

Circadian Rhythms and Feed Management

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Circadian/Daily Rhythms in the Dairy Cow

- Circadian rhythms are 24 hour repeating cycles
- Many biological functions follow a 24 cycle
 - Activity and Alertness
 - Nutrient Metabolism
 - **Milk Synthesis**
 - **Intake**

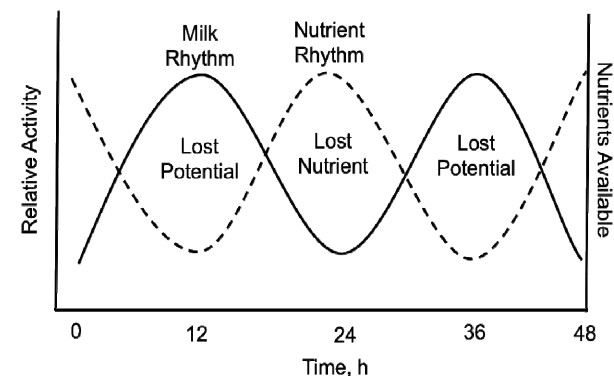
Why??

Allows the animal to anticipate changes and adapt before they occur

Key Principles

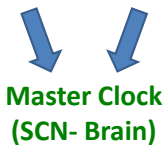
- There is a daily (circadian) pattern of intake that has a major impact on the rumen
- There is a daily pattern of milk synthesis
- Maximizing efficiency requires synchronizing nutrient absorption and mammary needs
- Considering daily patterns provides opportunities to optimize milk production

Are the Daily Patterns of Nutrient Absorption and Milk Synthesis Synchronized?



How Does the Cow Know What Time of Day It Is?

Environmental Cues
Light/Dark



Master Clock
(SCN- Brain)

Peripheral
Clocks

Other
Environmental
Cues
e.g. Feeding
Times

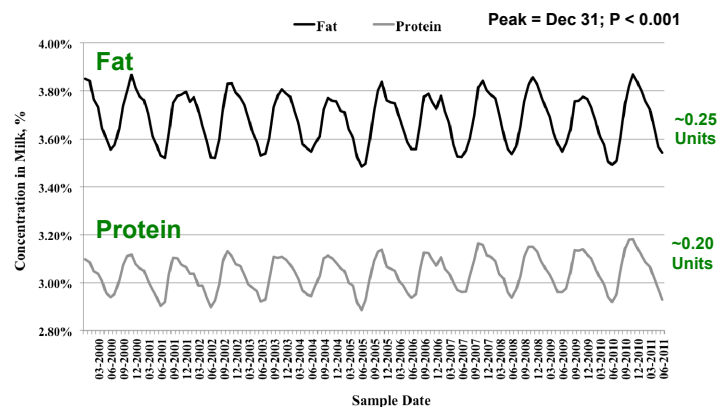
- **Main environmental cues:**
 - Light/Dark
 - Feeding Times
 - Milking Time?
 - **A disconnect between environmental cues can cause metabolic issues in humans and rodents**
 - This occurs in restricting feed to the day in nocturnal animals and night shift work in humans
- Asher, Schibler 2011

Seasonal Rhythms are Also Common in Biology

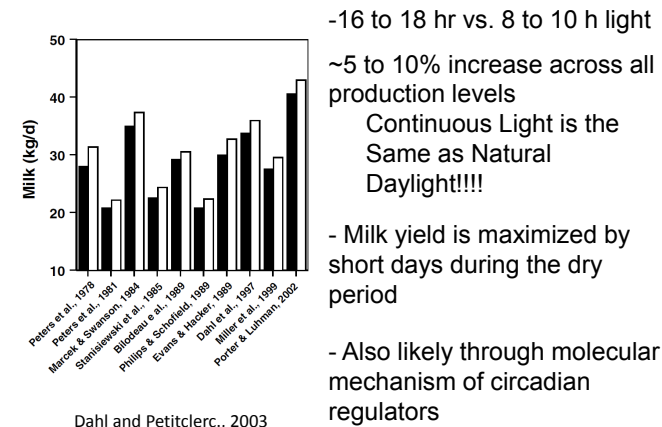
- **Patterns that repeat every year**
- **Mostly driven by day length and/or changes in day length**
- **Regulated through the same molecular system as circadian rhythms**

