Understanding the Impact of Seasonal Rhythms on Milk and Component Yield

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Much of this work done by Dr. Isaac Salfer during his PhD at PSU (Now at U MN)!

PennState College of Agricultural Sciences

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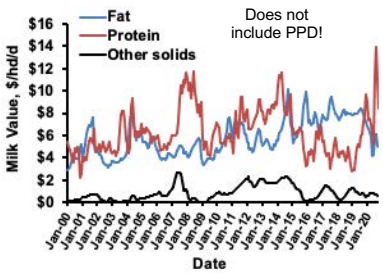
Milk fat and protein yield are the main drivers of cash flow ($/hd/d @80 lb of 3.9 fat & 3.1 protein)



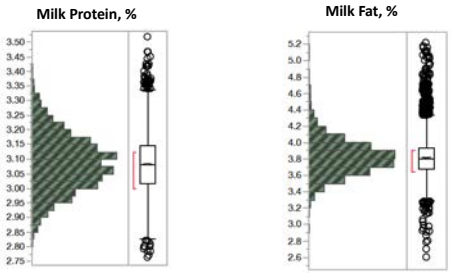
5 year average:
Fat = $2.40/lb
Prot = $2.20/lb
Other Solids = $0.16/lb

Harvatine unpublished based on USDA NASS milk price

- **Fat + Protein yield is best management goal!**

2

There is considerable variation between herds in milk protein and fat (RHA of 5926 herds)



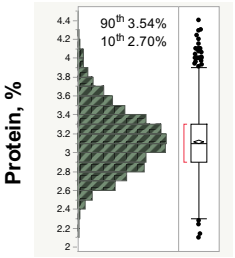
Mean = 3.08
Stdev = 0.097
10^{th} = 2.95
90^{th} = 3.21

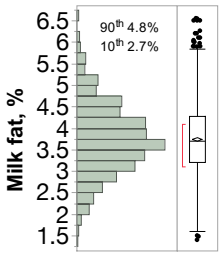
Mean = 3.82
Stdev = 0.24
10^{th} = 3.55
90^{th} = 4.08

Harvatine unpublished from DRMS Dataset

3

There is larger variation in milk protein and fat between cows within a herd





1720 cows from 5 herds

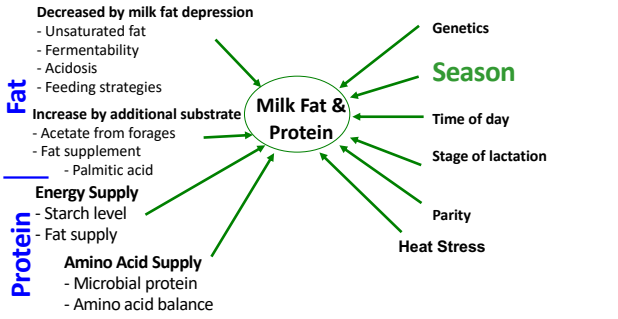
1720 cows from 5 herds

- Differences between cows likely influenced by DIM, feeding behavior etc

Harvatine Unpublished

4

Milk fat and protein is affected by many nutritional and non-nutritional factors!



5

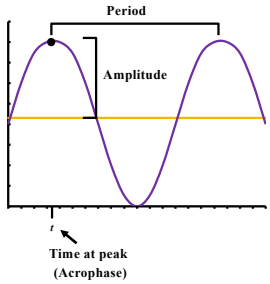
What are we trying to understand?

- **Determine response to a treatment?**
  - Nutrition researchers are great at asking the yes/no question, but it is probably more complex than that
- **Explain differences in responses to treatment between cows?**
- **Explain variation between cows?**

- By stepping back and parameterizing the influence of each factor on milk fat and protein we can determine the most influential and identify ones that we can manage (but may have previously overlooked)!

