PennState
College of Agricultural Sciences

High Oleic Soybeans – Where Do They Fit into Dairy Diets?

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HO Soybeans provide many "Opportunities", but it is going to be different for every farm!

- Lower risk of milk fat depression
  - Ability to feed more rumen-available unsaturated FA
- More economical source of dietary fat?
- "Homegrown" dietary fat?
- Another option for crop rotation

Key interactions
- Available acreage
- Local source of HO beans
- Competition from crushers (Sets premium)
- Distance to crushers
- Cost of competing protein and fat sources

Key nutrition questions: How much & How to process

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What is oleic acid?

- *cis*-9 18:1 or "18:1 n-9"
- 55 to 80% of olive oil, which is part of the Mediterranean diet
- ~20% of normal corn and soybean
- Synthesized from 18:0 by Stearoyl Co-A desaturase in the body (~65% of 18:0 converted to 18:1 n-9)
- Has emulsifier properties

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Genetically selection to change fatty acid profile of plant oils is not new!

Feedstuff (% FA)	16:0	18:0	18:1	18:2	18:3	20:1	22:1
Rapeseed	3	1	**17**	13	6	10	42
Canola	5	2	**60**	20	**9**	1.2	0.1
HO Canola	4	2	**76**	10	**2**	1.5	0.1
Sunflower	6	4	22	**70**	0.1	-	-
HO Sunflower	3	4	**>80**	<10	0.1	-	-
Safflower	4	3	12	**79**	0.5	-	-
HO Sallflower	4	4	**75**	14	0.5	-	-

- Why? Food industry looking for better oxidative stability and "fry life". Oleic considered "Healthly"

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Multiple approaches have been used to make high oleic soybeans

Feedstuff (% FA)	16:0	18:0	18:1	18:2	18:3
Conv. Soybean	11	4	23	**54**	8
High Oleic					
Plenish®	6.5	4	**75-80**	**7.5**	2.5
Vistive® Gold	2.5	3.5	**72**	**16**	3
Soyleic®	6	4	**78-84**	**<10**	<3
Ca-PFAD	46	4	**40**	7.9	-

Also, a CRSPR version by Calyxt®, which is not available

- HO soybeans have >2x "fry life" of conventional soybeans and Americans love the taste of soy oil!

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How do I know if my soybeans are "high-oleic"?

- **Source verified and segregated**
- **Full FA profile by GC**
  - Slow and expensive!
- **NIR Prediction**
  - Able to distinguish conventional from HO
    - Lab and hand-held (CVAS)

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High oleic soybean- Current state

Two sources of seed/genetics commercially available

- Plenish by Pioneer (GMO)
- Soyleic by MO Soybean Board (Non-GMO)

General agronomics

- Similar yield and growing number of varieties
- Stacked traits more limited

Current market

- Variable and dynamic premiums at crush plant
- Strong interest in dairy nutrition!

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Good example of short vs long term decision

Short term

- **Dynamics in the HO soybean and oil markets may present opportunities when supply outpaces demand**
- **An alternative when other fat markets spike or are not available**

Long term

- **Change crop rotations and strategies to make "home-grown"**
- **Better control of costs and risks**
- **Changes in oil, soybean, and meal markets**
  - **Renewable fuel credits and demand (aviation fuel etc)**
  - **Inc. in soybean crush capacity (+24% in next 3 years)**
  - **Cost of other protein sources**

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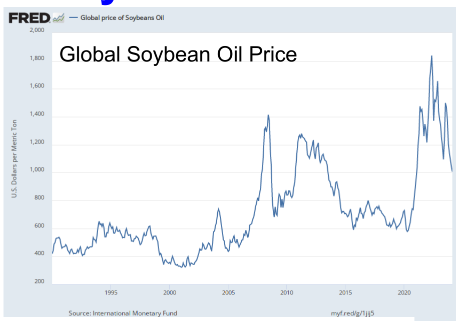
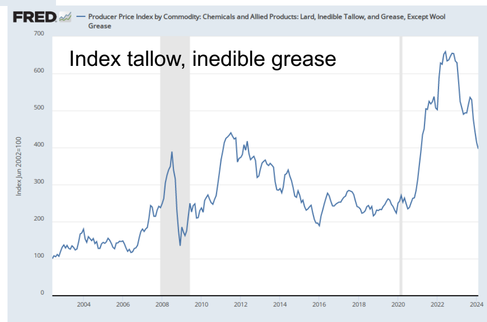
Fatty acids are an expensive nutrient