Some Amazing Examples in Biology

Seasonal Pattern of Milk Fat & Protein: Mid East US Milk Market

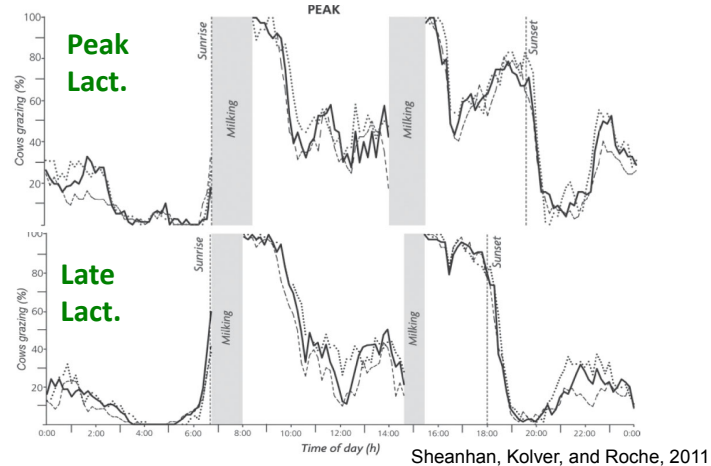


Long day photoperiod increases milk yield and milk fat yield, generally with no change in milk fat percent



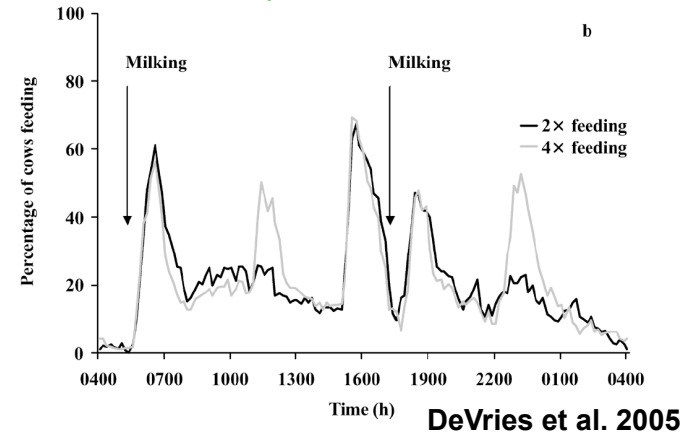
Is There a Circadian Pattern of Intake?

