Fat in dairy diets

Lou Armentano, UW Madison Emeritus

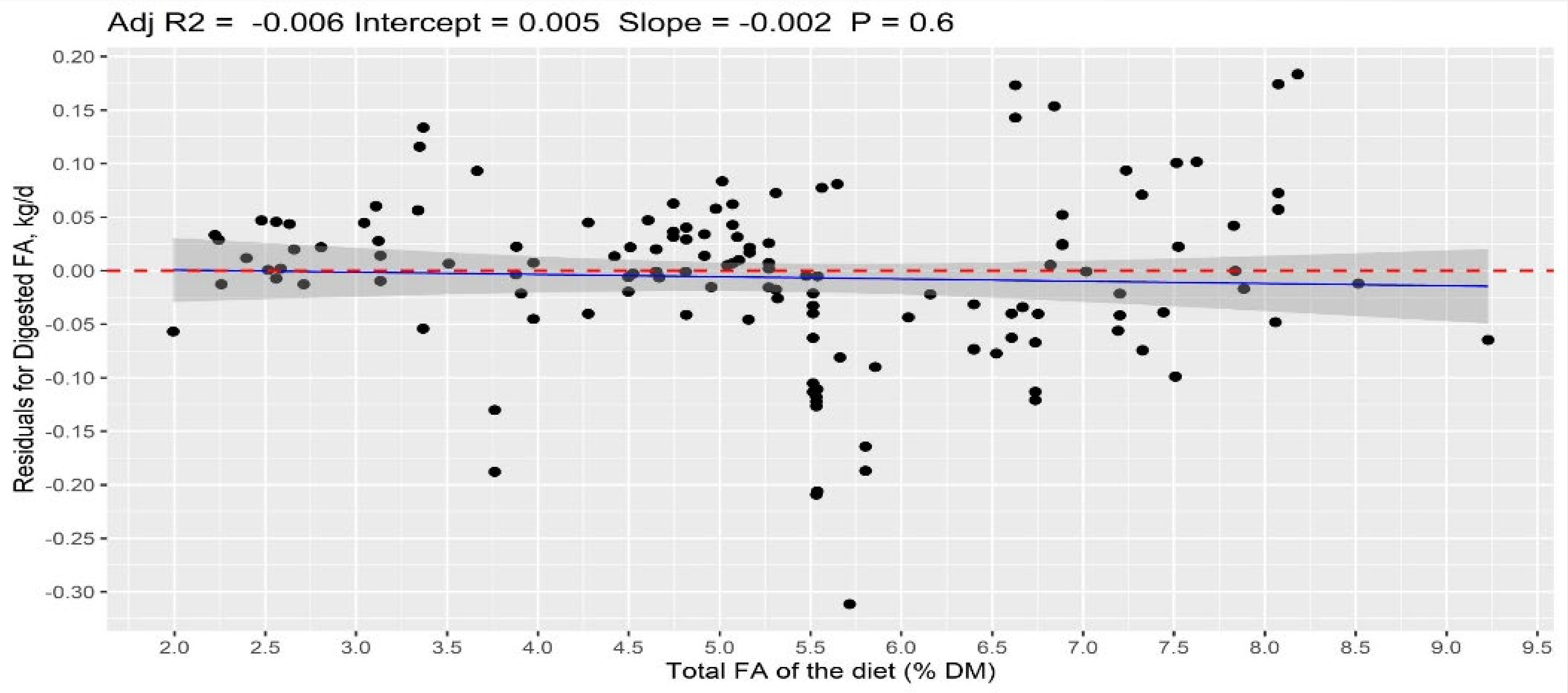
Major changes in NRC 8 vs. 7 (for your records)

	NRC 7	NRC 8	
Fat amount	Ether Extract (crude fat)	Fatty Acid – as COOH	In 8
FA content calculation	EEx-1	FA by measurement or regression from EEx	FA content a user variable in “new” feeds
FA Digestibility in basal	True dig. Set to 100% at maintenance DMI	Estimated by regression to be 73% true digest.	FA digestibility also a user variable for any new feed
FA Class (supplements)	TDN class – FAT or FAT with Glycerol	Can call FA nonesterified to calculate rOM correctly	
True vs Apparent Digestibility	TDN and DE are apparent Endogenous fecal energy	True=Apparent (no endogenous FA)	
Digestibility of FA supplements	5 supplements Included (digestibility <100%)	10 FA rich feeds included	
Fat on DE to ME efficiency	DE to ME increased for EEx over 3%	ME of diet increased with FA due to less Methane	All FA same from 0% up
Fat on ME to NE efficiency	80% for EEx > 3%, vs 70%	Same as all other ME	NE=.66*ME

