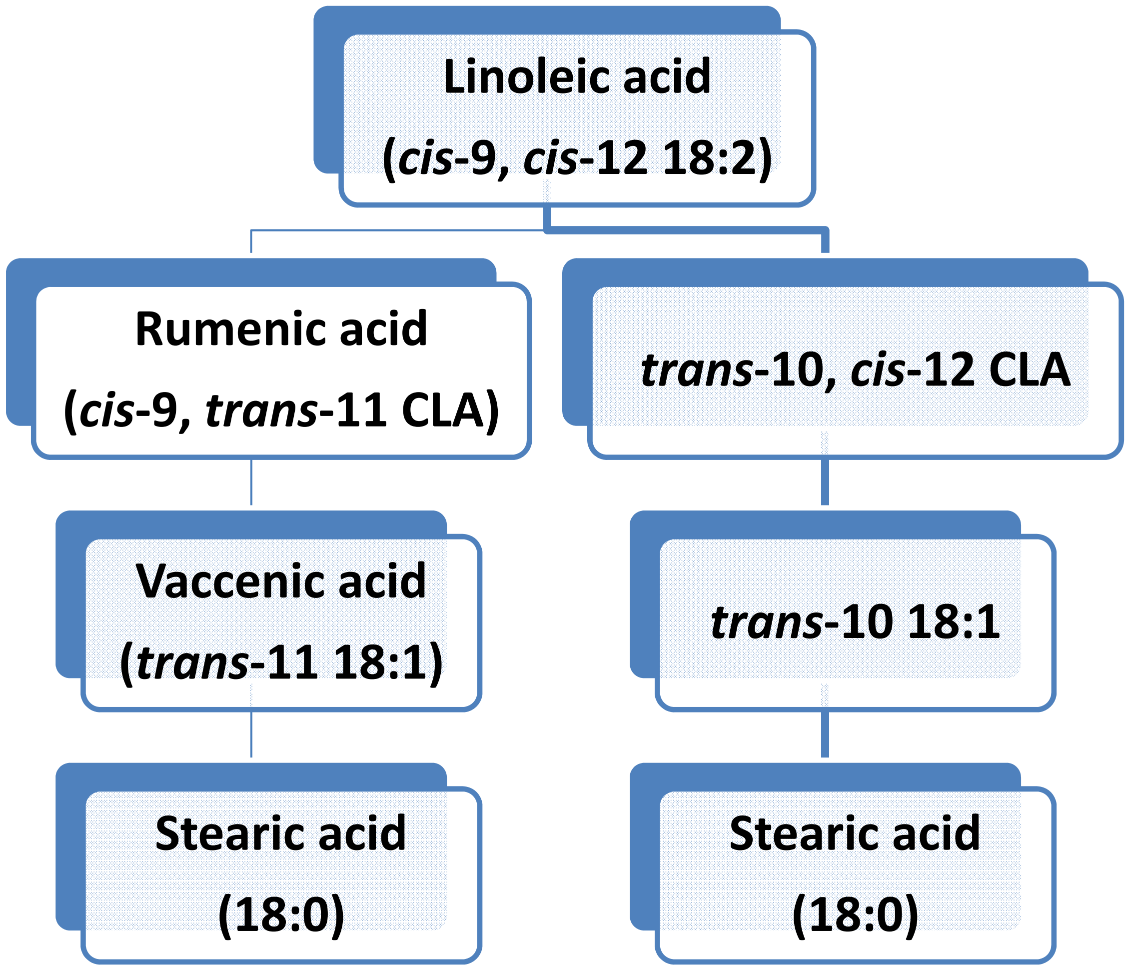
Hydrolysis

Lipids

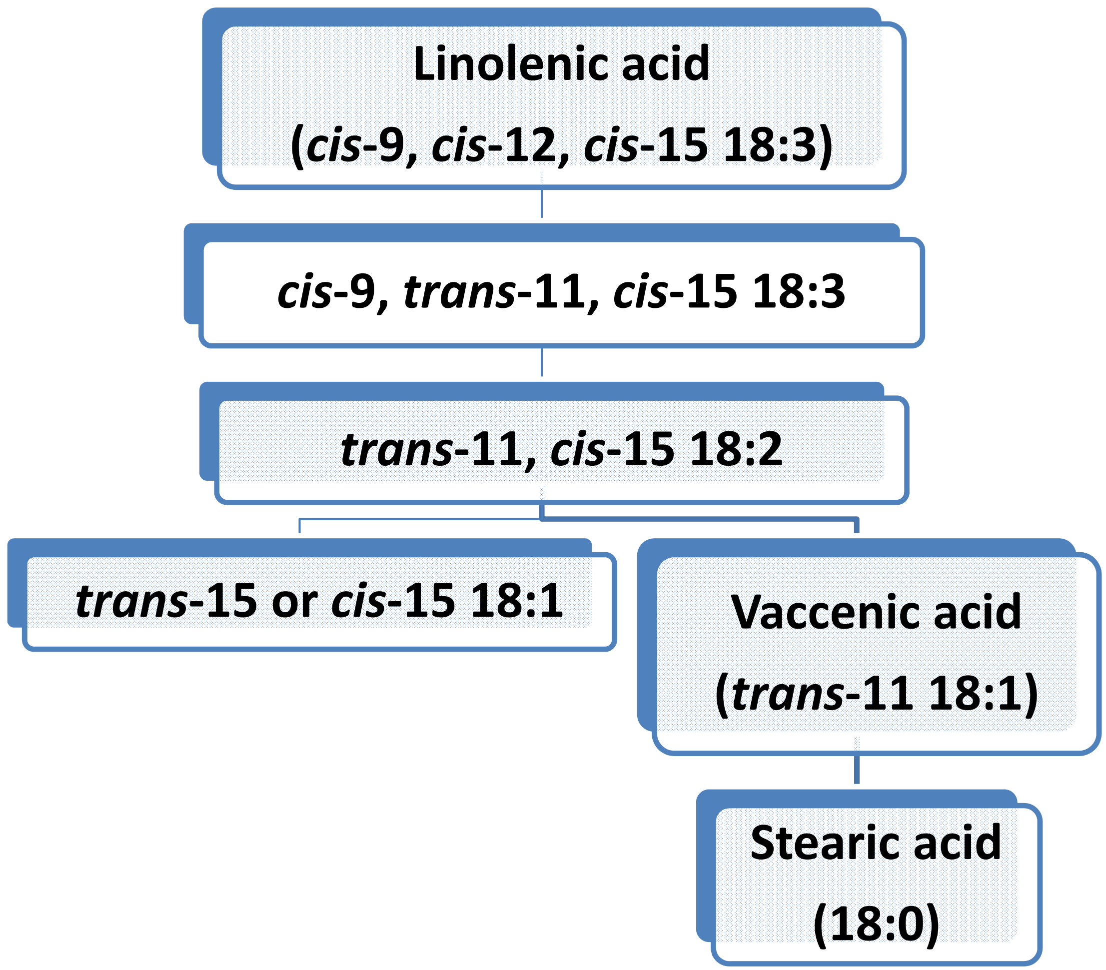
Free fatty acids



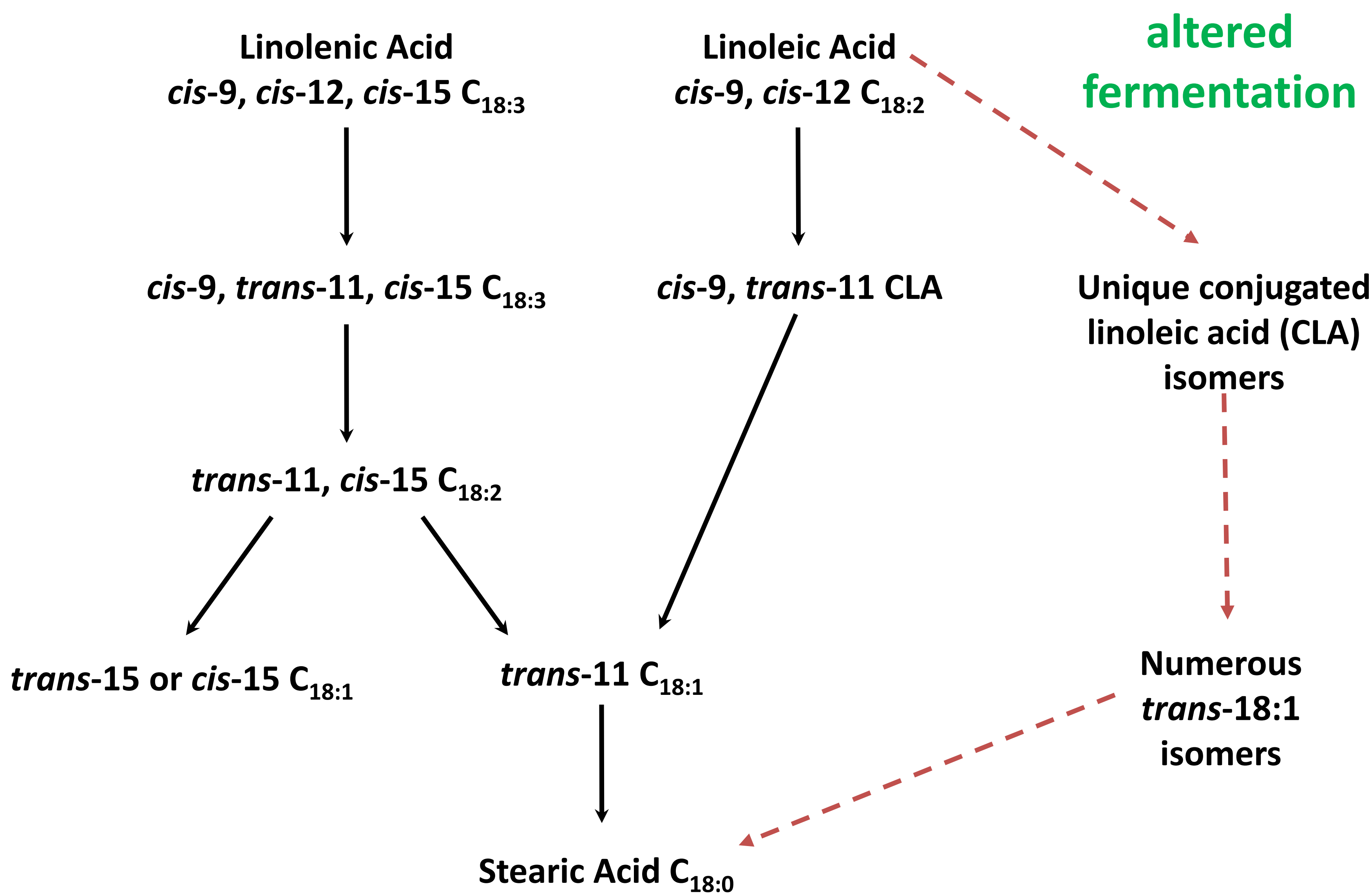
Biohydrogenation



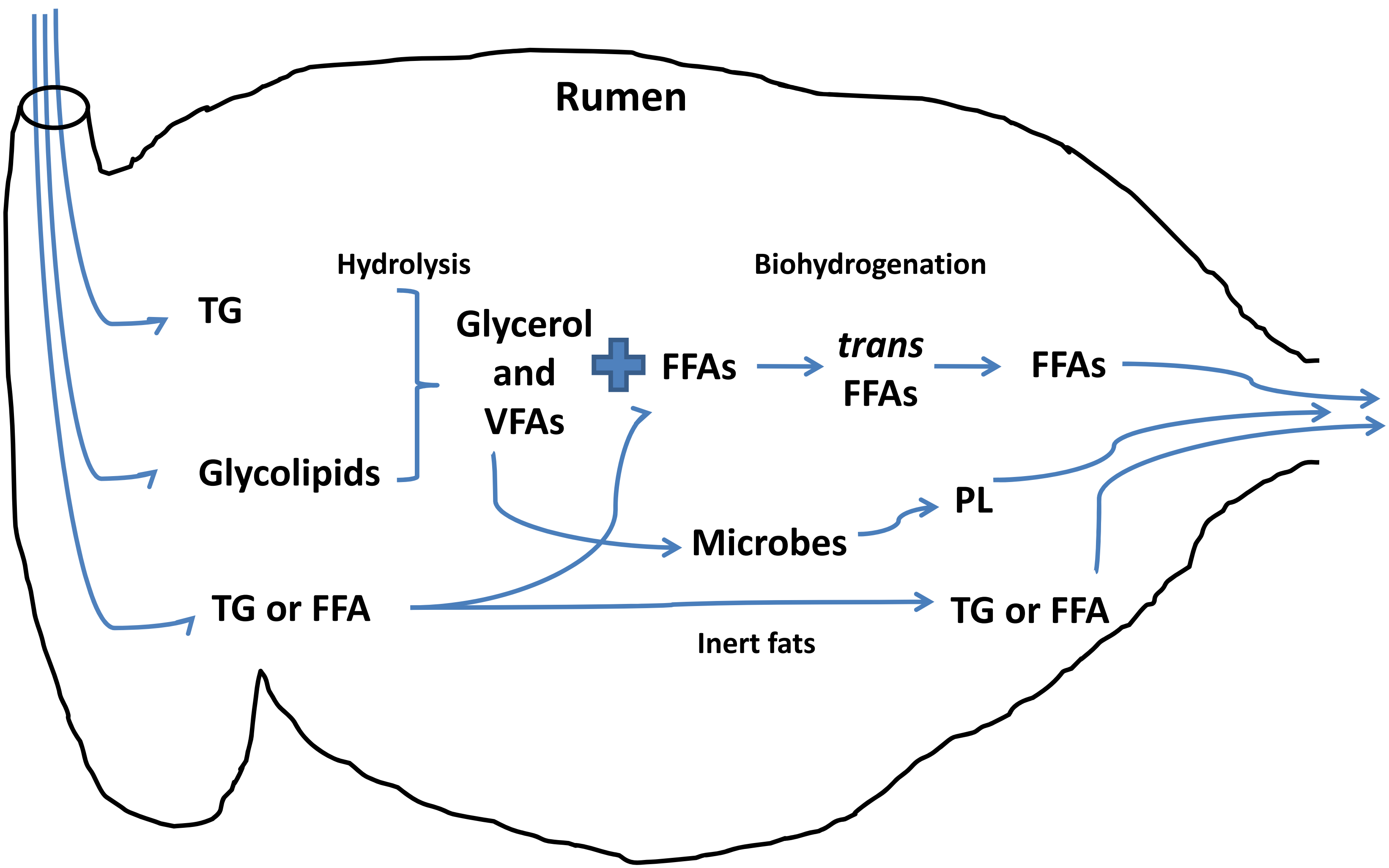
Biohydrogenation



