U.S. Dairy Sector at Crossroads

2019 Midsouth Ruminant Nutrition Conference

Grapevine, TX
August 7, 2019
Dr. Marin Bozic

UNIVERSITY OF MINNESOTA
Driven to Discover℠

World Milk Production Growth is Slowing Down

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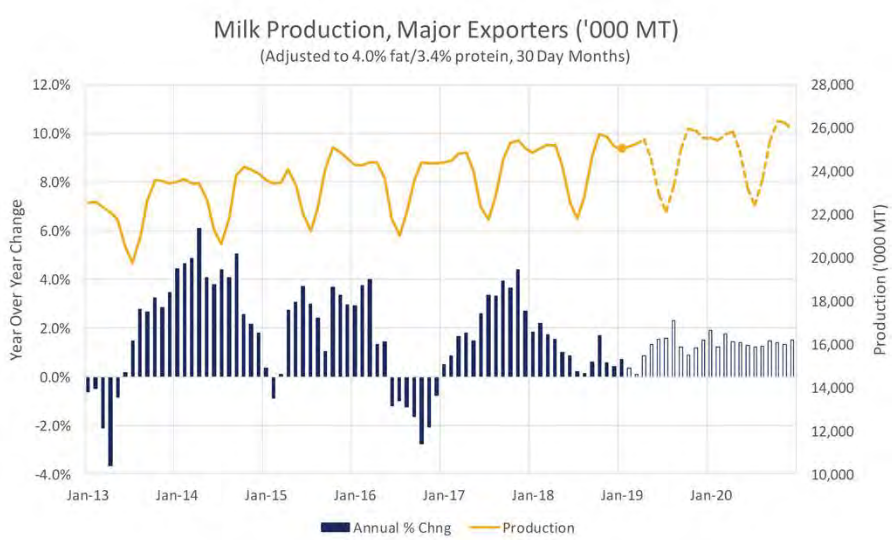

Source: INTLFC Stone, Reproduced with permission from Nate Donnay

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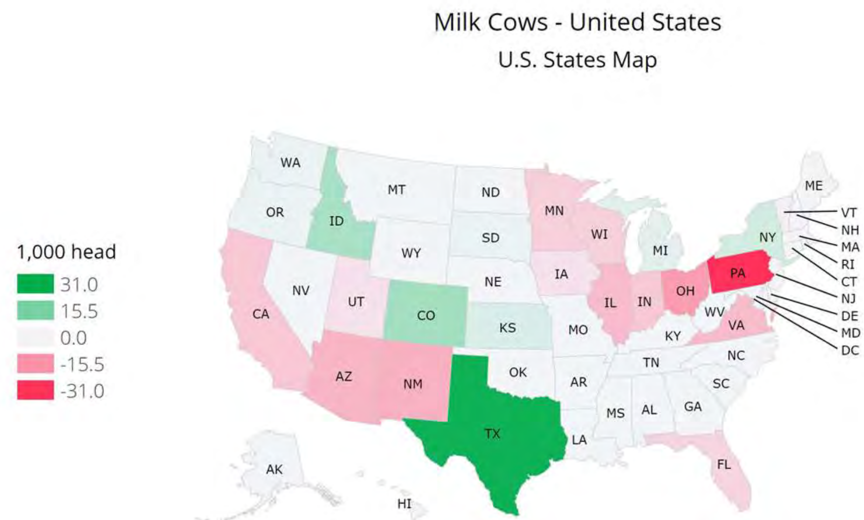
U.S. Dairy Herd: Year-on-Year Declines Almost in All States



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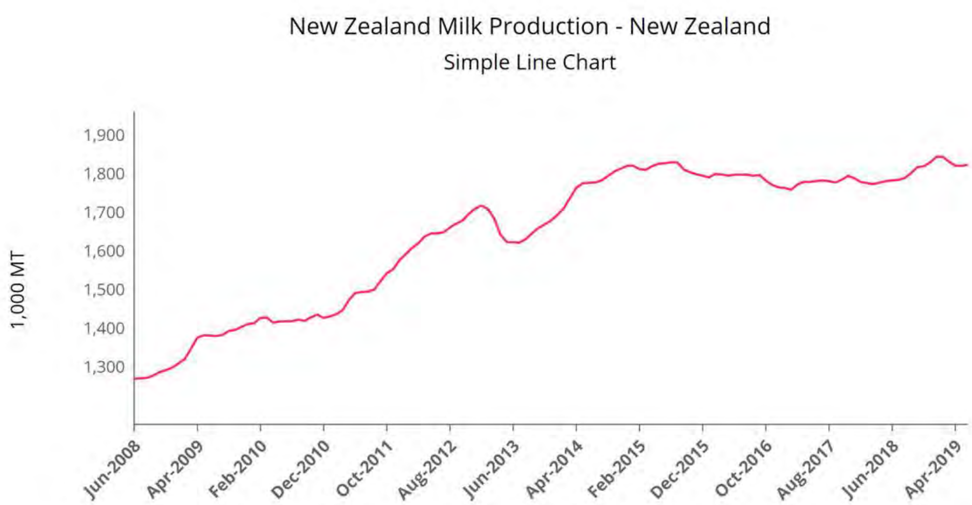
New Zealand Realizes It's an Island



When Production Slows, Prices Accelerate…

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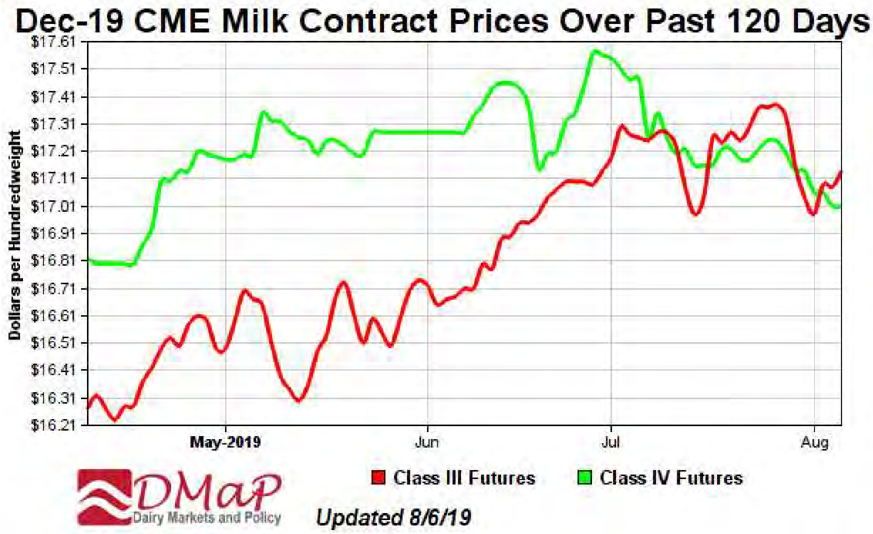

Slowing domestic and global milk production has lifted U.S. dairy prices.
Forecasted prices are $1.00-$1.50/cwt higher than in 2018.
But factors inflicting pain over 2015-2018 will remain, and need to be analyzed in detail…

Minnesota Dairy Farm – Net Return over Labor and Management

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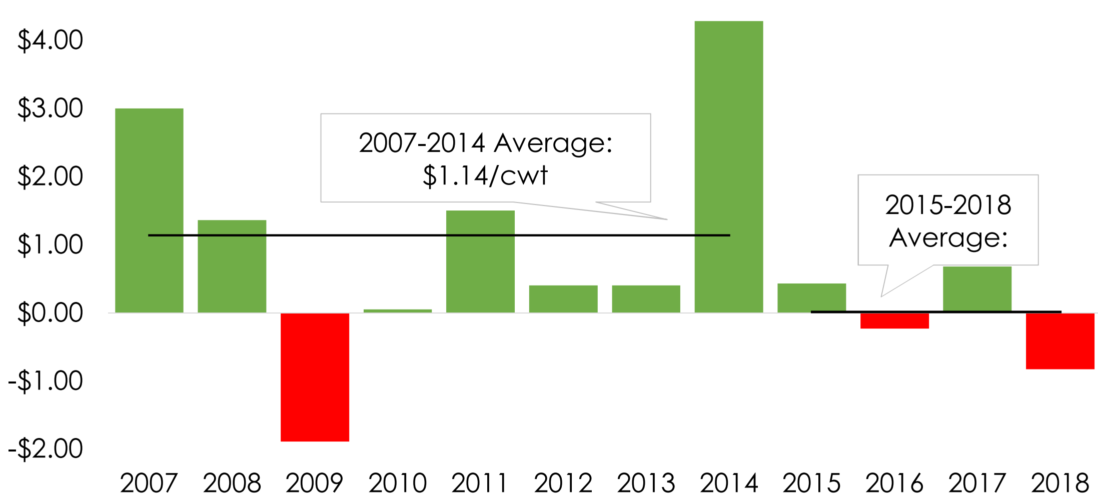

Source: CFFM FINBIN

2018 – the year that broke the dam

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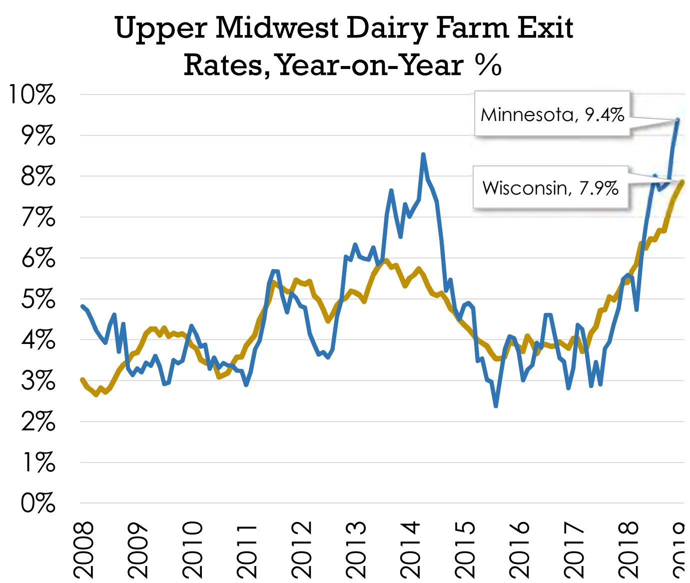

Consolidation pace over time

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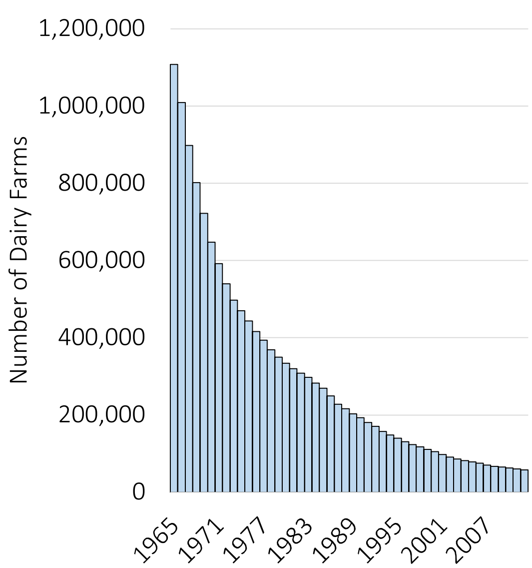

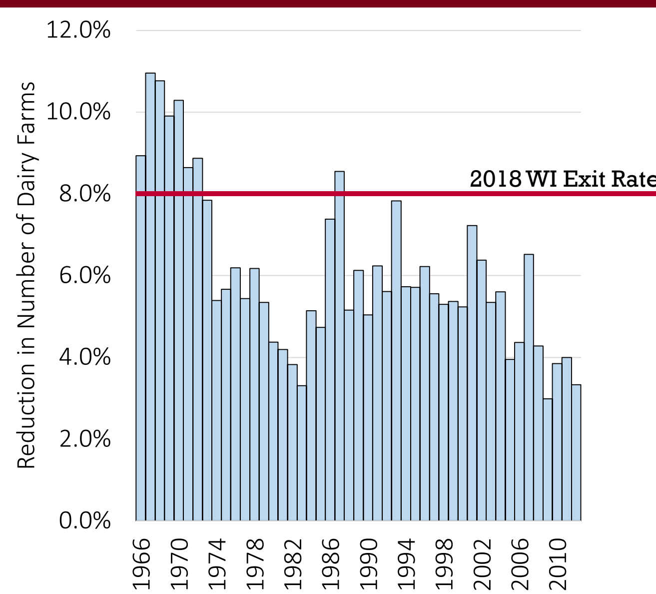

The number of dairy farms drops 40-50% every decade, while average farm size about doubles

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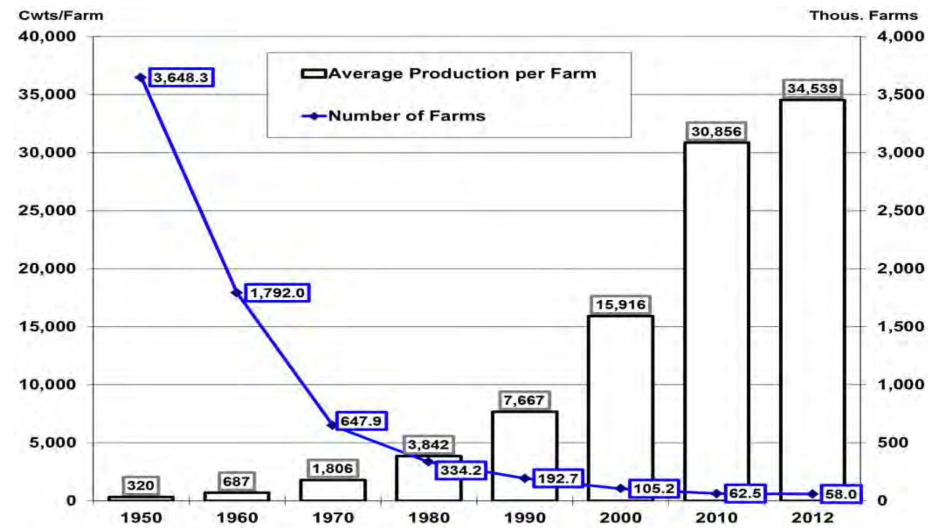

Source: Dr. Bob Yonkers, IDFA based on USDA, NASS

Changes in size and management/financing model

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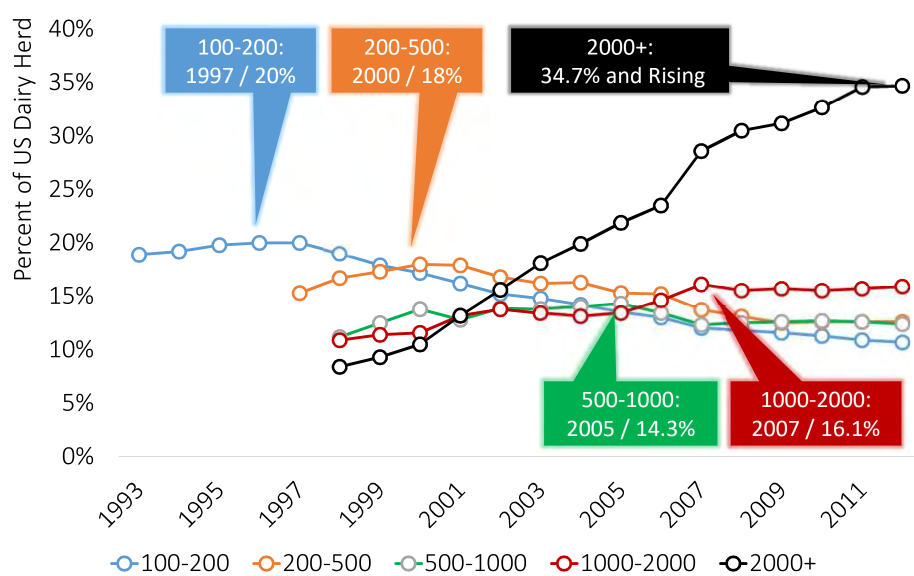
1) "large farms" → multi-site dairy agribusinesses
2) "family ownership" → non-family partnerships
3) external equity financing → no longer relying solely on retained earnings for expansions
4) No longer constrained to one milkshed → necessary to escape local processing capacity constraints
5) Larger % of milk by dairies that are not 'last-generation' dairies → exists are increasingly involuntary



U.S. Dairy Herd by Size of Operation

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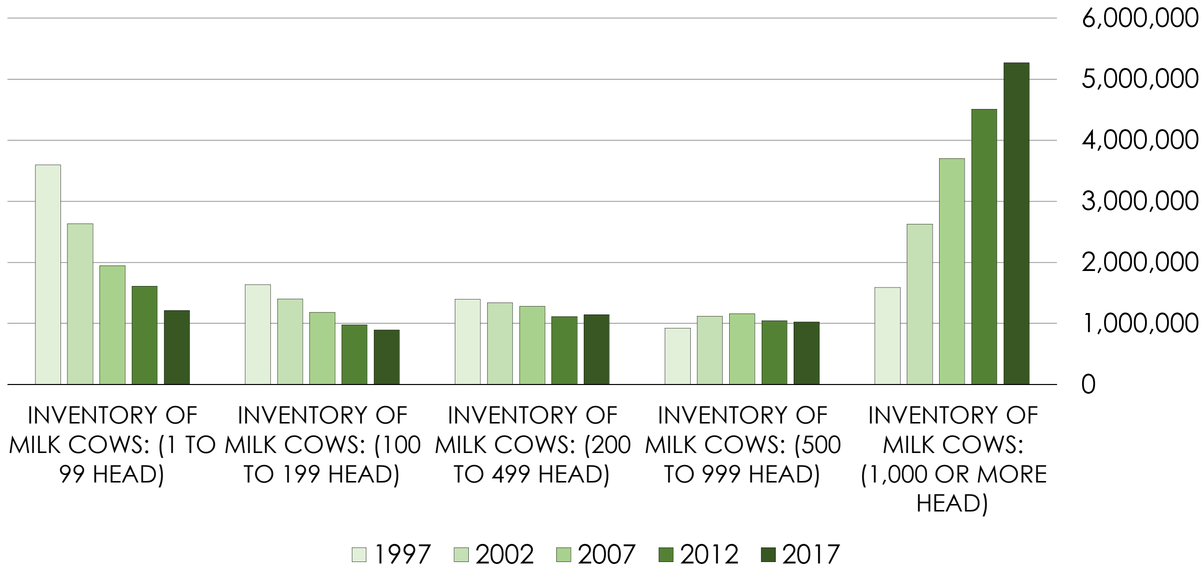

U.S. Dairy Herd by Size of Operation (2017)

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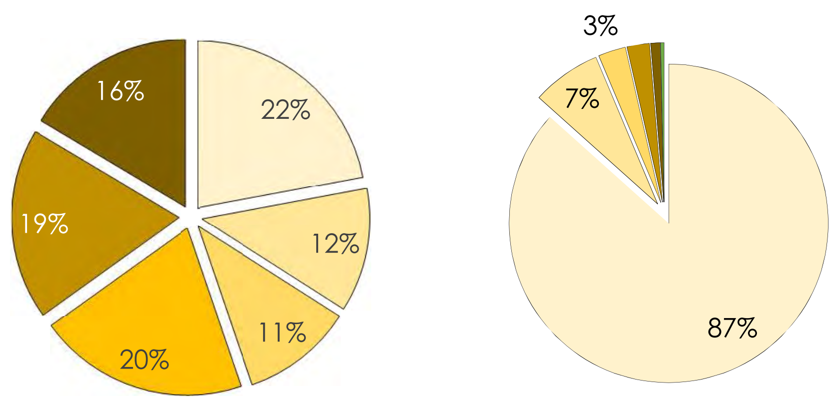
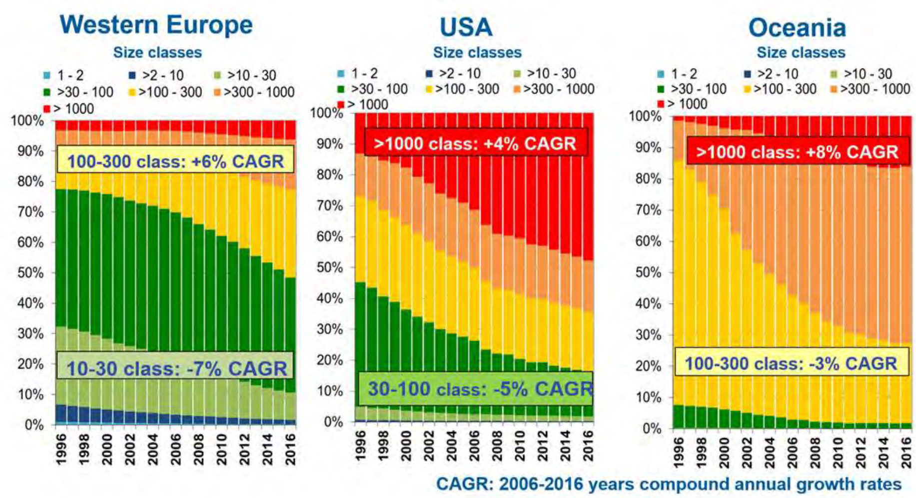


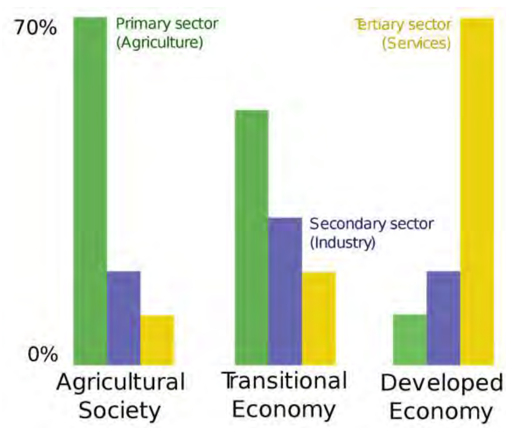
	< 200 HEAD	200 TO 499 HEAD	500 TO 999 HEAD	1,000 TO 2,499 HEAD	2,500 TO 4,999 HEAD	5,000 OR MORE HEAD
OPERATIONS	47,305	3,830	1,511	1,239	525	189
COWS	2,102,707	1,144,357	1,023,374	1,938,306	1,767,468	1,563,419

Dairy Herd Composition in 2016



Source: IFCN

Agricultural 'consolidation' is as old as the civilization itself



Agricultural surplus meant there was enough food around to feed soldiers, priests, artisans, government…
So why are we lamenting consolidation?

Dairy farm consolidation in United States under different exit rate scenarios

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Year	3%	7%	10%	15%
2018	**37,468**	**37,468**	**37,468**	**37,468**
2019	36,344	34,845	33,721	31,848
2020	35,254	32,406	30,349	27,071
2021	34,196	30,138	27,314	23,010
2022	33,170	28,028	24,583	19,559
2023	32,175	26,066	22,124	16,625
2024	31,210	24,241	19,912	14,131
2025	30,274	22,545	17,921	12,011
2026	29,365	20,966	16,129	10,210
2027	28,484	19,499	14,516	8,678
2028	27,630	18,134	13,064	7,376
2029	26,801	16,864	11,758	6,270
2030	25,997	15,684	10,582	5,330

Block-Barrel Spread is hurting Upper Midwest dairy producers

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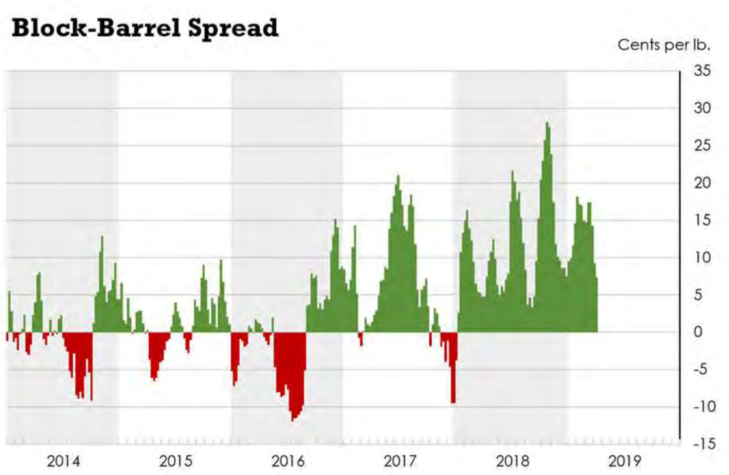
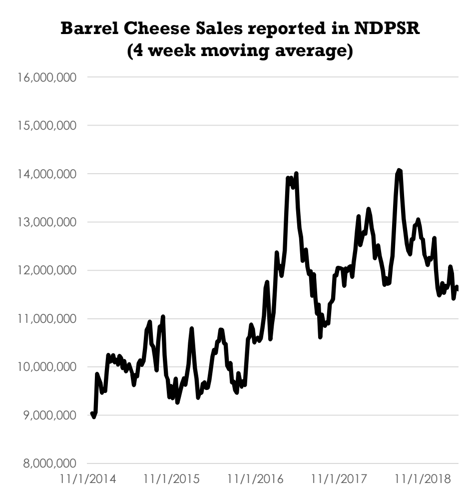
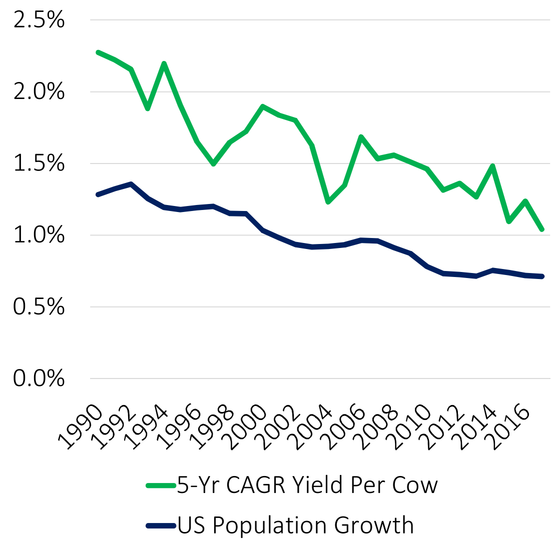
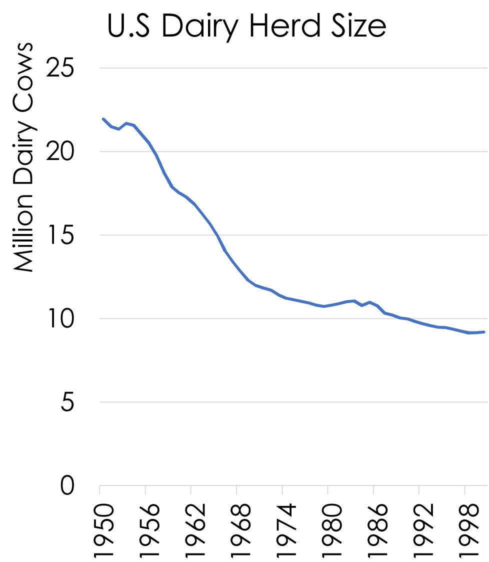




Implications of Cow Productivity Gains vs. Population Growth Rate





Cow Productivity Gains vs. U.S. Population Growth Rate: Implications

Supply
Milk pounds growth: 23,000 lbs/cow x 1% x 9,400,000 cows = 2.16 billion lbs
1.2% yield growth (276 lbs/cow or 0.75 lb/cow/day) → 2.6 billion lbs
1.5% yield growth (345 lbs/cow or 0.95 lb/cow/day) → 3.2 billion lbs

Demand
???