What is the future?
- **More competition from biodiesel?**
- **Overbuilt crush capacity?**

https://fred.stlouisfed.org/series/WPU06410132



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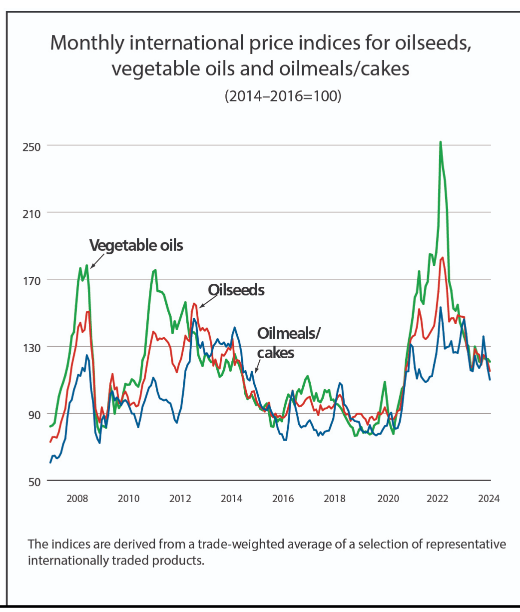
Long term value of beans vs meal?



-Long-term impacts on least-cost formulation for protein vs. fat in diets is unclear

- There have been significant changes with biofuels and crush capacity, and more changes are coming!

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We will focus our discussion on full fat soybeans and expeller pressed soybean meal

	Raw Soybean	Roasted Soybean	Expeller Meal
CP	40	40	40.5
NDF	13	13	9
FA	19	19	5-8
RUP	20±	50±	55±
RDP	80±	50±	45±

How can HO soy products reduce "feed cost" to improve "IOFC"?

Need to consider as both a protein and fat ingredient!

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To correctly value, you need to get a good number for total FA

	FA	EE	SD	N
NASEM Raw	17.0	20.7	1.7	212
NASEM Roasted	15.4	21.3	1.9	1005
CNCPS Raw	-	20.7	-	-
CNCPS Roasted		18.8	-	-
Rock River	-	21.3	-	780
Feedipedia	-	22.1	1.3	960
Soyleic	-	17.1-20.4	-	-

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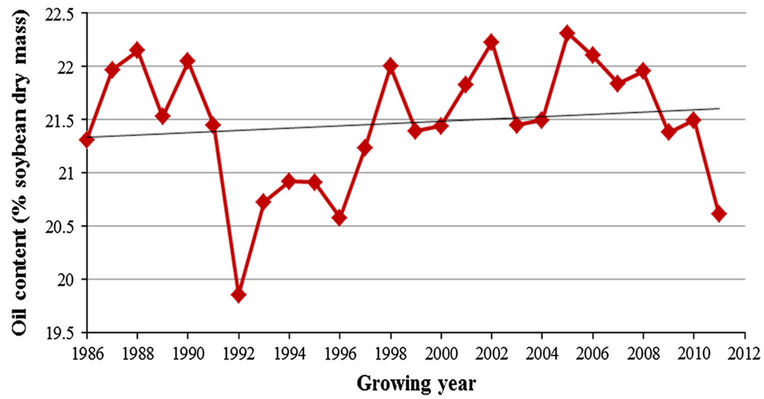
Fat concentration varies by year and likely between full season and double cropped



Oil concentration in US grown beans (37,762 samples with average of 1452 per year). Medic et al. (2014) J Am Oil Chem Soc. 91:363-384.

- Higher temperature at seed filling increases oil concentration (early vs late planted)

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NASEM applies one digestion coefficient for all oilseeds, but there is potential for additional benefit of oleic acid

Class	FA Digestibility Coefficient
Basal Diet	0.73
Oilseeds	**0.73**
Blended Triglycerides	0.63
Ca-Salts of palm FA	0.76
PA ~85%	0.73
PA or SA >90%	0.31

Daley et al. 2018 (2021 NASEM)

- **Recent work for MSU has shown increases in FA digestibility with abomasal infusion of oleic acid.**
  - Prom et al. 2021 (JDS 104:12616-1627)
- **We have observed increasing oleic acid in FA prills increases digestibility (Pierce et al. Unpubished)**

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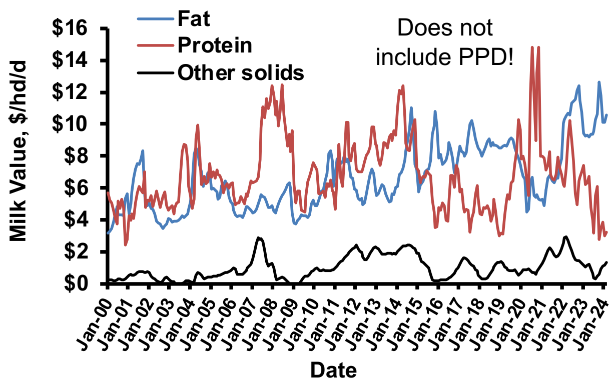
Milk fat and protein yield are the drivers of the "income" part of IOFC ($/hd/d @85 lb of 4.0 fat & 3.1 protein)



5 year average:
Fat = $2.48/lb
Prot = $2.70/lb
Other Solids = $0.26/lb

Harvatine unpublished based on USDA NASS milk price

- **We are going to focus on milk fat today, but remember soybeans are have a large impact on MP that is needed to maximize milk protein yield**