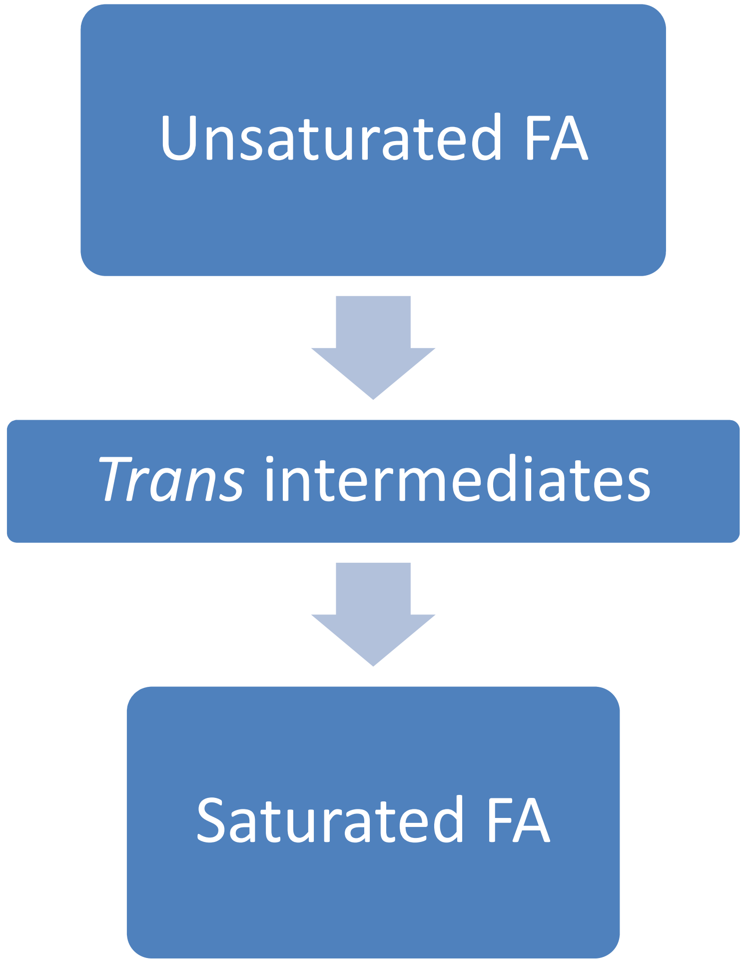
Rumen Biohydrogenation



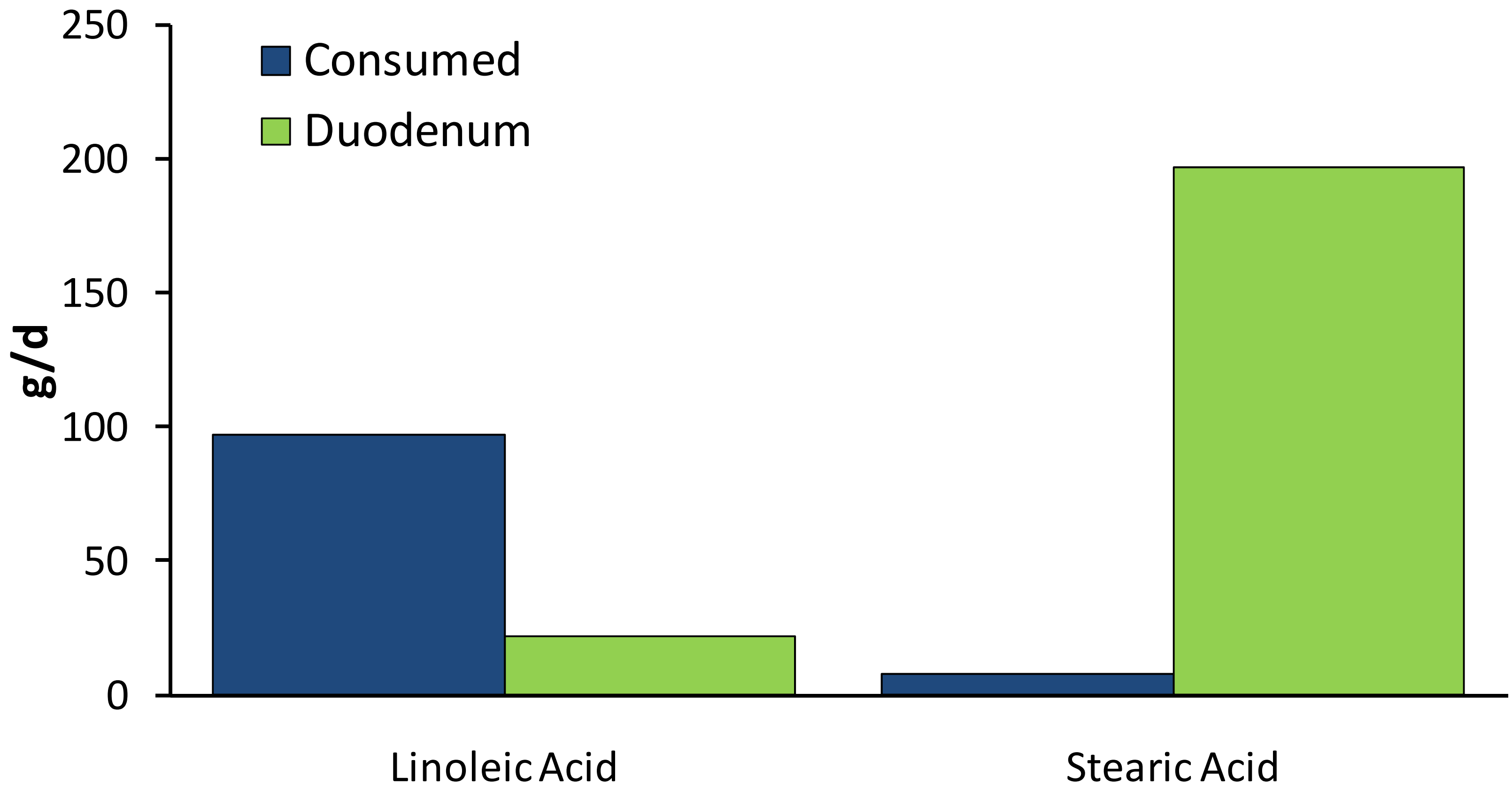
Fat Digestion in the Rumen



Rumen Biohydrogenation Pathways



Polyunsaturated fatty acid losses



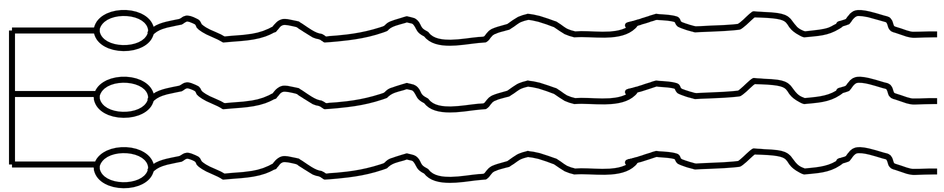
Loor et al. (2004)