Historical U.S. per capita dairy consumption

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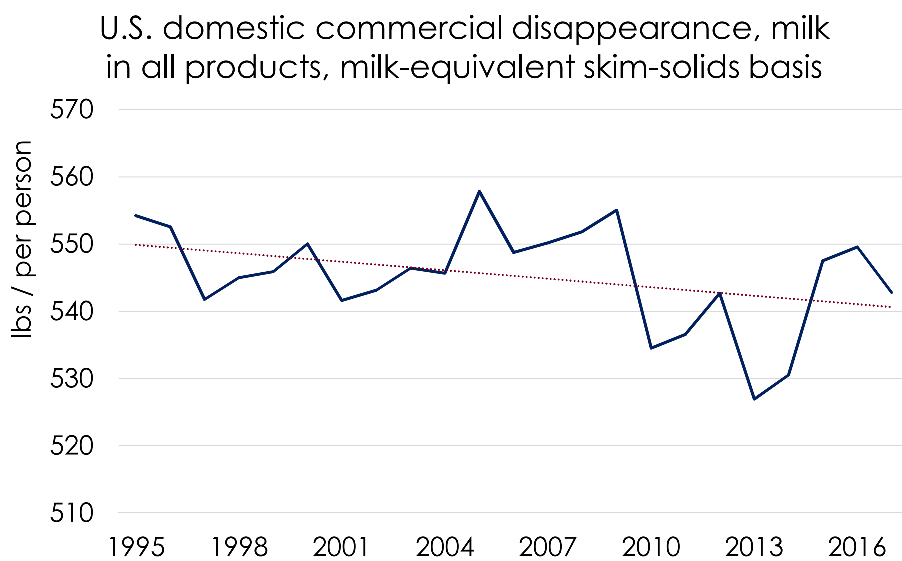

Historical U.S. per capita dairy consumption

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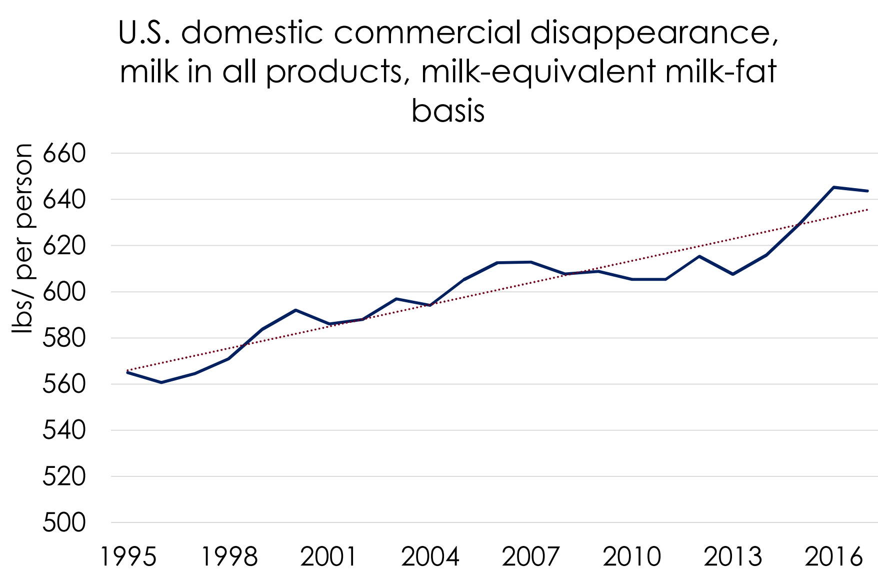

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Cow Productivity Gains vs. U.S. Population Growth Rate: Implications

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1.5% yield growth (345 lbs/cow or 0.95 lb/cow/day) → 3.2 billion lbs

Demand

Using per capita commercial disappearance, milk in all products, skim-solids basis (no per capita consumption growth)

542 lbs / per person x 330 million x 0.7% → 1.25 bil lbs

560 lbs / per person x 330 million x 0.7% → 1.29 bil lbs

Milk-fat basis

643 lbs / per person x 330 million x (0.7% + 0.5% per head) → 2.5 bil lbs

643 lbs / per person x 330 million x (0.7% + 1% per head) → 3.6 bil lbs

643 lbs / per person x 330 million x (0.7% + 2% per head) → 4.2 bil lbs

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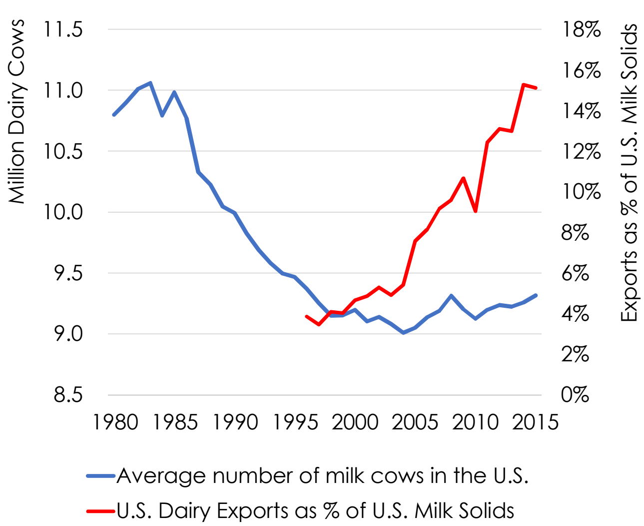
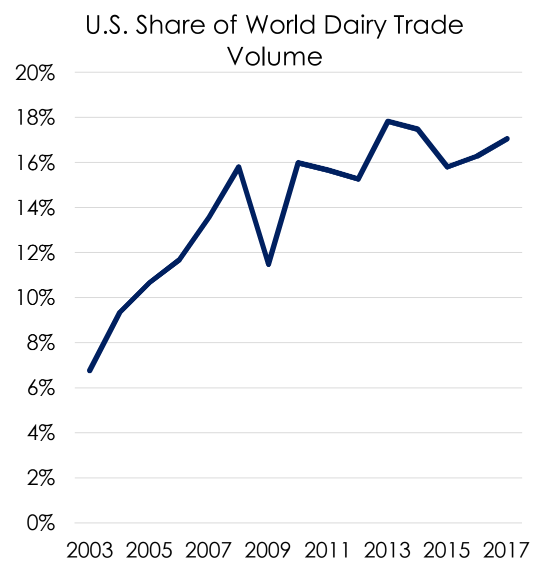
Why was the herd *stable* since 2000?





Golden era of U.S. exports lasted until 2015, when EU abolished milk quotas

Exports growth as % of milk production growth

Period	Milk-Fat Basis	Skim-Solids Basis
2007-2017	13%	59%
2007-2014	34%	79%
2014-2017	-31%	18%

To keep the U.S. dairy herd stable, U.S. needs to exports 40-50% of incremental skim solids (protein & lactose). The single most important reason why U.S. dairy producers did not enjoy decent profit margins since 2015 are languishing exports. Without exports, markets need to depress the milk price sufficiently to incentivize herd contraction.

REUTERS — Business Markets World Politics TV More

BUSINESS NEWS

Trump threatens action on WTO after reports he wants to withdraw

Forbes — Billionaires Innovation Leadership Money Consumer Industry Life

Trump Is Close To Shutting Down The WTO's Appeals Court

Menu Search — Bloomberg Businessweek

February 28, 2019, 3:00 AM CST

U.S.-China Negotiations Risk Shutting Out the Rest of the World

Most-favored-nation (MFN): treating other people equally. Under the WTO agreements, countries cannot normally discriminate between their trading partners. **Grant someone a special favor (such as a lower customs duty rate for one of their products) and you have to do the same for all other WTO members.**

Do these events confuse you?

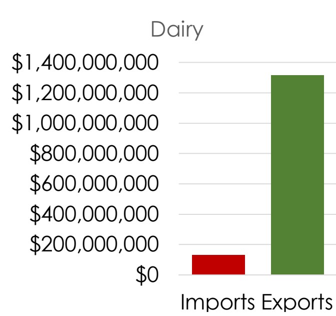
Donald J. Trump
@realDonaldTrump

Getting out of Syria was no surprise. I've been campaigning on it for years, and six months ago, when I very publicly wanted to do it, I agreed to stay longer. Russia, Iran, Syria & others are the local enemy of ISIS. We were doing there work. Time to come home & rebuild. #MAGA

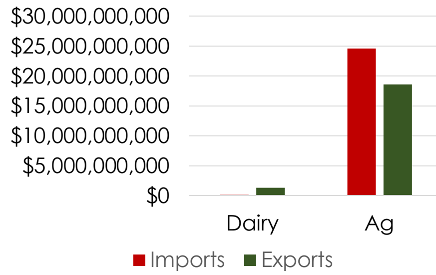
71.5K 6:42 AM - Dec 20, 2018

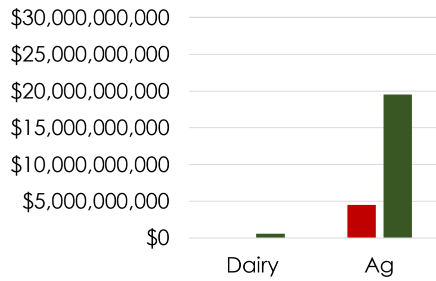
32.1K people are talking about this

U.S. Exports to Mexico and China

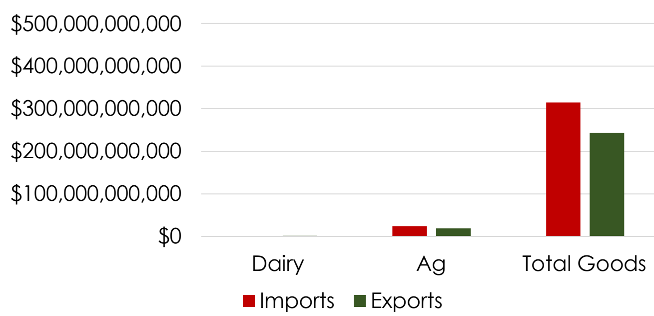


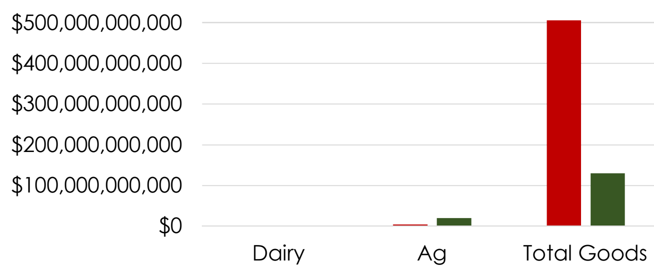
U.S. Exports to Mexico and China





U.S. Exports to Mexico and China






2019 Trade Policy Agenda
and
2018 Annual Report
of the President of the United States on the Trade Agreements Program

Office of the United States Trade Representative
Ambassador Robert E. Lighthizer

Source: https://ustr.gov/sites/default/files/2019_Trade_Policy_Agenda_and_2018_Annual_Report.pdf

"The current healthy state of the U.S. economy – and the recent boom in employment, including manufacturing employment – shows that the **U.S. government can and should adjust trade policy as necessary to avoid the type of challenges inherited by this Administration. Trade policy, like tax policy, must reflect the wishes, concerns, and priorities of the American people** – and should not be dictated by technocrats who are not responsible to Americans. The United States remains an independent nation, and our trade policy will be made here – not in Geneva. **We will not allow the WTO Appellate Body and dispute settlement system to force the United States into a straitjacket of obligations to which we never agreed."**

Meanwhile in China…


迪士尼中国
2013-9-2 17:31 专业版微博
#小熊维尼的智慧# 找到一样你所钟爱的事物，然后，永不放手。Find the thing you love and stick with it.


Xi Jinping becomes most powerful leader since Mao with China's change to constitution

Rare accolade puts Xi's Thought on Socialism with Chinese Characteristics into Communist charter and sets him on course for indefinite spell in power

Is Xi or isn't Xi? Who said it - Jinping or Mao Zedong?

China's Communist party enshrines Xi Jinping ideology in constitution – video

REUTERS

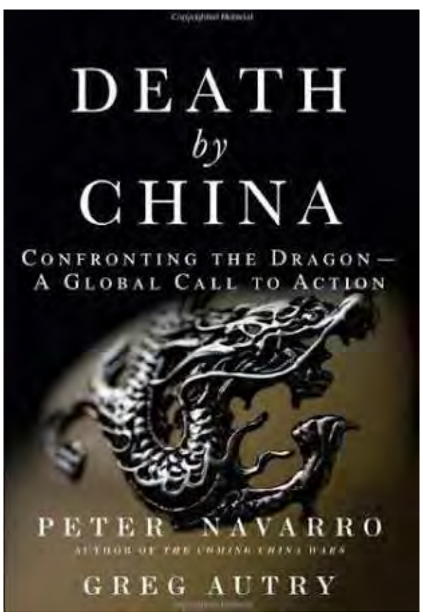
Business Markets World Politics TV More

WORLD NEWS OCTOBER 12, 2018 / 4:49 PM / 9 MONTHS AGO

U.S. security adviser Bolton vows tougher approach to China

5 MIN READ

WASHINGTON (Reuters) - U.S. national security adviser John Bolton has vowed to further intensify the Trump administration's tough approach to China, saying Beijing's "behavior needs to be adjusted in the trade area, in the international, military and political areas."



South China Morning Post

Top US negotiator Robert Lighthizer 'read Chinese the riot act' to get trade talks back on track, Larry Kudlow says

- US trade representative was not pleased when deputy-level negotiations hit an impasse last week, according to the White House economic adviser
- Kudlow appeared optimistic during an interview on CNBC, citing 'terrific' progress in talks

Owen Churchill
Updated: Friday, 1 Mar, 2019 11:31pm

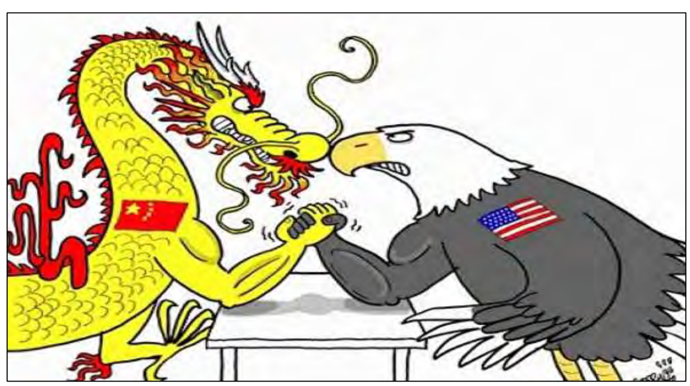
US Trade Representative Robert Lighthizer reportedly read the riot act to Chinese delegates during a stand-off in trade negotiations last week. Photo: Bloomberg

"Our Sovereign Lord the King chargeth and commandeth all persons, being assembled, immediately to disperse themselves, and peaceably depart to their habitations, or their lawful business, upon the pains contained in the Act made in the first year of King George the First for preventing tumults and riotous assemblies."

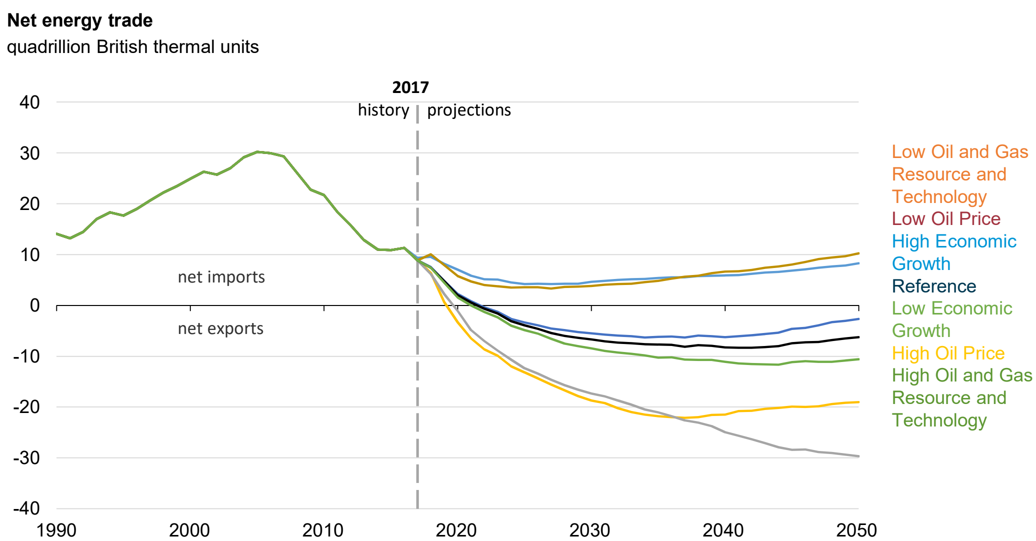
GOD SAVE THE KING

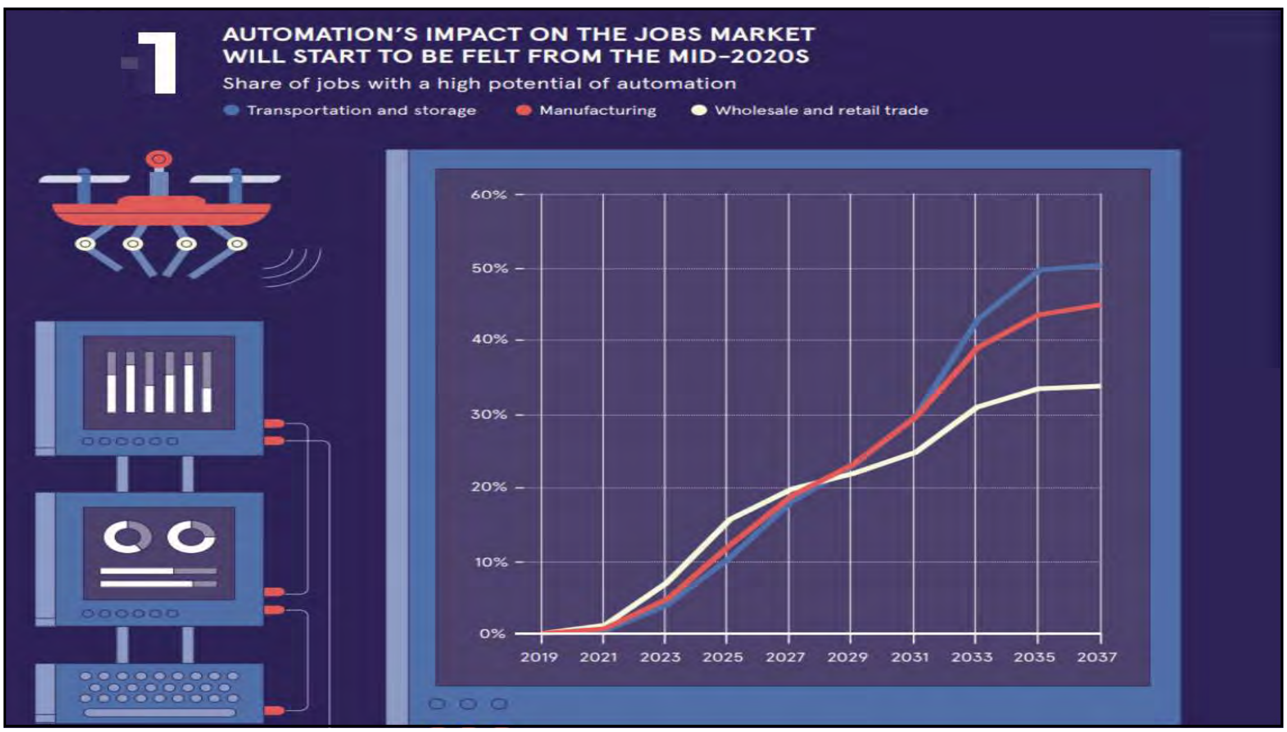
Does U.S. still have a primary strategic adversary?

If that is China, what is strategy for the new Cold War?

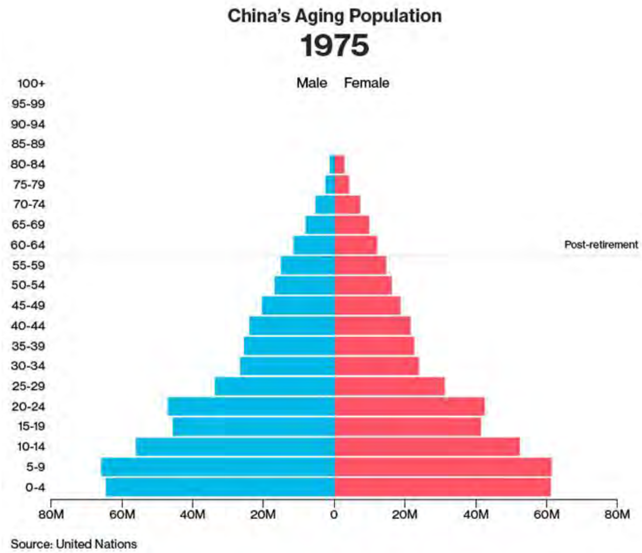


U.S. is Energy Independent





World is graying…



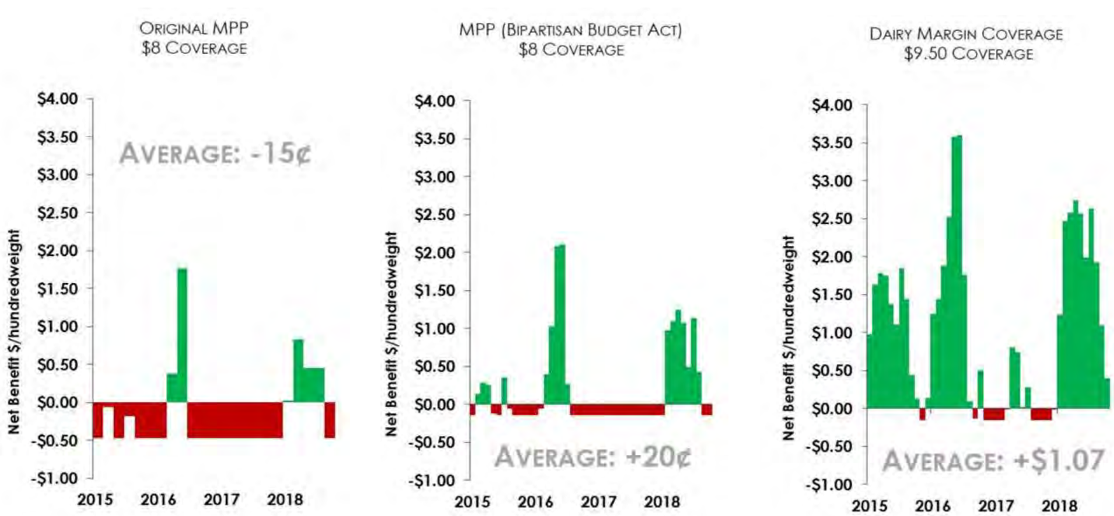
The world we face

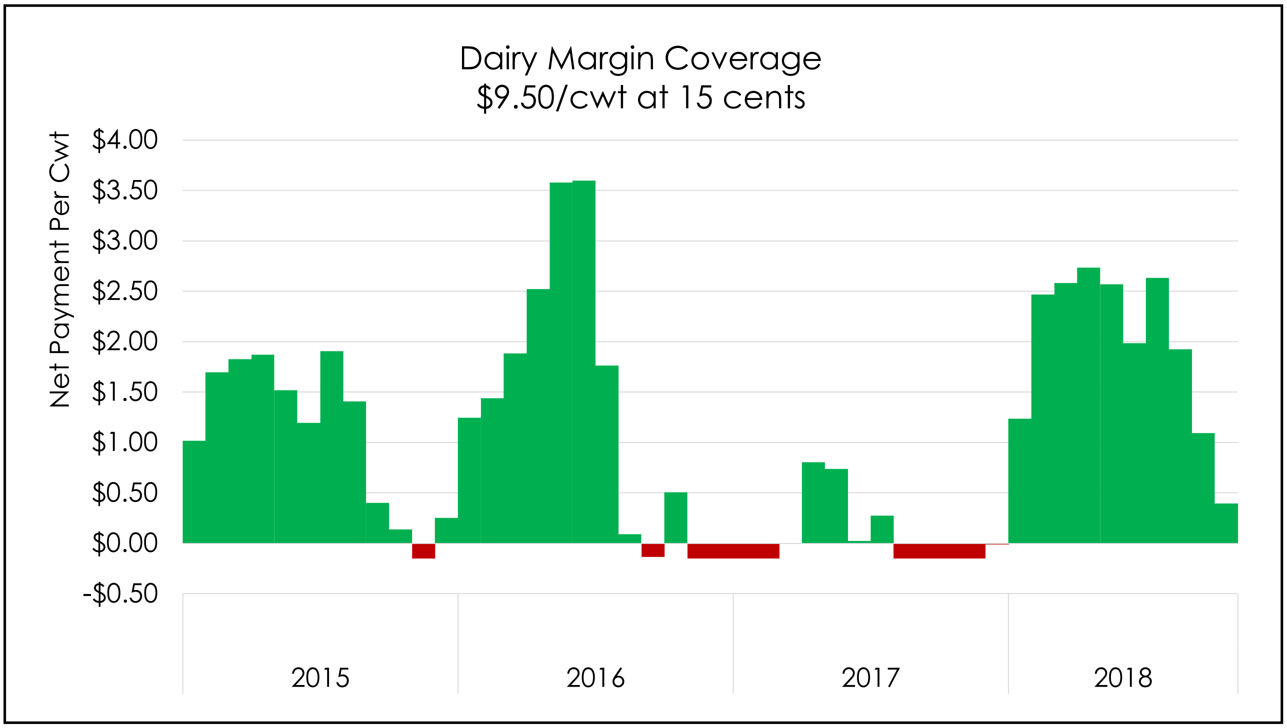
- Causes:
  - change in strategic adversary and optimal neutralization strategy (Russia to China)
  - Advances in artificial intelligence / robotics and impact on labor force
  - Energy independence
  - Aging population in countries providing cheap labor (e.g. China)
- Consequences:
  - Withdrawal from Trans Pacific Partnership and Paris Climate Agreement
  - Making conciliatory overtures to North Korea, abandoning Iraq, Syria, Afghanistan
  - New aggressively negotiated bilateral and regional trade agreements: South Korea, USMCA, Japan. Southeast Asia may follow
  - Trump wins 2nd term

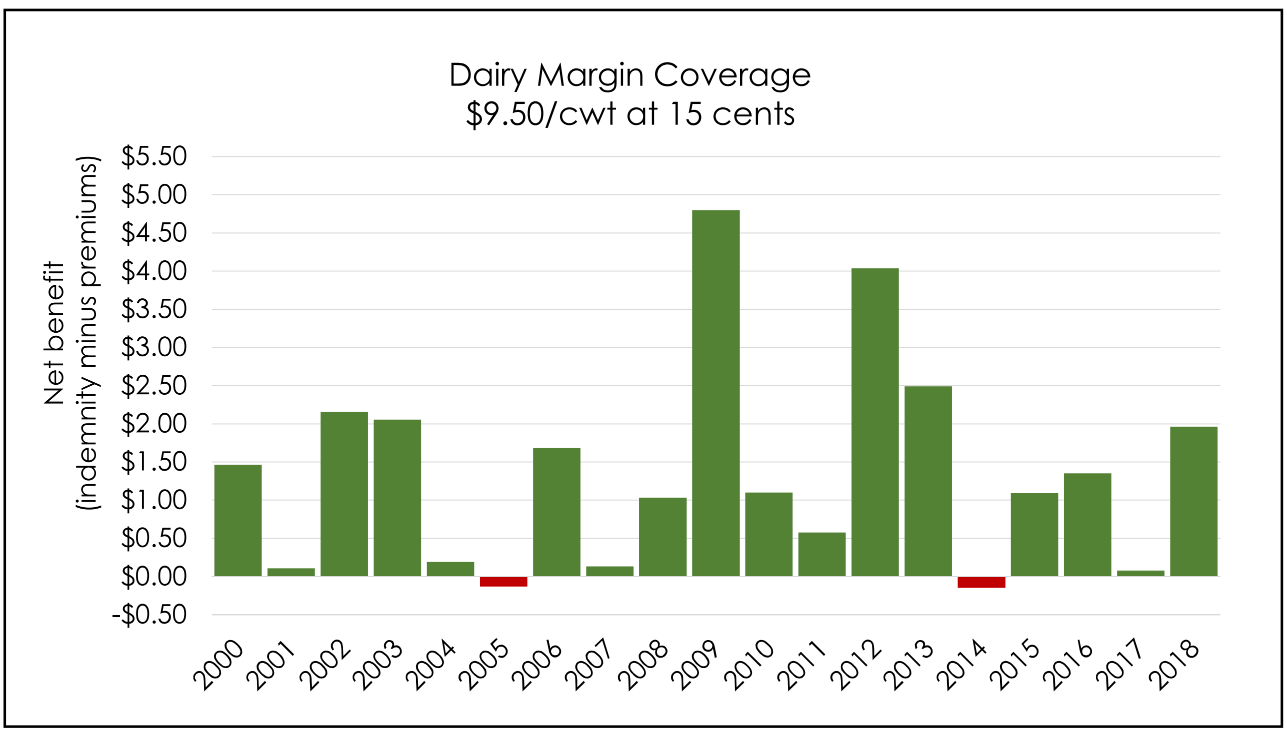
Implications for dairy

- USMCA will go through, tariffs will be dropped, exports to Mexico will resume, likely already in 2019
- FTA with Japan in 2019 or 2020
- FTA with Britain in 2020 – on U.S. terms
- 50% chance of deal with China in short-term. Strict implementation mechanism –U.S. to start making noise again after 2020 presidential elections
- Global recession coming soon (2020-21?) – global demand for dairy may be affected. U.S. may *not* import the recession.