Pasture Fed Cows

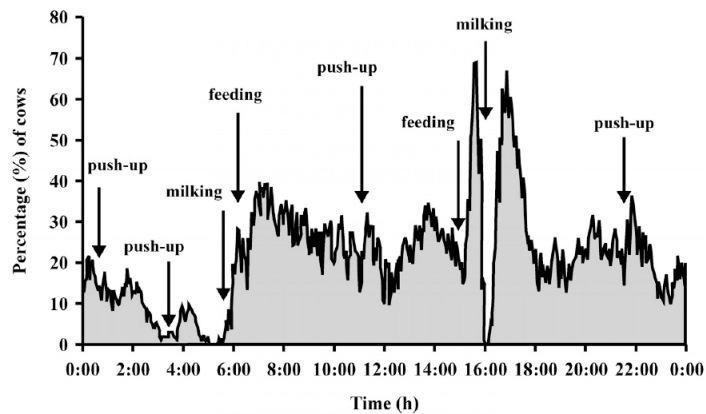


TMR Fed Cows: Feeding and Milking Times are Important

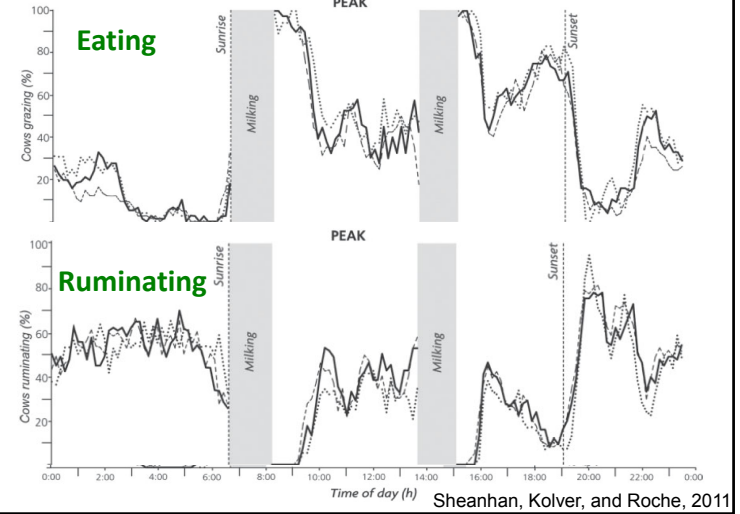
Feeding and milking commonly both near dawn & dusk in experimental data



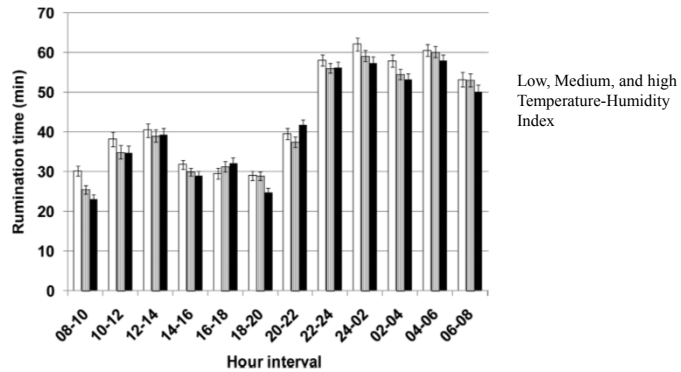
Pushing Up Feed Has Less Influence



Eating and Ruminating Tend to be Inverse



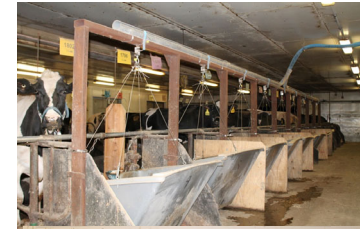
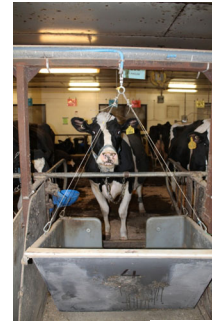
Rumination Pattern



Daily pattern of rumination time expressed in minutes per 2 h in 3 levels of daily maximum temperature-humidity index (THI).
White bars = THI <80; bars with vertical lines = THI from 80 to 85; black bars = THI >85.

Soriani et al. JDS 2014

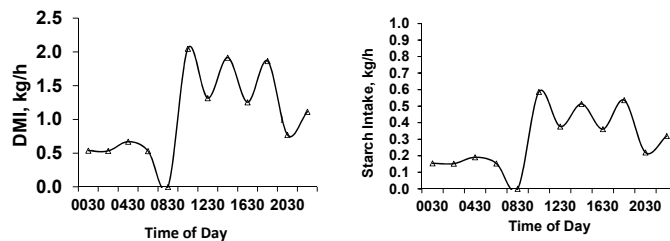
PSU Feeding Behavior System



MooMonitor+
Dairymaster
(Image Dairymaster.ie)