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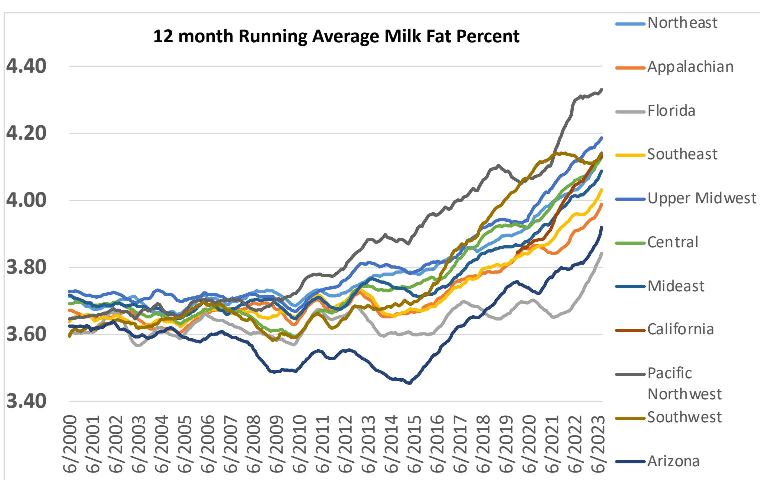
Milk fat has increasing since 2010 and we need to meet demands to make milk fat



Harvatine unpublished from USDA NASS

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Milk fat is responsive to nutrition in both directions

Decreased by milk fat depression
- Unsaturated fat (18:2)
- Fermentability
- Acidosis
- Feeding strategies and feed Mgmt

Increased by additional substrate
- Acetate from forages
- **Dietary Fat**
    - Fat level
    - Palmitic acid

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What does the cow need to make milk fat?

~55% taken up from the blood as preformed fatty acids
85% of this comes directly from absorption of dietary fat

Is there a "requirement" for fatty acids?

- **4 lb of milk fat x 55% Preformed = 2.2 lb**
- **2.2 lb / 55% transfer efficiency = 4 lb of dietary fat!**
- **4 lb / 55 lb DMI = 7.3% Dietary FA**

Don't try that, but gives idea of metabolic need

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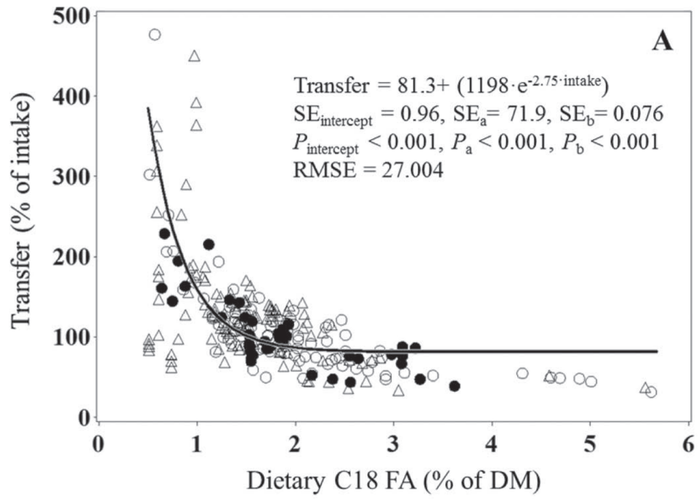
Many diets result in 18 carbon transfer efficiencies much higher than expected (>60%): Does this mean we are not feeding enough?



- Average TMR at CVAS is 2.3% 18 carbon FA

Khiaosa-ard et al. JDS 2015

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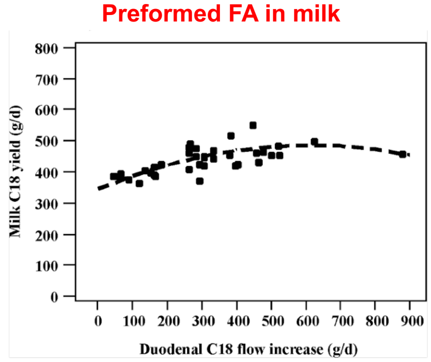
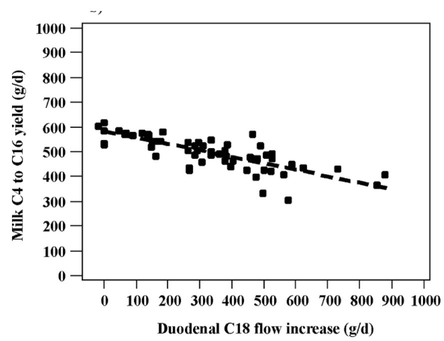
Feeding fat increases preformed FA in milk to a point, but decreases de novo FA (16:0 differs some from 18 C on this effect)

Preformed FA in milk



$C18milk\ (g/d) = \Delta_{exp} + 345\ (\pm 7)$
$+ 0.46\ (\pm 0.08) \times \Delta C18duo\ (g/d)$
$- 0.00038\ (\pm 0.00013) \times \Delta C18duo^2$
($Nexp = 26$, $Ntrt = 77$, $R^2 = 0.92$, $RMSE = 40.3$ g/d).

de novo FA in milk



$C4\ to\ C16milk\ (g/d) = \Delta_{exp} + 583\ (\pm 8)$
$- 0.26\ (\pm 0.03) \times \Delta C18duo\ (g/d)$
($Nexp = 29$, $Ntrt = 90$, $R^2 = 0.94$, $RMSE = 52$ g/d). [4]

- Mammary gland is "lazy"- why make if I can take up from blood?