6

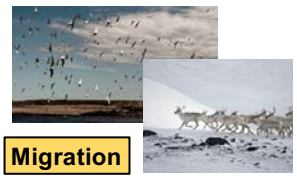
Biological rhythms are repeating cycles that are driven by a time keeping mechanism in the animal and can be reset (entrained) by external factors, like timing of lighting



- Will be maintained if animal is put under constant conditions (darkness)
- Are helpful as they allow the animal to prepare for upcoming changes

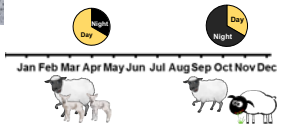
7

Seasonal rhythms coordinate physiological adaptations with upcoming changes in weather and food availability: Amazing examples in nature!



Migration

Hibernation



- Hair coat
- Activity/Behavior
- Fattening
- Breeding

Seasonal Breeding in Sheep

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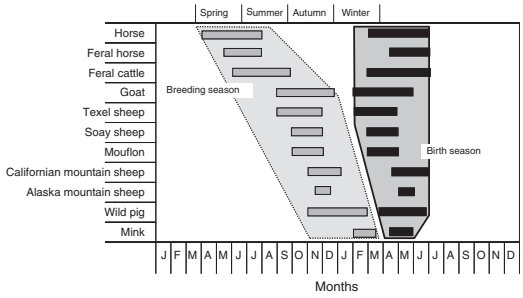
Seasonal breeding times birth of young to when it is warmer and more food available



Remember milk is food for offspring!

Chemineau et al. 2008 (Reprod Dom Anim 43:40-47)

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Annual rhythms can persist in constant darkness

- **Sheep, deer, and hamsters express annual reproduction rhythms in total darkness**
- **Birds continue to show migrating behavior even when in darkness year-round!**
- **Experimental models suggest the effect can be transgenerational**

"Endogenous" or "Internal" timekeeper

-The hibernating bear has to know when to wake up!

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There are also daily rhythms that coordinate physiology with changes across the day

Most processes in the body follow a 24 h cycle

- Activity and Alertness
- Nutrient Metabolism
- **Milk Synthesis**
- **Intake**

Why??

Improve survival by anticipating changes and adapt before they occur

- Reduce predator risk
- Maximize nutrient quality of feed
- Match milk to calf demand and need

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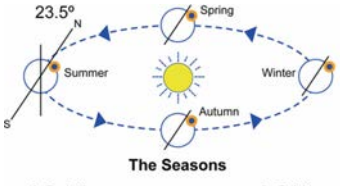
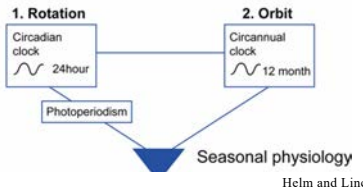
Endogenous timekeepers predict changes in earth's rotation and orbit





Helm and Lincoln, 2017

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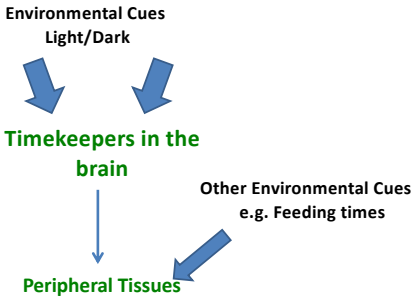
How does the cow know what time of year and day it is?



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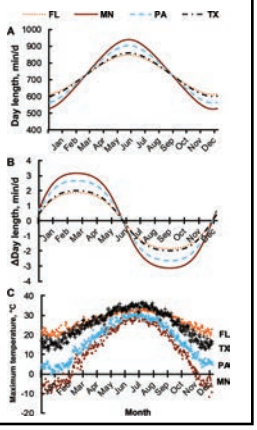
Seasonal rhythms repeat every year

- Mostly driven by
  - day length
  - lengthening/shortening days
  - change in day length
  - Also have changes in angle and distance from sun
- Regulated through the same molecular systems as circadian rhythms
- Hard to separate from temperature in the real world