Rate of Feed Intake is Variable Over the Day



Ying et al. 2015

What is the Impact of the Daily Pattern of Intake

Intake =

Entrance of fermentable organic matter into the rumen

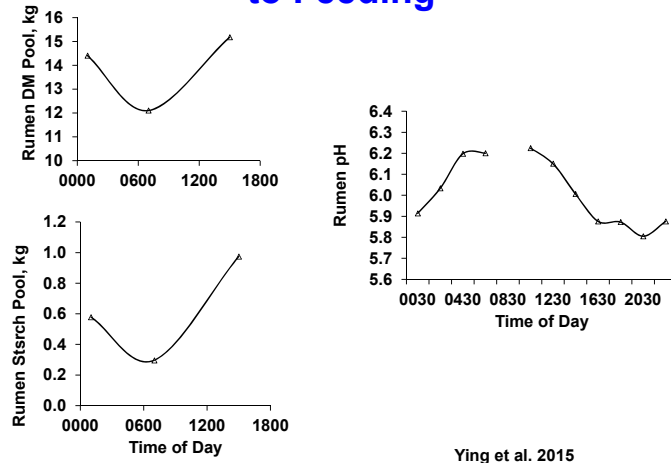
Fermentable organic matter =

Synthesis of VFA's & microbial protein

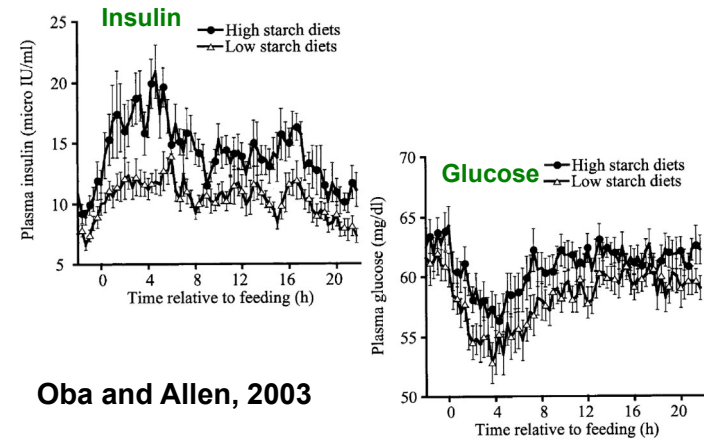
VFA's =

Rumen Acid Load
&
Nutrient supply for cow

Rumen Pool Size Changes Relative to Feeding



Intake Creates a Circadian Pattern of Plasma Metabolites and Hormones



How Flexible is the Daily Pattern of Feed Intake?

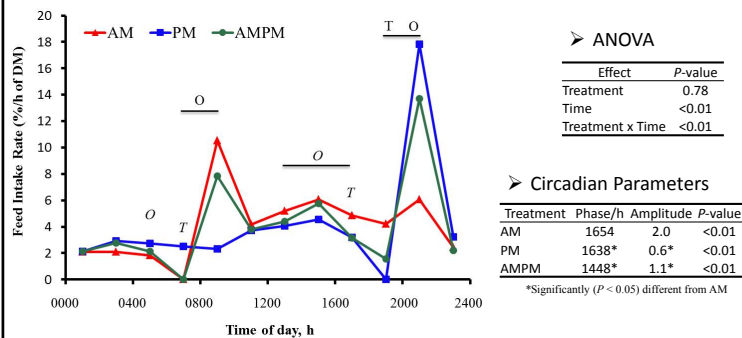
- Feeding stimulates intake, but what is the impact of feeding time
- Fed TMR:**
 - 1x/d at 0830 h (AM)
 - 1x/d at 2030h (PM)
 - 2x/d at 0830 and 2030 h (AMPM)