Dairy Margin Coverage is a ***massive*** improvement over MPP




Dairy Margin Coverage
$9.50/cwt at 15 cents
Net Payment Per Cwt
$4.00
$3.50
$3.00
$2.50
$2.00
$1.50
$1.00
$0.50
$0.00
-$0.50
2015
2016
2017
2018


Dairy Margin Coverage
$9.50/cwt at 15 cents
Net benefit
(indemnity minus premiums)
$5.50
$5.00
$4.50
$4.00
$3.50
$3.00
$2.50
$2.00
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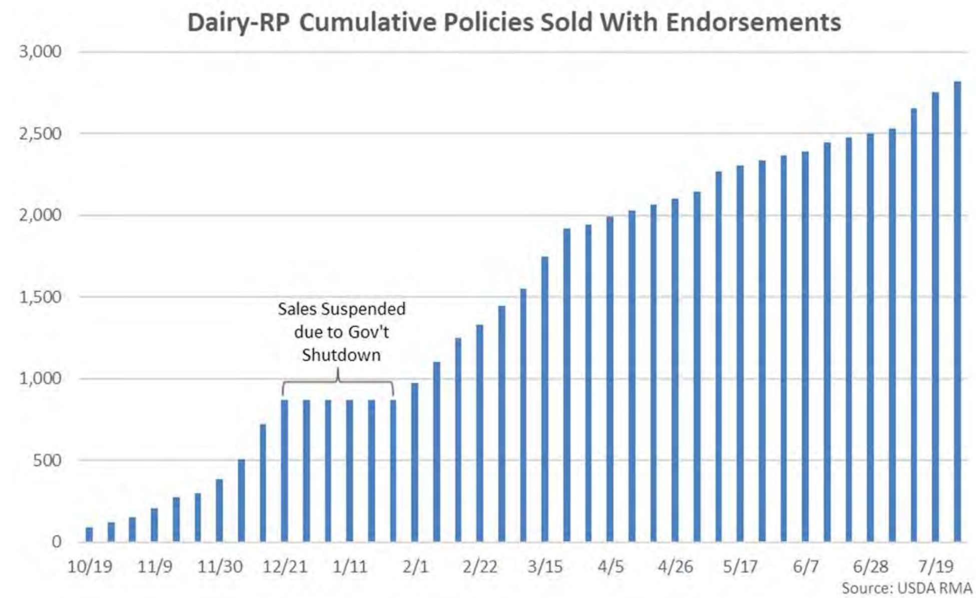
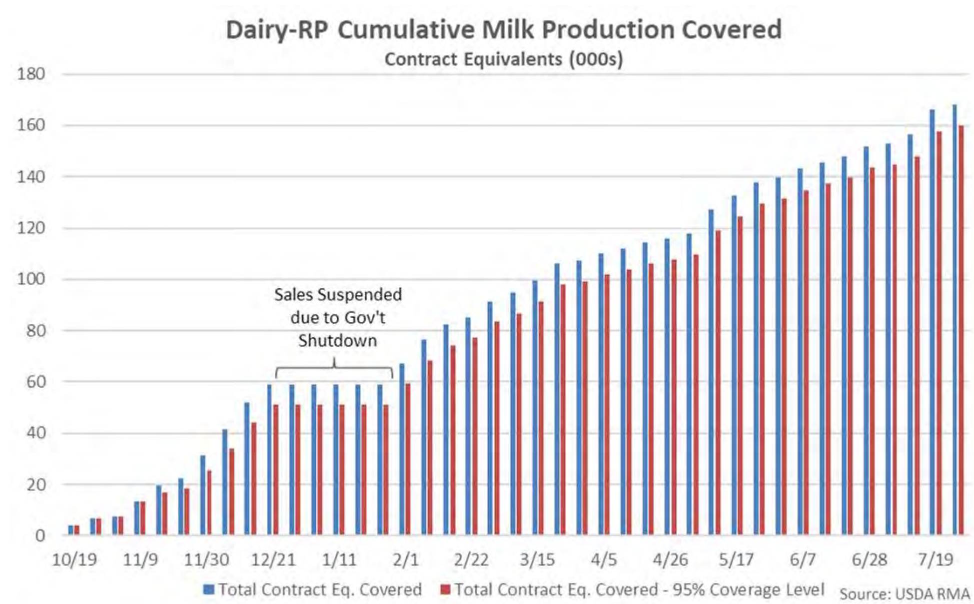


Source: Atten Babbler Insurance Services



Source: Atten Babbler Insurance Services

Historical Performance

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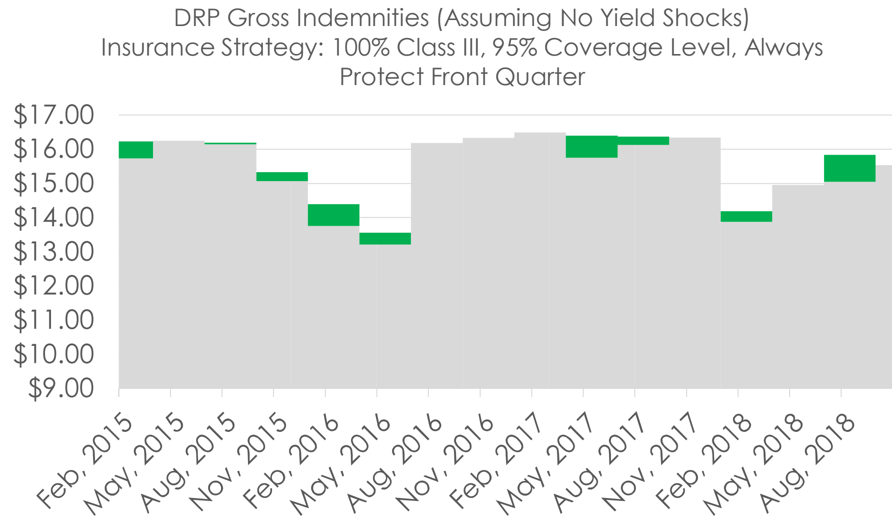

Historical Performance

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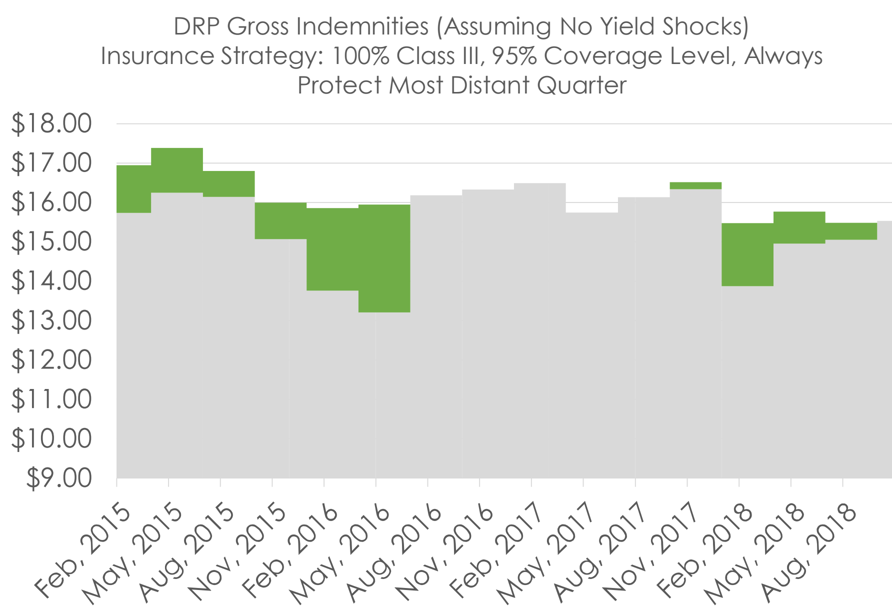

The road ahead

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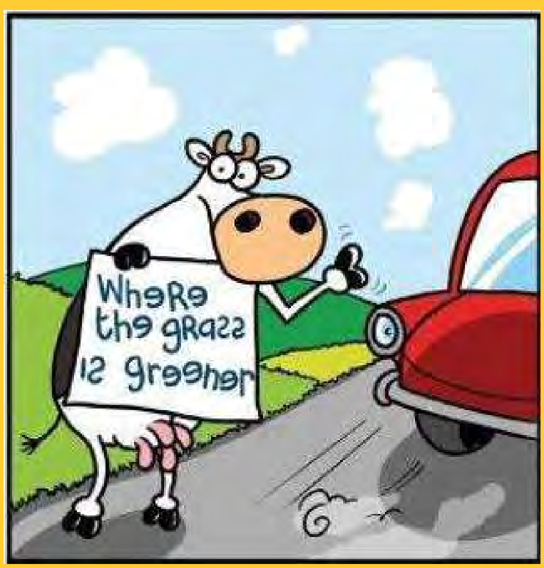
- Global and US Milk Production slowing, prices expected $1-$1.50 higher in 2019 vs 2018.
- Productivity gains, changes in dairy production models, liberalization of milk production in EU and trade disorders are factors driving consolidation in U.S.
- Recent changes in U.S. dairy safety net will likely slow down U.S. consolidation rates in Q4 2019 and later. As small dairy farms (under 300 cows) start feeling less pressure to exit, medium-size farms (500-2000 cows) will carry more of the burden for matching supply and demand, and we may see higher exit rate in this category.
- Adverse block – barrel spread will continue to burden Minnesota, and to some extent Wisconsin dairy sectors – regional exit rates likely to stay higher than national.



Thank You!

Dr. Marin Bozic
mbozic@umn.edu
Department of
Applied Economics
University of
Minnesota-Twin Cities
317c Ruttan Hall
1994 Buford Avenue
St Paul, MN 55108

Dry Period Heat Stress: Carryover Effects on Dam and Daughter

G. E. Dahl
Department of Animal Sciences
Institute of Food and Agricultural Sciences
gdahl@ufl.edu

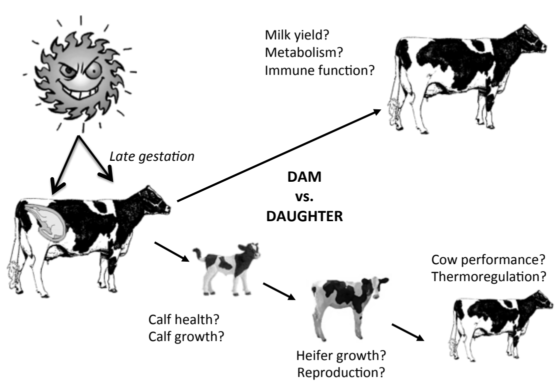
Mid-South Ruminant Nutrition Conference
6 August 2019

UF | UNIVERSITY of FLORIDA

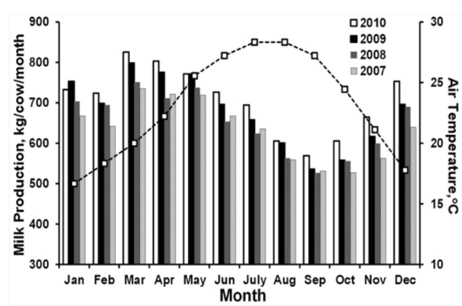
Heat Stress During Lactation

- Depresses DMI
- Reduces milk yield
- Recent studies suggest additional metabolic effects beyond DMI
- Recovery dependent on duration

What about dry cows?

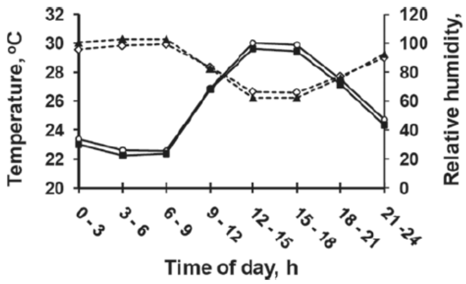


Heat Stress Effects on Yield Linger



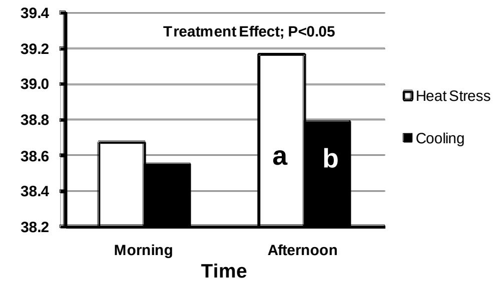
Tao & Dahl, *J. Dairy Sci.* 96:4079-4093

Study Design: Heat Load of Dry Cows



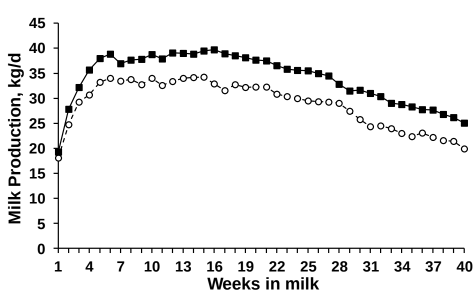
Do Amaral et al., *J. Dairy Sci.* 94:86–96

Heat Stress Increases Mean Rectal Temperature



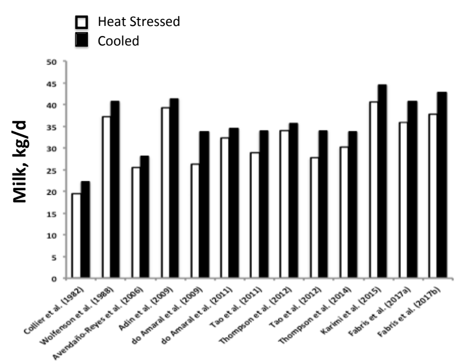
Do Amaral et al., *J. Dairy Sci.* 94:86–96

Cooling Dry Cows Increases Milk

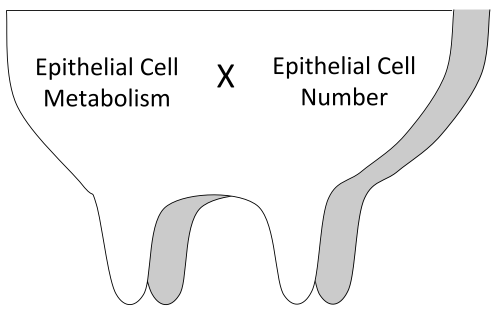


Tao et al., *J. Dairy Sci.* 94:5976–5986

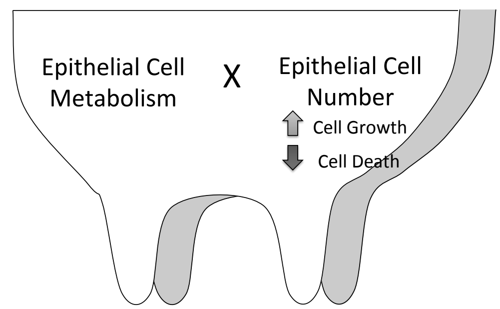
Cooling Dry Cows Increases Milk



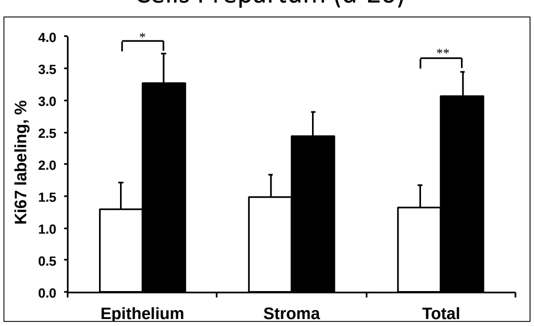
Milk Production



Milk Production

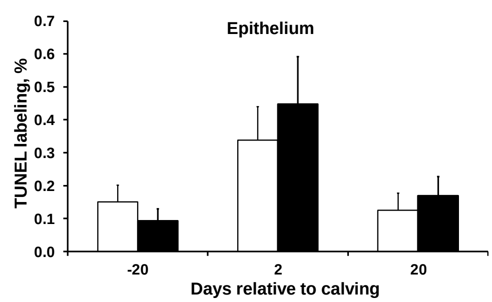


Cooling Increased Proliferation of Mammary Cells Prepartum (d-20)



Tao et al., *J. Dairy Sci.* 94:5976–5986

Heat Stress During Dry Period – No Effect on MEC Apoptosis

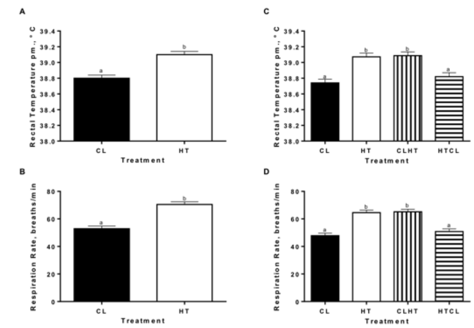


Tao et al., *J. Dairy Sci.* 94:5976–5986

Dry Period Cooling Duration

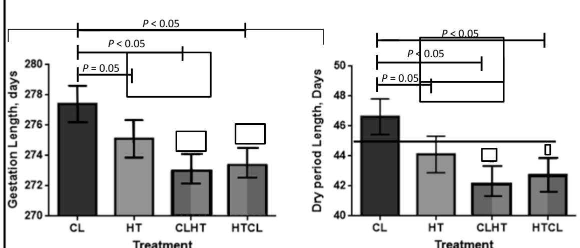
- Do I have to cool cows the entire dry period?
- Can I just cool during the close-up phase?

Heat Stress Increases Rectal Temperature and Respiration Rate



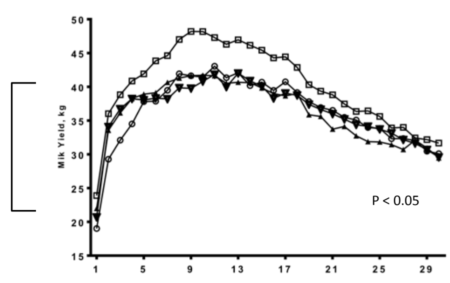
Fabris et al., *J. Dairy Sci.*, 102:5647-5656

Heat Stress Decreases Gestation Length and Dry Period Length at Any Time



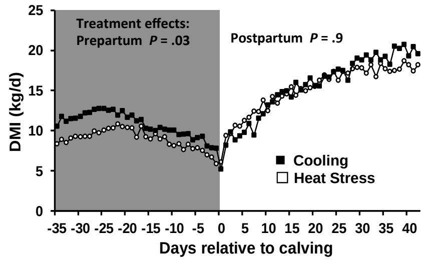
Fabris et al., *J. Dairy Sci.*, 102:5647-5656

Heat Stress Imposed at Any Time in the Dry Period Reduces Milk Yield



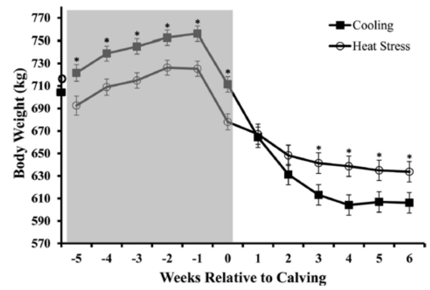
Fabris et al., *J. Dairy Sci.*, 102:5647-5656

Heat Stress Reduces DMI Prepartum But Not Postpartum



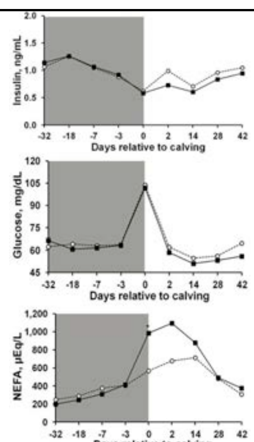
Tao et al., *J. Dairy Sci.* 94:5976–5986

Cooling Dry Cows Increases BW Prepartum, Decreases Postpartum



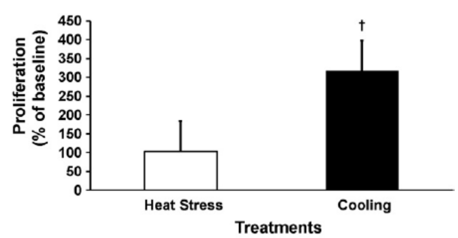
Thompson et al., *J. Dairy Sci.* 97:7426-7436

Effect of Cooling Dry Cows on Metabolic Profile



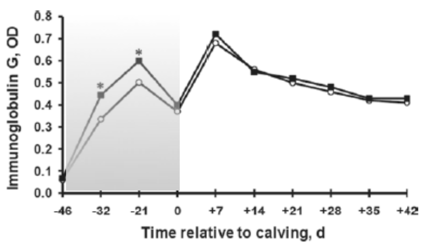
Tao et al., *J. Dairy Sci.* 95:5035-5046

Cooling Dry Cows Increases Lymphocyte Proliferation



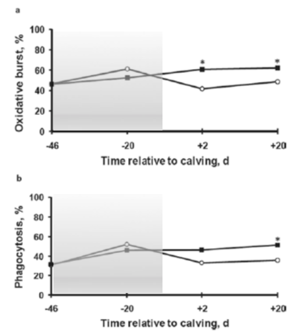
Do Amaral et al., *Domest. Anim. Endo.* 38:38-45

Cooling Dry Cows
Effects on Acquired Immunity



Do Amaral et al., *J. Dairy Sci.* 94:86–96

Cooling Dry Cows Increases
Neutrophil Action Postpartum



Do Amaral et al., *J. Dairy Sci.* 94:86–96

Dry in COOL Months Improves Performance

Table 1. Milk production and occurrence of mastitis, digestive and respiratory problems, retained fetal membranes, and metritis in cows dried during HOT months (Jun, Jul, Aug) or COOL months (Dec, Jan, Feb) in the first 80 DIM of the subsequent lactation

	Dry during HOT months (Jun, Jul, Aug), n = 1,569				Dry during COOL months (Dec, Jan, Feb), n = 1,044				
Item	Value	Disease[1]	n	%	Value	Disease[1]	n	%	*P*-value
Milk production (kg)	10,351 ± 59.8				10,902 ± 73.3				0.01
Mastitis		0	1,286	82.0		0	950	91.0	0.01
		1	283	18.0		1	94	9.0	
Digestive		0	1,516	96.6		0	973	93.2	0.01
		1	53	3.4		1	71	6.8	
Respiratory		0	1,346	85.8		0	942	90.2	0.01
		1	223	14.2		1	102	9.8	
Retained fetal membranes		0	1,500	95.6		0	1,013	97.0	0.06
		1	69	4.4		1	31	3.0	
Metritis		0	1,500	95.6		0	1,007	96.4	0.35
		1	67	4.2		1	38	3.5	

[1]Disease: 0 = cows without the disease; 1 = cows with the disease.

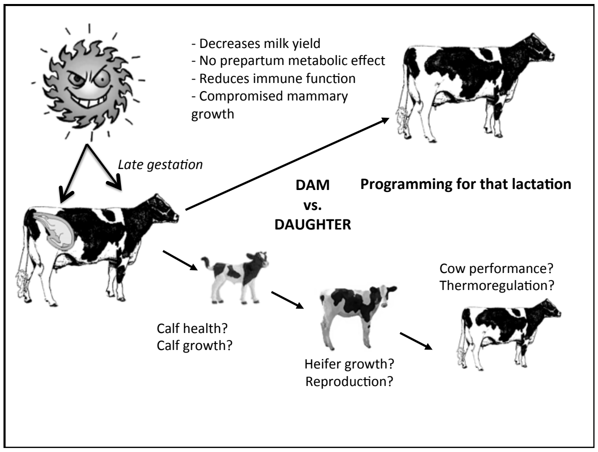
Thompson & Dahl, *Prof. Anim. Sci.* 28:628-631

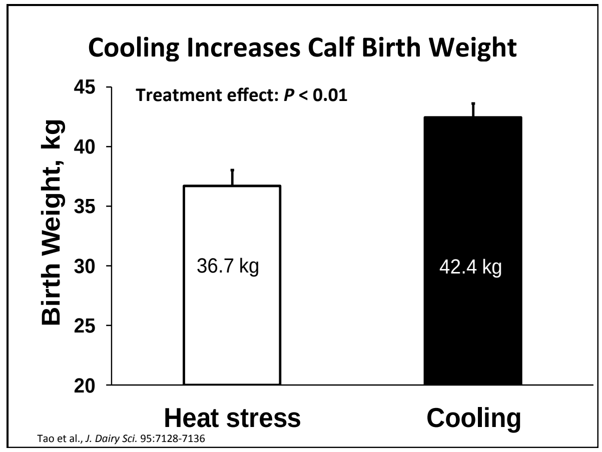
Dry in COOL Months Improves Reproductive Performance

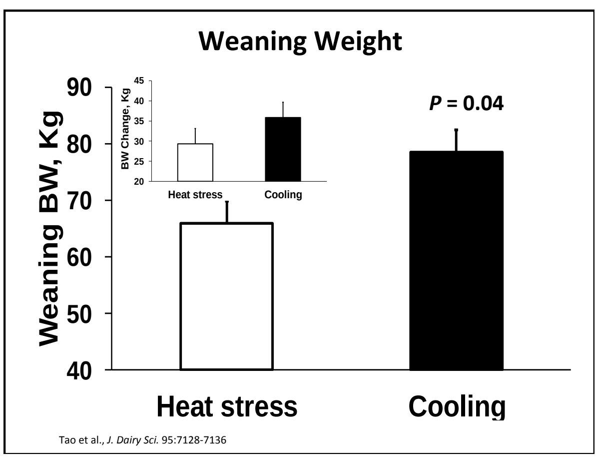
Table 3. Milk production and reproductive performance of cows dried during HOT months (Jun, Jul, Aug) or COOL months (Dec, Jan, Feb) in the first 150 DIM of the subsequent lactation on a commercial farm in Florida

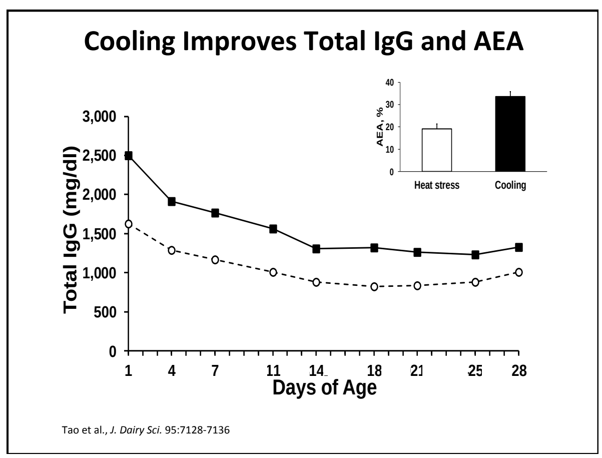
Item	Dry during HOT months (Jun, Jul, Aug)	Dry during COOL months (Dec, Jan, Feb)	*P*-value
Milk production (kg)	10,547 ± 67.0	11,005 ± 83.38	0.01
Number of breedings (n)	1,048	676	0.03
Mean (no.)	1.59 ± 0.02	1.51 ± 0.03	
DIM to breeding (n)	1,047	676	0.01
Mean (d)	97.0 ± 0.74	91.8 ± 0.92	
DIM to pregnancy (n)	1,051	679	0.01
Mean (d)	131.1 ± 0.85	125.9 ± 1.06	

Thompson & Dahl, *Prof. Anim. Sci.* 28:628-631

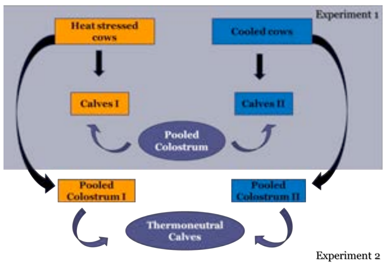

- Decreases milk yield
- No prepartum metabolic effect
- Reduces immune function
- Compromised mammary growth
Late gestation
DAM
vs.
DAUGHTER
Programming for that lactation
Calf health?
Calf growth?
Heifer growth?
Reproduction?
Cow performance?
Thermoregulation?


Cooling Increases Calf Birth Weight
Treatment effect: P < 0.01
Birth Weight, kg
45
40
35
30
25
20
36.7 kg
42.4 kg
Heat stress
Cooling
Tao et al., J. Dairy Sci. 95:7128-7136


Weaning Weight
Weaning BW, Kg
90
80
70
60
50
40
BW Change, Kg
45
40
35
30
25
20
Heat stress
Cooling
P = 0.04
Heat stress
Cooling
Tao et al., J. Dairy Sci. 95:7128-7136

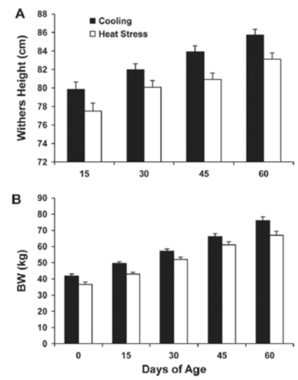

Cooling Improves Total IgG and AEA
Total IgG (mg/dl)
3,000
2,500
2,000
1,500
1,000
500
0
1
4
7
11
14
18
21
25
28
Days of Age
AEA, %
40
30
20
10
0
Heat stress
Cooling
Tao et al., J. Dairy Sci. 95:7128-7136

Why Does Cooling Affect AEA? Calf or Colostrum Effect?



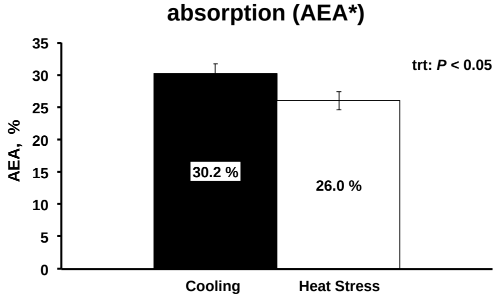
Monteiro et al., *J. Dairy Sci.* 97:6426-6439

Experiment 1 - In utero heat stress for ~6 weeks reduces body weight and height to weaning



Monteiro et al., *J. Dairy Sci.* 97:6426-6439

Cooling Increased Apparent efficiency of IgG absorption (AEA*)



* AEA = [Serum [IgG] (g/L) * birth weight (kg) * 0.091 / IgG fed (g)] x 100

Experiment 2 – **No Effect** of Colostrum from Cooled or Heat Stressed Cows on Calf Performance

Growth performance of calves born to cows under thermoneutral conditions during the dry period and fed frozen colostrum from cows exposed to either heat stress or cooling during the dry period

Parameter	Heat Stress LSM ± SE	Cooling LSM ± SE	*P*-value
Birth Weight (kg)	38.8 ± 1.4	39.2 ± 1.5	0.8
Weaning Weight (kg)[1]	68.4 ± 2.5	64.8 ± 2.6	0.4
Preweaning BW Gain (kg)[2]	29.6 ± 2.3	25.6 ± 2.4	0.3
Avg. Daily Gain (kg/d)	0.49 ± 0.7	0.43 ± 0.8	0.2
Weaning Withers Height (cm)[1]	84.3 ± 0.8	83.0 ± 0.9	0.4
Preweaning Height Increase (cm)[2]	7.8 ± 1.1	6.2 ± 1.0	0.3

[1]Weaning weight and weaning height were measured at d 60 of age.
[2]Preweaning BW gain and height increase was calculated by individually subtracting data at d 60 of age by data at birth.

Monteiro et al., *J. Dairy Sci.* 97:6426-6439

Heat Stress Summary – Short Term Effects on Calves

- Cooling increases weight at birth and weaning
- In utero heat stress reduces apparent efficiency of IgG absorption, but not an effect on colostrum quality
- In utero heat stress alters carbohydrate metabolism, consistent with greater fat deposition

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Heat-stress abatement during the dry period: Does cooling improve transition into lactation?