FA as energy source greatly simplified in NRC 8

- FA not Ether extract or crude fat
- No endogenous FA used so apparent and true digestibility are same
- ‘native’ FA digestion variable set at 73% in library to get DE (digestible energy)
- Supplements classified by FA content and grouped into classes
- DE to ME uses diet methane production
  - Fat reduces diet methane
  - Therefore higher FA diets have increased DE to ME by that diet methane prediction
- ME to NE efficiency same for FA as all other energy sources (.66)
- Dry matter intake
  - Diet adjusted DM Intake equation does not reduce intake with FA in diet
  - Increased DM Intake does not reduce FA digestibility
  - Increased FA in diet does not reduce FA digestibility
  - adding FA no direct effect on NDF digestion (but removing starch increases NDF digestion)

Model with no DMI or FA concentration induced depression of FA digestibility fits data well



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- In 7 DMI affected all DE, in 8 no effect of DMI on FA digestion
- Amount of FA (or EEX) does not alter FA digestion in either model

Basal

Feed Ingredient	% of DM	
Corn Grain, fine grind	37.4%	
Corn Silage	24.2%	
Corn Oil, 70% dig FA	0%	
Grass-Legume	24.2%	
Soy Bean Meal	10.0%	
Salt	4%	
[FA]	(2.6%)	
[EEX-1]	(1.8%)	

24.75 kg DM/day

	Mcal/kg DM	% of GE	% of DE	% of ME
NRC 8				
DE	3.01	72.0		
ME	2.61	62.5	86.7	
NE	1.72	41.2	57.2	66.0
NRC 7				
TDNd?	*61.1*			
DE(?)	*2.46*			
ME	2.37		*96.5*	
NE	1.57		*61.1*	63.3

Corn Oil replaces **Salt**

Feed Ingredient	% of DM
Corn Grain, fine grind	37.4%
Corn Silage	24.2%
Corn Oil, 70% dig FA	4.0%
Grass-Legume	24.2%
Soy Bean Meal	10.0%
Salt	0%
[FA]	(6.1%)
[EEX-1]	(6.2%)

	Mcal/kg DM	% of GE	% of DE	% of ME
		NRC 8		
DE	3.28	72.2		
ME	2.94	64.7	89.5	
NE	1.94	42.7	59.1	66.0
		NRC 7		
TDNd?	*69.0*			
DE?	*2.87*			
ME	2.66		*92.6*	
NE	1.71		*59.6*	64.3

Oil for salt substitution (Δ = delta = effect of added FA)

	Δ FA%	Δ DE	Δ ME	Δ NE	Δ ME/Δ DE)	Δ NE/Δ ME
		---------Mcal/kg DMI--------				
Corn Oil – NRC 8	**3.5**	**0.27**	**0.33**	**0.22**	**1.22**	**0.67**
Corn Oil – NRC 7	**4.4**	*0.42*	**0.29**	**0.21**	*.70*	**0.72**

Methane (Mcal/d) = + .294 * Dry Matter Intake kg
- .347 * %Fatty acid in DM
+ .0409* %digest NDF in DM

Methane loss is ~7 Mcal/d, so -.347 is a **big** coefficient

This is the only non-additive effect of FA addition on any Energy intake fraction

Note: NRC 7 feed library data changed feed Fat to equal Crude Fat reported in NRC 8

Why did I replace salt?

- Not what you would do in practice
- To show model results without associative effects of OTHER components that are reduced when replaced by FA
- Energy system in NRC 8 and associative digestion effects:
  - Dry matter intake and Starch cause loss of disgestion
  - It is only NDF digestion that is reduced

Oil or starch substitution for salt in NRC 8

	Δ FA%	Δ DE	Δ ME	Δ NE	Δ ME/Δ DE)	Δ NE/Δ ME
		---------Mcal/kg DMI--------				
Corn Oil for salt	**3.5**	**0.27**	**0.33**	**0.22**	**1.22**	**~0.66**
Starch for salt	**0**	**0.13**	**0.13**	**0.09**	**1.00**	**~0.66**

Diet	NDF digestion	Gas energy (Mcal/d)
Salt	45.67%	6.86
Oil	45.67%	5.62
Starch	43.29%	6.83

Regression Model ttNDFd

	ΔttNDFd (%)			
Fat Supplement Type	Δ	Δ3	SE	P-value
C12/C14	-2.7	-8.0	0.4	**<0.001**
Oil	-0.6	-1.9	0.2	**0.01**
C16	-0.3	-0.9	0.4	0.47
Animal – Vegetable	-0.1	-0.2	0.3	0.87
Tallow	-0.1	-0.3	0.3	0.66
Calcium Salts Palm	0.5	1.6	0.3	0.12
Calcium salts LCFA	0.3	0.8	0.3	0.32
Saturated	0.4	1.3	0.3	**0.09**

ME to NE conversion: should it be higher for FA? And would it matter?