Glasser et al. 2008 JDS 91:2771-2785

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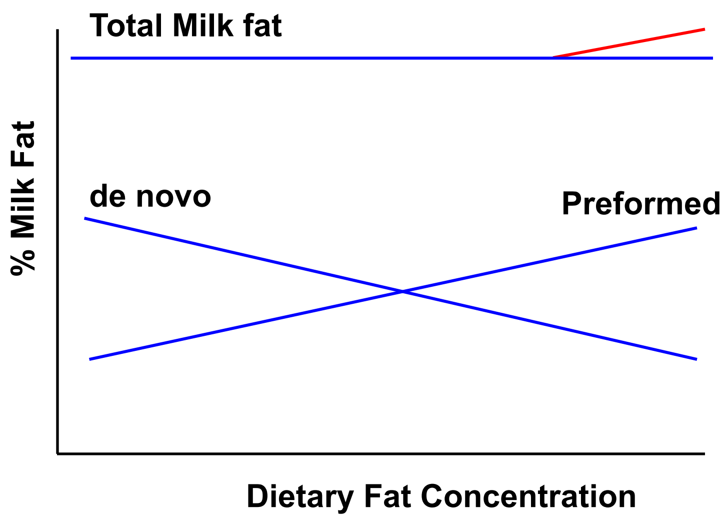
How does the cow use preformed FA?
Often dietary de novo fatty acids are decreased and milk fat yield does not change



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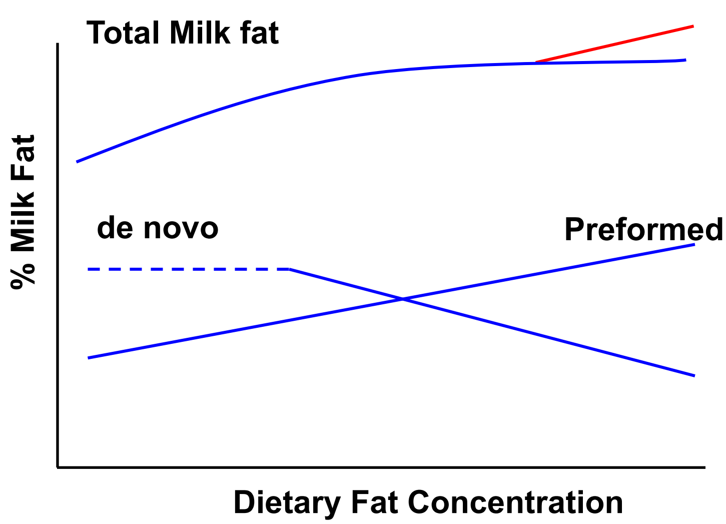
However, if de novo synthesis hits its maximum capacity we will then lose milk fat yield with low fat diets



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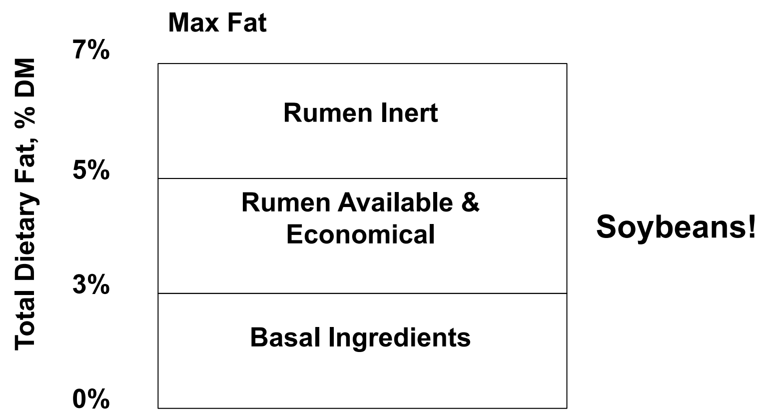
I think we need to consider all the sources of FA in the diet



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How much rumen available unsaturated FA can we feed depends on:

1. The fat
   - FA profile (18:2 vs 18:1 & 18:3 vs 16:0 & 18:0)
   - Rate of release of the FA in the rumen

2. Rumen environment that changed microbes
   - Fermentable CHO level and rate
   - rumen pH
   - Many other factors

3. Your risk aversion for MFD!

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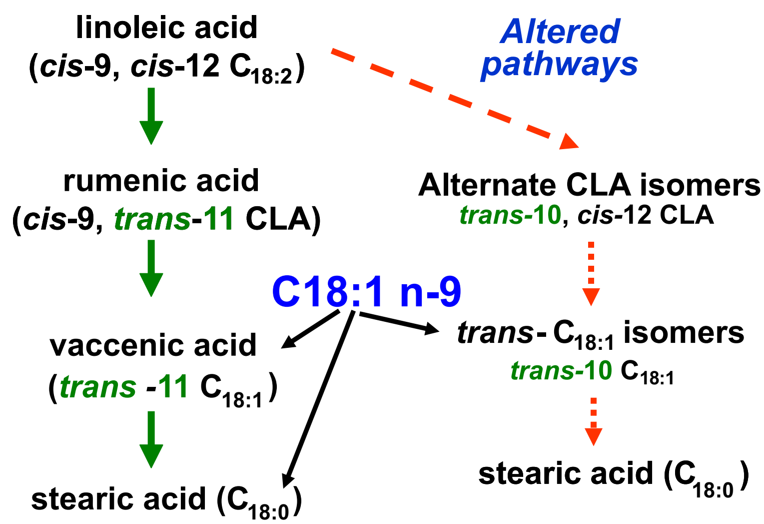
"Diet induced Milk Fat Depression" occurs when rumen metabolism of unsaturated fatty acids is altered



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How do unsaturated FA contribute to MFD?

1. **Modify microbial population**

2. **Are substrate for biohydrogenation**
   - **18:2 pathways results in the bioactive intermediates**

What is important?

1. Amount of 18:1, 18:2, and 18:3

2. Rate of availability in the rumen
   - Cottonseed vs DDGS

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The ability of 18:2 to cause MFD is higher than 18:1

	Corn	Low FA	18:2	18:1	Palm	Ca-PFAD	SEM
Milk, kg	45.1	40.7	43.8	44.8	44.6	42.3	1.43
Fat, kg	1.55	1.41	**1.31**	**1.44**	1.51	1.44	0.07
Fat, %	3.53	3.54	**3.03**	**3.29**	3.44	3.46	0.10
trans-10 18:1	0.61	0.50	**1.54**	**1.11**	0.86	0.63	0.22

Stoffel et al. 2015 (JDS 98:431-442)

Corn diet = 1.8% total FA and low FA = 1.2% FA. Oils added at 1.7% of diet.

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Dorea and Armentano (2017) using meta-regression found 18:2 to be ~2x impact of 18:1 on milk fat yield

Milk Fat =

1178 +
–34 x Diet 18:1 +
–75 x Diet 18:2 +
–25 x diet 18:3

Anim. Prod. Sci. 57:2224-2236

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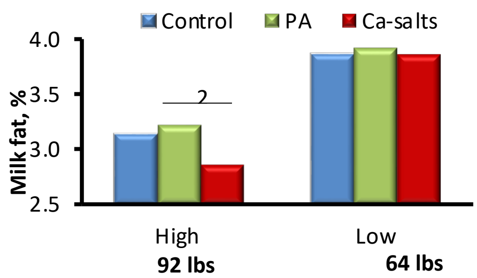
We have the most experience with 18:1 from feeding Ca-PFAD, which can cause MFD



Milk fat concentration

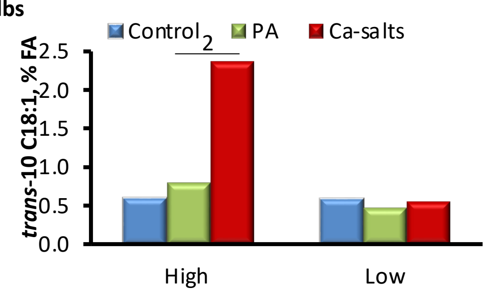
	P value
Trt	<0.01
Level	<0.01
Trt x level	<0.05
SE	0.23

Alternative Pathway

***trans*-10 C18:1**

	P value
Trt	<0.001
Level	<0.001
Trt x level	<0.001
SE	0.18

Con vs. PA , 1= P<0.05; 1†=P<0.1
PA vs Cal-salts, 2= P<0.05; 2†=P<0.1



Rico et al. 2014

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How much unsaturated fat is too much? It depends! Example of interaction with particle size

	0% oil		2% Corn Oil		
	Short	**Long**	**Short**	**Long**	**SEM**
Fat					
%	**3.62a**	**3.62a**	**2.27c**	**3.02b**	**0.23**
lb	**2.60a**	**2.79a**	**1.54b**	**2.02b**	**0.22**
<16C	**27.8a**	**28.4a**	**19.4c**	**22.7b**	**0.58**
16C	**25.2a**	**24.7b**	**21.0c**	**21.1c**	**0.46**
>16C	**47.1c**	**47.0c**	**59.6a**	**56.2b**	**0.68**
***trans*-10 C18:1**	**0.67bc**	**0.56c**	**5.32a**	**16.1b**	**0.39**
Ruminating, min/d	**401bc**	**542a**	**400c**	**465b**	**37**