B. C. do Amaral,* E. E. Connor,† S. Tao,* J. Hayen,* J. Bubolz,* and G. E. Dahl*[1]
*Department of Animal Sciences, University of Florida, Gainesville 32611
†Bovine Functional Genomics Laboratory, USDA-ARS, Beltsville Agricultural Research Center, Beltsville, MD 20705

J. Dairy Sci. 94:86–96
doi:10.3168/jds.2009-3004
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Heat stress abatement during the dry period influences metabolic gene expression and improves immune status in the transition period of dairy cows

B. C. do Amaral,*[1] E. E. Connor,† S. Tao,* M. J. Hayen,* J. W. Bubolz,* and G. E. Dahl*[2]
*Department of Animal Sciences, University of Florida, Gainesville 32611
†Bovine Functional Genomics Laboratory, USDA-ARS, Beltsville Agricultural Research Center, Beltsville, MD 20705

J. Dairy Sci. 94:5976–5986
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Effect of heat stress during the dry period on mammary gland development

S. Tao, J. W. Bubolz, B. C. do Amaral,[1] I. M. Thompson, M. J. Hayen, S. E. Johnson, and G. E. Dahl[2]
Department of Animal Sciences, University of Florida, Gainesville 32611

J. Dairy Sci. 95:5035–5046
http://dx.doi.org/10.3168/jds.2012-5405
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Effect of cooling heat-stressed dairy cows during the dry period on insulin response

S. Tao,* I. M. Thompson,* A. P. A. Monteiro,* M. J. Hayen,* L. J. Young,† and G. E. Dahl*[1]
*Department of Animal Sciences, and
†Department of Statistics, Institute of Food & Agricultural Sciences, University of Florida, Gainesville 32611

J. Dairy Sci. 97:7426–7436
http://dx.doi.org/10.3168/jds.2013-7621
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Effect of cooling during the dry period on immune response after *Streptococcus uberis* intramammary infection challenge of dairy cows

I. M. T. Thompson, S. Tao, A. P. A. Monteiro, K. C. Jeong, and G. E. Dahl[1]
Department of Animal Sciences, University of Florida, Gainesville 32611

Retrospective analysis of records of calves from 5 studies between 2007 and 2011

Monteiro et al. , *J. Dairy Sci.* 99:8443-8450.

J. Dairy Sci. 92:5988–5999
doi:10.3168/jds.2009-2343
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Heat-stress abatement during the dry period: Does cooling improve transition into lactation?

B. C. do Amaral,* E. E. Connor,† S. Tao,* J. Hayen,* J. Bubolz,* and G. E. Dahl*[1]

Heat Stress Experiments 2007 - 2011			
	Bulls	Heifers	**Total**
Cooling	31	41	72
Heat Stress	30	44	74
Total	61	85	147

J. Dairy Sci. 97:7426–7436
http://dx.doi.org/10.3168/jds.2013-7621
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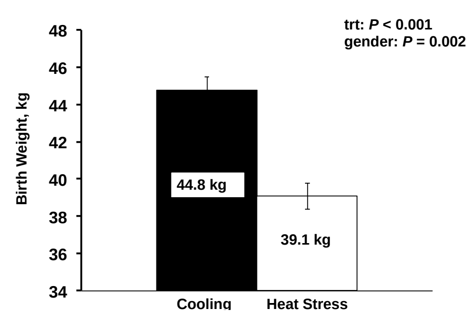
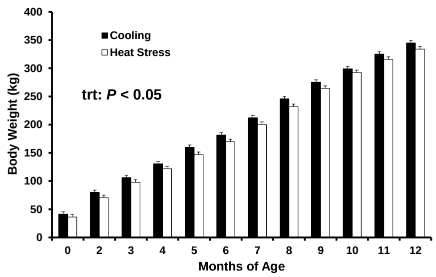
Department of Animal Sciences, University of Florida, Gainesville 32611

Birth Weight



Monteiro et al. , *J. Dairy Sci.* 99:8443-8450.

In Utero Heat Stress Decreases Calf Bodyweight to Puberty



Monteiro et al. , *J. Dairy Sci*. 99:8443-8450.

In Utero HS Decreases Calf Survival

Table 1. Effect of maternal heat stress (HT) or cooling (CL) during late gestation on calf survival

	CL				HT				*P*
Parameter	AI	IVF[1]	Total	%[2]	AI	IVF	Total	%	Trt[3]
Bull calves, n	30	1	31	---	28	2	30	---	---
Heifer calves, n	29	12	41	---	29	15	44	---	---
DOA[4]	0	0	0	0.0	2	1	3	4.1	0.25
Males mortality by 4 mo of age	1	0	1	3.2	3	0	3	10.0	0.35
Heifers leaving herd before puberty	1	4	5	12.2	3	7	10	22.7	0.26
Due to sickness, malformation or growth retardation	1	0	1	2.4	3	5	8	18.2	0.03
Heifers leaving herd after puberty, before first lactation	1	0	1	2.4	3	0	3	6.8	0.62
Heifers completing first lactation	27	8	35	85.4	22	7	29	65.9	0.05

[1] IVF = in vitro fertilization.
[2] Percentage of animals (AI + IVF) affected out of total animals (males or females) in the respective treatment.
[3] Treatment.
[4] Dead on arrival. Includes male and female calves.

Monteiro et al. , *J. Dairy Sci*. 99:8443-8450.

In Utero Heat Stress Decreases Reproductive Performance

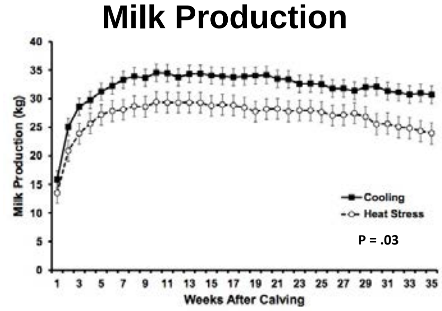
Table 2. Effect of maternal heat stress (HT) or cooling (CL) during late gestation on reproductive performance before first lactation of heifers born to HT or CL dams

Parameter	CL	HT	SEM	*P*
N	36	32	---	---
Age at first AI, mo	13.6	13.8	0.2	0.32
Services per pregnancy d[1] 30	2.0	2.5	0.2	0.05
Age at pregnancy d[1] 30, mo	16.1	16.9	0.3	0.07
Services per pregnancy d[1] 50	2.3	2.6	0.2	0.32
Age at calving, mo	24.8	25.0	0.4	0.72

[1] Days after insemination.

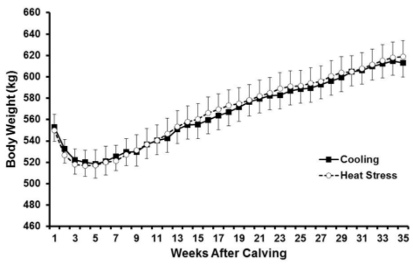
Monteiro et al. , *J. Dairy Sci*. 99:8443-8450.

In Utero Heat Stress Reduces Milk Production

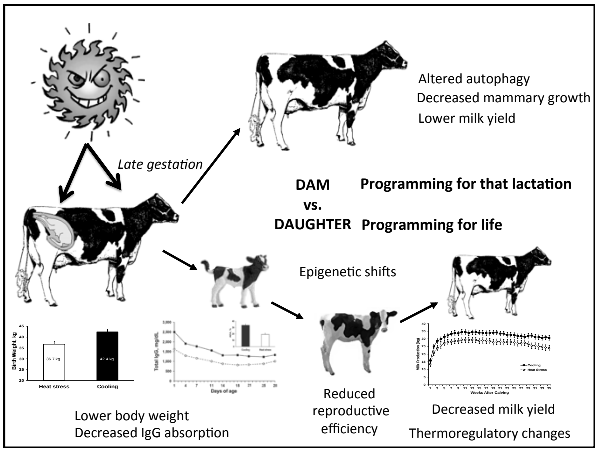


Monteiro et al. , *J. Dairy Sci*. 99:8443-8450.

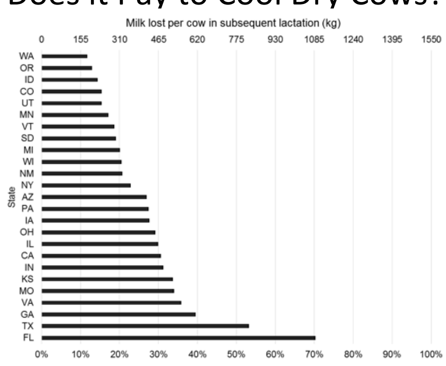
In Utero Heat Stress Does Not Affect Mature Bodyweight



Monteiro et al. , *J. Dairy Sci*. 99:8443-8450.

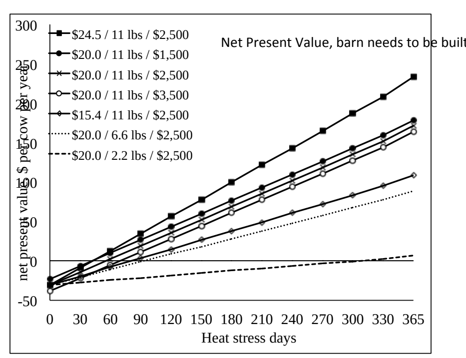


Does it Pay to Cool Dry Cows?



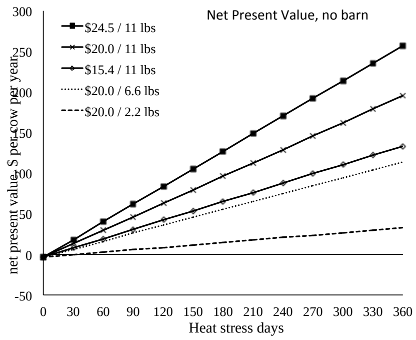
Ferreira et al. , *J. Dairy Sci*. 99:9931-9941.

Does it Pay to Cool Dry Cows?



Ferreira et al. , *J. Dairy Sci*. 99:9931-9941.

Does it Pay to Cool Dry Cows?



Ferreira et al. , *J. Dairy Sci*. 99:9931-9941.

Cooling Dry Cows: Impacts on the Cow and the Calf

Geoffrey E. Dahl, Ph.D.
Harriet B. Weeks Professor
Department of Animal Sciences, IFAS, University of Florida
Gainesville, FL, 32611

Whereas the beneficial effects of cooling cows during lactation are clear, less work has been done to examine the impact of dry cow cooling on subsequent performance and health, and on the developing fetus. This summary explores the recent work related to late gestation cooling on milk yield, metabolism, and immune status in the cow, and also reviews the effects of in utero heat stress on the heifer calf. Finally, economic implications of heat stress in the dry period are explored.

Compared with cows that are cooled, dry period heat stress causes a reduction in milk yield in the next lactation, along the order of ~9 lbs/cow per day (Dahl et al., 2017). This reduced yield is apparent from calving and extends for the entire lactation. Late gestation heat stress reduces mammary cell proliferation in the dry period, possibly as a result of placental dysfunction and hormone output. Mammary cell death, as measured by apoptosis, appears to be less affected later in the dry period, although autophagy is slowed early in the dry period with heat stress (Tao et al., 2011; Wohlgemuth et al., 2016). These observations suggest that overall mammary functional capacity is increased with cooling in the dry period relative to heat stress, consistent with the impact on milk yield.

It is important to understand that heat stress at any point in the dry period will reduce subsequent yield. In a recent study, we compared heat stress effects for the initial half of the dry period with that of the final half, and with heat stress exposure for the entire dry period (Fabris et al., 2019). In contrast to cows cooled for the entire dry period, heat stress for the first 3 weeks, or the final 3 weeks of the dry period both caused similar negative effects on subsequent yield to those of full dry period heat stress. Using gestation length as a proxy for placental function, it was clear that heat stress at any point in the dry period had negative consequences for placental function, and likely the developing fetus as well. Thus, cows should be cooled for the entire dry period.

As with lactating cows, heat stress decreases DMI compared with cooling, even at the relatively low level of DMI normally observed (Tao et al., 2012). Of interest, this lower DMI does not alter circulating concentrations of insulin, glucose or NEFAs, nor do heat stressed dry cows express any indication of altered responsiveness to insulin or glucose challenge. A lack of a direct metabolic response to heat stress (other than DMI) in comparison with the lactating cow is likely due to the dry cow maintaining positive energy balance in the absence of milk production.

Heat stress abatement will also improve immune status of cows in late gestation relative to heat stress, and there appear to be residual effects in the next lactation as well (do Amaral et al., 2011). Specifically, cooled dry cows have greater lymphocyte proliferation versus heat stressed cows, and immunoglobulin responses to antigens are improved with cooling. The innate immune system appears to be unaffected by direct heat stress, but there is evidence for a carryover effect of late gestation heat stress on neutrophil activity in the next lactation. Indeed, neutrophil oxidative burst and phagocytosis are enhanced by dry period cooling, even though those cows are at a higher level of production and lower energy balance. Immune system impacts, therefore, are improved with dry period cooling.

In addition to the impacts on the dam, late gestation heat stress also negatively affects the developing fetus such that early life growth and immune function are compromised (Monteiro et al, 2016). Calves born to heat stressed dams have lower birth and weaning weights, lower immunoglobulin transfer from colostrum, and leave the herd before calving at a higher rate relative to calves from cooled dams. In addition, calves that experience heat stress in utero produce ~ 10 lbs/d less milk in the first lactation compared with those from cooled dams. Recent studies support the concept that these effects are epigenetic in nature as they persist in the calf for life and are also transmitted to their offspring (Dahl et al., 2019). Thus, in utero heat stress programs a lower yield phenotype.

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Strategies to improve nutritive value of corn and sorghum silage

Luiz F. Ferraretto, Ph.D., PAS
Department of Animal Sciences
University of Florida

1

Objectives

- Introduce indicators of corn silage nutritive value
- Highlight the use and application of these indices
- Discuss practical strategies to enhance these quality indices

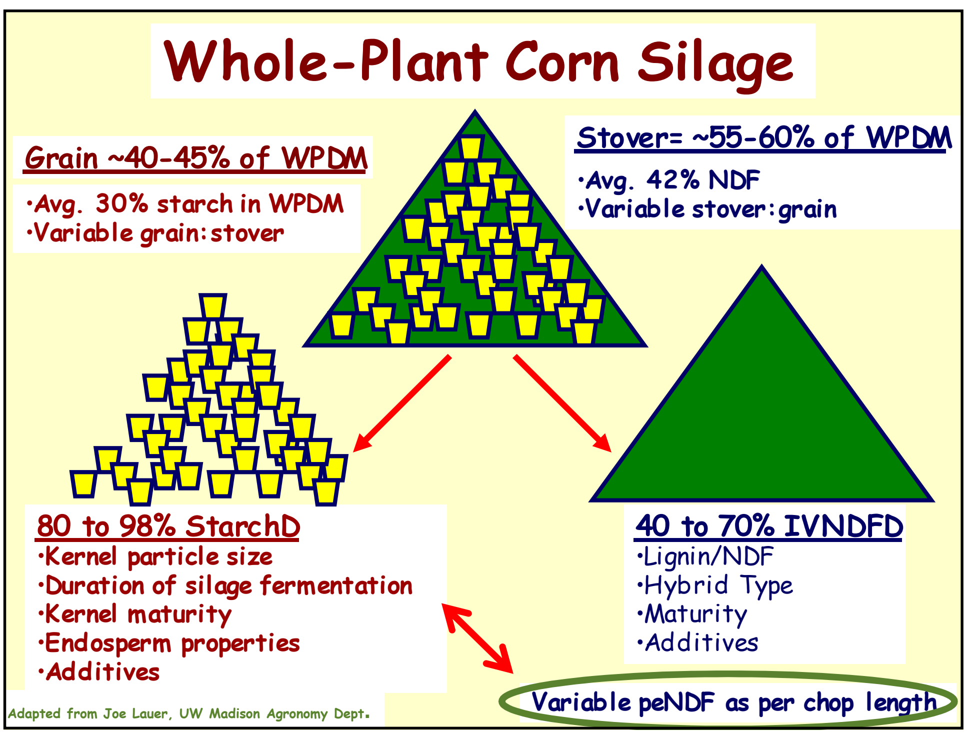
2

Starch quality indicators

Indicator	Practical Implication
Starch (% DM)	▪ Alter energy density ▪ Impact milk yield or feed efficiency
StarchD (% starch)	
Prolamin (% DM)	
Corn silage / Berry processing score (% of starch below 4.75 / 1.70 mm sieve)	

Methods may vary across laboratories and may include calculation of rates of digestion.

3



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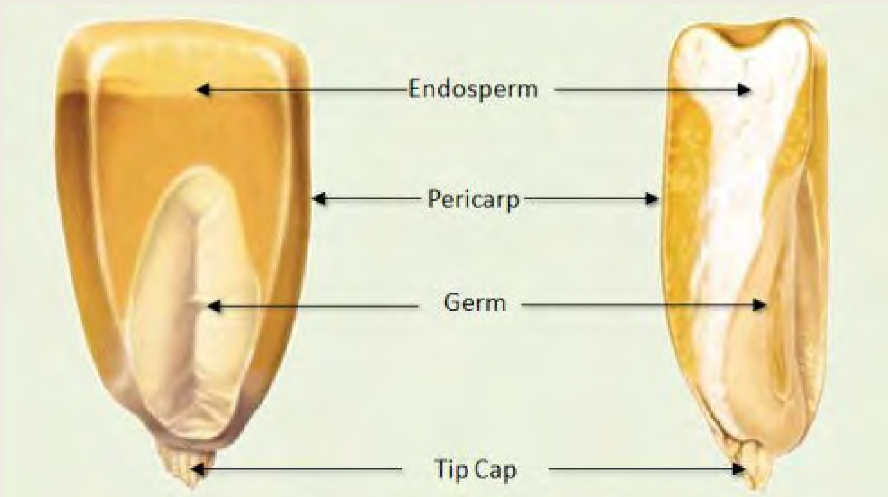
Corn Kernel



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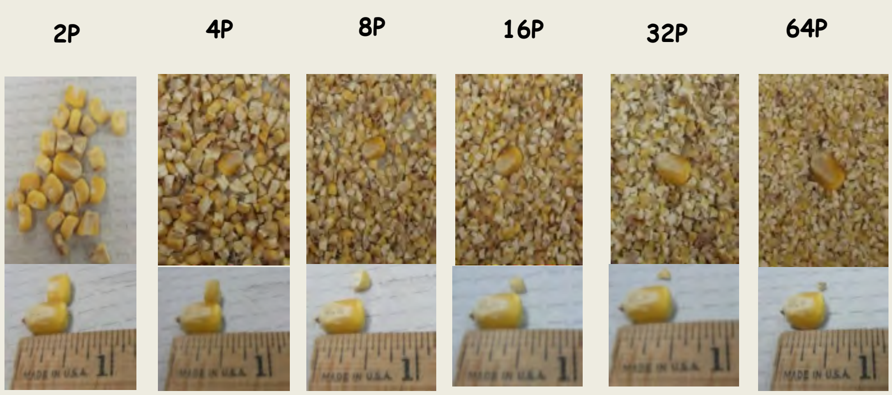
Kernel particles

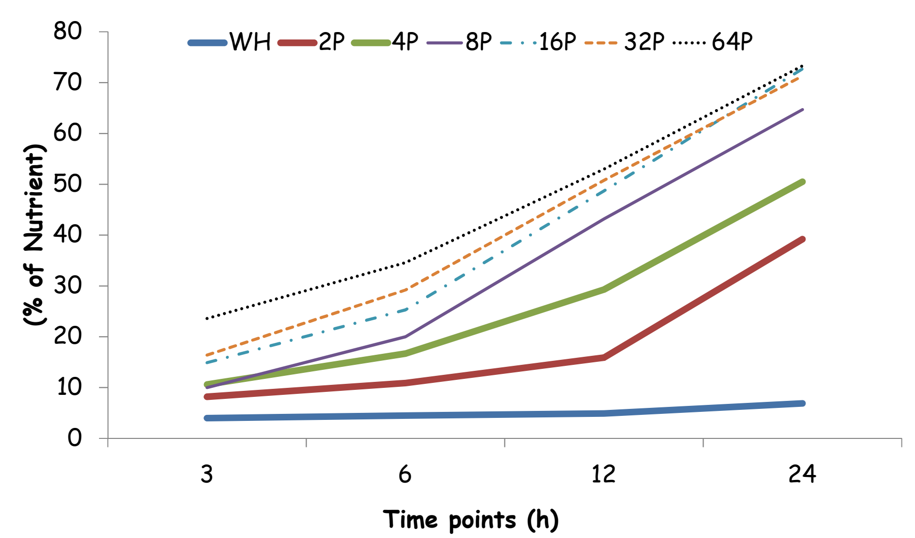


P = pieces

Dias Junior et al., 2016

6

Ruminal in situ DM digestibility of unfermented kernels



Dias Junior et al., 2016

7

Corn silage processing score and fecal starch

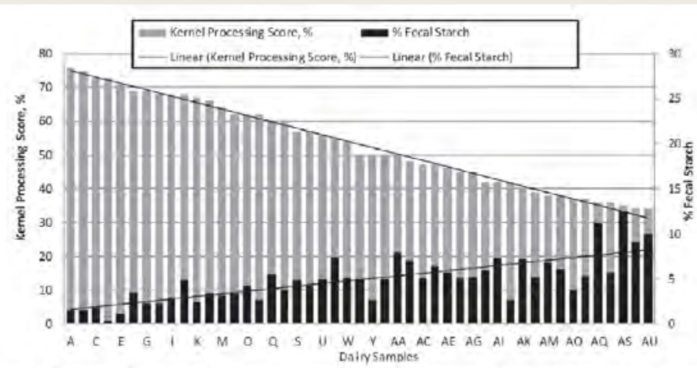


Figure 1 Percent fecal starch plotted against respective corn silage kernel processing score (%) for each dairy sample (n=47).

Braman and Kurtz, 2015

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Sorghum Kernel particles

1P 2P 4P

McCary et al., 2019; ADSA Abstract

P = pieces

9

Ruminal in situ incubation

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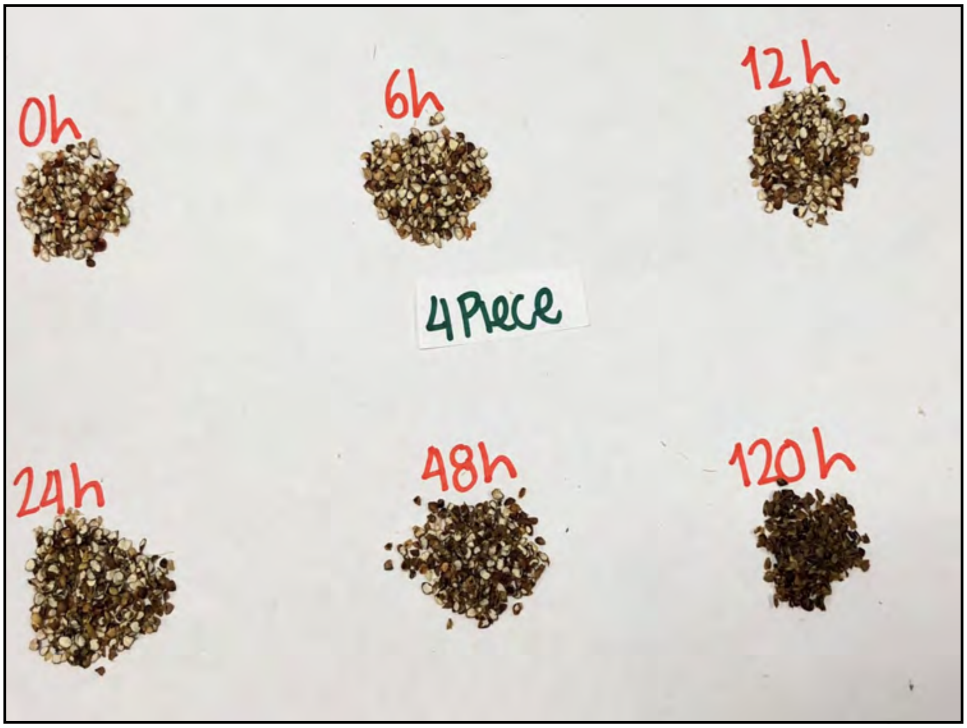

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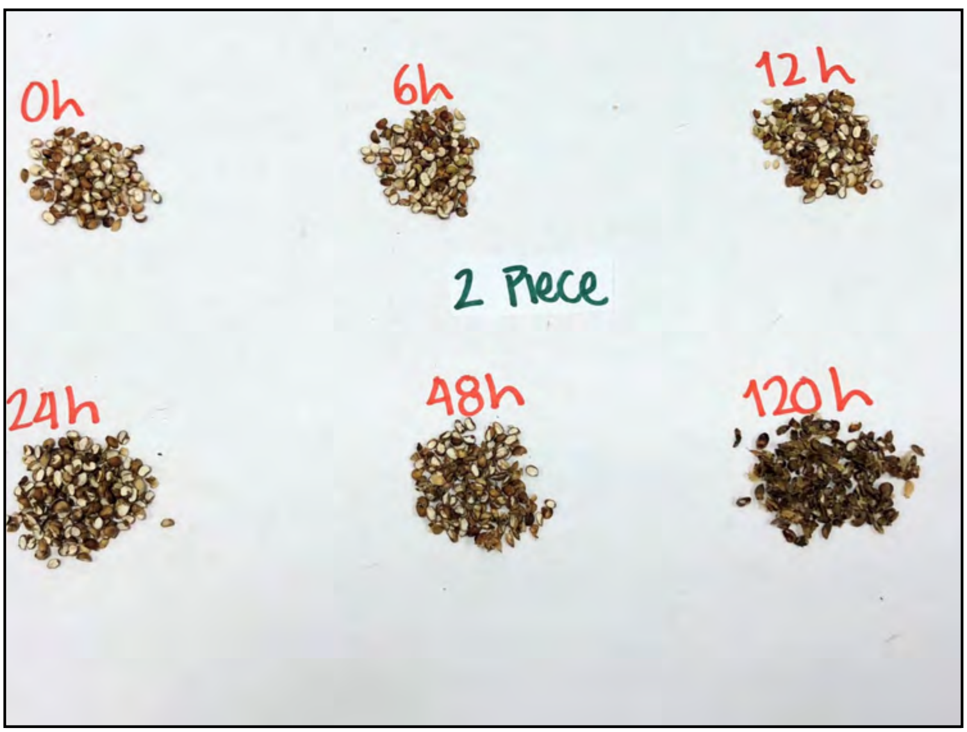

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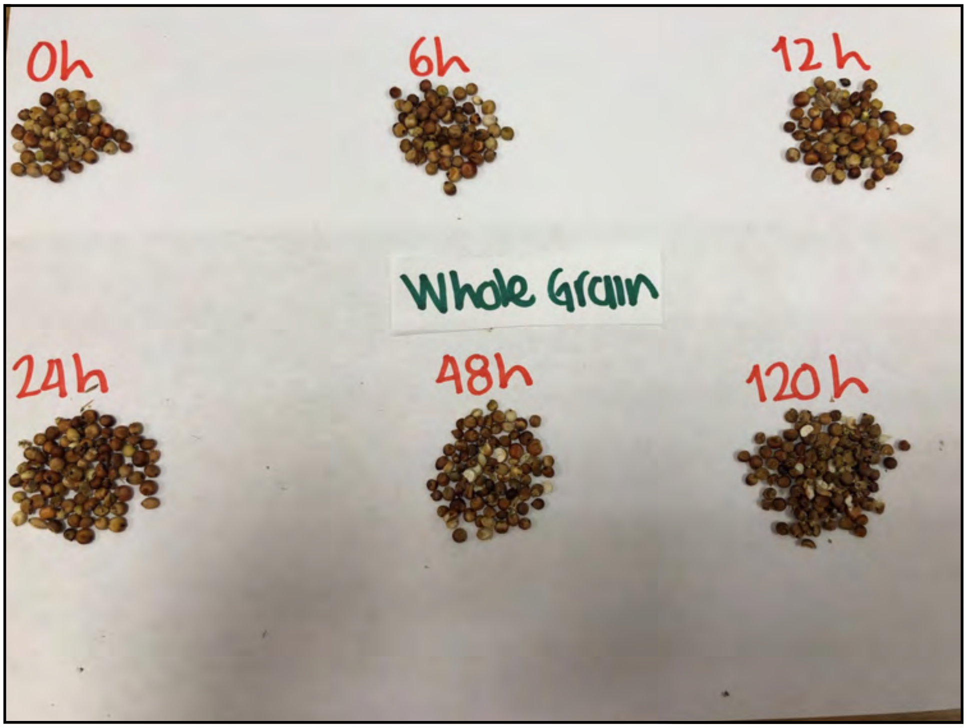

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Particle size and BPS

Item	1P	2P	4P
Sieves, mm			
6.70	0.00	0.00	0.00
4.75	0.00	0.00	0.00
3.35	19.64	3.52	0.00
2.36	77.81	45.06	14.11
1.70	2.54	48.39	59.77
1.18	0.00	2.89	23.79
0.59	0.00	0.13	1.45
0.30	0.00	0.00	0.56
Pan	0.00	0.00	0.32
GMPS, μm	2,152	1,695	1,277
Surface area, cm^2/g	19	22	27

McCary et al., 2019; ADSA Abstract

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UF Sorghum Processing Trial

- 5 hybrids planted during the spring were used as replication
- 2 theoretical length of cut – 15 and 22 mm
- 2 roll gap settings – 1 and 3mm
- 2 storage length – 30 and 90 d

McCary et al., 2019; ADSA Abstract

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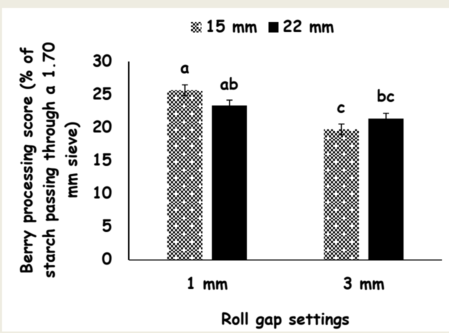
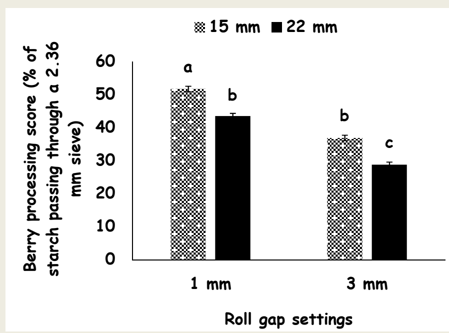
BPS – 1.70 vs. 2.36 mm sieve





McCary et al., 2019; ADSA Abstract

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How to obtain excellent processing?