Major Fatty Acids in Milk Fat

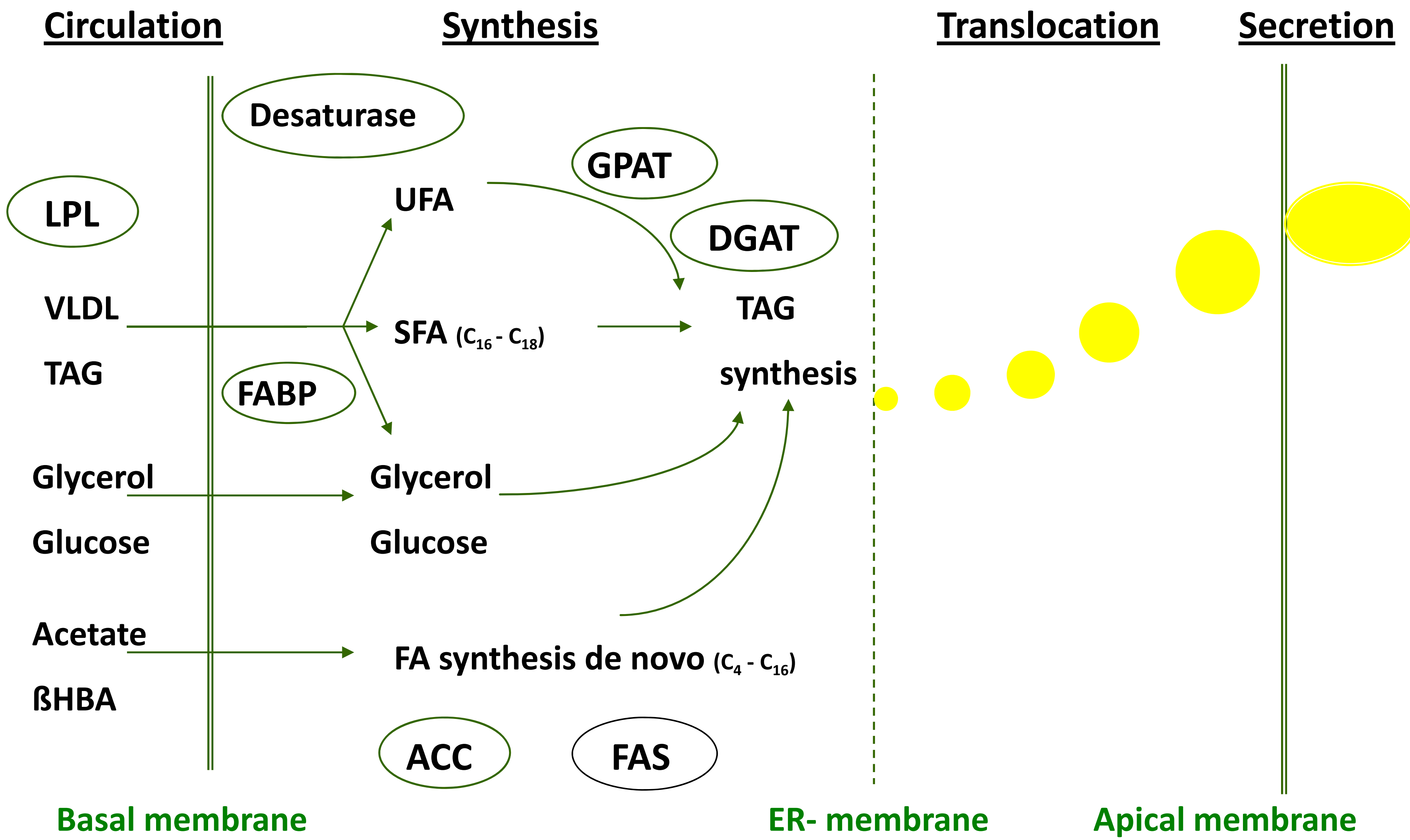
Fatty Acid	% (weight basis)	Common Name
4:0	4	Butyric
6:0	3	Caproic
8:0	2	Caprylic
10:0	3	Capric
12:0	4	Lauric
14:0	11	Myristic
16:0	29	Palmitic
16:1	2	Palmitoleic
18:0	12	Stearic
18:1	25	Oleic
18:2	2	Linoleic
18:3	1	Linolenic

Triglyceride Synthesis

- 98% of milk fat is triglcyeride
- Glycerol backbone with 3 ester-linked FA



Milk Fat Synthesis



Major Fatty Acids in Milk Fat

Fatty Acid	% (weight basis)	Fatty Acid Source
4:0	4	
6:0	3	
8:0	2	*De novo* synthesis
10:0	3	
12:0	4	
14:0	11	
16:0	29	*De novo* and preformed
16:1	2	
18:0	12	
18:1	25	Uptake of preformed
18:2	2	
18:3	1	