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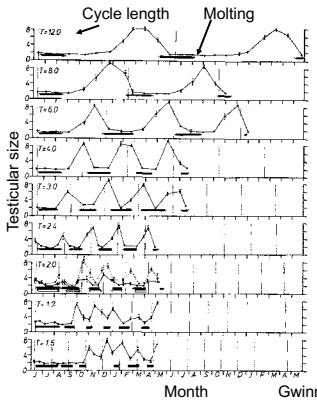
You can cycle rhythm faster controlling by lights

Sparrows cycled through seasons over 1.5 to 12 months



Gwinner 1981

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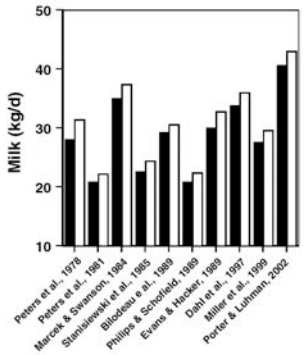
We know "Photoperiod" has a large impact on milk yield



Dahl and Petitclerc., 2003

Constant 16 to 18 h vs. 8 to 10 h light

- ~5 to 10% increase in milk yield and no change in milk composition
- Eliminated by constant light

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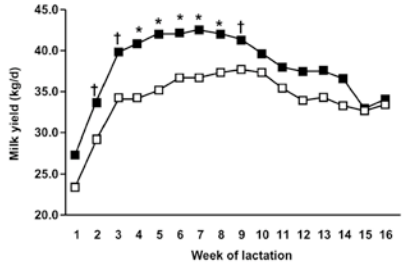
Short photoperiod during dry period increases milk yield in the next lactation!



Auchtung et al., 2005

- Spring calving cows would normally be dry during short days
- Likely driven by increased mammary development so more milk secreting cells

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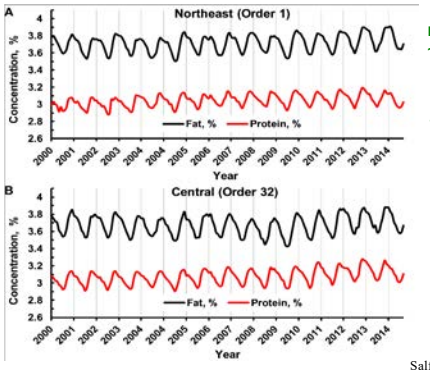
Seasonal pattern of milk fat & protein: NE and Central US Milk Market



Fat ~0.25 units

Protein ~0.20 units

Salfer et al. JDS 2019

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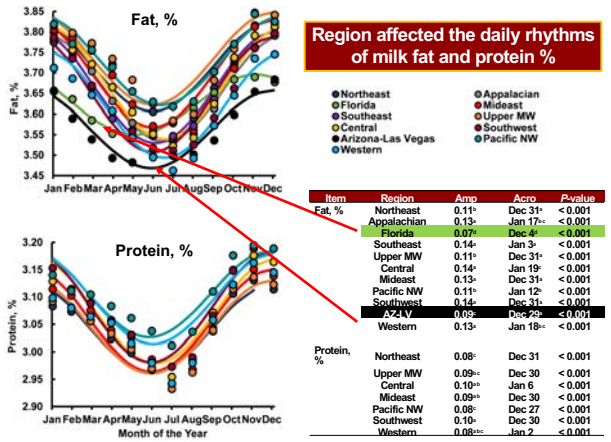

Region affected the daily rhythms of milk fat and protein %

- Northeast
- Florida
- Southeast
- Central
- Arizona-Las Vegas
- Western
- Appalacian
- Mideast
- Upper MW
- Southwest
- Pacific NW