- The key: adequate and constant monitoring

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Focus on Forage

Wisconsin TEAM Forage

Making Sure Your Kernel Processor Is Doing Its Job

by Kevin J. Shinners and Brian J. Holmes

www.uwex.edu/ces/crops/uwforage/KernelProcessing-FOF.pdf

Figure 1. Chopped whole-plant corn placed into water.

Figure 2. Gently agitating material to help the kernels sink to the bottom of the container.

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Figure 3. Skimming and removing the floating stover.

Figure 4. Carefully draining the water so only the kernels remain in the container.

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Fecal Starch Economics

- Dietary starch – 25%
- Dry matter intake (55 lb/cow/d)
- Corn grain starch – 70% starch (1lb corn = 0.7 lb starch)
- Corn grain ivStarchD – 70% ivStarchD (1 lb corn = 0.49 lb digestible starch)
- Corn grain price – 140 US$/ton (0.07 $/lb)

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Fecal Starch Economics

CSPS, %	30	55	80
Starch intake, lb/d	13.75	13.75	13.75
Fecal starch, %	8.40	4.65	0.90
TTSD, % Starch	89.5	94.2	98.9
Starch loss, lb/d	1.45	0.80	0.15
Corn grain, lb/d	2.96	1.63	0.31
Corn grain, $/d	0.19	0.11	0.02

Starch intake = (55 lbs DMI * 25% starch)/100
Fecal starch = 12.9 – (0.15 * CSPS) Braman and Kurts (2015)
TTSD = 100 – (1.25 * fecal starch) Fredin et al. (2014)
Starch loss = starch intake – ((starch intake * TTSD)/100)

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Silage Fermentation Increases Starch Digestibility!

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Response across multiple trials

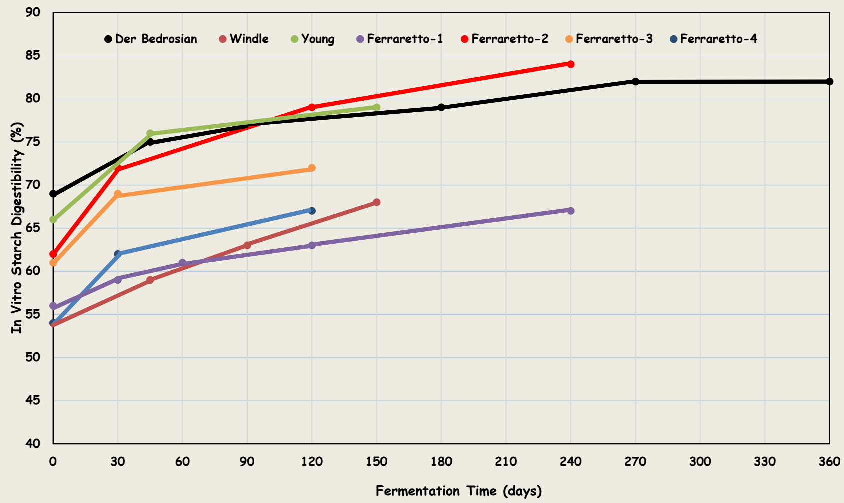

Figure 1. Effect of days of ensiling on ruminal in vitro starch digestibility. Data from Der Bedrosian et al., 2012; Windle et al., 2014; Young et al., 2012; Ferraretto-1, Ferraretto et al., 2015a; Ferraretto-2, Ferraretto et al., 2015b; Ferraretto-3,4, Ferraretto et al., 2016.

Kung et al., 2018

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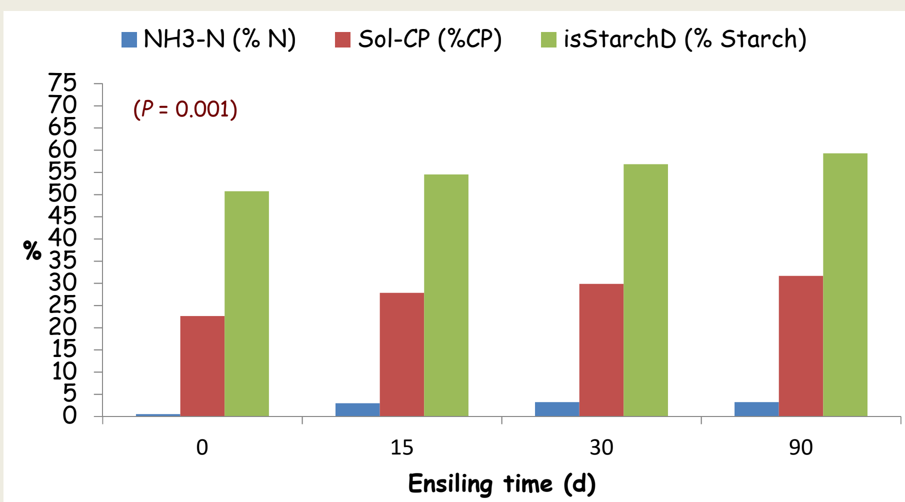
Storage length effect – sorghum silage



Fernandes et al., unpublished

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Initial research

- Research supports the use of inventory planning so a newly harvest crop would be fed only after 90-120 days in storage
- Ensiling time does not attenuate differences in starch digestibility caused by hybrids or maturity
- It requires proper management during filling, packing and covering

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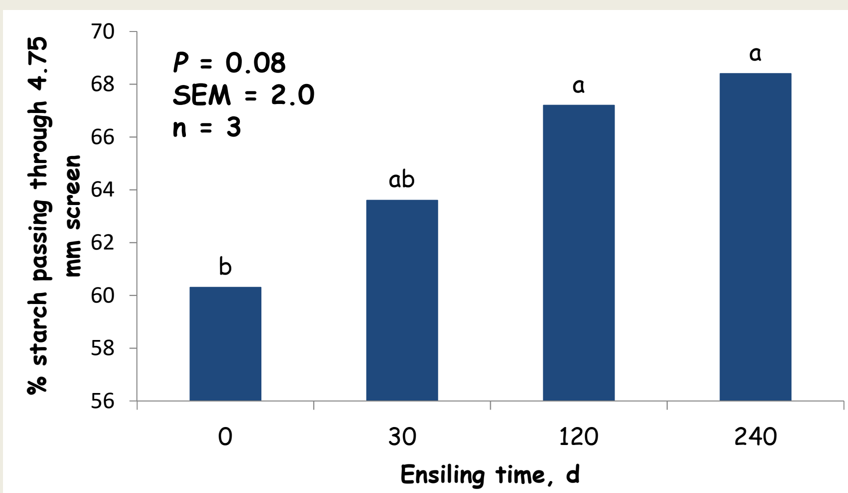
Corn Silage Processing Score



vacuum sealed experimental mini silos

Ferraretto et al., 2015c

26

Is this the case if silage is poorly processed?

Item	0 d	120 d	*P*-value
DM, % as fed	36.6	35.6	0.29
pH	5.74	4.00	0.001
Lactate, %DM	0.03	7.74	0.001
Acetate, %DM	0.01	1.01	0.001
Starch, %DM	31.4	31.1	0.89
CSPS, % starch < 4.75 mm	28.8	28.8	0.97

Agarussi et al., 2018

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US Fiber Quality Summary

Parameter	Indicates Better Quality	n	Normal Range
NDF (% DM)	↓	384,715	36 - 46
Lignin (% DM)	↓	344,134	3 - 4
$uNDF_{240}$ (% DM)	↓	81,418	8 - 13
$NDFD_{30}$ (% NDF)	↑	170,634	48 - 60
TTNDFD (% NDF)	↑	27,954	36 - 46

Summary of combined multi-year, multi-lab (CVAS, DairyOne, RRL, DLL) data, except TTNDFD only from RRL

Adapted from slide courtesy of Dr. Randy Shaver, UW-Madison

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Corn Silage Quality Indicators

Indicator	Practical Implication
NDF (% DM)	▪ Intake limitation through rumen fill
Lignin (% DM)	
$uNDF_{240}$ (% DM)	▪ Impact milk yield and the establishment of high-forage diets
$NDFD_{30}$ (% NDF)	
TTNDFD (% NDF)	

Methods vary across laboratories and may include calculation of pools and rates of digestion.

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Forage NDF digestibility and cow performance

For every 1 percentage-unit increase in NDF digestibility

- +0.40 lb/d DMI
- +0.55 lb/d 4%FCM (Oba and Allen, 1999)

>40% corn silage in diet

- +0.26 lb/d DMI
- +0.31 lb/d 3.5%FCM (Jung et al., 2010)

Slide courtesy of Dr. Rick Grant, Miner Institute

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Fiber digestibility and chewing behavior

Study	Intake	Eating time
Grant et al., 1994	88.3	120.7
Aydin et al., 1999 Exp. 1	85.0	117.9
Aydin et al., 1999 Exp. 2	95.6	105.6
Oliver et al., 2004	95.5	114.9

Data presented as percentage of control treatment

Grant and Ferraretto, 2018; JDS

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Effect of eating time on lactation performance

Item	n	Intercept	Slope	*P*-value
Milk, kg/d	415	39.2	-0.024	0.001
3.5% FCM, kg/d	415	35.8	-0.011	0.03
ECM, kg/d	405	38.0	-0.016	0.001
Milk protein, %	405	3.28	-0.0005	0.04
Milk protein, kg/d	405	1.27	-0.0009	0.001

Krentz et al., 2018; ADSA Abstract

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Brown mid-rib mutant hybrids

- BMR mutation reduces forage lignin
- Characteristic brown mid-rib color
- Improved digestibility outweighs lower yields?
- No. reflects genes encoding enzymes in the lignin synthesis pathway

33

Nutrient composition of corn hybrids

Item	BMR	CONS	*P*-value
DM, % as fed	33.7	33.9	0.27
CP, %DM	8.1	7.8	0.07
NDF, %DM	43.0	42.8	0.34
Lignin, %DM	2.0[b]	2.9[a]	0.001
ivNDFD, % NDF[1]	58.1	46.7	0.001
Starch, %DM	28.7[ab]	29.7[a]	0.05

[1]Ruminal in vitro NDF digestibility after 30 or 48 h of incubation

Ferraretto and Shaver, 2015

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Effect of BMR corn silage on lactation performance

Item	Control	Difference
DMI, lb/d	53	+2
Milk, lb/d	82.2	+3.3
Fat, %	3.63	-0.11
MUN, mg/dL	15	-1
NDFD, % NDF	42.3	+2.5
TTSD, % Starch	92.7	-1.4

Adapted from Ferraretto and Shaver, 2015

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Effect of BMR sorghum silage on lactation performance

Item	Difference to conventional
DMI, lb/d	0.69
Milk, lb/d	1.83
Fat, %	0.34
Fat, lb/d	1.70
Protein, %	0.17
Protein, lb/d	1.39

Adapted from Sanchez-Duarte et al., 2019

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BMR sorghum effects on yield, NDFD, and lodging

Item	NON-BMR	BMR
Yield, DM tons/acre	6.2	5.1
ivNDFD, % NDF	39.2	48.2
uNDF 240 h, % DM	18.7	15.9
Lodging score	1.1	1.0

Adapted University of Florida Variety Trials, Spring 2018

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Whole-plant material

Whole-plant CS

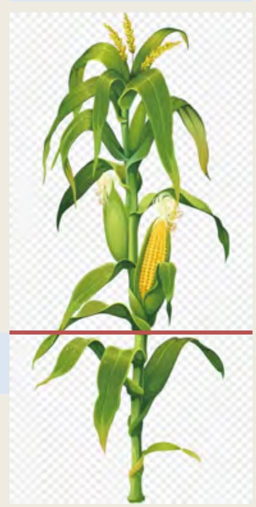
8 in

High-cut CS

16 to 24 in

Toplage

45 in



Stalklage

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Whole-plant material

	Whole-plant CS	High-cut CS	Toplage	Snaplage
Cutting height, inches	10	40	45	51
DM, %	37.7[c]	40.6[b]	42.2[b]	53.3[a]
CP, % of DM	8.2[b]	8.9[a]	8.9[a]	8.8[a]
NDF, % of DM	40.3[a]	34.5[b]	32.1[b]	19.5[c]
Lignin, % of DM	4.0[a]	3.4[b]	3.1[c]	2.2[d]
Starch, % of DM	33.9[d]	38.8[c]	43.0[b]	58.6[a]
Ash, % of DM	3.7[a]	3.4[ab]	3.1[b]	1.7[c]
Yield, DM ton/acre	10.3[a]	9.14[b]	7.85[c]	5.58[d]

Nigon et al., 2016

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Normal vs. high cutting height

	Average of 7 studies	
Cutting height, inches	7	21
NDF, %	40	37
ivNDFD, % of NDF	52	56
Starch, %	32	35
Yield, ton of DM/ac	7.7	6.8
Milk, lb/ton	3291	3422
Milk, lb/ac	21407	19917

Ferraretto et al., 2018

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Take-home message

- Cutting height improves quality but at the expense of reduced yield
- Cutting height may be a feasible option to improve forage quality when area is not a limiting factor
- Perhaps the combination of greater plant population and cutting height could lead to improved quality without compromising yields

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Predicting the benefits of CH

- Several studies have evaluated the influence of cutting height corn silage yield and quality
- However, an evaluation across multiple studies has yet to be conducted
- Our objective was to assess the influence of cutting height on nutrient composition and yield of whole-plant corn silage through a meta-analysis

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Cutting Height Equations

Item	n	Intercept	Slope	P - value
DM, % of as fed	62	32.50	0.218	0.02
Starch, % of DM	55	27.70	0.208	0.01
NDF, % of DM	64	43.54	-0.248	0.001
Lignin, % of DM	25	3.65	-0.029	0.08
NDFD[1], % of NDF	49	50.31	0.202	0.01
DM yield, t/ha	52	17.82	-0.122	0.001

[1]NDFD = ruminal in vitro or in situ NDF digestibility at 30 or 48 h

Paula et al., 2019; ADSA Abstract

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Simulation

	CS	High-cut CS	High-cut simulation
Cutting height, inches	6	24	24
NDF, % of DM	37.7	33.8	33.2
Starch, % of DM	37.5	41.7	41.1
NDFD, % of NDF	49.6	52.7	53.2
Yield, DM ton/acre	8.9	8.1	8.0

Data adapted from Ferraretto et al., 2017
Simulation performed with equations by Paula et al., 2019

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Conclusions

- Many factors alter nutrient digestibility of whole-plant corn and sorghum silage
- Processing and maturity at harvest remains the most important factors to improve digestibility
- Storing feedstuffs for longer or increasing cut height may be viable options but inventory planning is required

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Questions

lferraretto@ufl.edu

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UNIVERSITY of FLORIDA

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Strategies to improve nutritive value of corn and sorghum silage

Luiz F. Ferraretto
Assistant Professor of Livestock Nutrition
Department of Animal Sciences
University of Florida
lferraretto@ufl.edu

Forages are the primary feed ingredients of dairy diets and are fundamental for keeping animal productivity and health. Besides providing energy for maintenance and lactation, forages stimulate chewing and salivation, rumination, gut motility and health, regulate feed consumption and are the structural basis of the ruminal mat, which is crucial for ruminal digestion. Whole-plant corn silage (**WPCS**) is the predominant forage used in dairy cattle diets worldwide. Although WPCS is the predominant forage used to feed dairy cows in the United States, sorghum has become an important silage crop for dairy farmers. This is related to some of its unique characteristics. Compared to corn, sorghum uses water more efficiently, have lower fertilizer requirements, may potentially reduce soil erosion and pesticide usage, and have reduced seed and irrigation costs. Furthermore, whole-plant sorghum silage (**WPSS**) can be used as a second crop after corn silage harvesting. Starch and fiber are the main sources of energy for dairy cows fed corn silage-based diets and therefore improvements in digestibility of these nutrients may increase milk production or reduce feed costs through enhanced feed efficiency. Greater digestibility of fiber and starch is desired for productivity, profitability and environmental reasons. The purpose of this paper is to review selected recent developments and strategies that may influence the nutritive value of WPCS.

Corn kernels and sorghum berries have a hard coat, the pericarp, which surrounds the endosperm and is highly resistant to microbial attachment and inhibits digestion of starch; therefore, the breakdown of the pericarp and correspondent exposure of the starch endosperm must be the primary objective at harvest to maximize energy availability. In addition, starch accessibility is dependent upon the intricate starch-protein matrices surrounding starch granules.

Recently, prolonged storage has been featured an important tool to optimize starch digestibility in starchy feeds. Hoffman et al. (2011) observed a decrease in zein protein concentrations, as well as an increase in concentrations of soluble CP and ammonia-N, when HMC was ensiled for 240 d. These data suggested that proteases in the silo were responsible for degrading the zein protein matrix surrounding starch granules in corn kernels. Because the protein matrix is hydrophobic and represents a physicochemical barrier to rumen microorganisms, degradation of the matrix with prolonged storage was suggested to improve ruminal starch digestibility (Hoffman et al., 2011). Both, plant and microbial proteases in the silo are capable of degrading plant proteins to peptides and free amino acids. Experiments evaluating extended storage length in WPCS, earlage, and HMC consistently reported a gradual increase in ruminal in vitro or in situ starch digestibility (**ivSD** or **isSD**, respectively) as fermentation progressed. Recently, we observed a similar scenario for WPSS (Fernandes et al., unpublished).

Lignin is the key obstacle to fiber digestion as it obstructs the enzyme access to the digestible fiber fractions, cellulose and hemicellulose. In addition, rumen microorganisms cannot breakdown lignin. Due to its importance to animal performance, this association between lignin and other fibrous fractions (i.e. cellulose and hemicellulose) is considered in many diet formulation models. This undigested or indigestible NDF fraction is estimated using either lignin or quantified as the proportion of NDF remaining after in vitro or in situ ruminal incubations (i.e. 240 h uNDF). Thus, the reduction of lignin or indigestible NDF fractions in forages improves fiber digestibility.

A harvesting management option to reduce lignin concentration is chop height. With enhanced chop height more lignin is left with the portion that remains in the field, and thus, digestibility of the harvested material is greater. A previous study from our group compared 6 vs. 24 inches, these results are similar to other trials comparing 6 vs. 18 inches of chop height. Briefly, DM yield is reduced as the row-crop head is raised. This is consistent across several studies conducted across the United States. However, decreased DM yields are offset by an increase in the milk per ton estimates at the higher chop height. Greater milk estimate is a response to the greater fiber digestibility and starch concentration of the harvested material. In addition, most studies reported that estimated milk per acre is reduced by only 1 to 3% with high-chop. Also, increased quantities of high-chop silage could be included in the diet, rather than corn grain being added to the diet, providing an economic benefit to implementing increased chop heights. As a follow-up study, we conducted a meta-analysis to evaluate the effects of chop height on nutrient composition and yield of WPCS (Paula et al., 2019). Yield of DM was reduced by 0.05 ton/ac for each inch of increased chop height. However, for each inch of increase in chop height there was an increase of 0.23, 0.20, and 0.20%-units in DM, starch, and ruminal in vitro NDF digestibility, respectively. A negative linear effect was observed for NDF, with a 0.25%-unit decrease per inch of increase in chop height.

Low lignin hybrids are also a very important alternative to enhance fiber digestibility. Brown-midrib corn hybrids had 0.9%-units lower lignin concentration and 11.4%-units greater ruminal in vitro NDF digestibility (% of NDF); this translated into greater total tract fiber digestibility (% of NDF). Cows fed BMR corn hybrids consumed 2.0 lb/d more DM and improved milk yield by 3.3 lb/d (Ferraretto and Shaver, 2015). As for corn, BMR sorghum has reduced lignin concentration and greater fiber digestibility compared to conventional sorghum. A meta-analytic review (Sanchez-Duarte et al., 2019) reviewed that cows fed BMR sorghum silage had greater intake (+1.8 lb/d), milk production (+3.6 lb/d) and milk fat concentration (+0.09%-units) than cows fed conventional sorghum. It was also reported that compared with conventional corn silage, cows fed BMR sorghum had greater milk fat (+0.10%-units) but lower milk protein (-0.06%-units) concentrations. No differences in intake and milk yield were observed.

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Understanding fiber for profitable ration decisions[1]

John P Goeser, PhD, PAS & Dipl. ACAN
Nutrition Director, Rock River Laboratory, Inc.
Adjunct Assistant Professor, University of Wisconsin - Madison, WI, Dairy Science Dept.
Consultant, Cows Agree Consulting, LLC

Fiber in dairy diets

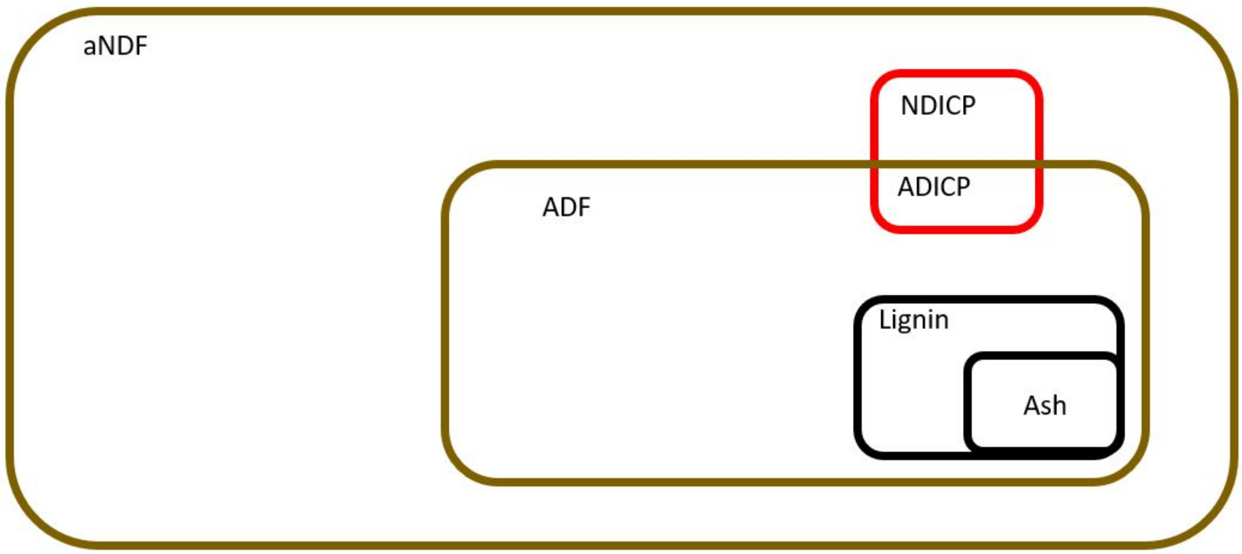
Carbohydrate impact upon animal and ruminant nutrition is not a new focal point for nutritionists. Hall and Mertens (2017) recently reviewed 100 years of carbohydrate research relative to ruminant nutrition. Fiber, defined as Neutral Detergent Fiber (aNDF; Goering and Van Soest, 1970**)** in dairy nutrition, contributes two major facets of dairy diets. It is important for both physical and energetic aspects. Energetically, fiber theoretically contains equivalent calories per g as do starch and sugars - however a substantial portion of calories in fiber remain locked in undigestible form. Hence, fiber provides the least energy per pound of all nutrients in the total mixed ration (TMR). From a physically effectiveness factor standpoint, fiber is also essential to maintain rumen health and function. It's important to simultaneously consider both fiber's physically effective and energetic attributes together, as these are important in their own right but also combined into newer nutrition metrics.

Fiber analysis

Considerable confusion exists yet today within the industry around fiber analyses. **Figure 1** demonstrates the detergent fiber fractions after the detergent system of fiber analysis developed by Prof Peter Van Soest and colleagues (Goering and Van Soest, 1970). Forage analysis laboratories sequentially rinse (like a laundry machine) feed samples with neutral, mildly acidic and then strongly acidic solutions to wash away portions and then weigh back the residue post rinse. Each detergent insoluble fraction is determined by relating the residue weight to original dry matter. There is typically a small amount of ash (for example, soil contamination) contained within each detergent insoluble fraction. Think of this like gravel or sand in your jean pockets after putting them through the wash. This is corrected for by ashing the residue post detergent rinsing.

[1] This article has been adapted and modified from that originally published in the Proceedings to the 2018 Four State Dairy Nutrition Conference, Dubuque, IA; then modified further and published in Proc. 2019 Pacific Northwest Animal Nutrition Conference, Boise, ID.

Figure 1: The fiber nesting doll. The acid detergent fiber (ADF), neutral and acid detergent insoluble crude protein (NDICP, ADICP), lignin and ash are nested within aNDF. Image Adapted from the March 10, 2018 Hoard's Dairyman article, "Dairy nutrition's tribal language: speaking fiber."



Fiber - Physical attributes

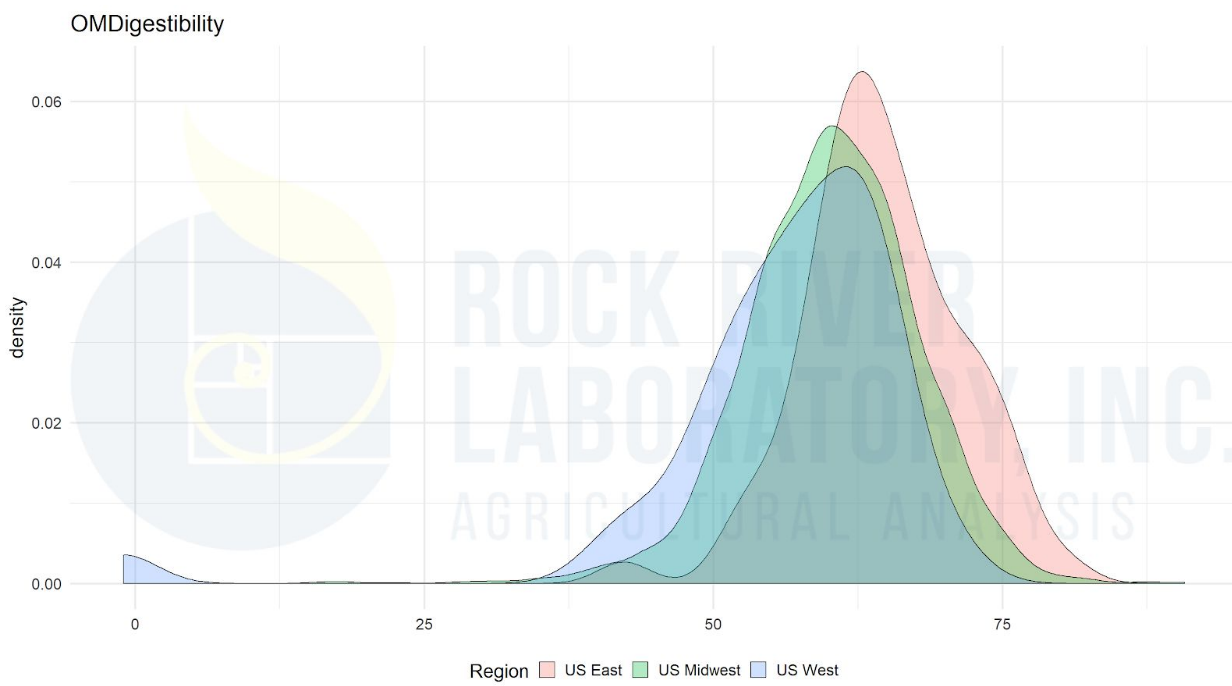
With dairy diets, we typically feed adequate fiber to maintain sound rumen function and metabolism. While at times there may be perception of clinical acidosis or subacute rumen acidosis (SARA), my experience has been that very few of today's formulated diets are responsible for clinical symptoms. Rather, management factors such as feed delivery timing or feed mixing are more contributing factors toward rumen health and SARA.

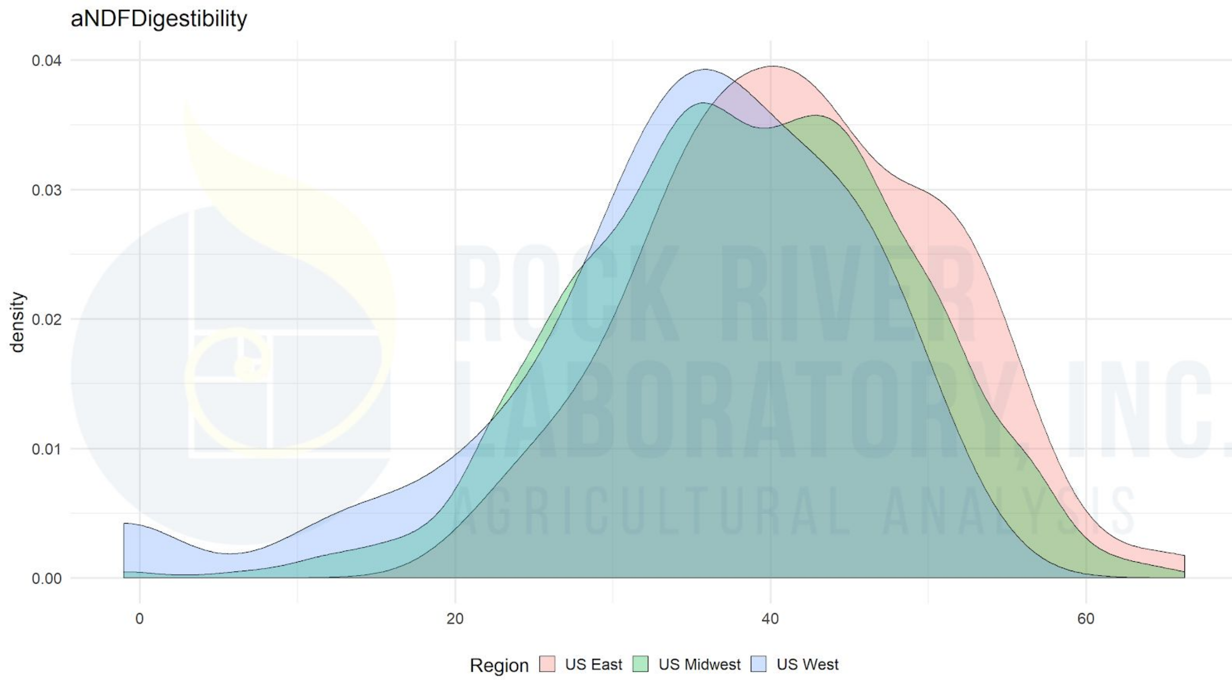
To date, there is no accepted "standard" in quantifying physically effective aNDF (peNDF, % of aNDF or DM). Prof Mertens' work suggested the 1.18 mm size was ideal, and that 21 to 23% of DM was ideal for TMR. Yet work from Penn State and others suggested the 4 mm size may be more accurate in determining effectiveness factor. Both 1.18 and 4 mm sieves are now incorporated within the Penn State particle size separator and the aNDF percentage or particles (% of total) greater than these sizes can be readily determined (Heinrichs, 2013). Of note, the NRC (2001) held back from making recommendations for fiber effectiveness. Rather, the National Research Council committee provided recommendations for forage NDF, % of DM, at varying fiber to NFC (starch and sugar) ratios. Fragility (i.e. alfalfa fiber being more fragile than grass fiber; Allen, 2000) is another concept contributing to fiber's effectiveness that warrants further exploration but is vaguely understood and characterized today.