- By my calculation using NE = .8 x ME for pure FA:
  - at 1% FA NE/ME= .658
  - at 7% FA NE/ME= .666
  - NRC 8 uses .66 constant
  - Difference negligible over practical range

Intake?

- No direct FA effect on dry matter intake in NRC diet adjusted DMI
  - Given a 2 “random” diets, FA content does not help you predict DMI
  - Best general intake equation mostly driven by fiber and forage but includes Milk Yield
- Restricting analysis to only studies where FA was added, FA decreased DMI
  - Given two related diets, adding (some kind) of FA can reduce intake
- Measure herd intake when changing FA in diet
- Remember intake affects associative effects on fiber and starch digestion and also methane production

Effect of 1% or 3% added FA on DM Intake

Fat Supplement Type	ΔDMI in kg/d			
	Δ1	Δ3	SE	P-value
C12/C14	-1.1[c]	-3.2	0.2	**<0.001**
Oil	-0.3[abc]	-0.9	0.1	**0.01**
C16	-0.1[ab]	-0.4	0.2	0.45
Animal – Vegetable	-0.2[ab]	-0.6	0.2	0.31
Tallow	-0.3[abc]	-1.0	0.1	**0.01**
Calcium Salts Palm	-0.4[abc]	-1.2	0.2	**0.02**
Calcium salts LCFA	-0.6[bc]	-1.8	0.1	**<0.001**
Saturated Fat	0.2[a]	0.7	0.1	**0.09**

Weld and Armentano 2017

Looking forward

- Cows are fed (mostly) 5 fatty acids:
  - C16:0 Palmitic
  - C18:0 Stearic
  - C18:1 Oleic
  - C18:2 Linoleic
  - C18:3 Linolenic
- These are included in feed library
- You can count them on one hand !
- Pay attention to them individually

Effect of different diet FA on total Milk FAT yield

Milk FA class	Diet C16:0	Diet C18:0	Diet C18:1 & C18:3	Diet C18:2
<C16	No effect	No effect?	Decreases	**Decreases**
C16	**Increases**	No effect?	Decreases	**Decreases**
C18	No effect	Increase?	**Increase**	Increase?
Total	Increase	Increase?	Decrease	Decrease

Milk	Intercept (±SE)	P-value	FA as % of Diet	Slope (±SE)	P-value	AIC
<C16, g/d	340.8 (±19.1)	<.001	∑C18:1,2,3	-30.1 (±2.18)	<.001	970
<C16, g/d	**346.7 (±19.5)**	**<.001**	**C18:1**	**-27.1 (±4.6)**	**<.001**	**968**
			C18:2	**-36.7 (±3.9)**	**<.001**	
			C18:3	**-26.0 (±3.9)**	**<.001**	
<C16, g/d	346.5 (±20)	<.001	C16:0	0.39 (±7.60)	0.95	973
			C18:0	0.39 (±25.2)	0.98	
			C18:1	-27.2 (±4.8)	<.001	
			C18:2	-36.7 (±4.0)	<.001	
			C18:3	-26.0 (±4.0)	<.001	

Best fitting model, C18:2 gets bigger negative effect

2019 data set

Milk	Intercept (±SE)	P-value	FA as % of Diet	Slope (±SE)	P-value	AIC
C16, g/d	453.0 (±25.4)	<.001	∑C18:1,2,3	-35.8 (±3.4)	<.001	1040
C16, g/d	461.7 (±26.1)	<.001	C18:1	-31.2 (±7.3)	<.001	1037
			C18:2	-45.8 (±6.2)	<.001	
			C18:3	-29.6 (±6.3)	<.001	
C16, g/d	414.0 (±21.3)	<.001	C16:0	79.0 (±7.1)	<.001	969
			C18:0	-15.2 (±23.6)	0.52	
			C18:1	-41.6 (±4.4)	<.001	
			C18:2	-51.8 (±3.7)	<.001	
			C18:3	-26.5 (±3.8)	<.001	

Milk FA yield	Intercept (±SE)	P-value	Diet % Variable	Slope (±SE)	P-value	AIC[3]
C18 total, g/d	307.9 (±25.3)	<.001	C18:1,2,3	26.0 (±3.39)	<.001	1037
C18 total, g/d	320.6 (±25.4)	<.001	C18:1	31.9 (±7.0)	<.001	1033
			C18:2	11.8 (±5.9)	0.05	
			C18:3	35.4 (±6.0)	<.001	
C18 total, g/d	309.6 (±25.8)	<.001	C16:0	6.8 (±10.9)	0.53	1030
			C18:0	82.4 (±36.2)	0.02	
			C18:1	27.5 (±6.95)	<.001	
			C18:2	8.2 (±5.8)	0.16	
			C18:3	32.6 (±5.8)	<.001	