Ramirez Ramirez et al. 2016 JDS 99:392-398

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Increasing processing of soybeans will increase risk for MFD

	CON	Oil	Whole	Roasted	SEM
Milk, kg	26.2	26.8	25.7	26.9	0.56
Fat, %	3.53	2.75	3.59	3.59	0.09

Mohamed et al. 1998. JDS 71:2677-2688

- Grinding oilseeds increases the rate of releases the FA in the rumen

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Impact of soybean meal grind size when feeding 18% of diet DM

		-----------Roasted-----------					
	Raw	**W/H**	**H/Q**	**Q/<**	**Grd**	**SEM**	***P***
Milk Fat, kg	1.22	1.31	1.27	1.17	1.20	0.04	0.09
TT CP Dig, %	57.1[b]	60.8[ab]	61.7[a]	61.8[a]	63.2[a]	1.2	0.03
SB passed in feces							
% feces DM	6.13[a]	3.10[b]	3.34[b]	2.27[c]	1.06[c]	6	0.001
% intake	12.0[a]	6.9[b]	7.8[b]	4.2[bc]	2.4[c]	1.3	0.006

Dhiman et al. 1997

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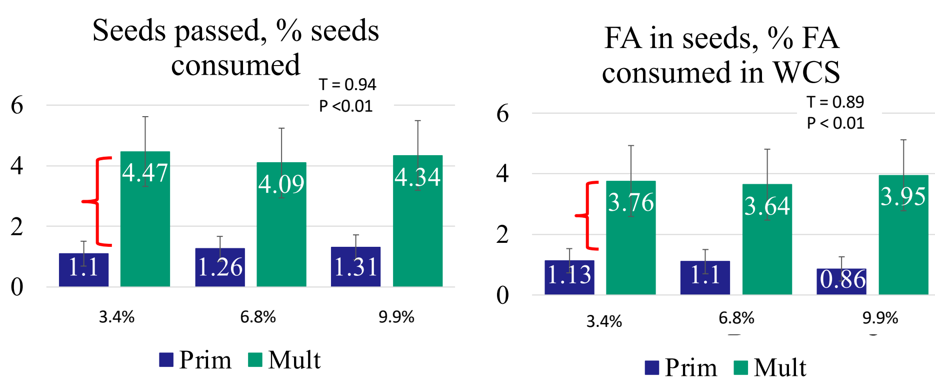
We similarly saw a small percent of whole cottonseed pass undigested in manure



Pierce et al. JDS 2023

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Another example, grinding may not increase digestibility beyond cracking

	CON	Whole	Crk	Grnd	SE	Lin	Quad
MY, kg	16.0	19.4	18.9	18.3	0.7	0.18	0.57
Fat, %	3.19	3.25	2.93	2.98	0.17	0.22	0.32
N Dig, %							
SI	66.3	67.3	69.9	70.1	1.6	0.08	0.25
TT	72.5	62.6	67.5	67.5	1.4	0.11	0.23
FA Dig, %							
SI	70.7	57.5	56.9	59.1	5.1	0.88	0.61
TT	73.0	60.5	60.2	61.4	3.7	0.74	0.53

Mean PS **2.65 mm** **0.63 mm**

Tice et al. 1993

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What data is there on feeding HO soybeans and expeller meal?

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Lopes et al. (2017) observed increased milk fat percent with HO expeller and roasted soybeans compared to conv. expeller

		Milk composition		
	Milk, lb	Fat, %	Fat, lb	t10 18:1, % FA
Conv. Expeller	93.9	3.55	3.37	0.48
HO Expeller	92.4	3.74	3.52	0.42
HO RWSB	92.0	3.76	3.52	0.40
P **(C vs HO Exp)**	NS	<0.01	NS	<0.01
P **(C vs RWSB)**	NS	<0.01	NS	<0.01

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Weld et al. (2018) first compared Conv. vs HO whole soybeans on an equal fat basis in primiparous and multiparous cows

	Milk composition			
	Milk, lb	Fat, %	Fat, lb	t10 18:1, % FA
Primiparous Cows				
Conv. WSB	89.1	4.13	3.63	0.30
HO WSB	84.5	4.08	3.48	0.23
Multiparous Cows				
Conv WSB	99.2	3.84	3.74	0.38
HO WSB	99.0	4.07	4.05	0.3
P (Conv vs HO)	NS	NS	NS	NS

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Weld et al. (2018) also compared a low-fat control to Conv and HO soybeans either as ground or whole beans

	Milk, lb	Fat, %	Fat, lb
Low Fat	105.6	3.25	3.39
Ground Raw Soybeans			
Conv	107.4	3.09	3.28
HO	103.8	3.50	3.61
Whole Raw Soybean			
Conv	106.7	3.40	3.61
HO	103.0	3.53	3.59
***P* (HO)**	<0.01	NS	NS
***P* (HO Grd)**	NS	<0.01	0.01
***P* (HO WSB)**	NS	NS	NS