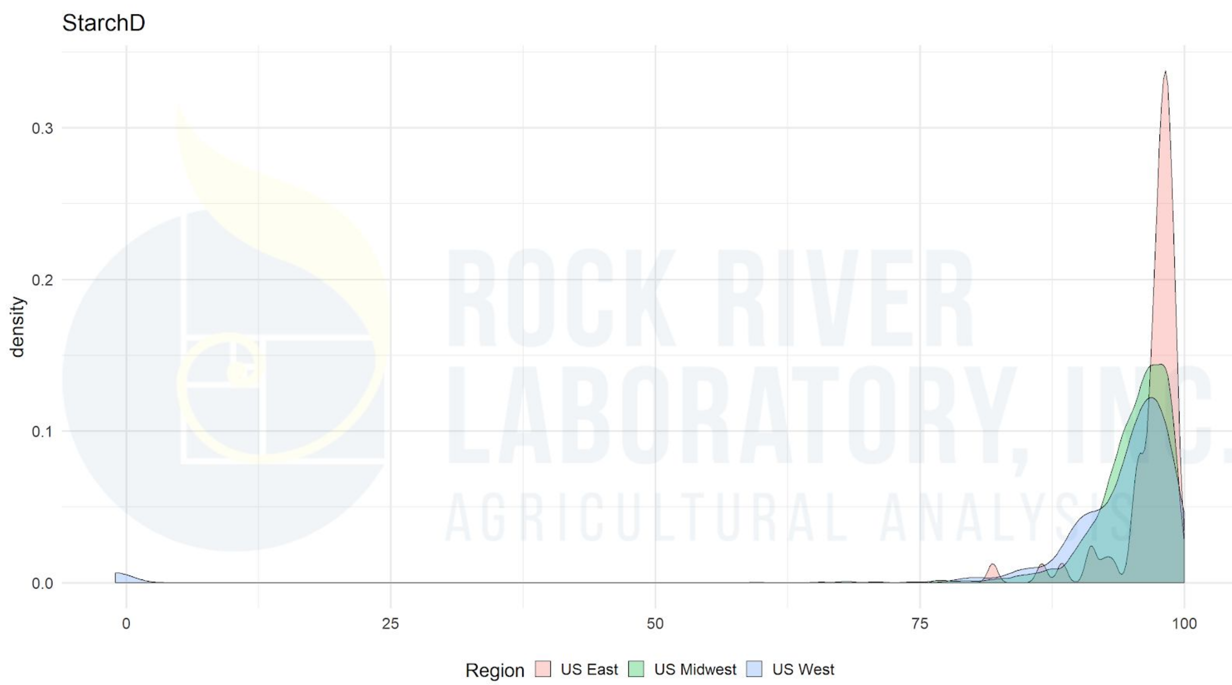
Energetic attributes

Starch, sugar and fiber are all carbohydrates, containing the same calorie content, around 4 calories per gram. Both starch and fiber (cellulose) are generally chains of glucose bonded together. Yet the energy available to the cow varies greatly between these two nutrients. The enormous difference in energy available is due both the type of glucose-glucose bond (alpha- vs beta- bond configurations) as well as lignin and cell wall crosslinking that further zippers cellulose into a less digestible complex. In 2014, I surveyed several meta-analyses and summarized fiber and starch digestion data from more recent published lactating cow feeding studies. Total-tract fiber digestion in lactating cows averages about 40 to 50% whereas total-tract starch digestion averages over 90% (Goeser, 2014). Commercial dairy cow apparent fiber and starch digestion, assessed by TMR apparent digestion (TMRD) approach, are similar to published research (**Figure 2**).

Figure 2: Apparent total-tract fiber digestibility measures for commercial dairies (Rock River Laboratory, Inc; unpublished data since 2015). Organic matter digestibility (% OM), total tract NDF digestibility (% of NDF) and total tract starch digestibility (% of starch) distributions.







In the 2014 summary, the aim was to revisit laboratory fiber and starch digestion measures relative to *in vivo* apparent digestion results for commercial dairies, ultimately recognizing that 30h *in vitro* NDF digestion values overestimate real aNDF digestion, thus questioned the value of a 30h NDFD measure.

Since the 2014 survey and time, the industry has better embraced the notion that single time point fiber digestion measures (i.e. NDFD30) are inadequate to describe complex rumen nutrient digestion. In conjunction with this better recognition, forage analyses laboratories have advanced multi-time point rumen fiber digestion predictions by near infrared reflectance (NIR) spectroscopy.

To merge the two points together and bring functional nutrition decision making tools to the field, two practical nutrition models have come online in the US:

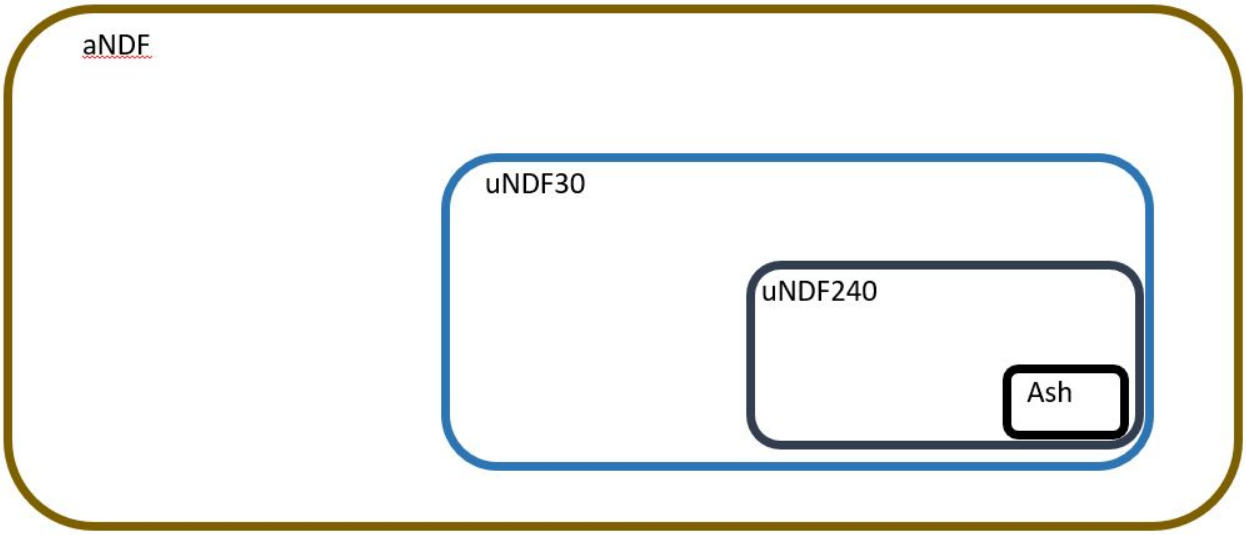
1. Cornell Net Carbohydrate and Protein System v6.55 (Van Amburgh et al., 2015)
2. Total Tract NDF Digestibility (Combs, 2013)

Fermentrics™ also makes many observations with an in vitro rumen digestion over time (www.fermentrics.com, accessed online; Johnston, personal communication). This tool was developed using methodology and concepts described by Pell and Schofield (1993). Gas production is intriguing, as these models allow one to consider thousands of data measures over time and predict energetics. However, the model fiber and starch digestion rates are determined via gas production curve peeling and not direct fiber quantification. All of these tools incorporate non-linear digestion parameters into compartmental models to predict fiber digestibility.

uNDF and NDFD meaning and relationship

Similar to how the detergent fiber parameters can be depicted with a nesting doll analogy, uNDF30 and uNDF240 (% of DM or NDF) can be better understood relative to aNDF with a picture (**Figure 3**). Within the laboratory, the sample (and it's fiber) is digested for a time period and then it's washed with neutral detergent to determine the amount of fiber that's left. This ends up being a gram divided by gram type equation and NDF digested at time = x ($NDFD_x$, % of NDF) is then calculated by: (aNDF – $uNDF_x$) / aNDF x 100. Alternatively, the amount of fiber left after 30 or 240 hours may be a better lignified fiber indicator, thus comparing uNDF (% of DM) has become another measure we evaluation. In this case, the uNDF is looked at as a % of the original sample. Just like is the case with aNDF.

Figure 3: The undigested fiber nesting doll. Each uNDF30 and uNDF240 are nested within aNDF (% of DM).



Building a campfire within the rumen: kindling and a bundle of firewood

Continuing with the analogies, rumen fiber (or any other nutrient) digestion can be more simply understood by comparing to our experience with building a campfire. Both the wood pile size and moisture (i.e. dry vs wet wood) contribute the heat we feel through the night from the fire pit. Similarly, digestible fiber pool size (akin to the wood pile size) and fiber digestion rate (akin to wood moisture) must be accounted for to accurately predict rumen fiber digestion across different diets and intake levels. The same forage consumed in a high cow or dry cow TMR will actually be digested differently due to passage rate (i.e. rumen retention time). The only way this can be accurately predicted is by combining digestible fiber pool size and digestion rate in a model that also includes a passage rate. Reason being, fiber leaves the rumen in two ways; digestion or passage. Both the CNCPS and TTNDFD models combine passage rate ($k_{p,}$ % hr^{-1}) with potentially digestible fiber pool (pdNDF) and digestion rate (pdNDF k_d, % hr^{-1}) in the following equation:

Rumen NDF digestion (% of aNDFom) = potentially digestible fiber pool x [pdNDF kd / (pdNDF kd + pdNDF kp)], where:

- *pdNDF, % of aNDFom = NDFD240om = (aNDFom – uNDF240om)/aNDFom x 100*
- *fiber k_d, % pdNDF hr^{-1} = non-linear model parameter, determined using multi-time point NDFD measures (i.e. 24, 30, 48 or 30, 120, 240)*

Fiber digestion term dictionary

- aNDF = NDF determined with amylase in the neutral detergent solution
- aNDFom = aNDF corrected for ash
- uNDF = undigested aNDF following a discrete digestion time (i.e. 30 or 240 h)
- iNDF = indigestible aNDF, theoretical value determined only by nonlinear modelling
- uNDFom = undigested fiber corrected for ash
- NDFD = digested aNDF, expressed as a percent of aNDF
- dNDF = digested aNDF, expressed as a percent of DM
- pdNDF = potentially digestible NDF, % of aNDF or aNDFom
- pdNDF k_d = fiber digestion rate, % of pdNDF / hour

Semantics

Often, “k_d rate” has been used to describe fiber or starch digestion rates. “k_d rate” is grammatically incorrect as the “k” is defined as the *rate coefficient* and the “d” is defined as *digestion*. Hence, “k_d rate” is redundant and akin to stating, “Digestion rate rate”.

Breeding and managing forages for better NDF digestibility

While uNDF and digestion rate are related to one another, they both can be improved. Reduced lignin forages have lesser uNDF levels and correspondingly greater digestible NDF pools. Reducing uNDF in feeds can be achieved in two ways; 1) diluting the uNDF with more digestible nutrients such as starch, protein or sugar or 2) breeding or managing to lessen the uNDF as a percentage of total aNDF. Brown midrib corn mutants and low-lignin alfalfa varieties improve quality by decreasing uNDF as a percent of total fiber. Beyond lessening uNDF, Prof David Combs (personal communication) has suggested that digestion rate may also be heritable.

In managing forages, harvesting alfalfa and grass crops earlier both lessens uNDF and increases fiber digestion rates. Cross linking within cell walls develops as plants mature and decreases bacterial access to cellulose, thus decreasing both digestion speed and extent. Cut first crop alfalfa each year at 22 to 24” height on the PEAQ stick (Hintz and Albrecht, 1993). Do not assume 28 day cutting intervals result in dairy quality forage. Scout fields starting about 17 days after the prior cutting and monitoring plant maturity every 3 to 5 days then with scissors clipping.

Decision making with specific uNDF or NDFD metrics

With forages harvested or purchased and stored, making decisions solely based upon 30 or 48 h NDFD can now be considered “old school”. Both uNDF (or pdNDF) and the pdNDF k_d should be used in decision making, balancing and modeling. The pdNDF k_d

should never be interpreted by itself, as it depends upon the uNDF level. However, uNDF values have utility as a better lignification measure.

uNDF

Monitor uNDF240 levels (% of DM) in diets, on a herd by herd basis. To my knowledge, there is not an industry accepted or published benchmark for a certain uNDF level that will limit intakes, however within a herd these metrics can prove valuable to help formulate forage inclusion rates when switching forage sources. Further, uNDF level can be used to project cash flow in certain circumstances. For example, Dr. Sam Fessenden (AMTS technical services; personal communication) has taught to use uNDF (g CHO-C) as a tool to consider when forecasting intake responses on a herd by herd basis. Sam has suggested that diet projections can be compared by using different forages at similar dry matter intakes but further by also comparing the diet scenarios and maintaining CHO-C level relatively constant between diets.

TTNDFD

Prof David Combs (personal communication) has taught to use forage TTNDFD as practical decision making parameter for feed allocation. Feeds with TTNDFD values greater than 45 to 47% (of aNDF) should be allocated to fresh and high performing diets. Feeds with values less than 40% should be directed to heifers and dry cows or later lactation pens.

peuNDF240

Prof Rick Grant and his former graduate student, Wyatt Smith, have assessed both TMR uNDF240 and physically effective factor, and combined these two parameters into peuNDF240 (Grant et al., 2018 and R. Grant, personal communication). To this point, Prof Grant's group have evaluated data pooled from several experiments at Miner Institute. Diet peuNDF240 appears to be more tightly correlated with dry matter intakes and performance in high producing dairy cattle at the Miner Institute. While field data are lacking currently, our group is in the process of a collaborative research project evaluating field TMR samples for peuNDF240 and to what extent this factor is related to intakes and performance. This project stems from a recent internship field survey, which will be discussed later in this article (Geiser and Goeser, 2019).

Reduced lignin feed impact on farm profitability

Research investigating reduced lignin corn silage, published by both plant breeders and animal scientists, dates back decades and *brown-midrib* mutations appear to largely impact the pdNDF but not the pdNDF digestion rate (Cherney et al., 1991). The production response often discussed however additional factors beyond milk production per cow per day need to be considered in whole-farm partial budget evaluations. Crop production costs, yield per acre, and dry matter intake (or feed conversion) need to be incorporated into cash flow projections.

Production response: Prof Ferraretto and Prof Shaver's meta-analysis approach observed slightly greater than 3 pounds per cow per day milk response for BMR relative to conventional silages. This milk production gain was slightly offset by a significant decrease in butterfat production and approximate 2 pound per cow increase in dry matter intake. Note that in many cases these silages were managed in similar styles, with similar chop lengths which may interact with uNDF.

Forage yield: Data summarized by Prof. Joe Lauer, after evaluating several years of WI hybrid trials, detailed roughly 15 percent less yield with *brown-midrib* mutant corn hybrids relative to other conventional varieties (Lauer et al., 2016 and prior years; accessed online, http://corn.agronomy.wisc.edu/HT/Default.aspx). Transgenic alfalfa also reported lesser yield when managed in a similar manner to conventional lines. Though the reduced lignin alfalfa though may better maintain quality though with extended cutting intervals (Getachew et al., 2018), thus improving digestible yield or exposure to risk due to delayed harvest conditions.

Disease resistance: Prof Damon Smith (personal communication) has taught that lignin is a plant defense mechanism. Thus, crops with a lesser ability to lignify will likely also be more prone to disease pressure and warrant additional scouting or crop protection. Crop protection inputs should be considered in crop production costs per acre as part of the cash flow projection.

Feed conversion: the balance between intake and performance gain needs to be considered when evaluating reduced lignin feed potential. The aim should be to increase feed conversion efficiency. According to Oba and Allen (1999), a 1-unit gain in forage *in vitro* rumen NDF digestion corresponds to roughly 0.38 lb increase in DMI and just over 0.55 lb increase in 4% fat corrected milk production per cow per day. With a roughly 2:1 milk to intake increase per unit ivNDFD, theoretically feed conversion should improve via reduced lignin forages assuming ivNDFD increases. Though Ferraretto and Shaver (2015) reported no improvement in feed conversion with *brown-midrib* corn silage relative to convention following meta-analysis. Again note, in nearly all cases the *brown-midrib* variety was managed and harvest similar to the conventional hybrid.

Summary: completing the partial budget

Recapping the points discussed here, ensure you incorporate both fiber kd and uNDF in animal performance projections. *Consider using the independent pairwise correlations discussed in the case study presented below as well to add to animal response projections.* With these relationships in hand,combine forage quality measures with yield and crop production costs for a true partial budget evaluation. The University of

Wisconsin Extension team (Shaver, Goeser, Lauer and Jones, 2019) released a partial budget tool to help, allowing users to evaluate BMR versus conventional seed corn impact on farm cash flow. The tool clearly identifies all the animal performance and crop inputs that must be included for an appropriate cash flow projection and can be accessed at Prof. Joe Lauer's website: http://corn.agronomy.wisc.edu/Season/DSS/CornBMRSilage_Milk_v_YieldCalculator_v22.xlsx

Case study: Corn silage NDFD and uNDF in relation to commercial dairy performance (Geiser and Goeser, 2019)

In 2018, Geiser and Goeser conducted a field survey as part of a summer internship project with the support of CP Feeds and Rock River Laboratory, Inc. in Eastern WI. Commercial dairies (n=59) were surveyed and sample for corn silage kernel processing, rumen starch digestibility and high pen fecal starch to investigate potential correlations. The study is described in further depth in the abstract published by Geiser and Goeser (2019). The dairies ranged in production and dry matter intakes (Table 1), presenting a unique opportunity to assess various nutrition factors relative to performance and efficiency (i.e. feed conversion to energy corrected milk). Summary statistics from the survey are presented in Table 1.

Materials and Methods

Data from four farms were excluded due to missing data or TMR aNDF levels being less than 25%, which likely indicated non-Dairy TMR or sampling errors. Thus, 55 farms out of the 59 were further investigated to compare corn silage aNDF digestibility factors with animal performance data. As part of the initial investigation, corn silages were assayed for starch digestibility and kernel processing scores. Corn silage samples were also assessed by near-infrared reflectance spectroscopy for nutrient and NDF digestibility parameters. The corn silage fiber digestibility at 30 and 240 hours, Goering and Van Soest technique (1970), and TTNDFD (Combs, 2013) were then evaluated against production metrics using multivariate methods, multivariate analysis, in JMP Pro v14.0. The independent pairwise correlations were deemed significant at $P<0.05$ and trends recognized at $P<0.10$.

Observations and impact

Several interesting independent pairwise correlations are presented here as a case study, for discussion purposes (Table 2). In alignment with Oba and Allen's (1999) observations, corn silage in vitro NDF digestibility appears significantly related to intake and milk production. Corn silage NDFD30, TTNDFD and uNDF240 each demonstrated significant independent pairwise correlations with dry matter intake and energy corrected milk production (ECM, calculated as 12.95 x milk lbs x milk fat % + 7.65 x milk lbs x milk protein % + 0.327 x milk lbs; Table 2). The results suggest a one-unit increase in corn silage NDFD30 or TTNDFD (% of aNDF) are related to 0.45 and 0.62 lb increase in DMI (*P*<0.01; Figure 4), and 0.98 and 0.78 lb increase in ECM (*P*<0.05; Figure 5), respectively. Further, a one unit increase in corn silage uNDF240 appeared to correspond to a 0.60 lb decrease in dry matter intake and 1.29 lb decrease in ECM (*P*<0.05; Figures 4 and 5). Lastly, feed conversion efficiency was evaluated by dividing ECM by dry matter intake and then appeared related to NDFD30 in a trend (*P*<0.09; Figure 6). This trend suggests a one-unit increase in corn silage NDFD30 could equate to a 0.005 unit increase in FCE. Should this relationship prove real, a 50% (below average) vs 60% (above average) NDFD30 in corn silage would equate a 0.05 unit improvement in ECM feed conversion efficiency. Projecting out to the economic impact with 2019 US average feed costs, this would equate to roughly $0.20 per CWT in reduced feed costs.

These case study observations are numerically greater than those published nearly 20 years ago by Oba and Allen (1999) however suggest that greater responses may exist for commercial dairy cattle today. Note, these case study results do not represent a controlled research experiment thus relationships should be interpreted with caution. Further investigation and research is warranted.

Table 1: Commercial dairy case study: Summary statistics for dairies surveyed by Geiser and Goeser (2018).

Parameter, % DM unless noted	n	Mean	Std Dev	15th perc.	85th perc.
TMR					
CP	55	16.80	0.61	16.23	17.49
aNDF	55	28.00	2.56	25.84	30.36
Starch	50	26.44	2.39	23.77	29.03
Percent corn silage	54	36.94	7.86	28.33	44.40
Percent forage	52	57.33	4.95	53.13	62.22
Corn silage					
DM	59	33.00	4.40	31.00	38.00
aNDFom	59	37.56	4.10	32.96	40.41
Starch	58	33.28	4.73	30.29	37.61
KPS, % starch < 4.75 mm	59	65.45	6.99	58.91	71.73
isSD0, % starch	59	80.94	9.11	75.37	87.39
isSD7, % starch	59	88.73	3.68	85.88	91.11

NDFD30, % aNDF	55	64.34	4.97	58.61	70.40
uNDF240	55	11.53	2.60	8.97	14.24
TTNDFD, % aNDF	55	41.53	3.79	37.11	45.95
Dairy cattle measures					
Fecal Starch	59	2.14	1.67	0.96	3.07
Total Tract Digestibility, % starch	59	97.33	2.08	96.16	98.80
DMI, kg	58	26.26	2.49	23.55	28.22
ECM, kg	59	40.27	4.31	35.97	45.16
ECM/DMI	58	1.53	0.11	1.41	1.66

Table 2: Commercial dairy case study: Independent pairwise correlations for corn silages and commercial dairy performance surveyed by Geiser and Goeser (2018)

Parameter (%aNDF, %DM, or lb)	Y (response)	Intercept	Slope (x)	Input	*P*<
NDFD30, ECM	89.90	25.97	0.98	65.00	0.00010
NDFD30, FCE (ECM/DMI)	1.46	1.19	0.0054	50.00	0.08540
TTNDFD, ECM	91.97	56.56	0.79	45.00	0.02200
uNDF240, ECM	88.04	104.10	-1.29	12.50	0.00980
uNDF240, DMI	57.47	64.98	-0.60	12.50	0.04130

Figure 4: Commercial dairy dry matter intake (lbs. / cow) independent pairwise correlations with NDFD30 (% aNDF), TTNDFD (% aNDF), and uNDF240 (% DM).

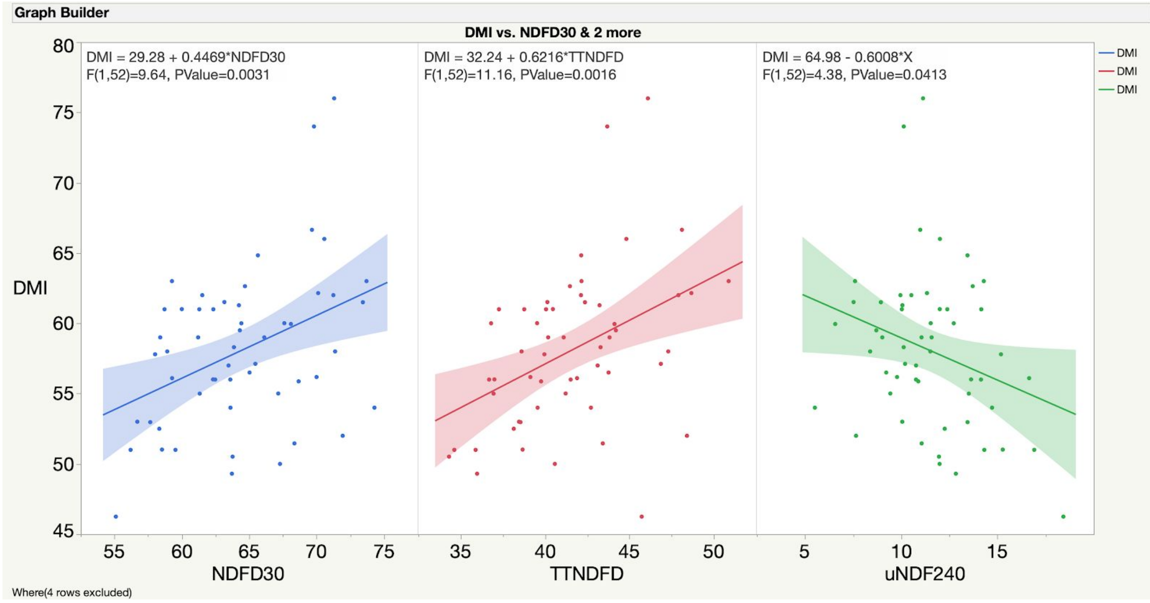


Figure 5: Commercial dairy energy corrected milk (lbs. / cow) independent pairwise correlations with NDFD30 (% aNDF), TTNDFD (% aNDF), and uNDF240 (% DM).

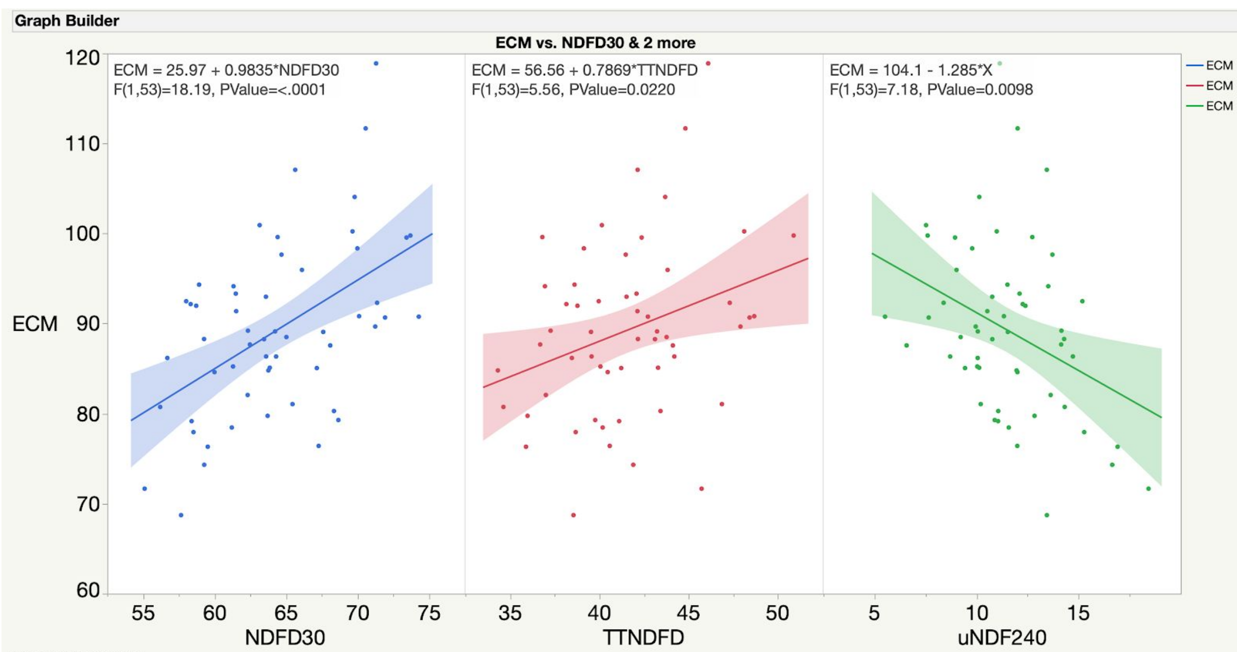
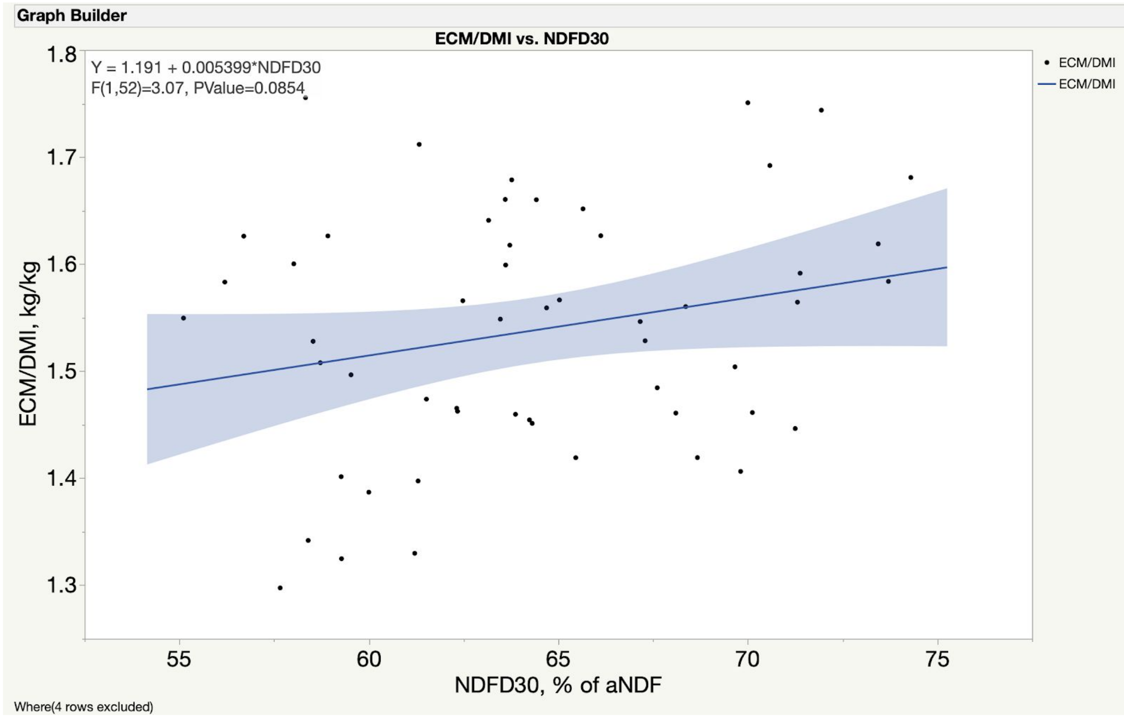


Figure 6: Commercial dairy feed conversion efficiency (energy corrected milk, lbs. / dry matter intake, lbs.) independent pairwise correlation with NDFD30 (% aNDF).