2019 data set

	Intercept (±SE)	Diet Variable	Slope (±SE)	P-value	AIC[3]
Milk FA[1], g/d	1099.3 (±59.1)	∑C18:1,2,3	-38.5 (±6.4)	<.001	1165
Milk FA[1], g/d	1127.6 (±60.1)	C18:1	-24.7 (±12.7)	0.05	1157
		C18:2	-70.2 (±10.8)	<.001	
		C18:3	-18.0 (±10.9)	0.10	
Milk FA[1], g/d	**1070.1 (±57.2)**	**C16:0**	**83.7 (±17.8)**	**<.001**	**1137**
		C18:0	**68.9 (±59.2)**	**0.25**	
		C18:1	**-39.8 (±11.2)**	**<.001**	
		C18:2	**-79.5 (±9.4)**	**<.001**	
		C18:3	**-19.0 (±9.5)**	**0.05**	

2019 data set

Effect of different diet FA on total Milk FAT yield

Milk FA class	**Diet C16:0**	**Diet C18:0 ???**	**Diet C18:1 & C18:3**	**Diet C18:2**
<C16	No effect	No effect?	Decreases	**Decreases**
C16	**Increases**	No effect?	Decreases	**Decreases**
C18	No effect	**Increase**	**Increase**	Increase?
Total	Increase	Increase?	Decrease	Decrease

De novo inhibition vs. substitution

- Substitution theory (wrong one?)
  - adding dietary FA into milk fat <u>displaces</u> shorter chain FA
  - Implies that milk fat secretion is regulated not FA synthesis and transport
  - Why doesn't palmitic do this? Only C18 FA do this? Stearic too?
- De novo inhibition (what I think)
  - Unsaturated FA form bioactive FA in rumen to reduce de novo FA synthesis in Mammary
  - Also provide exogenous C18 FA for milk fat
  - Later compensates for former
  - Definitely true for linoleic; Linoleic even inhibits its own transfer into milk fat
  - Lessor effect for oleic and linolenic (for sure) / no effect for stearic(?)
- Could be all of oleic and linoleic effect and part of linoleic effect is substitution
  - But then stearic should do same as oleic and linoleic
- Remember biological mechanisms should work on a molar basis

	Intercept (±SE)	Diet Variable	Slope (±SE)	P-value	AIC[3]
Milk FA[1], mol/d	4.80 (±0.25)	∑C18:1,2,3	-0.21 (±0.03)	<.001	197
Milk FA[1], mol/d	**4.91 (±0.25)**	**C18:1**	**-0.15 (±0.05)**	**0.008**	**190**
		C18:2	**-0.35 (±0.04)**	**<.001**	
		C18:3	**-0.13 (±0.04)**	**<.001**	
Milk FA[1], mol/d	4.70 (±0.25)	C16:0	0.32 (±0.08)	<.001	175
		C18:0	0.27 (±0.27)	0.31	
		C18:1	-0.21 (±0.05)	<.001	
		C18:2	-0.40 (±0.04)	<.001	
		C18:3	-0.14 (±0.04)	0.001	

2019 data set

Current and future FA digestion

- Current model uses classes of FA for digestibility of “FA” in that feed
    - These are user adjustable variables with library defaults
- These are then summed linearly by feed for diet
- Cannot measure digestion of the 4 individual C18:? FA
    - eg: C18:2 consumed – C18:2 in feces could be absorption or luminal biohydrogenation
- Can measure digestion of combined C18 FA (ΣC18 eaten–ΣC18 in feces)
- And also C16 (separately from C18)
- Future models may predict effect of 5 individual diet FA on digestion of C18 and C16
    - Something like this:
    - C16 dig = B0 + B1*C16 + B2*C18:0 + B3*C18:1 + B4*C18:2 + B5*Diet C18:3
    - C18 dig = B6 + B7*C16 + B8*C18:0 + B9*C18:1 + B10*C18:2 + B11*Diet C18:3
    - Quadratic and interaction terms might be needed

Measuring DE is doable

- DE is a large and variable loss
- Diet DE can be measured DIRECTLY by most research laboratories
  - Need a shovel, scale, and a bomb calorimeter (students useful too!, plus some cows)
  - Actual is always better than predicted
- Then use NRC model predictions to get at <u>predicted</u> ME and NE
  - better (I think) than going from diet chemistry to predicted DE then predicting ME then predicting NE
  - NRC 8 much more transparent about this process
- So measure digestible Organic Matter fractions <u>PLUS</u> direct DE
  - Combustible energy (bomb calorimeter)
  - Starch, N, NDF, OM
  - C16 and C18 FA digestibility

FA effect on methane?

- Do all FA affect methane equally?
- Especially FA we feed, and not C12 or C14