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Increasing roasted soybeans from 5 to 10% increased milk fat at PSU

	Treatment Means[1]							
	Conv. Soybean		High 18:1 Soybean			*P*-Values[2]		
Item	5%	10%	5%	10%	SEM	Type	Level	Type* Level
Milk, kg/d	43.8	43.7	43.4	44.8	1.28	0.69	0.28	0.18
Milk Fat								
%	3.28	3.46	3.42	3.66	0.12	<0.05	0.01	0.69
g/d	1393	1464	1461	1574	108	0.08	0.01	0.55
Milk Fatty acids, % FA								
>16C[5]	37.4	41.5	37.8	41.5	0.70	0.42	<0.001	0.57
*t*10 C18:1	0.79	0.89	0.62	0.63	0.13	0.01	0.96	0.67
OBCFA	3.88	3.37	4.13*	3.66*	0.09	<0.001	<0.001	0.76

But, we have not been successful in titrating this effect with soybeans or cottonseed

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Increasing roasted HO soybeans tended to linearly increase milk fat in multiparous cows.

	High Oleic Soybean					*P*-Values		
	0%	5%	10%	15%	SEM	TxP	L	Q
Milk								
Fat, %	4.02	4.02	4.06	4.16	0.29	0.97	0.17	0.47
Prim.	4.07	4.08	4.15	4.24	0.11		0.44	0.75
Multi.	3.97	3.96	3.96	4.09	0.11		0.24	0.48
Fat, kg	1.62	1.63	1.67	1.71	0.16	0.19	0.10	0.80
Prim.	1.44	1.47	1.56	1.46	0.06		0.60	0.29
Multi.	1.80	1.79	1.79	1.96	0.06		0.07	0.16

Prim. = primiparous; Multi. = multiparous; Trt = treatment; TxP = the interaction effect of treatment and parity

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Increasing roasted HO soybeans linearly decreased de novo FA (<16C) and quadratically increased preformed FA (>16 C)

	High Oleic Soybean					*P*-Values		
	0%	5%	10%	15%	SEM	TxP	L	Q
∑<16 C	271	254	249	238	17.8	0.66	<0.001	0.52
∑ >16 C	328	363	383	404	29.6	0.13	<0.001	0.36
Trans-10, C18:1	0.43	0.44	0.45	0.46	0.05	0.26	0.06	0.70

Prim. = primiparous; Multi. = multiparous; Trt = treatment; TxP = the interaction effect of treatment and parity

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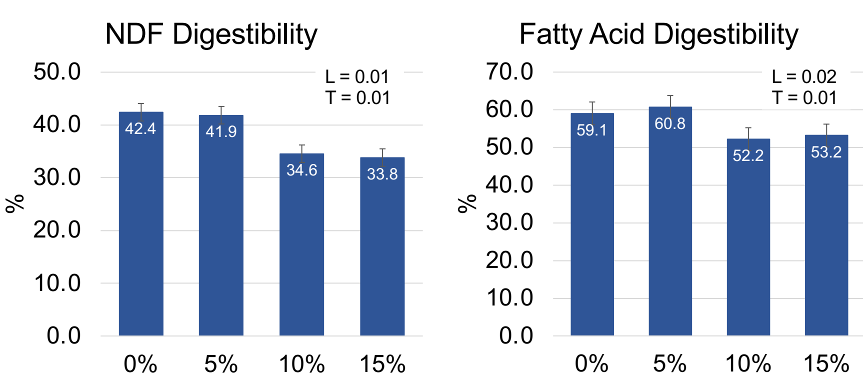
There was a linear decrease in NDF and FA digestibility, especially after 5% HO soybeans



Harvatine Lab, unpublished

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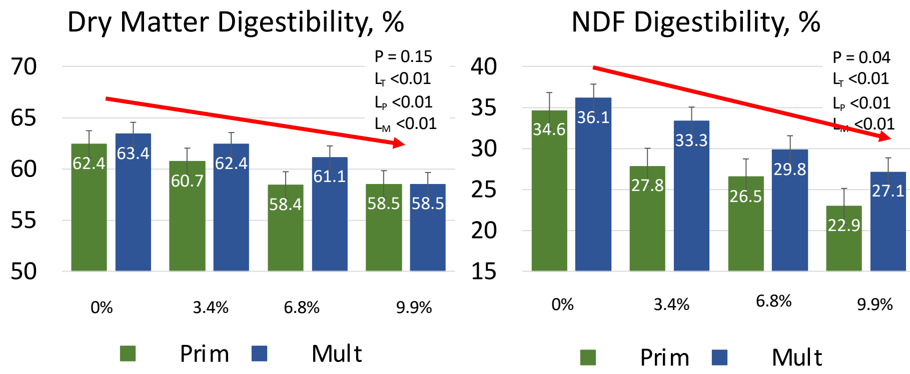
Dry matter and NDF digestibility were also decreased by increasing cottonseed