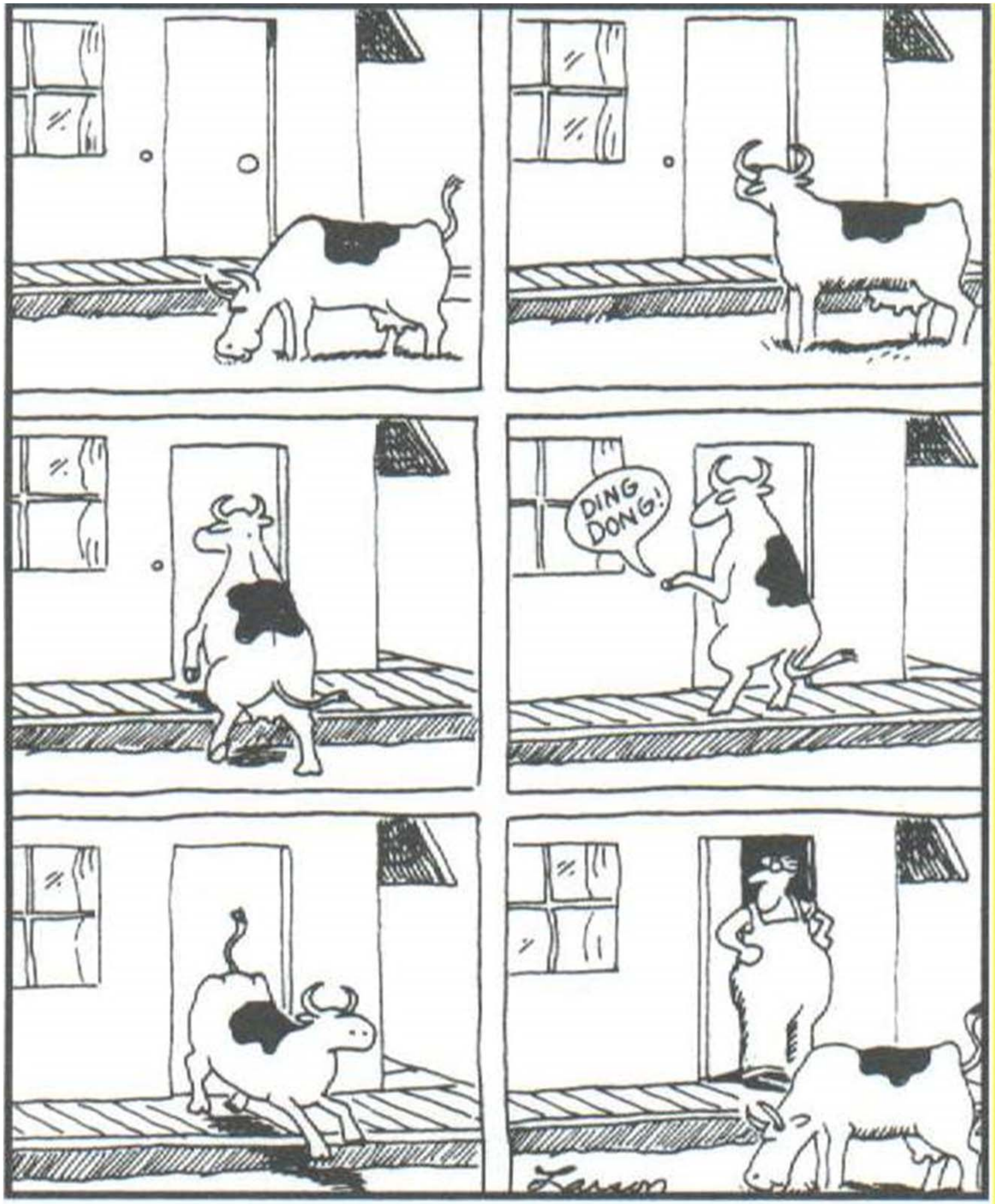
Factors Influencing Milk Fat

Nutritional Factors

- Dietary fiber
- Specific feeds
- Feeding strategy
- Ionophores

Non-nutritional Factors

- Genetics
- Stage of lactation
- Season
- Parity
- Ambient temperature


DING DONG!
Larson

Milk Fat Depression in the Dairy Cow

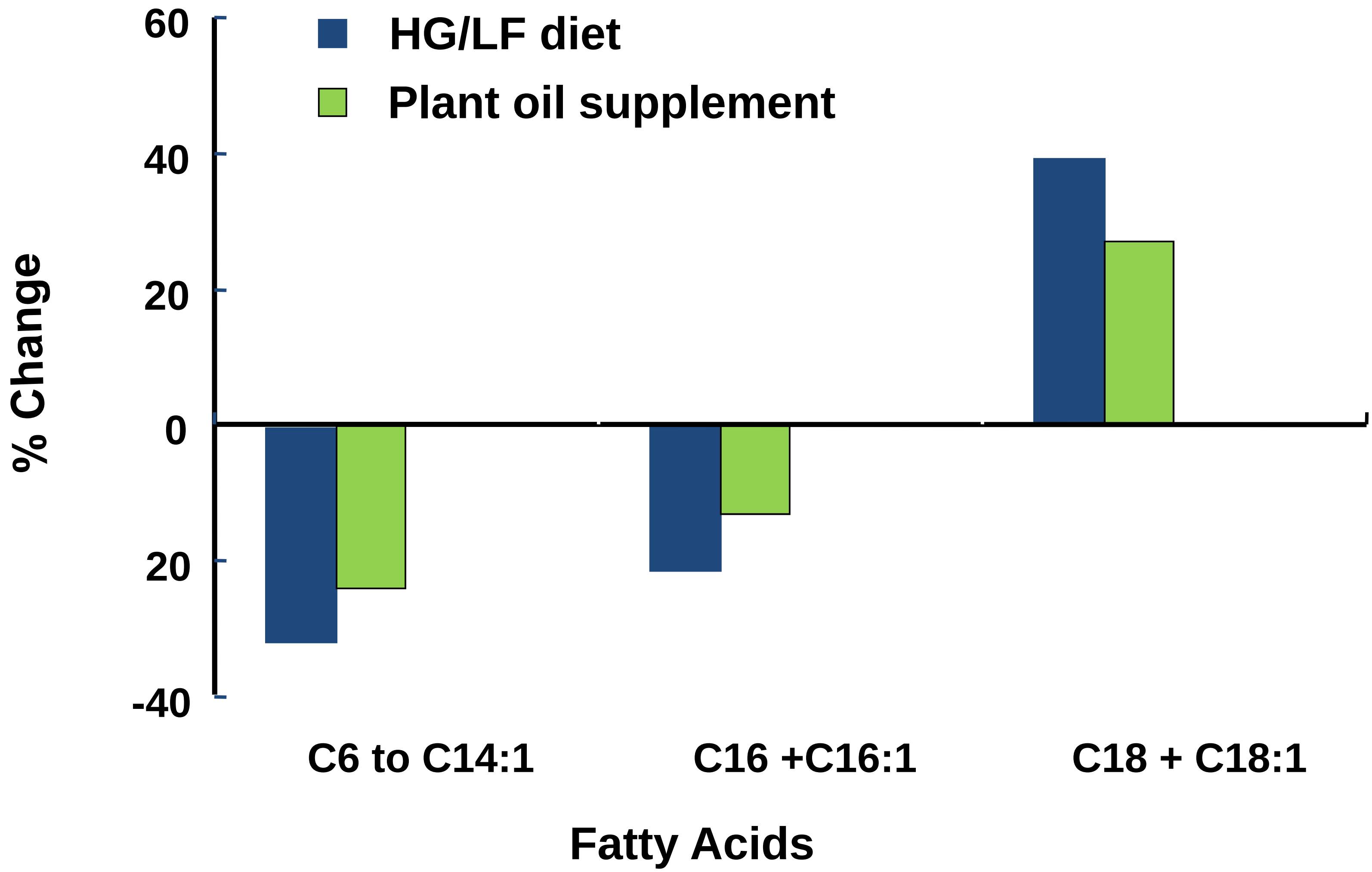
Boussingault

- Recognized by Boussingault in 1845
- Naturally occurs with certain diets
- Milk fat reduced but milk yield and other components unaffected

Milk Fat Depression Characteristics

- Diet-induced
  - High concentrate, low fiber
  - Low in effective fiber
  - Plant and marine oil supplements
  - Unsaturated fatty acids
- Specific for milk fat, up to 50% decrease
- Decreased yield of all fatty acids, but greatest for de novo synthesized fatty acids

MFD Changes Milk Fat Composition



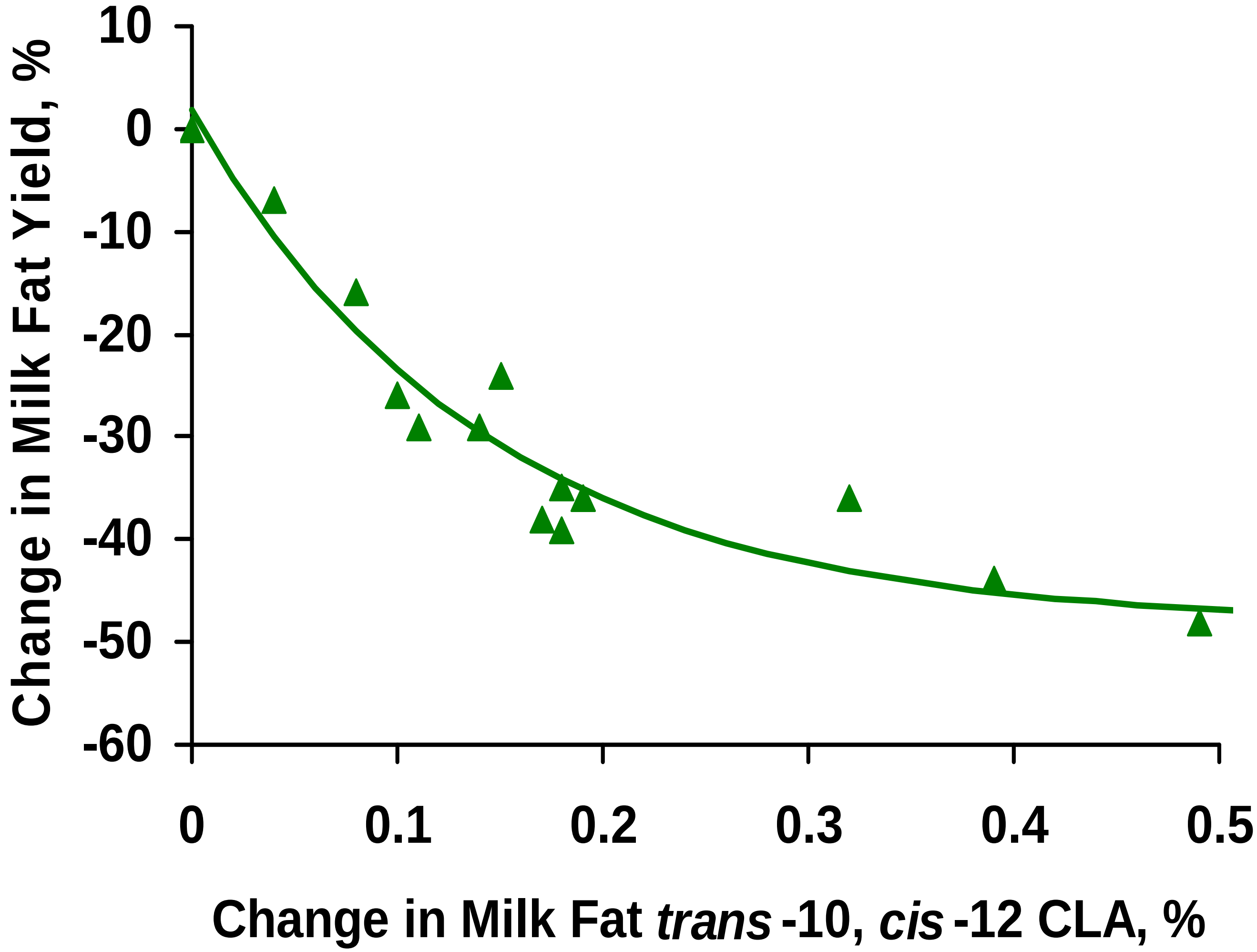
Bauman and Griinari (2003)

Biohydrogenation Theory

- MFD is the result of direct inhibition of milk fat synthesis at the mammary gland by unique fatty acid intermediates formed during rumen biohydrogenation of PUFA.

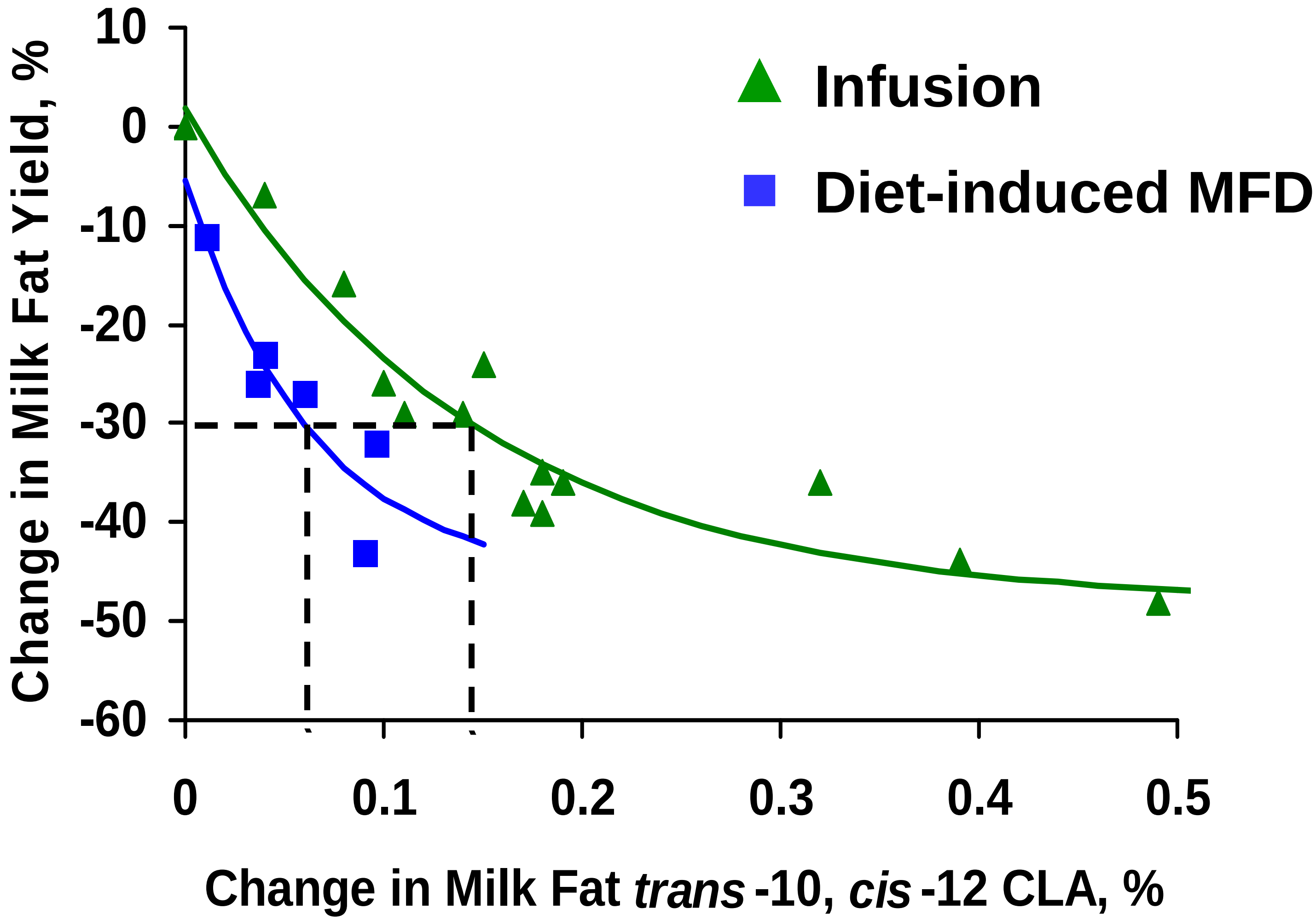
Bauman and Griinari (2003)