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TEXAS TECH UNIVERSITY

New Insights into health of dairy calves during the pre-weaning period

Vinicius Machado, DVM, Ph.D.
Assistant Professor of Dairy Health and Management
Department of Veterinary Sciences

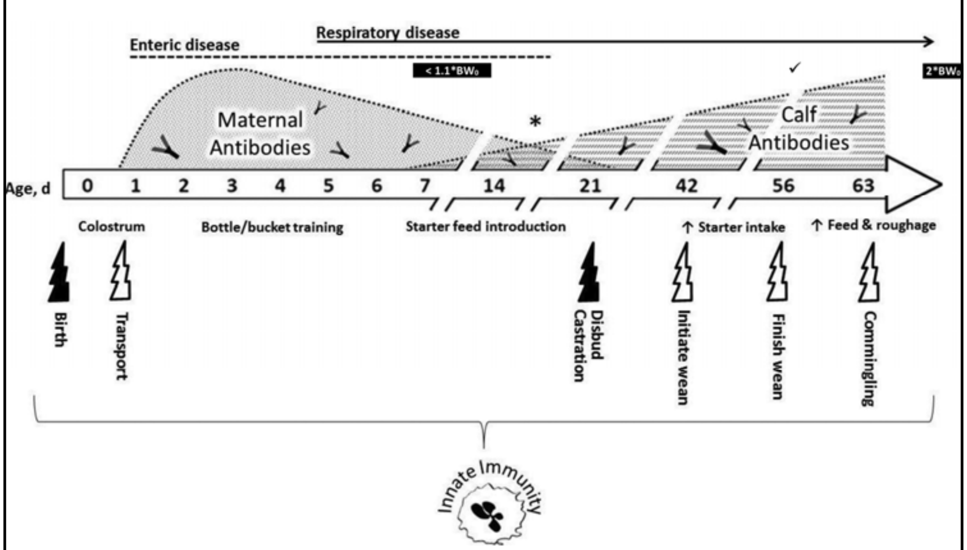
1

OUTLINE

- Introduction
- Common health issues
  - *BRD and diarrhea*
  - *Metagenomic studies*
- On going research at TTU

2

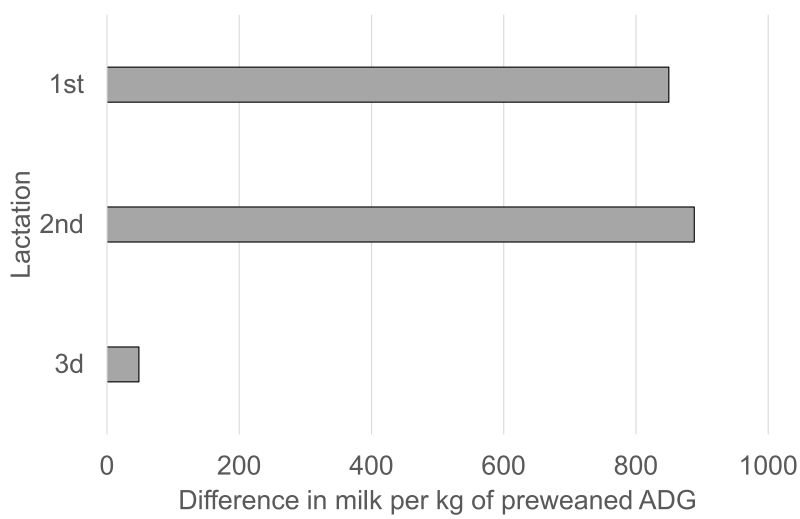
INTRODUCTION



Hulbert and Moisa, *J Dairy Sci*, 2016

3

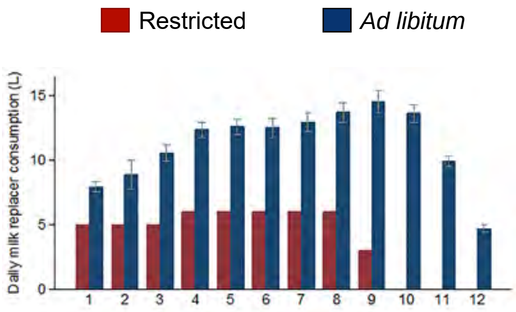
GROWTH DURING PRE-WEANING PERIOD HAS LONG TERM IMPACT ON PERFORMANCE



Soberon et al. (2012)

4

FEEDING CALVES



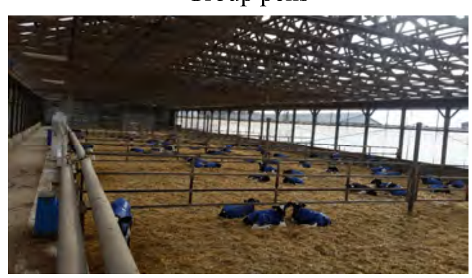
Curtis et al. Veterinary Record , 2018

5

COMMON HOUSING SYSTEMS

Individual pens

Group pens



- Goals:
  - *Deep, clean and dry bedding*
  - *Good ventilation / air quality*

6

INDIVIDUAL HOUSING

- Pros:
  - *Isolated animals*
  - *Decreased disease / pathogens transmission*
  - *Easy to monitor milk consumption and health*
- Cons:
  - *Feeding is labor intensive (ad libitum systems often not practical)*
  - *Cleaning is hard and labor intensive*
  - *Welfare / socialization / public perception*

7

GROUP HOUSING

- Pros:
  - *Easy to clean*
  - *Easy to adopt ad libitum feeding systems*
  - *Socialization and public perception*
- Cons:
  - *Transmission of pathogens*
  - *Difficult to monitor intake*
  - *Difficult to detect sick animals*

8

DIFFERENT HOUSING SYSTEMS – DIFFERENT CHALLENGES

Individual pens

Group pens

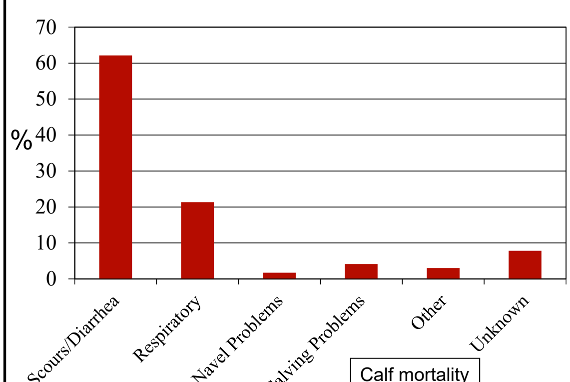
- Lower incidences of disease
- Difficult to feed

- Higher incidences of disease
- Higher feed intakes

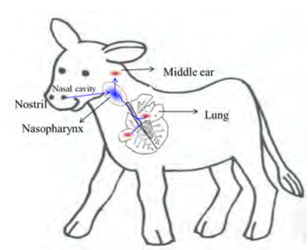
9

COMMON HEALTH ISSUES

- Diarrhea – Scours
- Bovine respiratory disease
  - *Pneumonia – Otitis*



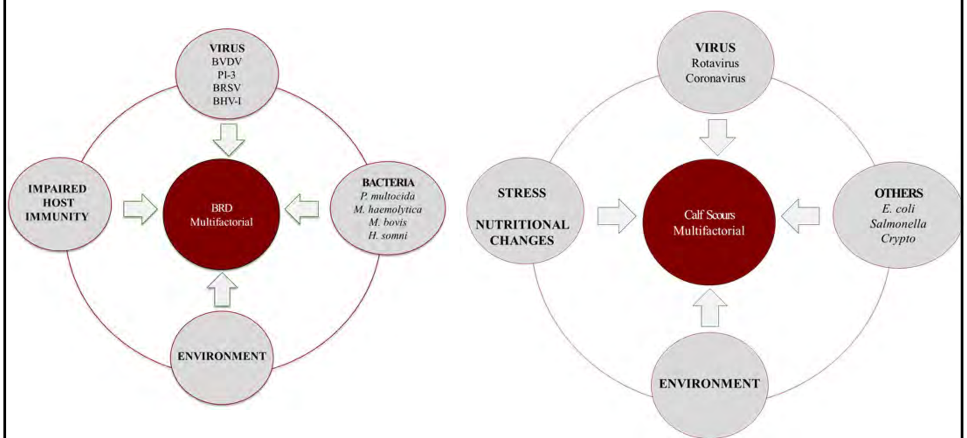
NAHMS-USDA 2007



nasopharynx is connected to the middle ear via the Eustachian tube

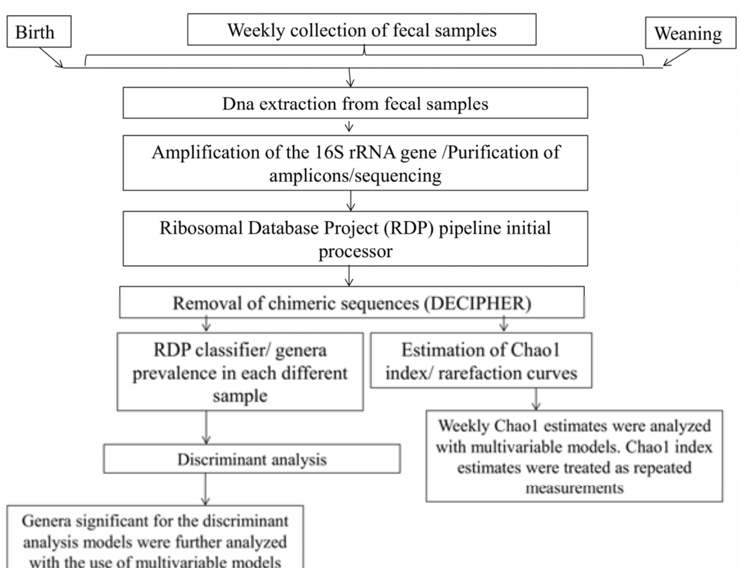
10

MULTIFACTORIAL DISEASES



11

METAGENOMICS – SCOURS

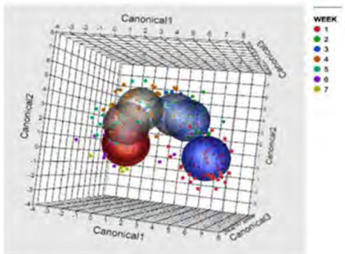


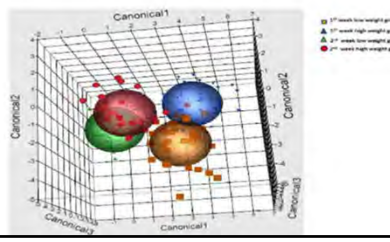
Oikonomou et. al, PLOS ONE, 2013

12

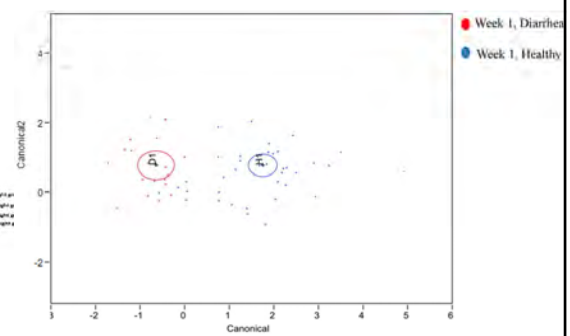
METAGENOMICS – SCOURS

Discriminant analysis of fecal microbiomes by week of life





Discriminant analysis of fecal microbiomes for the first week of calf life and for calves that suffered or not from diarrhea

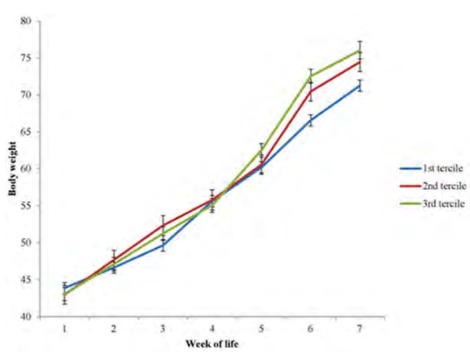


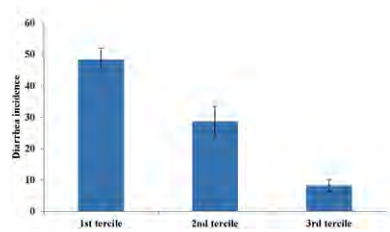
Oikonomou et. al, PLOS ONE, 2013

13

METAGENOMICS – SCOURS

Adjusted means of body weight by week of life as well as adjusted means of diarrhea incidence for different *Faecalibacterium spp.* terciles

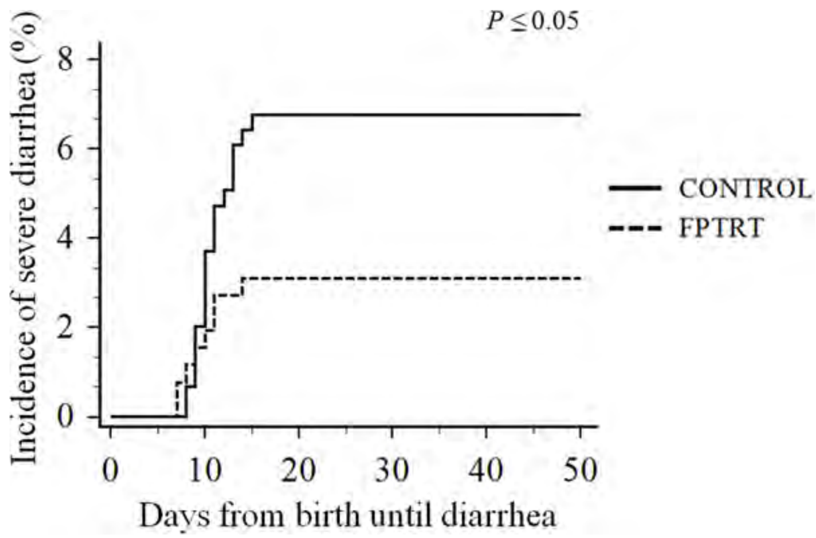




Oikonomou et. al, PLOS ONE, 2013

14

Oral Administration of *Faecalibacterium prausnitzii*



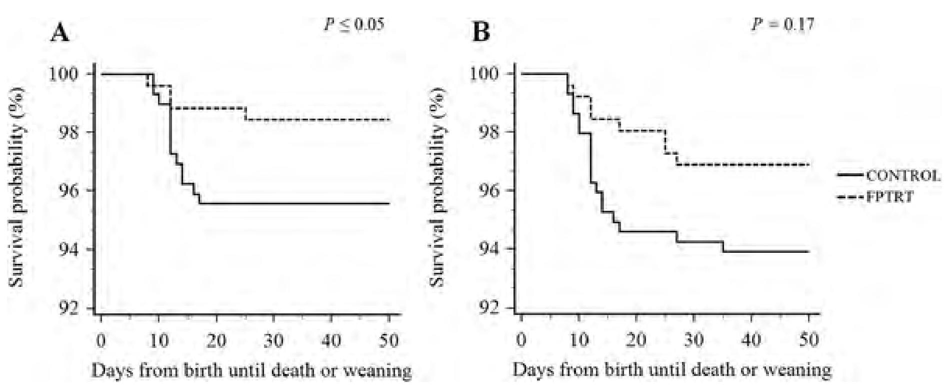
N = 296

N = 258

Foditsch et. al, PLOS ONE, 2015

15

Oral Administration of *Faecalibacterium prausnitzii*



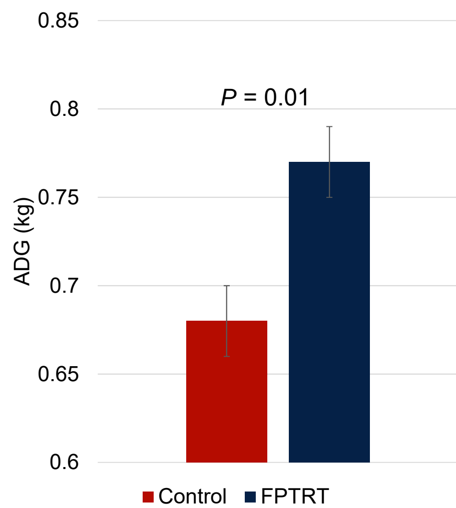
Mortality due to severe diarrhea

Overall mortality

Foditsch et. al, PLOS ONE, 2015

16

Oral Administration of *Faecalibacterium prausnitzii*

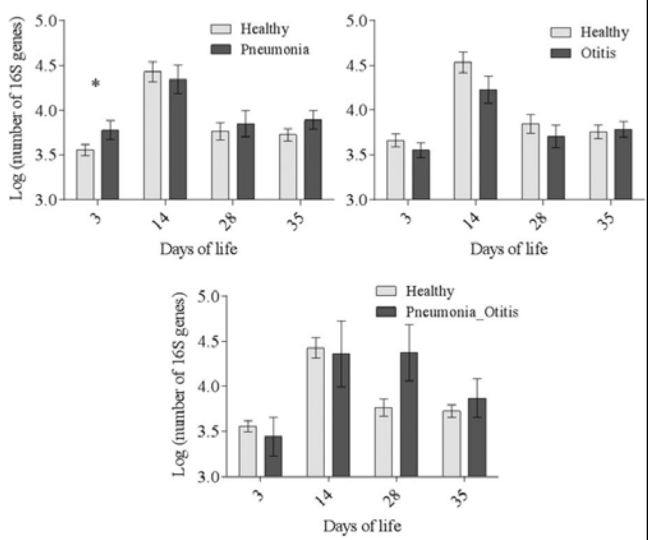


Foditsch et. al, PLOS ONE, 2015

17

METAGENOMICS – BRD

- 174 calves
- Nasal swabs collected at 3, 14, 28, and 35 days of life
- 16s rRNA gene sequencing



Lima et. al, Scientific Reports, 2016

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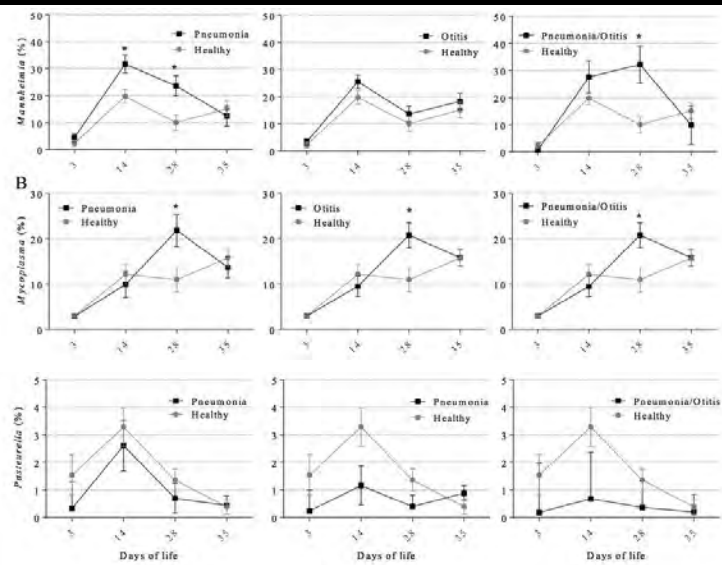
METAGENOMICS – BRD



Lima et. al, Scientific Reports, 2016

19

METAPHYLAXIS – BRD

- CTR = untreated
- M1 = one tildipirosin injection administered at 10 days of life
- M2 = two tildipirosin injections at 10 days and 35 days of life

		Hazard ratio (95% confidence limit)	P value
Mortality	CTR	Reference	
	M1	0.51 (0.30–1.13)	0.11
	M2	0.62 (0.28–1.29)	0.21
BRD	CTR	Reference	
	M1	0.68 (0.47–0.97)	0.07
	M2	0.70 (0.49–1.01)	0.09
Otitis	CTR	Reference	
	M1	0.85 (0.67–1.23)	0.34
	M2	0.80 (0.62–1.15)	0.30
BRD and/or otitis	CTR	Reference	
	M1	0.70 (0.58–0.95)	0.009
	M2	0.72 (0.60–0.98)	0.01

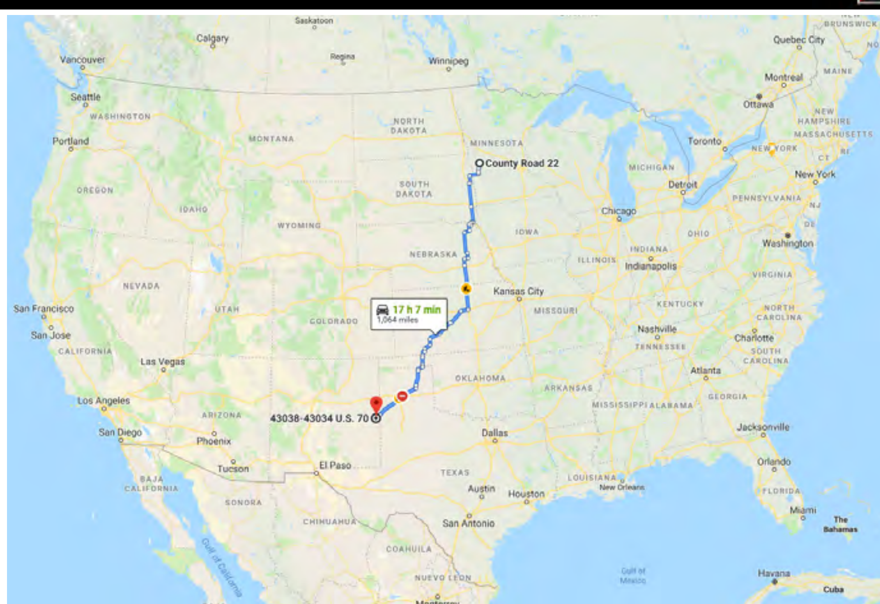
Teixeira et. al, The Vet J, 2016

20

TRADITIONAL CALF RAISING MANAGEMENT

21

TRANSPORTATION CHALLENGES – HIGH RISK FOR BRD



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MANAGEMENT OF HIGH RISK CALVES

Total n of animals enrolled = 1,360

After transport

Active ingredient is mycobacterium cell wall fraction (MCWF) of *Mycobacterium phlei*, a non-pathogenic, soil-borne bacterium

BIRTH 2d Transport 3d Weeks1, 2 & 3 Weaning

Before transport

23

Disease treatment events were lower than the national average

Item	Enrolled (%)	Treated (%)	Dead (%)
Calves	1,360	155 (11.3)	16 (1.2)
CON	458	60 (13.1)	6 (1.3)
BTIS	449	44 (9.8)	5 (1.1)
ATIS	453	51 (11.4)	5 (1.1)

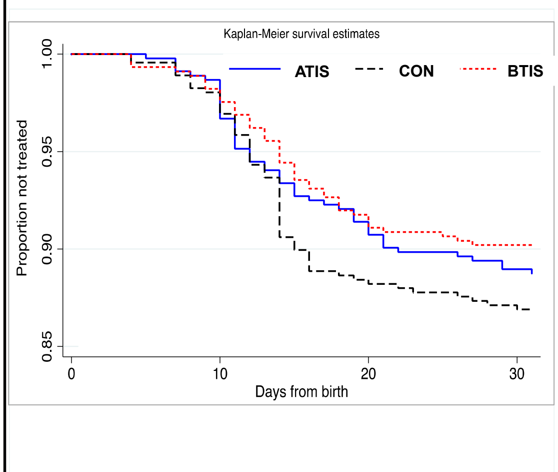
CON: control; BTIS: before transport; ATIS: after transport

University of Minnesota

Courtesy of Luciano Caixeta

24

No difference in hazard of treatment within first month of life



Group	Adjusted Hazard ratio	95% CI	*P* - value
CON	*Ref.*	-	-
BTIS	0.74	0.50 – 1.09	0.14
ATIS	0.84	0.57 – 1.2	0.35

CON: control;
BTIS: before transport;
ATIS: after transport

Courtesy of Luciano Caixeta

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BTIS reduced hazard of treatment for pneumonia but not for scours within first month of life

Group	Pneumonia			Scours		
	HR	95% CI	*P*-value	HR	95% CI	*P*-value
CON	*Ref.*	-	-	*Ref.*	-	-
BTIS	0.54	0.31 – 0.94	0.02	1.04	0.58 – 1.88	0.87
ATIS	0.88	0.55 – 1.42	0.60	0.75	0.40 – 1.42	0.38

CON: control;

BTIS: before transport;

ATIS: after transport

Courtesy of Luciano Caixeta

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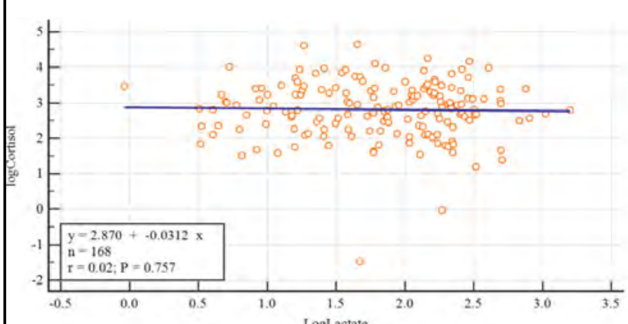
SERUM BIOMARKERS OF STRESS AND INFLAMMATION AFTER TRASNPORTATION OF NEWBORN CALVES

- 168 calves
  - Control (untreated) group
- Biomarkers measured
  - Haptoglobin
  - Cortisol
  - L- lactate

27

Correlation between biomarkers



- Haptoglobin
  - 67.9 µg/ml
- Cortisol
  - 17.36 ng/ml
- L-lactate
  - 6.5 mM

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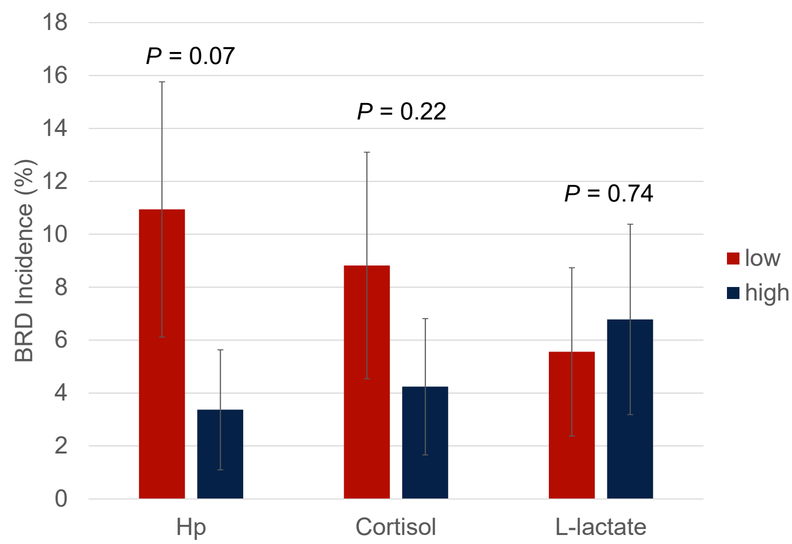
Association between biomarkers and BRD



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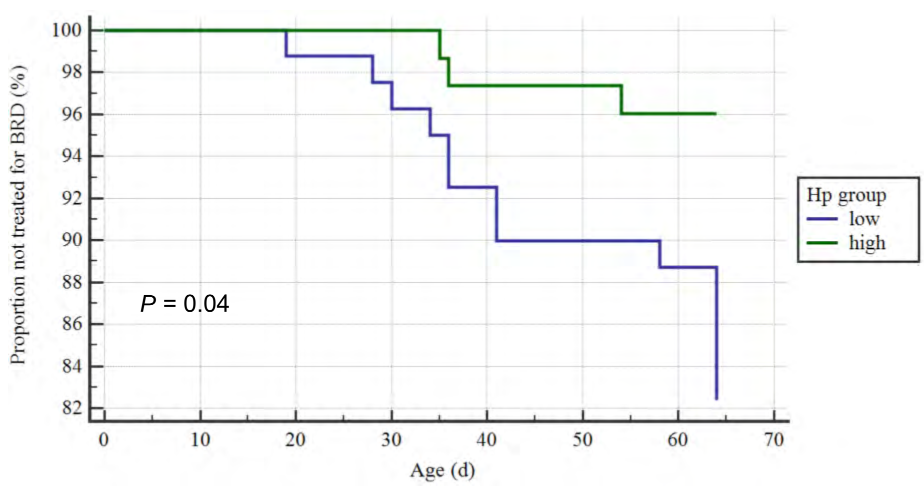
Association between Hp and BRD