Item	Region	Amp	Acro	*P*-value
Fat, %	Northeast	0.11[b]	Dec 31[a]	< 0.001
	Appalachian	0.13[a]	Jan 17[bc]	< 0.001
	Florida	0.07[c]	Dec 4[c]	< 0.001
	Southeast	0.14[a]	Jan 3[a]	< 0.001
	Upper MW	0.11[b]	Dec 31[a]	< 0.001
	Central	0.14[a]	Jan 19[c]	< 0.001
	Mideast	0.13[a]	Dec 31[a]	< 0.001
	Pacific NW	0.11[b]	Jan 12[b]	< 0.001
	Southwest	0.14[a]	Dec 31[a]	< 0.001
	Arizona-Las Vegas	0.09[c]	Dec 29[ab]	< 0.001
	Western	0.13[a]	Jan 18[abc]	< 0.001
Protein, %	Northeast	0.08[c]	Dec 31	< 0.001
	Upper MW	0.09[abc]	Dec 30	< 0.001
	Central	0.10[ab]	Jan 6	< 0.001
	Mideast	0.09[ab]	Dec 30	< 0.001
	Pacific NW	0.08[c]	Dec 27	< 0.001
	Southwest	0.10[a]	Dec 30	< 0.001
	Western	0.08[abc]	Jan 2	< 0.001

Salfer et al. JDS 2019

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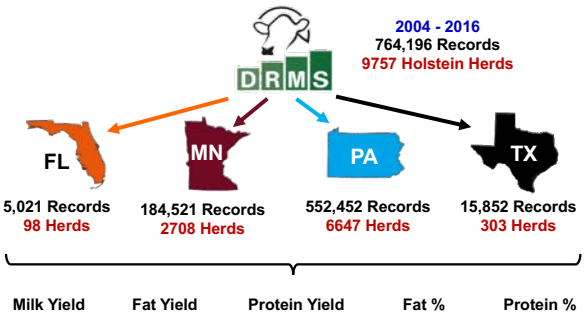
Herd level data from test day records



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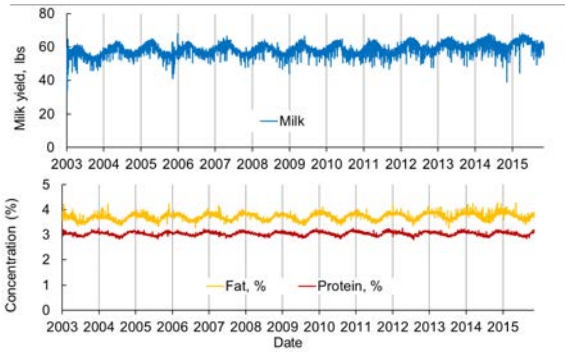

Yearly pattern of milk and milk components is consistent over time

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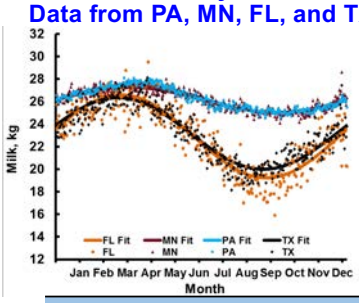
There is an annual rhythm of milk yield: Data from PA, MN, FL, and TX



All DHIA data from 2003 to 2016

764,196 records from 9,757 Holstein herds

State	Range, lb	Acrophase
MN	5.3	Apr 22
PA	5.3	Apr 15
TX	7.9	April 7
FL	9.2	April 9

Salfer et al. JDS 2020

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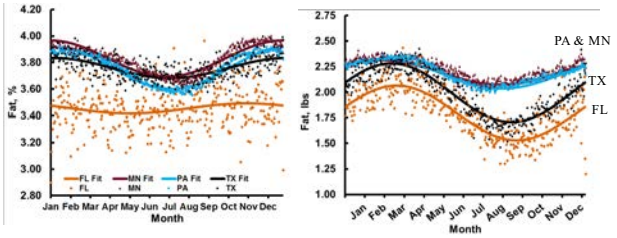
Milk fat percent peaks at end of year, but milk fat yield peaks in March and differ by region