trans-10, *cis*-12 CLA in Milk Fat



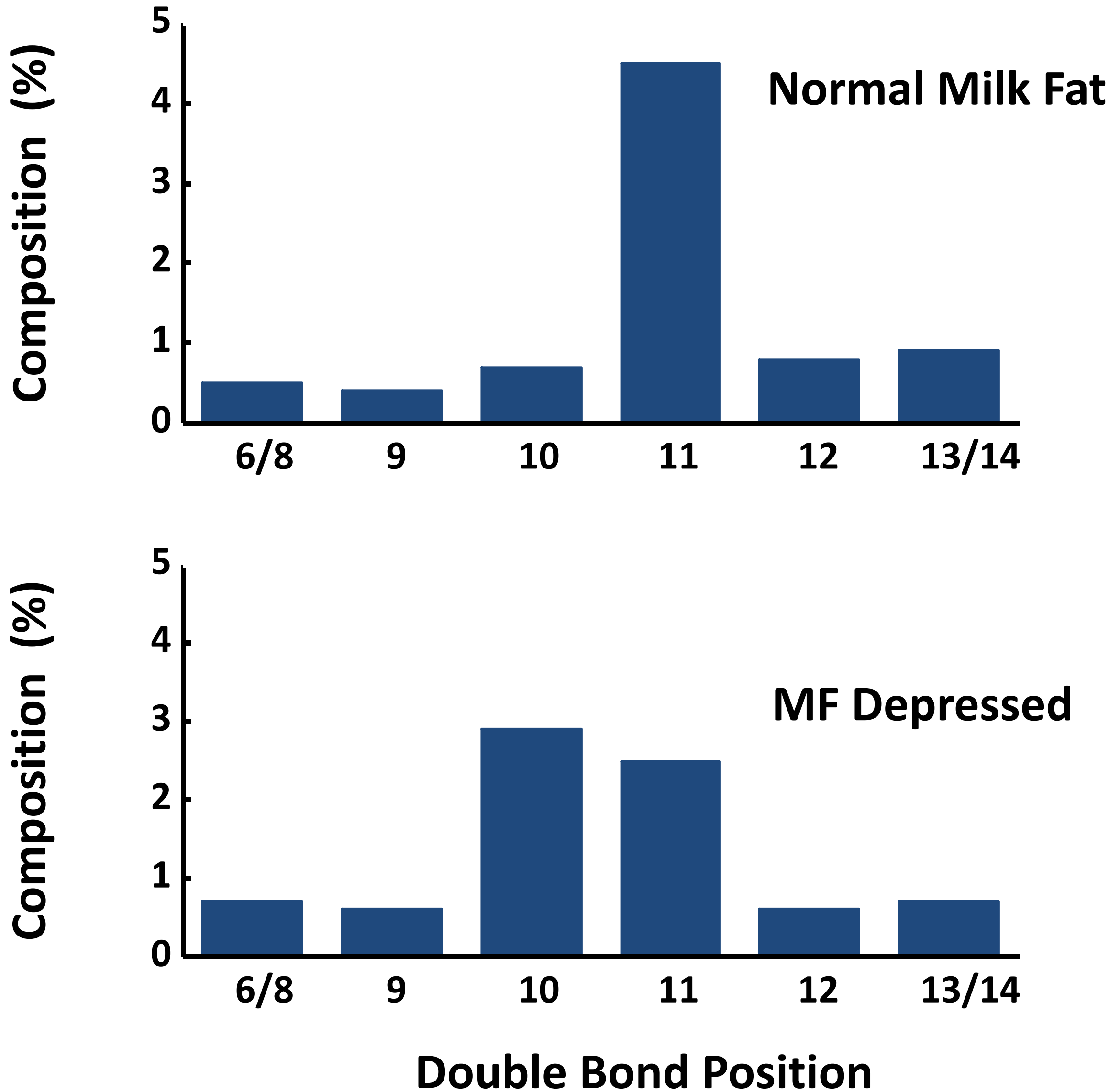
Adapted from de Veth et al. (2004)

Post-Ruminal Infusion vs. Diet-Induced MFD



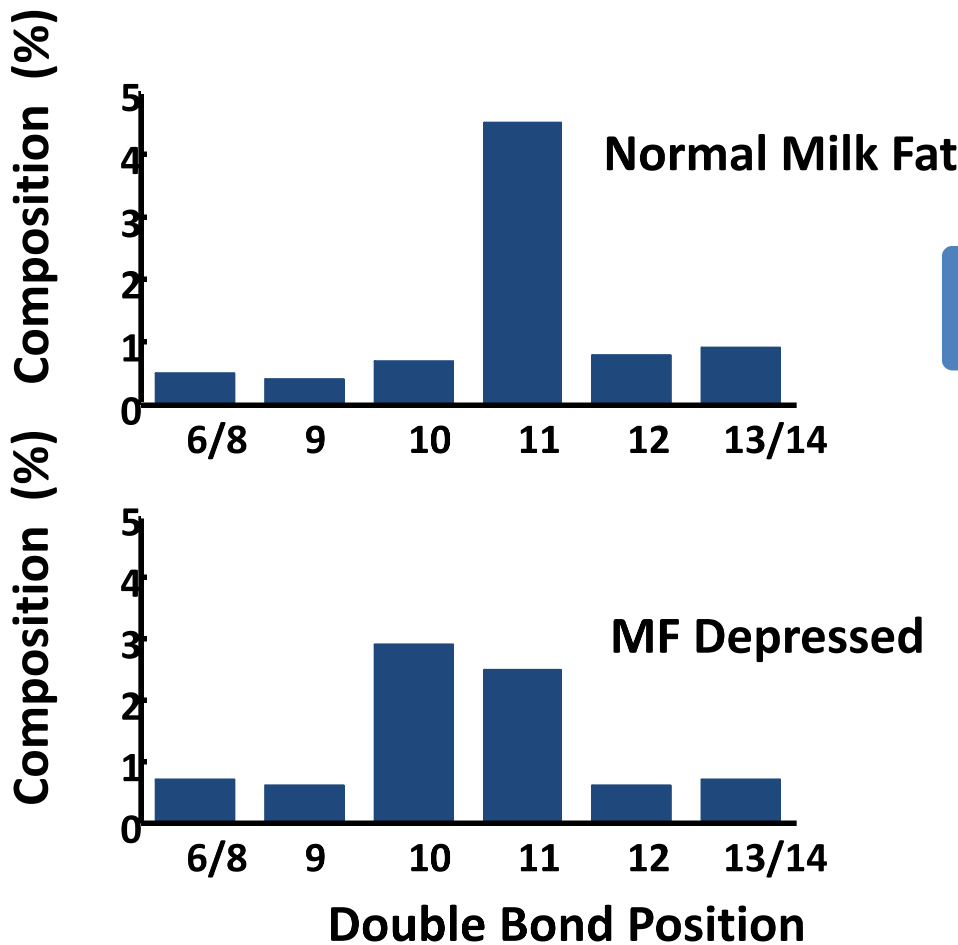
Adapted from Peterson et al. (2003) and Griinari and Bauman (2005)

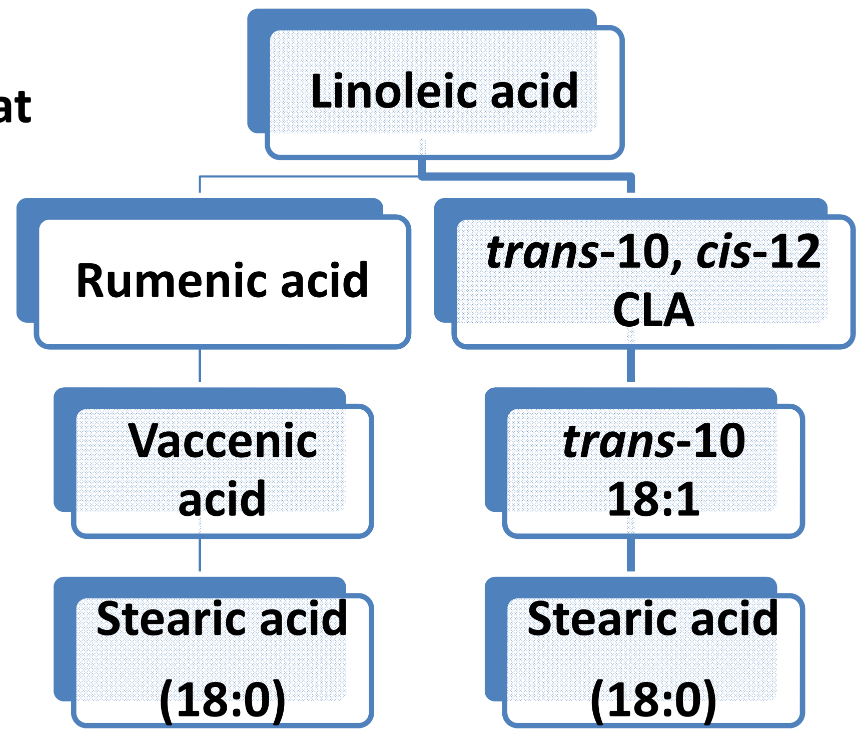
$C_{18:1}$ *trans* Fatty Acids



Griinari et al. (1997)