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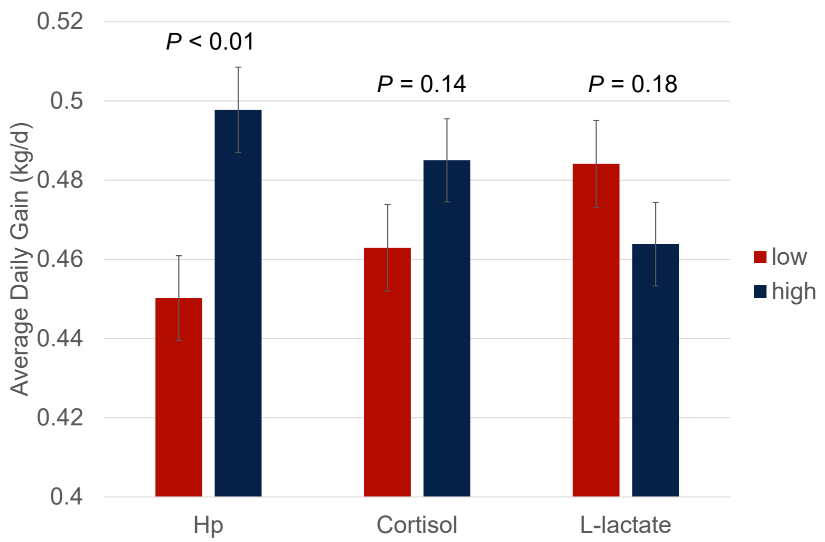
Association between biomarkers and weight gain



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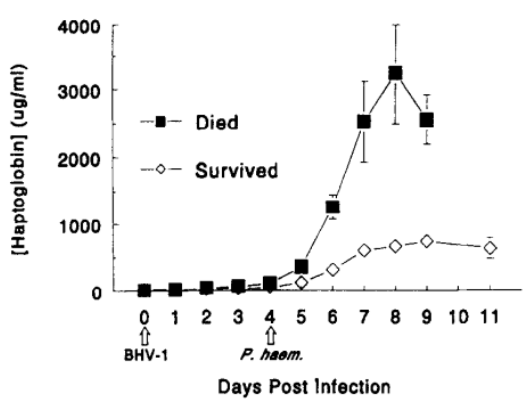
PHYSIOLOGIC VS PATHOLOGIC LEVELS OF HAPTOGLOBIN

D.L. Godson et al. / Veterinary Immunology and Immunopathology 51 (1996) 277–292



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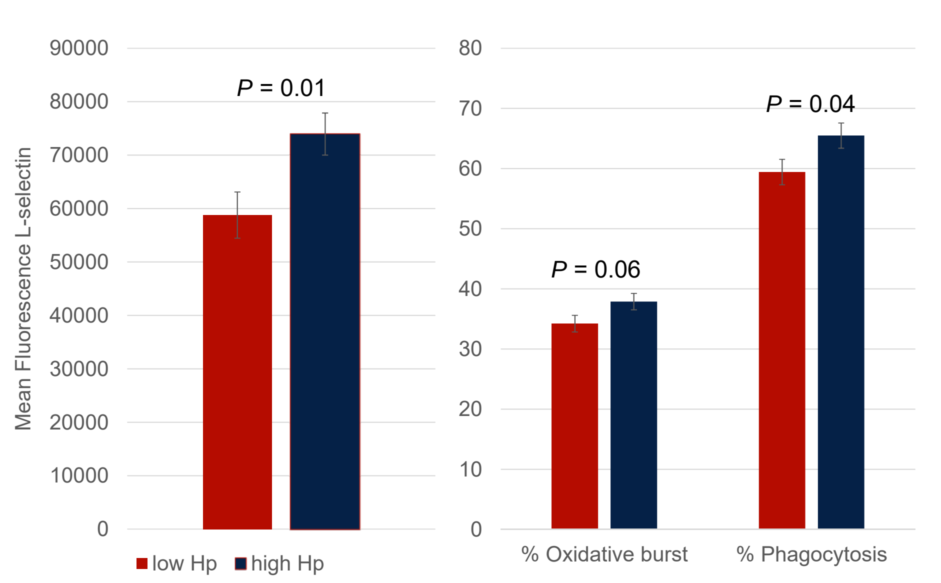
LEVELS OF HAPTOGLOBIN IS ASSOCIATED WITH IMMUNE SYSTEM ACTIVATION



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CONTINUING CALF RESEARCH

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Vinicius Machado
vinicius.machado@ttu.edu

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New insights into health of dairy calves during the pre-weaning period

Vinicius Machado, DVM, PhD
Department of Veterinary Sciences
Texas Tech University, Lubbock, TX

Optimal growth during the pre-weaning period is crucial for the post-weaning performance of dairy heifers. It was reported that for every 1 kg of pre-weaning average daily gain (ADG), heifers produce, on average, 850 kg to 1,113 kg more milk in their first lactation (Soberon et al., 2012). Growth during the pre-weaning period is impacted by many factors, including nutrition, management, environment, and incidence of diseases. Bovine respiratory disease (BRD) and diarrhea are the two most common disorders during the pre-weaned life of dairy calves. In addition to the economic losses due to delayed growth, BRD and diarrhea are the two most common causes of calf mortality during the pre-weaning period (USDA-NAHMS, 2007).

Both diseases have multifactorial nature. Diarrhea can be caused by infectious and non-infectious agents. Management (e.g., colostrum, housing), nutritional state, immunity, and pathogen exposure are risk factors associated with both diarrhea and BRD (Al Mawly et al., 2015; Dubrovsky et al., 2019). *E. coli*, *Salmonella spp*., *Cryptosporidium*, and rotaviruses are among the most common enteropathogens that causes diarrhea in pre-weaned dairy calves (Gulliksen et al., 2009). In addition to a complex of viruses, the major bacterial etiological agents of BRD are *Mannheimia haemolytica*, *Pasteurella multocida*, *Histophilus somni* and *Mycoplasma spp.* (Angen et al., 2009).

Metagenomics studies have been conducted in the last decade to investigate the bacterial diversity and abundance associated with diarrhea and BRD. It has been established that the fecal microbiome of dairy calves significantly changes as the calf ages. Additionally, the relative abundance of some bacteria in the feces is associated with diarrhea incidence and growth, in particular *Faecalibacterium prausnitzii.*, a butyrate producing organism (Oikonomou et al., 2013). Higher relative abundance of *Faecalibacterium prausnitzii* in the feces during the first week of life is associated with lower incidence of diarrhea, and with increased ADG. The impact of *Faecalibacterium prausnitzii* on the gut of other species have also been studied. It has been associated with obesity in children, and it was decreased in the gut of dogs with acute diarrhea, suggesting that it has anti-inflammatory roles as well as energy harvesting properties. In a subsequent study, *Faecalibacterium prausnitzii* live cultures were administered orally to dairy calves in their first week of life (Foditsch et al., 2015). Oral administration of *Faecalibacterium prausnitzii* lowered the incidence of severe diarrhea, decreased the mortality due to severe diarrhea, and accelerated the growth of dairy calves over the pre-weaning period. These are encouraging results regarding the use of this commensal bacterium as a probiotic that will promote health and growth of dairy calves.

High-throughput sequencing of the 16S rRNA gene was used to characterize the upper respiratory tract of dairy calves over the first 35 days of life, and to compare the microbiome of healthy and unhealthy calves (Lima et al., 2016). It was observed that the microbiome of the upper respiratory tract of dairy calves during the pre-weaning period is highly diverse. Calves diagnosed with BRD had a greater bacterial load in their upper respiratory tract. Results from this study supports the previous knowledge that Mannheimia and Mycoplasma are important in the pathogenesis of BRD, while suggests that Moraxella can also be an important etiological agent. Hence, it is likely that strategies that decrease the bacterial load in the respiratory tract of dairy calves, especially Mannheimia and Mycoplasma, will decrease the incidence of BRD during the pre-weaning period. In fact, it was reported that tildipirosin metaphylaxis on pre-weaned dairy calves housed in group pens decreases the combined incidence of pneumonia and otitis (Teixeira et al., 2017), but this strategy did not have any impact on growth or survival.

About 10% of dairy heifers in the United States are transported within the first 2 days of age to specialized calf raising facilities. Similarly to commingling, transportation is a known stressor of cattle that causes immunosuppression and can potentially impact the health of pre-weaned heifers. Recently, we evaluated the impact of a non-specific immune stimulant (mycobacterium cell wall fraction) on the health of calves that were transported (~18h from Minnesota to New Mexico) within the first 3 days of life to a calf raising facility. We observed that treating calves immediately before transportation decreased the hazard of BRD during the first 35 days of life, while treating immediately after transportation did not have a impact on disease incidence (Omontese et al., 2019).

It is known that after long-distance transportation, circulating levels of inflammatory and stress biomarkers are elevated. We have evaluated the association of serum levels of haptoglobin, cortisol, and l-lactate measured at time of arrival with health and growth of dairy calves transported to a grower facility within the first 4 days of life (Celestino et al., 2019). We hypothesized that high concentration of these biomarkers would be associated with greater disease incidence and delayed growth. However, we observed that calves categorized in the high haptoglobin group were less likely to develop BRD and had higher ADG compared to calves in the low haptoglobin group. Additionally, we did not observe any association of cortisol and l-lactate with health or weight gain. Because serum concentration of haptoglobin in our study animals were generally low in comparison to reported concentrations associated with pathological processes, we speculate that high haptoglobin in our study was suggestive of a more activated and protective immune system. More research is needed to better understand the interactions between early life transportation of calves, stress, immunity, and health.

Angen, Ø., J. Thomsen, L.E. Larsen, J. Larsen, B. Kokotovic, P.M.H. Heegaard, and J.M.D. Enemark. 2009. Respiratory disease in calves: Microbiological investigations on trans-tracheally aspirated bronchoalveolar fluid and acute phase protein response. Vet. Microbiol. 137:165–171. doi:10.1016/J.VETMIC.2008.12.024.

Celestino, M., P.R. Menta, L. Fernandes, D. Poit, R.C. Neves, Caixeta L S, and V.S. Machado. 2019. Associations of Serum Biomarkers of Stress and Inflammation Measured at Arrival with Bovine Respiratory Disease Incidence, Mortality, and Growth of Calves Transported within the First 4 Days of Life. Accessed July 12, 2019. https://aabp.org/meeting/display_research.asp?recnum=81.

Dubrovsky, S.A., A.L. Van Eenennaam, B.M. Karle, P.V. Rossitto, T.W. Lehenbauer, and S.S. Aly. 2019. Epidemiology of bovine respiratory disease (BRD) in preweaned calves on California dairies: The BRD 10K study. J. Dairy Sci.. doi:10.3168/jds.2018-14774.

Foditsch, C., R.V.V. Pereira, E.K. Ganda, M.S. Gomez, E.C. Marques, T. Santin, and R.C. Bicalho. 2015. Oral Administration of Faecalibacterium prausnitzii Decreased the Incidence of Severe Diarrhea and Related Mortality Rate and Increased Weight Gain in Preweaned Dairy Heifers. PLoS One 10:e0145485. doi:10.1371/journal.pone.0145485.

Gulliksen, S.M., E. Jor, K.I. Lie, I.S. Hamnes, T. Løken, J. Åkerstedt, and O. Østerås. 2009. Enteropathogens and risk factors for diarrhea in Norwegian dairy calves. J. Dairy Sci. 92:5057–5066. doi:10.3168/JDS.2009-2080.

Lima, S.F., A.G. V. Teixeira, C.H. Higgins, F.S. Lima, and R.C. Bicalho. 2016. The upper respiratory tract microbiome and its potential role in bovine respiratory disease and otitis media. Sci. Rep. 6:29050. doi:10.1038/srep29050.

Al Mawly, J., A. Grinberg, D. Prattley, J. Moffat, J. Marshall, and N. French. 2015. Risk factors for neonatal calf diarrhoea and enteropathogen shedding in New Zealand dairy farms. Vet. J. 203:155–160. doi:10.1016/J.TVJL.2015.01.010.

Oikonomou, G., A.G.V. Teixeira, C. Foditsch, M.L. Bicalho, V.S. Machado, and R.C. Bicalho. 2013. Fecal Microbial Diversity in Pre-Weaned Dairy Calves as Described by Pyrosequencing of Metagenomic 16S rDNA. Associations of Faecalibacterium Species with Health and Growth. PLoS One 8. doi:10.1371/journal.pone.0063157.

Omontese, B., M. Celestino, D. Paiva, A. Garcia-Munoz, A. Masic, V. Machado, and L. Caixeta. 2019. Effects of a Bovine Nonspecific Immune Stimulant on Health of Jersey and Jersey-Cross Heifer Calves in the First Month of Life. Accessed July 12, 2019. https://m.adsa.org/2019/abs/t/78582.

Soberon, F., E. Raffrenato, R.W. Everett, and M.E. Van Amburgh. 2012. Preweaning milk replacer intake and effects on long-term productivity of dairy calves. J. Dairy Sci. 95:783–793. doi:10.3168/jds.2011-4391.

Teixeira, A.G.V., J.A.A. McArt, and R.C. Bicalho. 2017. Efficacy of tildipirosin metaphylaxis for the prevention of respiratory disease, otitis and mortality in pre-weaned Holstein calves. Vet. J. 219:44–48. doi:10.1016/J.TVJL.2016.12.004.

USDA-NAHMS. 2007. Dairy 2007: Heifer Calf Health and Management Practices on U.S. Dairy Operations.

Perspectives in ruminant protein efficiency, recycling, and amino acids

Evan Titgemeyer
Kansas State University

Topics for today

Urea recycling

Should I add urea to the diet?

Amino acid requirements

Should be believe the NRC?

Kansas State University

Decreasing dietary CP

Reproduction, diet cost, environment

Still meet MP requirement?
- Increase RUP
- Supplement AA

But, are the bacterial happy?

Kansas State University

Predicting RDP requirements

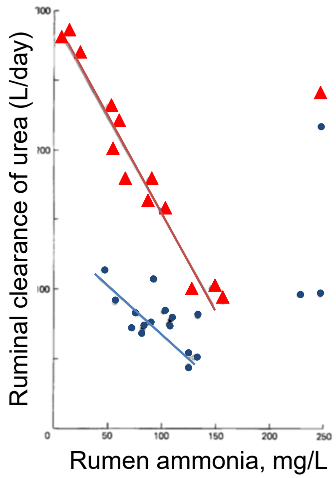
Estimate MCP (microbial protein)
Estimate efficiency of N capture
RAN requirement = MCP ÷ efficiency

RAN supply = RDP + recycled urea

(MCP = Microbial Crude Protein)
(RAN = Ruminally Available N)

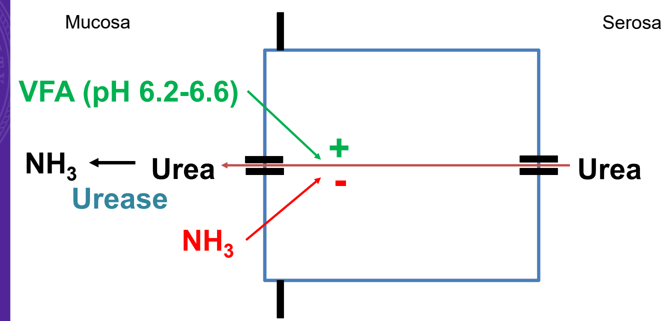
Kansas State University

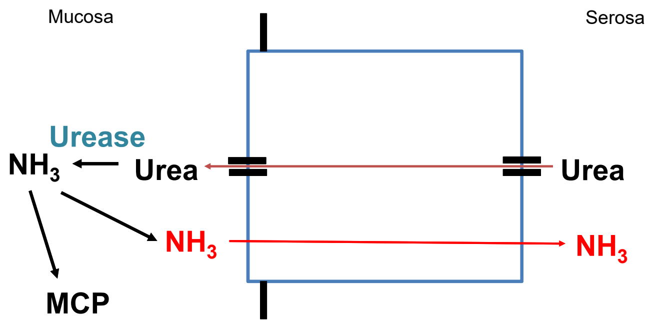
Ruminal Clearance of Urea



Kennedy, 1980

Urea movement across epithelium





Lactating dairy cattle

	Urea supplementation (% of DM)		
	0	0.4	0.8
Diet CP, %	12.6	13.7	14.9
DMI, kg/d	18.1	18.9	19.0
Milk, kg/d	32.7	33.8	34.0
Milk protein, kg/d	0.90	0.94	0.96
Rumen NH_3, m*M*	3.8	6.2	8.2
PUN, m*M*	3.3	5.5	7.8

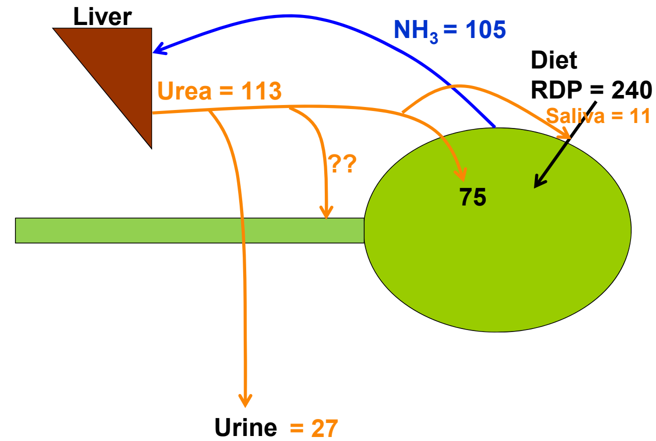
Rojen et al., 2011

Lactating dairy cattle

	Urea supplementation (% of DM)		
Nitrogen	0	0.4	0.8
N Intake, g/d	366	416	457
Urea			
Production, g/d	113	174	186
Recycled, g/d	75	104	96
Salivary, g/d	11	16	0
Recycled, %	66	60	52

Rojen et al., 2011

Dairy cows fed 12.6% CP diet



Rojen et al., 2011

How do we use this information?

Target optimal supply of RAN:

- If we know MCP and ruminally recycled urea, then we can calculate the necessary RDP

My perspective:

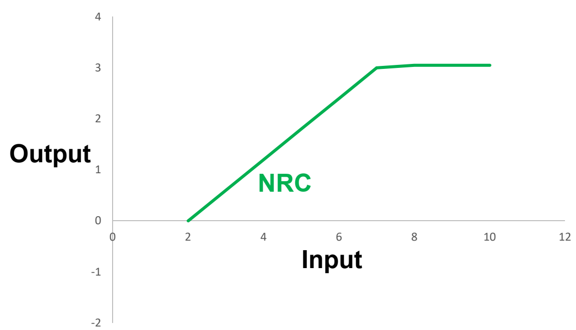
- For most lactation diets, deficiencies in RAN are unlikely to exist and certainly not likely to be severe

MP Requirements

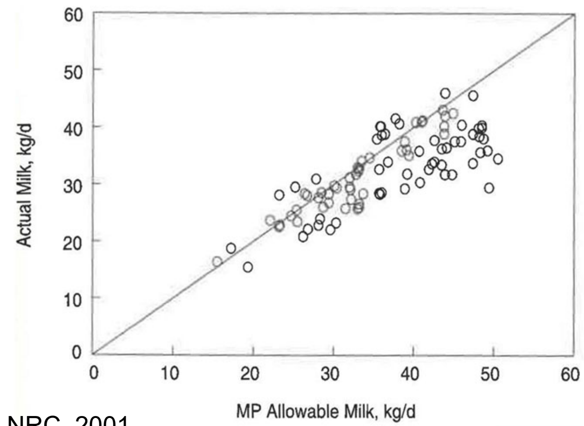
- NRC (2001) MP requirement =

  maintenance + milk protein/0.67
- Estimate of efficiency is key!
- Efficiency < 0.67
- Efficiency not constant, at least for a herd

Amino acid utilization

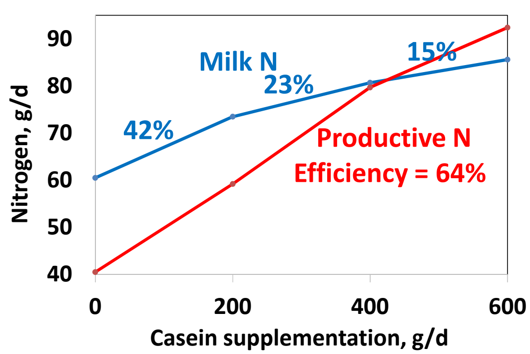


MP Requirements



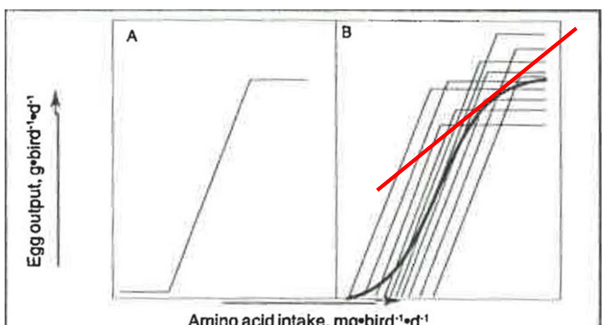
NRC, 2001

Efficiency of MP use in lactating cows

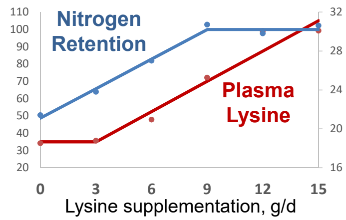


Whitelaw et al., 1986

Efficiency of nutrient use (Individuals vs. herds)

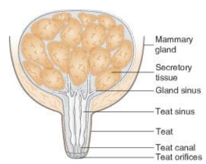


Source: Fisher, Br. Poult. Sci. 14:469 (1973)



Lesser affinity

Greater affinity



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AA Requirements

Efficiency of AA use isn't static

- **Energy effects**
- **AA role as anabolic stimulus**

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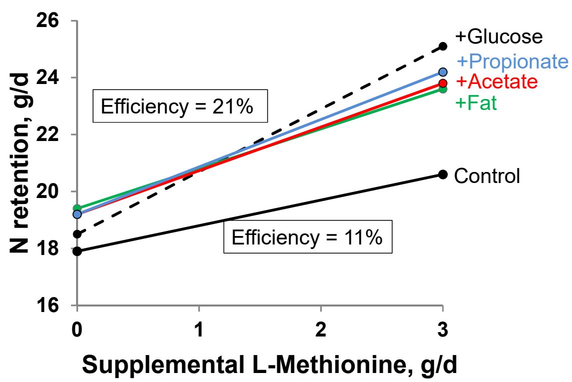
Effect of Energy Supply on Methionine Use



Schroeder et al., 2006

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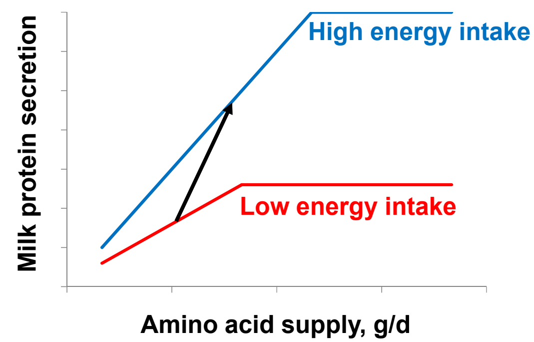

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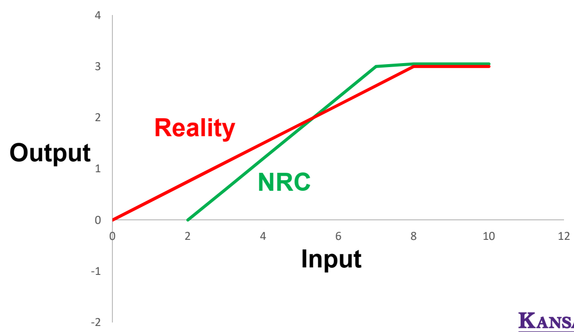
MP Requirements

- Estimates of maintenance and efficiency are correlated with each other



Efficiency of use varies among AA

Average efficiency of AA utilization for <u>growth</u>

- Methionine = 26% (11 trials)
- Leucine = 38% (4 trials)
- Histidine = 64% (2 trials)
- Lysine = 47% (3 trials)

AA Requirements

Why hasn't the 0.67 efficiency ruined the dairy industry?

- No one uses it as gospel
- Overestimated maintenance requirement balances the underestimated efficiency
- MP supply correlated to energy supply
- We work over a fairly narrow range

AA Requirements

We have a lot to learn!

- Empirical observations of responses to methionine and lysine are useful in predicting times to supplement
- At some point, perhaps in 10-15 years, we'll have answers on some other amino acids

Perspectives in ruminant protein efficiency, recycling, and amino acids

Evan Titgemeyer
Department of Animal Sciences and Industry
Kansas State University, Manhattan, KS 66506

There are a number of issues related to protein nutrition of dairy cattle that remain enigmatic to researchers yet are critical to appropriate formulation of diets for dairy cattle. This presentation will discuss several of these areas, with the goals of describing the issues and providing a brief overview of my current perspectives on the topic.

Urea recycling

Historically, dairy diets contained excess crude protein to ensure that metabolizable protein (MP) supply to the cow was adequate to support lactation. Under these conditions, there were no concerns about meeting the need of ruminal microbes for ruminally available nitrogen (RAN), because these over-formulated diets provided excess RAN. With efforts to improve reproduction, reduce diet cost, and reduce environmental degradation, dietary crude protein concentrations have decreased in recent years, leading to concerns that RAN could become limiting in lower protein diets.

RAN is provided to the microbes through ruminally degraded dietary protein (RDP) as well as through recycling of urea to the rumen, either through saliva or through transport across the ruminal wall. Our predications of RDP are reasonably accurate, but predictions of ruminal urea recycling are not very good. We also have difficulty in determining how efficiently microbes capture ammonia.

It is possible to find situations where dairy cows respond to urea supplementation with increases in intake and production. However, even in those cases, there is abundant blood urea that is excreted in the urine rather than recycled to the gut (Røjen et al., 2011). This suggests there might be features of urea recycling that limit the efficiency of urea transfer. Most research on urea recycling uses intravenous infusion of doubly-labeled urea to assess urea kinetics, but this method cannot separate movement of urea into the rumen from movement into other regions of the gut (i.e., the intestine); this limits our ability to accurately predict RAN.

Effects of amino acid supplements on bovine metabolism

Amino acids are the building blocks of protein. Tissues therefore require amino acids for protein synthesis, but amino acids also play important roles in metabolism and metabolic regulation. Methionine is the predominant methyl donor in the body, and methyl groups are transferred in hundreds of reactions. Choline and creatine synthesis are the quantitatively most important consumers of methyl groups. Choline supplementation presumably reduces the need for endogenous synthesis and spares methyl groups, although endogenous synthesis of choline may not be adequate for optimal performance, even if methyl groups are made available.

As regulatory molecules, amino acids can control rates of protein synthesis (Arriola Apelo et al., 2014). Amino acid supply may affect concentrations of regulatory hormones, and they also act within cells to stimulate protein synthesis through mTOR-related pathways. mTOR is a key regulatory kinase, with the mTORC1 complex being capable of phosphorylating other regulatory proteins within the cell, ultimately increasing protein synthesis. Thus, amino acid supply may affect protein synthesis not only by providing substrate, but also by regulating the protein synthetic machinery with the cell.

Amino acid requirements

The NRC (2001) model describes metabolizable protein (MP) requirements for lactating cows as a maintenance requirement plus a requirement for lactation, assuming a constant 67% efficiency of MP use for milk protein synthesis. This estimate of efficiency is greater than reality (Arriola Apelo et al., 2014), which leads to an overestimation of the cow's response to protein supplementation (i.e., an underestimation of the requirement). Moreover, the efficiency is not likely constant over broad ranges of MP supply, but rather decreases with increasing supply.

There are various reasons that efficiency of MP use for milk protein is not constant. One explanation is that populations of cattle yield response surfaces (milk protein vs. MP supply) that differ from those of individual cows. For example, a single cow may demonstrate a nearly linear response to MP supply until her capacity for milk protein synthesis is maximized, at which point there is a plateau in the response. In a population of cows with different maximal production levels, the pooling of the individual responses leads to a response surface with a slope that begins decreasing at the point where the first cow's performance is maximal and continues to decrease until a plateau is reached at the maximal production level of the highest producing cow.

From a metabolic perspective, one can suggest that individual cows should not have constant efficiencies of amino acid use because there are multiple tissues/pathways in the body that compete for amino acids (Arriola Apelo et al., 2014). As amino acid supply increases, concentrations also increase. At low concentrations, catabolic pathways will be minimal, which allows a large portion of the amino acid to be used for protein synthesis by the mammary gland. However, as concentrations increase with supply, catabolic pathways progressively increase, leading to a smaller fraction of the amino acid being used for protein synthesis. Moreover, the efficiency of amino acid use for protein synthesis likely differs among amino acids, because the catabolic and anabolic pathways of different amino acids have differing affinities for the amino acids.

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Arriola Apelo SI, JR Knapp, MD Hanigan. 2014. Invited review: Current representation and future trends of predicting amino acid utilization in the lactating dairy cow. J. Dairy Sci. 97(7):4000-4017.

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Røjen BA, PK Theil, NB Kristensen. 2011. Effects of nitrogen supply on inter-organ fluxes of urea-N and renal urea-N kinetics in lactating Holstein cows. J. Dairy Sci. 94(5):2532-2544.