State	Range	Peak
PA	0.28	Jan 4
MN	0.34	Jan 5
TX	0.28	Jan 3
FL	0.24	Jan 2

State	Peak
PA	Feb 23
MN	Feb 27
TX	March 13
FL	March 31

Salfer et al. JDS 2020

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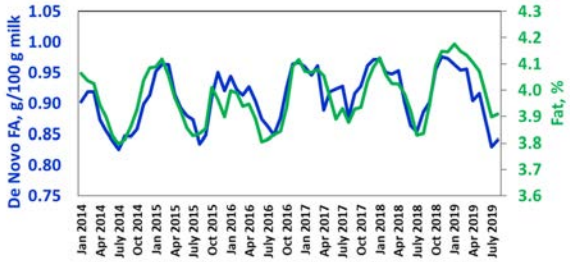
Half of the seasonal variation in milk fat is due to de novo synthesized (FA <16 C; Miner Data)



40 St. Albans Coop herds

Dann (Miner Institute) PSU Dairy Nutr. Workshop
https://scholarsphere.psu.edu/downloads/zkh04dr731

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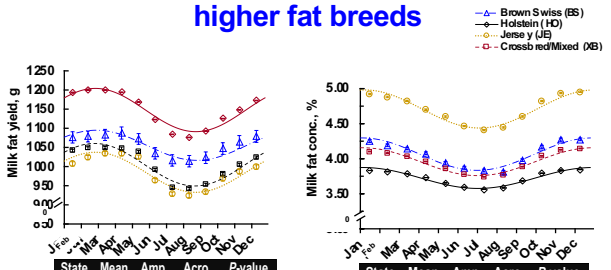
Seasonal rhythms were well conserved between breeds, but greater amplitude in higher fat breeds



State	Mean	Amp	Acro	*P*-value
BS	1056[b]	39[d]	Mar 1	< 0.0001
HO	1148[a]	56[a]	Feb 27	< 0.0001
JE	985[d]	52[c]	Feb 27	< 0.0001
XB	1005[c]	55[b]	Feb 26	< 0.0001

State	Mean	Amp	Acro	*P*-value
BS	4.07[b]	0.23[b]	Jan 3	< 0.0001
HO	3.73[d]	0.15[d]	Jan 4	< 0.0001
JE	4.71[a]	0.27[a]	Jan 7	< 0.0001
XB	3.96[c]	0.20[c]	Jan 4	< 0.0001

Salfer et al. JDS 2020

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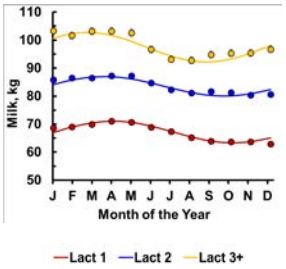
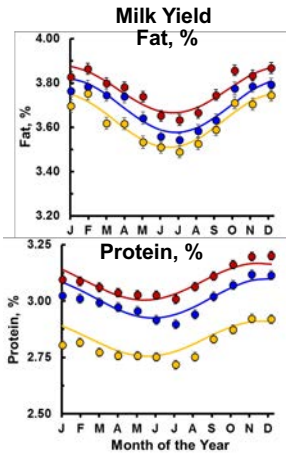
The seasonal pattern is consistent by parity





Salfer et al. JDS 2019

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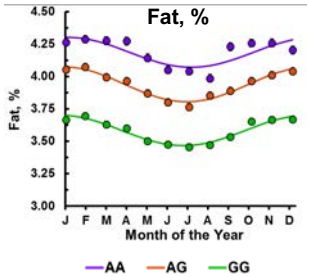
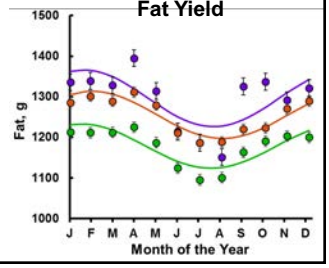
The seasonal pattern is also consistent between DGAT1 genotypes