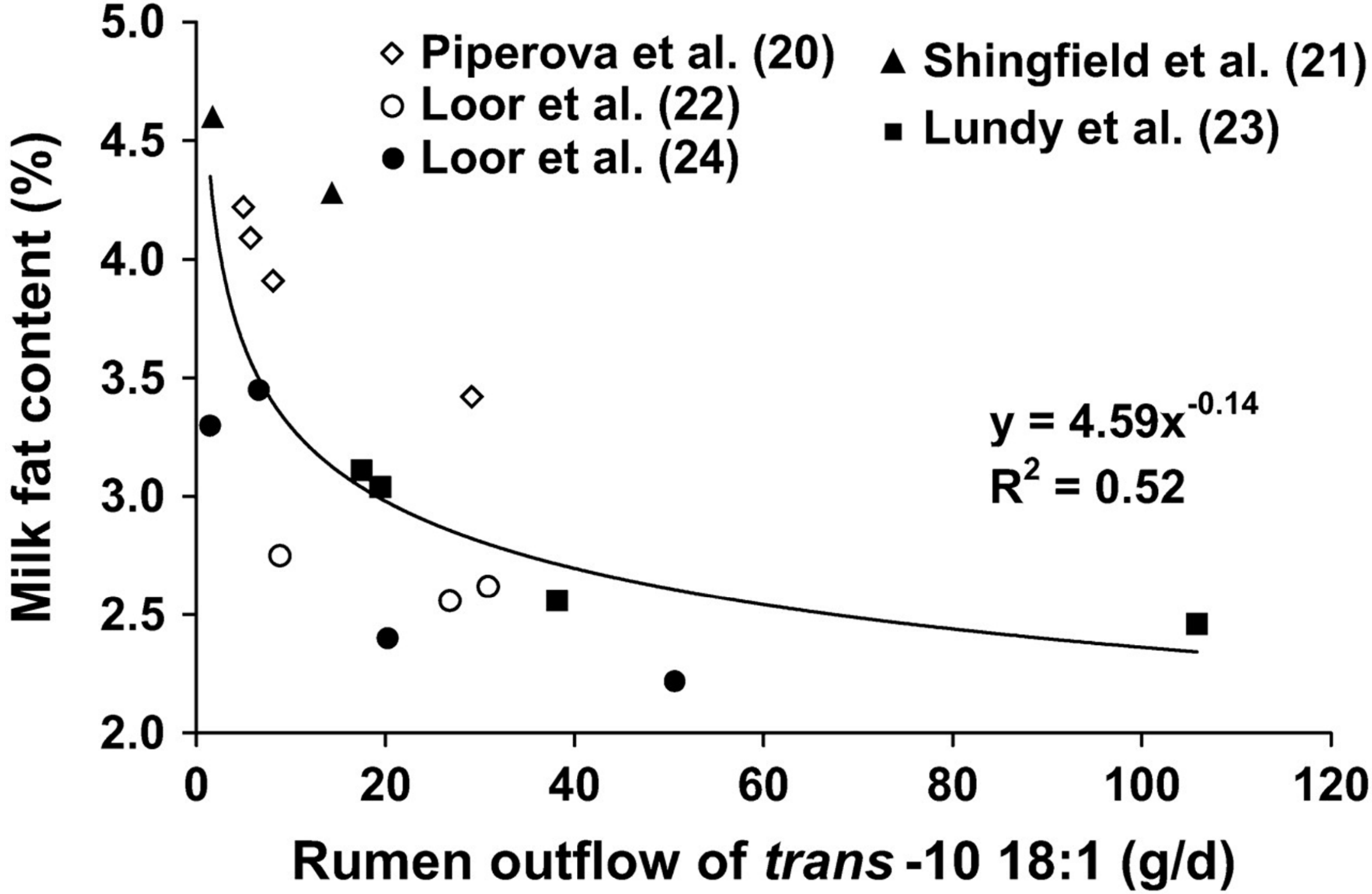
$C_{18:1}$ *trans* Fatty Acids





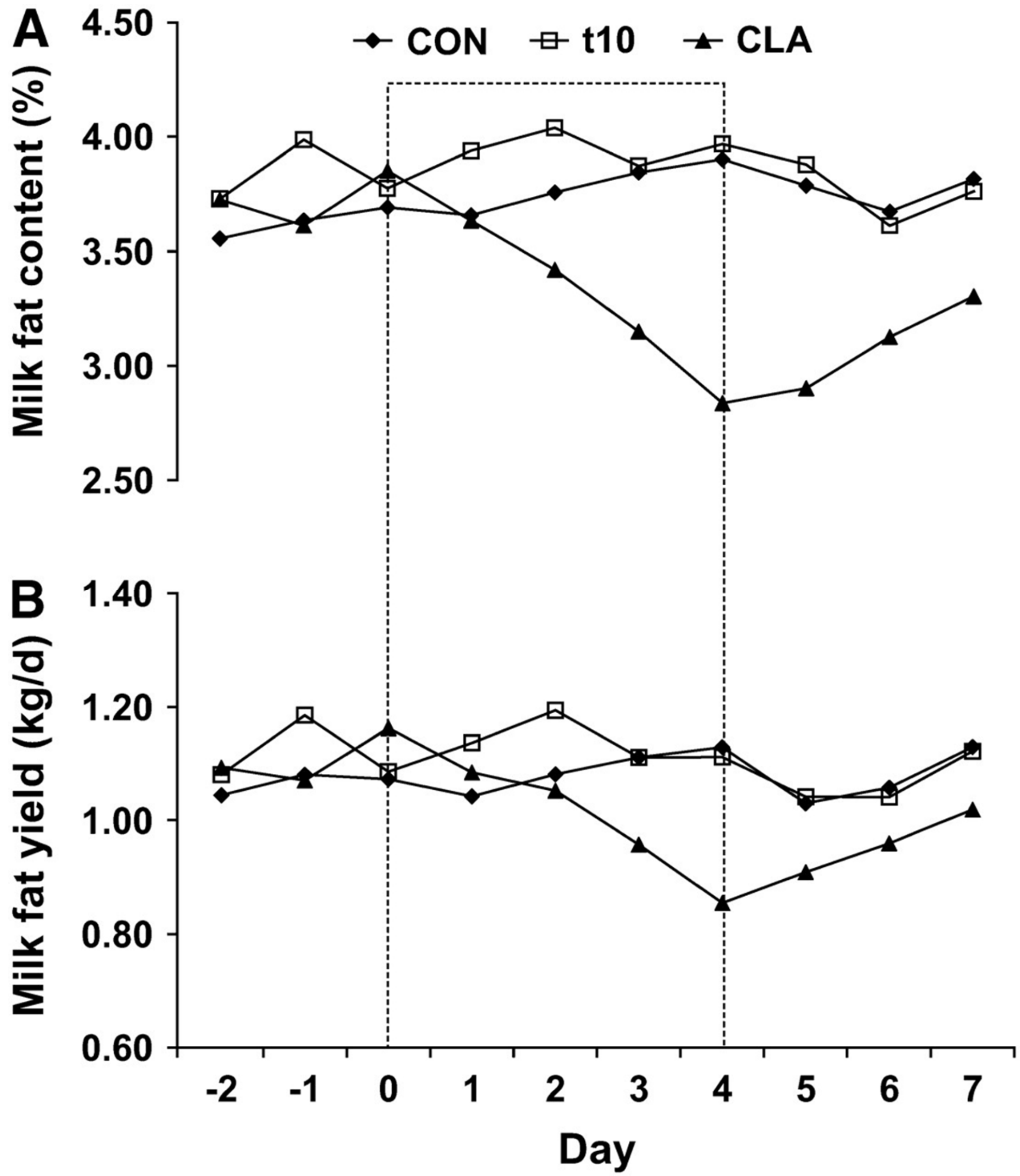
Griinari et al. (1997)

JN THE JOURNAL OF NUTRITION



Lock A L et al. J. Nutr. 2007;137:71-76

JN THE JOURNAL OF NUTRITION



Lock A L et al. J. Nutr. 2007;137:71-76

Role for *trans*-10 18:1

- *trans*-10, *cis*-12 *CLA* is the most extensively studied potent inhibitor of milk fat synthesis
- MFD is correlated with *trans*-10 rumen outflow
  - Does not directly inhibit milk fat synthesis
  - Marker of altered biohydrogenation
- Other *trans* and conjugated PUFA may decrease milk fat