Pierce et al. JDS 2023

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We also compared HO expeller meal to conventional soybean meal and did not see a response with diets with low or moderate risk for MFD

	Treatment			*P* value		
Item	**CON**	**HO**	**SEM**	**Treatment**	**Phase**	**T*Ph**
Milk Yield, lb/d	108.2	110.2	4.91	0.12	0.11	0.64
Low-risk phase	107.6	108.9	4.98	0.44		
Moderate-risk phase	108.9	111.3	4.96	0.12		
Fat, %	3.42	3.48	0.11	0.50	0.01	0.76
Low-risk phase	3.70	3.73	0.14	0.83		
Moderate-risk phase	3.14	3.22	0.11	0.28		
Fat, lb/d	3.68	3.77	0.20	0.29	0.01	0.65
Low-risk phase	3.97	4.01	0.22	0.74		
Moderate-risk phase	**3.42**	**3.55**	0.20	0.24		

Burtnett et al. Unpublished

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Overall, what do high oleic soybean get us?

- Armentano and Harvatine review of data in 2022 concluded 65 g/d with ~5% feeding rate
- This agrees with Dorea and Armentano (2017) that each 1% of dietary C18:2 switched for C18:1 will result in a 44 g increase in milk fat.
  - A 1% substitution of C18:2 for C18:1 equates to substitution of conventional for high oleic soybeans at 5% of the diet (2.75 lb/d).

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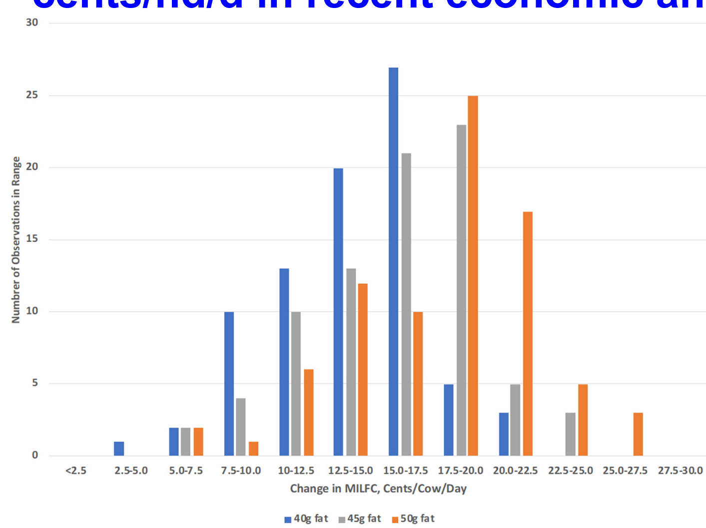
IOFC estimated to be 15 to 20 cents/hd/d in recent economic analysis



Nicolson et al. 2024 JDS

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Oleic acid may also have an impact on physiology when absorbed

Abou-Rjeileh et al. 2023 abomasally infused 50 g/d for the first 14 d of lactation

- Decreased plasma NEFA and ketones
- Inhibited decrease in adipocyte size at 14 d
- Increased insulin and decreased glucose clearance during a glucose tolerance test
- Increased insulin-stimulated lipolysis in explants
- Increased number of mitochondria in adipocytes

JDS 106:4306-4323

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Other common questions?

Should I still feed a dry fat supplement?
- Lock lab found little interaction of 10% cottonseed and PA supplements

How much oleic escapes the rumen?
- Probably not much based on the small increase in milk fat 18:2 with conventional soybeans

What is ”recommended feeding rate”?
- Depends on goal. Careful to least cost based both on FA and protein/AA balancing

Can I feed them raw?

- Trypsin inhibitor likely broken down in rumen
- Careful because urease activity will degrade urea
- Don’t store ground long- FA rancidity issues

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In summary, HO soybeans are a great opportunity for many dairies!

- Home-grown fatty acids!
- Reduces risk of rumen-available unsaturated FA
  - Allows higher feeding rates of soybean
- Rumen escape oleic may increase digestion of other fatty acids
- Moderate to high feeding rates depend on approach taken
  - Maximize amount of fat
  - RDP/RUP and amino acid balancing

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USDA United States Department of Agriculture National Institute of Food and Agriculture

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- Harvatine is the founder and owner of Hardscrabble Innovations LLC, an independent consulting LLC.
- Harvatine has also received speaking honorariums from Elanco Animal Health, Cargill, Virtus Nutrition, NDS, Nutreco, Mycogen, Holtz-Nelson Consulting, Renaissance Nutrition, Progressive Dairy Solutions, Intermountain Farmers Association, Diamond V, Purina, Pioneer, Adessio, Standard Nutrition, Hubbard, VitaPlus, and Milk Specialties Global.

Thank You!

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