DGAT1	Mean	Amp	Acro	*P*-value
AA	4.19[a]	0.12[a]	Feb 4[a]	<0.001
KA	3.94[b]	0.14[a]	Jan 28[a]	<0.001
KK	3.58[c]	0.12[a]	Jan 23[a]	<0.001

DGAT1	Mean	Amp	Acro	*P*-value
AA	1296[a]	70.0[a]	Feb 18[a]	<0.001
KA	1256[a]	57.6[a]	Mar 1[a]	<0.001
KK	1178[b]	54.6[a]	Feb 15[a]	<0.001



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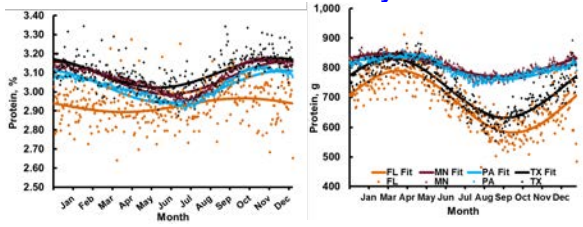
There is also an annual pattern to milk protein concentration and yield!



State	Range	Peak
PA	0.18	Dec 21
MN	0.20	Dec 22
TX	0.22	Dec 17
FL	0.12	Dec 1

State	Peak
MN	Mar 3
PA	Mar 1
TX	Mar 3
FL	Mar 27

Salfer et al. JDS 2020

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Seasonal rhythms are well conserved…..

Dr. Salfer (U MN) is leading an analysis of 129,530 monthly herd averages in 332 large herds from the Diamond V database (2006 to 2019)

- **Rhythms were observed in CA, Pacific NW, California, Pacific Northwest, Southwest, Rocky Mountains, and Upper Midwest**
  - Similar time at peak, but differed in amplitude
- **Freestalls and open lots had similar rhythms**
- **2x and 3x milking frequency had similar rhythms**

Sanchez, Johnson, Harvatine, and Salfer. 2020 ADSA

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What does heat stress do to milk yield and composition?

Reference	MY, lb	Fat, %	Prot, %
Rungruang et al. 2014	-7.8	0.20	-0.10
Baumgard et al. 2011	-13.6	0.28	-0.12
Wheelock et al. 2010	-21.1	0.60	-0.27
Rhoads et al. 2009	-23.3	0.34	-0.13
Schwartz et al. 2009	-22.2	0.06	-0.22

- **Generally a decrease in milk yield and milk protein percent and an increase in fat percent**

- An annual rhythm explains the data better than temperature variation

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What do I think is going on?

Two seasonal time-keepers:

- **Milk composition is driven by lengthening and shortening days and aligns with the solstice**
- **Milk yield is driven by rate of change in day length and aligns with the equinox**

- **Constant long days appears to be setting physiology of the spring equinox (increased milk yield and no change in composition)**
  - **This may be because of "photo-refractoriness", where an animal held under constant conditions will revert to the opposite season**

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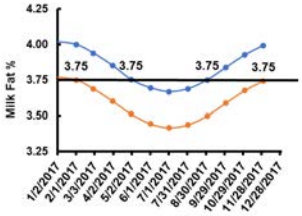
What can do we?

1. Accurately and precisely change goals across the year!!

~0.25 units of fat and ~0.2 units of protein

(adjustment factors in Salfer et al. J. Dairy Sci. 2020)

- Don't chase ghosts and don't lose opportunities!



- May need to change input in your model to account for change in requirements

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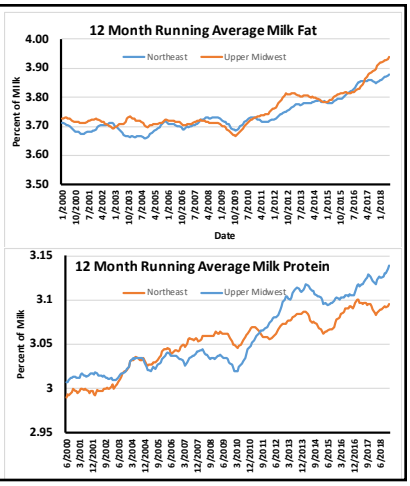
Average milk fat and protein has also been increasing

USDA Milk Market Database



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2. We do not have an experimentally validated way to manage out of the seasonal rhythms, but…..