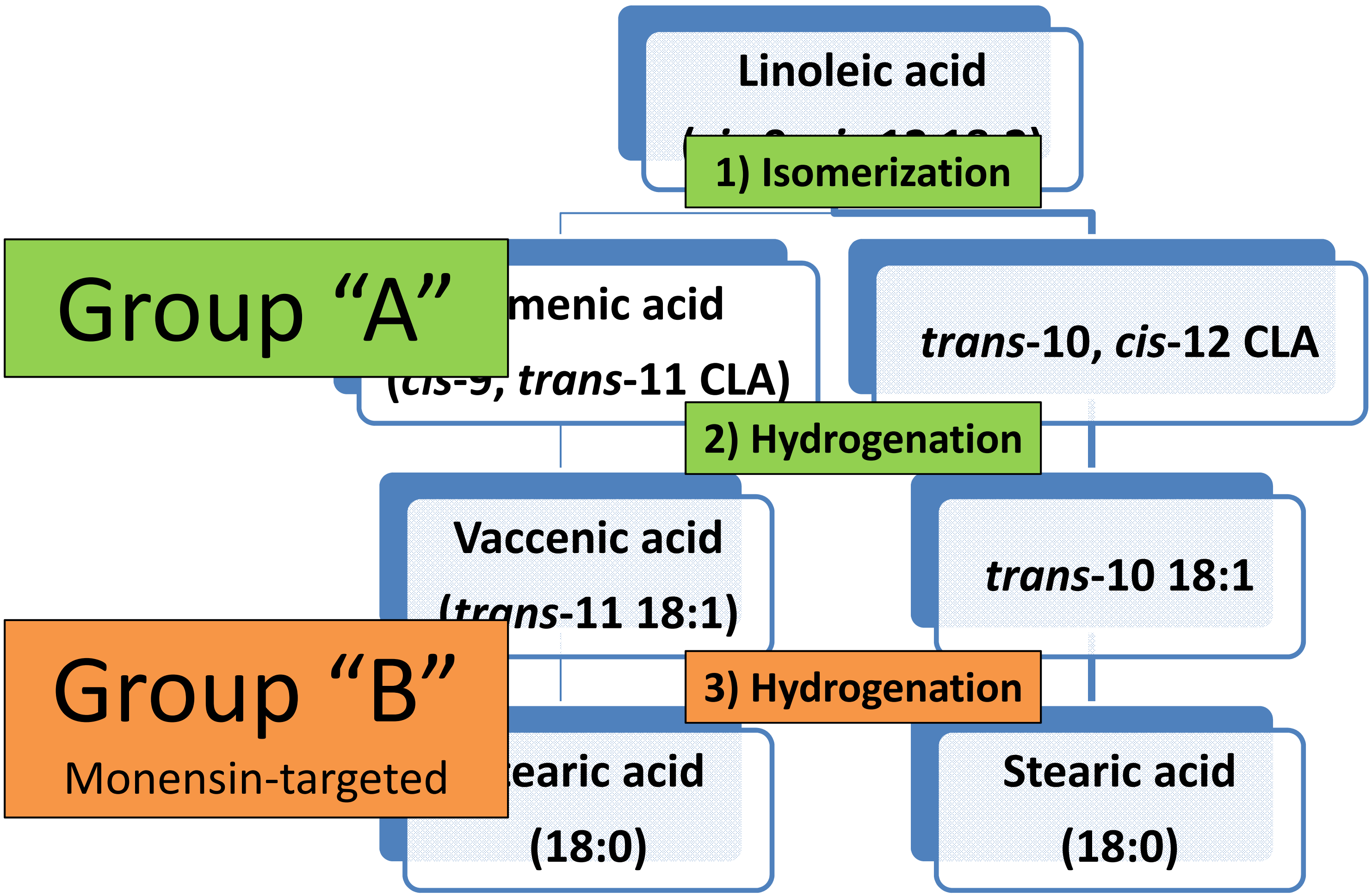
Lock et al. (2007)

Monensin and Milk Fat Depression

- Ionophores disrupt biohydrogenation
- Monensin targets gram positive bacteria
  - Includes group “B” bacteria that hydrogenate monenes
  - Potentially results in build-up of intermediates
  - Not a problem in normal biohydrogenation pathways

Fellner et al. (1997)

Biohydrogenation



Monensin and Milk Fat Depression

- No single risk factor for MFD
- Monensin has potential to amplify the effect of other risk factors
- Monensin decreased milk fat content 0.13%
- Decreases in fat yield seem related to increased presence of dietary unsaturated FA

Duffield et al. (2008)

Rumen Unsaturated FA Load

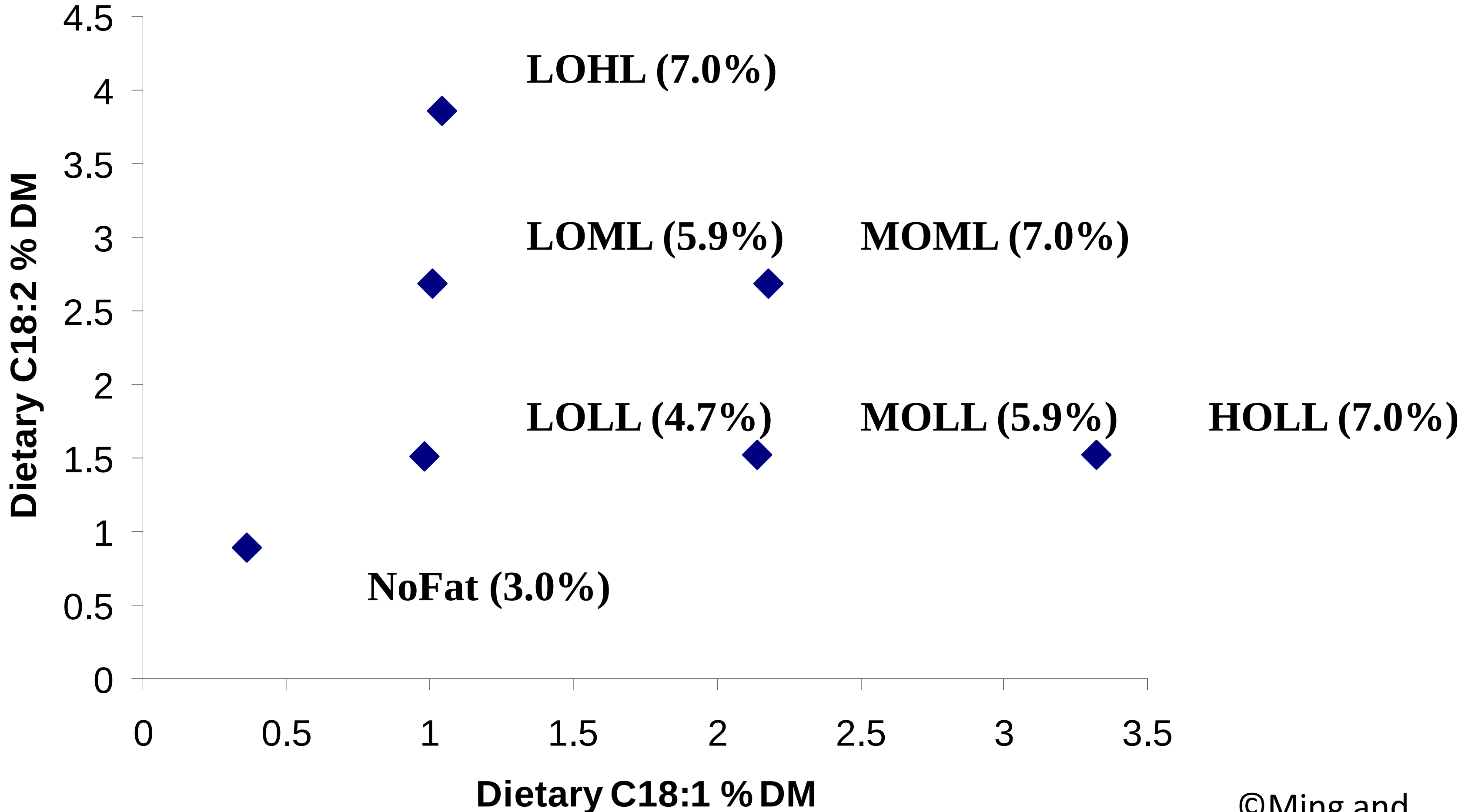
- RUFAL reflects total dietary unsaturated FA supply entering the rumen daily
  - Total feed ingredient fatty acid composition
    - Oleic (C18:1)
    - Linoleic (C18:2)
    - Linolenic (C18:3)
  - Marker for altered biohydrogenation

Lock and Jenkins (2009)

Unsaturated FA $\times$ Monensin

- Lack of available data to support interaction of monensin and unsaturated FA
- Heterogeneity of data in meta-analysis

Dietary C18:1 and C18:2 Concentrations



- Total dietary EE% in parentheses
- 6 fat blend trts test C18:1, C18:1^2, C18:2, C18:2^2, C18:1 × C18:2 interaction

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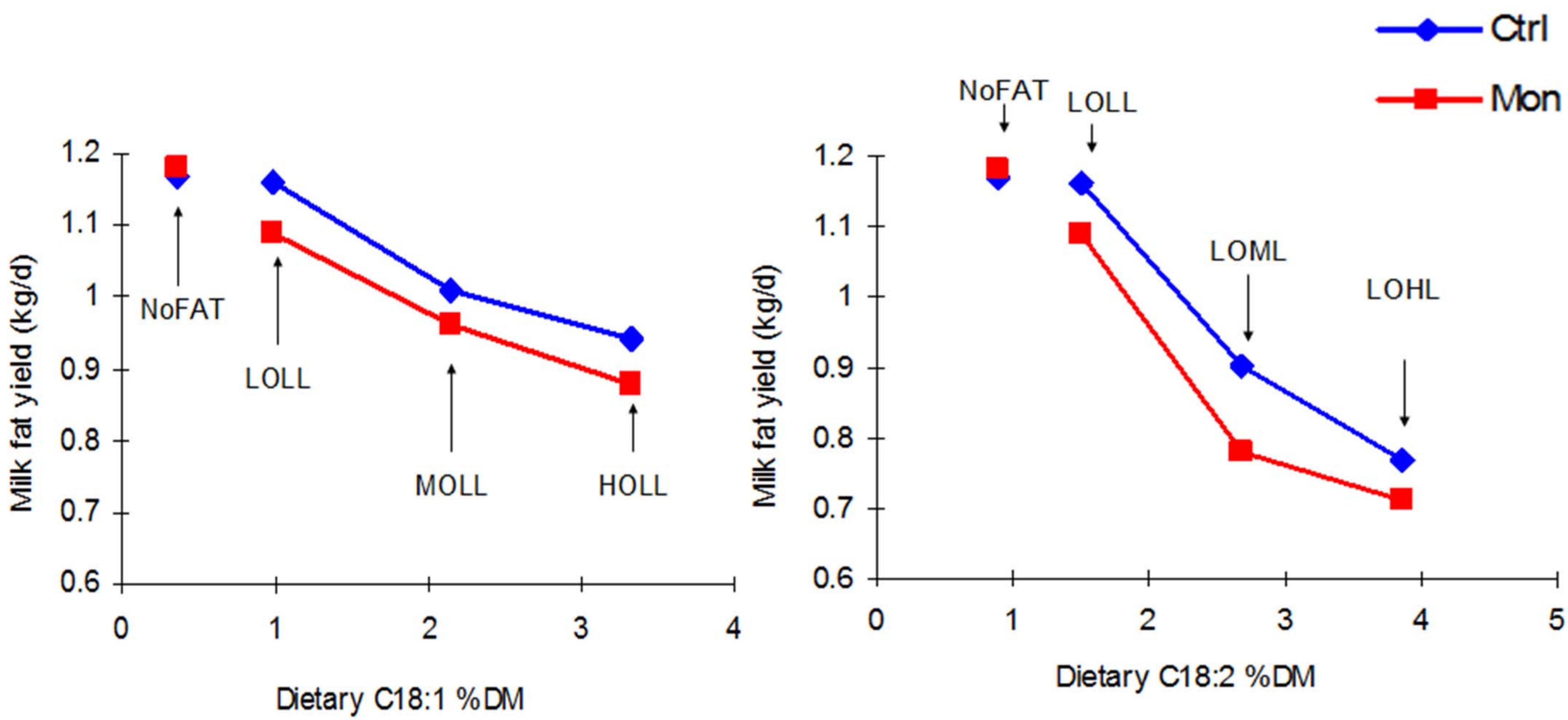
No monensin × C18:1 or C18:2 effect on milk fat yield