- A constant long-day photoperiod is best recommendations for lactating cows for now
  - Need dark phase of the day
- Think about short day lighting for dry cows at least for short days of the year
- It is possible if you had good light control you could cycle cows faster through the low yield season

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Some other things to think about…..

3. Remember, the capacity for milk fat, and especially de novo synthesis, is highest in January

- Might be good time to feed more digestible fiber?
  - Good forages and BMR?
  - High digestibility non-forage fiber?

4. Make sure you are not hurting peak production in the spring

- Providing enough feed
- Limit overcrowding

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Try not to make it worse!

1. Account for energy needed when outside of thermoneutral zone (too hot or cold)

- This changes protein to energy ratio
- Watch MUNs to track this

2. Manage to reduce additional effect of heat stress during the summer

- Cow cooling
- Watch feeding behavior (Slug feeding)
- Silages and feed stability
  - At the silage face
  - In the feed bunk (especially if in the sun)

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Fixing "seasonal" management issues!

- Corn silage
  - Try to have enough carry-over
  - Factor in increased fermentability as stored
- Maintain herd DIM through good repro program
  - Some seasonality to fertility plus heat-stress
- Seasonal pattern in colostrum synthesis appears to also happen and is lowest in the fall
  - Make sure to stockpile!
  - Short-day lighting during dry period might help, but has not been investigated

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Key Principles

- The is a seasonal rhythm of milk yield and composition that varies by region, so we need to change our goals across the year
- Managing for long day photoperiod is a well supported recommendation
  - Requires a dark period of the day
- Right now, we do not know how to eliminate the rhythm, but we should try to not make it worse!
  - Heat stress and forage changes etc.

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Lab Members: Cesar Matamoros, Beckie Bomberger, Alanna Staffin, Abiel Berhane, Sarah Bennett, and Ahmed Elzennary.

Previous Lab Members: Reilly Pierce, Dr. Rachel Walker, Dr. Chengmin Li, Elle Andreen, Dr. Isaac Salfer, Dr. Daniel Rico, Dr. Michel Baldin, L. Whitney Rottman, Dr. Mutian Niu, Dr. Natalie Urrutia, Richie Shepardson, Andrew Clark, Dr. Liying Ma, Elaine Brown, and Jackie Ying

Disclosures

- Harvatine's research in the past 10 years were partially supported by the Agriculture and Food Research Initiative Competitive Grant No. 2010-65206-20723, 2015-67015-23358, 2016-68008-25025, and 2018-06991- 1019312 from the USDA National Institute of Food and Agriculture [PI Harvatine], USDA Special Grant 2009-34281-20116 [PI Harvatine], Berg-Schmidt, Elanco Animal Health, BASF, Novus International, PA Soybean Board, Phode Laboratories, Kemin International, Milk Specialties Global, Adisseo, Micronutrients Inc., Organix Recylcing, Insta-Pro Intl., Cotton Inc., United Soybean Board, and Penn State University.
- Harvatine has consulted for Milk Specialties Global, a manufacturer of prilled saturated fat supplements, Cotton Inc, and Micronutrients as a member of their science advisory boards and United Soybean Board.
- Harvatine has also received speaking honorariums from Elanco Animal Health, Cargill, Virtus Nutrition, NDS, Nutreco, Mycogen, Holtz-Nelson Consulting, Renaissance Nutrition, Progerssive Dairy Solutions, Intermountain Farmers Association, Diamond V, Purina, Standard Nutrition, Hubbard, VitaPlus, and Milk Specialties Global in the past four years.

Thank You

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