Monensin and Milk Fat Depression

- Monensin changes the rumen environment
- Diets with the capacity to lead to MFD are further influenced by monensin
- With most diets, an effect is not observed and reductions are only apparent for content, not yield

"Butter is just a little stick of smiles and happiness"
– Paula Deen

http://inventorspot.com/articles/food_sculpture_16966

Increasing Milk Fat Yield

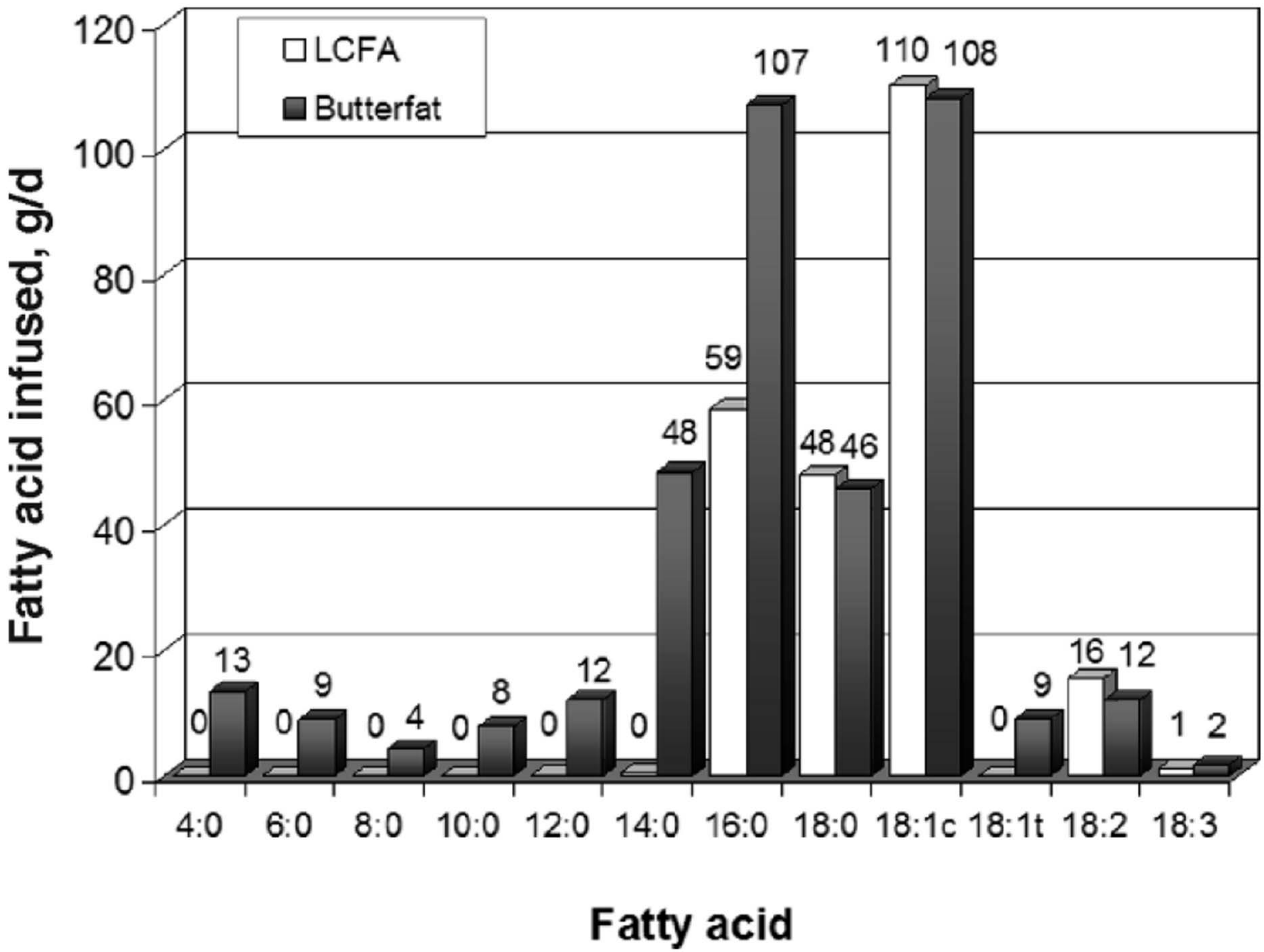
- Milk fat composition is easily manipulated
- Increases with saturated LCFA infusion
  - Decreases proportion of de novo FA
  - Unsaturated FA can reduce DMI
- LCFA are derived from dietary sources
- Short- and medium-chain FA are essential for milk triacylglycerol synthesis

Kadegowda et al. (2008)

Abomasal Butterfat Infusion

- Treatments:
  - 400 g/d butterfat
  - 245 g/d LCFA mixture matching LCFA in butterfat
- Compare effects of short- and medium-chain FA
- Limited infusions to avoid DMI reduction

Kadegowda et al. (2008)



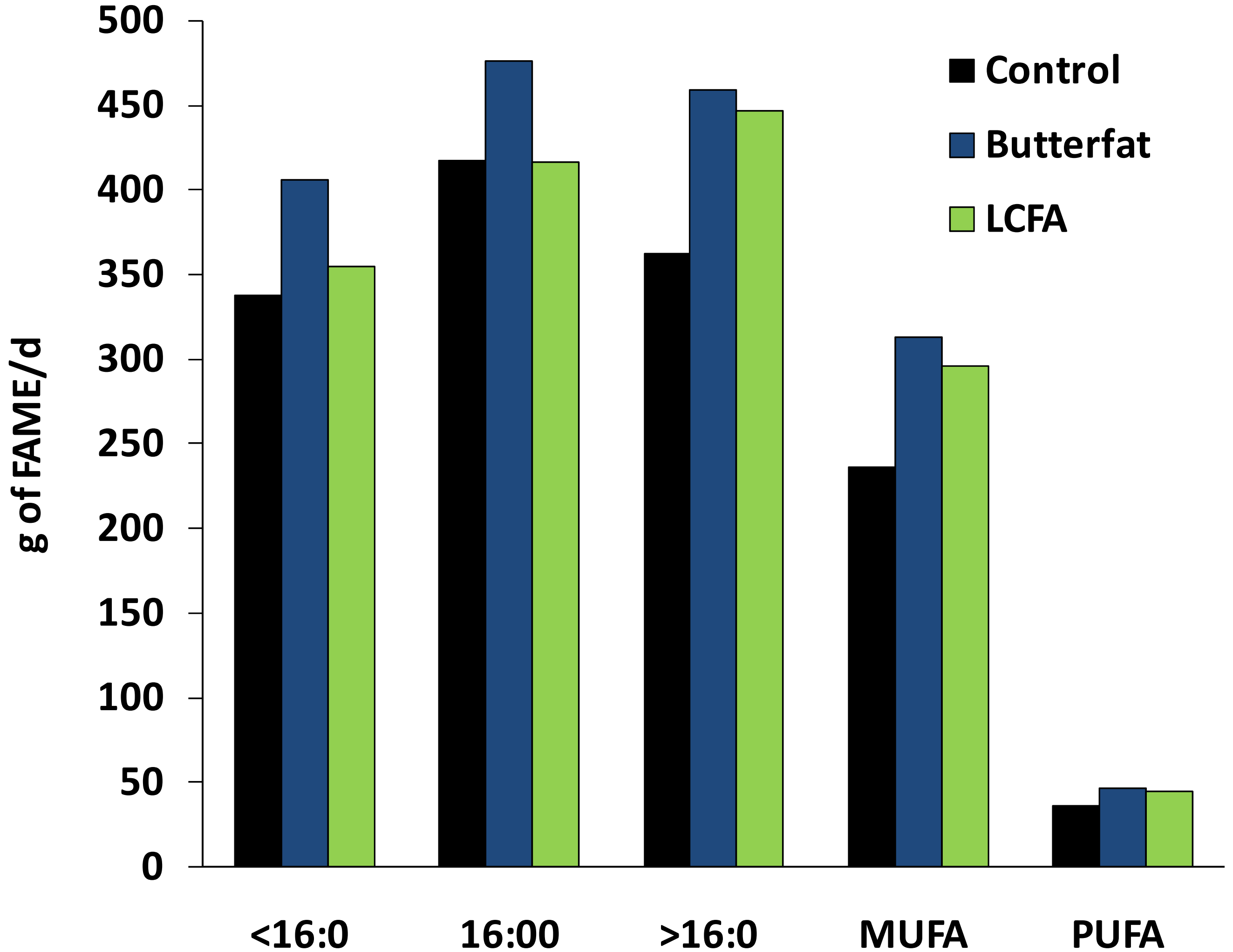
Kadegowda et al. (2008)

Abomasal Infusion of Butterfat Increases Milk Fat Yield

Item	Control	Butterfat	LCFA	SEM
Milk, kg/d	31.8	33.7	33.1	2.5
FCM, 3.5%	32.87	37.72	35.04	2.71
Fat, %	3.74	4.26	3.79	0.19
Fat yield, g/d	1,178	1,421	1,279	107.7

Kadegowda et al. (2008)

Abomasal Infusion of Butterfat Increases Milk Fatty Acid Yields



Kadegowda et al. (2008)

Increasing Milk Fat Yield

- Infusion of LCFA did not alter milk fat yield
  - FA <16:0 were not reduced, but maintained
- Butterfat and LCFA similarly increased FA >16:0
  - Changes in palmitate to stearate ratios may have influenced LCFA treatment fat yields
- Medium-chain FA transfer efficiency increased with chain length
  - Yield of 14:0 was greater for cows infused with butterfat
- Short- and medium-chain FA may be limiting factors for increasing milk fat synthesis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Take Home Message

- Milk fat yield can be increased with fat supplementation

Take Home Message

- Milk Fat Depression requires:
  - Altered rumen environment
  - Supply of PUFA

Take Home Message

- No single factor is responsible for MFD – interactions of potential risk factors can change the rumen environment and increase MFD risk.


Questions?
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