DMI and Milk Production

| Item | Treatment LS-Means | | | | P-value | | |
|---------------------|--------------------|-------|-------|------|-------------|-------------|-------------|
| | AM | PM | AMPM | SE | Trt | AM vs. PM | AM vs. AMPM |
| Yield, lbs/d | | | | | | | |
| Milk | 110.0 | 111.1 | 111.8 | 5.7 | 0.69 | 0.59 | 0.40 |
| Milk fat | 3.78 | 3.78 | 3.85 | 0.09 | 0.84 | 0.99 | 0.62 |
| Milk protein | 3.26 | 3.28 | 3.30 | 0.13 | 0.77 | 0.78 | 0.48 |
| Milk composition, % | | | | | | | |
| Fat | 3.51 | 3.49 | 3.48 | 0.15 | 0.90 | 0.83 | 0.66 |
| Protein | 2.97 | 2.95 | 2.96 | 0.07 | 0.80 | 0.52 | 0.69 |
| DMI, lbs/d | 71.7 | 69.1 | 70.2 | 2.0 | 0.40 | 0.18 | 0.44 |
| Feed Efficiency | 1.54 | 1.58 | 1.57 | 0.05 | 0.43 | 0.21 | 0.37 |

- Also no difference in milk FA profile

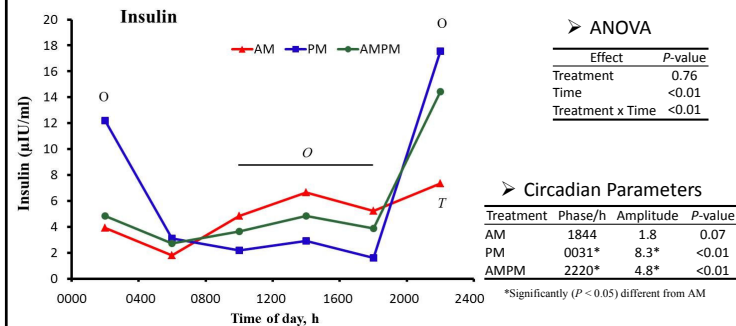
Daily Pattern of Feed Intake



❖ AM vs. PM ($^O = P < 0.01$, and $^T = P < 0.05$); AM vs. AMPM ($^T = P < 0.01$, and $^T = P < 0.05$)

- Conditional meals were larger at the evening feeding
- Modestly higher intake rate in the early afternoon for **AM**

Daily Rhythm of Plasma Insulin

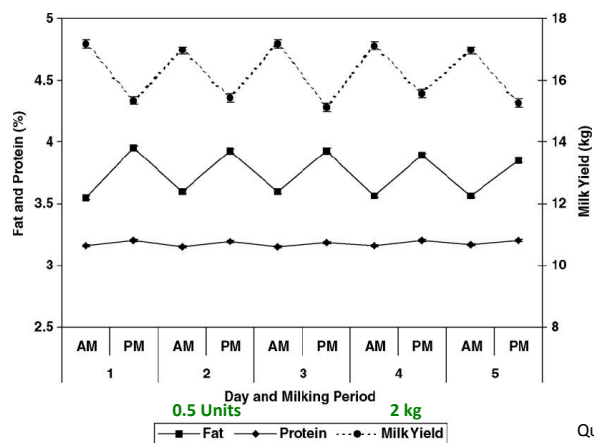


❖ AM vs. PM ($^O = P < 0.01$, and $^O = P < 0.05$); AM vs. AMPM ($^T = P < 0.01$, and $^T = P < 0.05$)

- Fresh feed delivery at night resulted in greater insulin secretion
- Morning feeding moderately increased insulin in the early afternoon

Milk Synthesis is Variable Over the Day

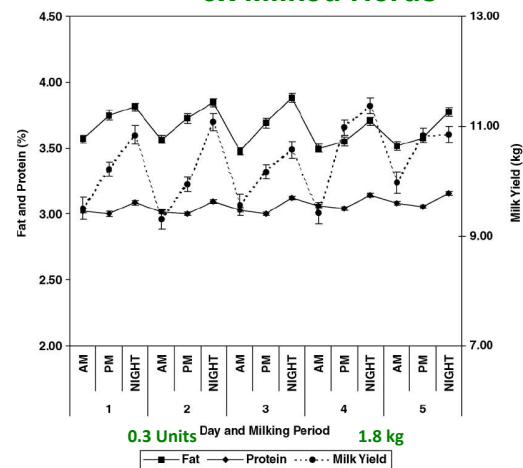
2x Milked Herds



Quist et al. 2008

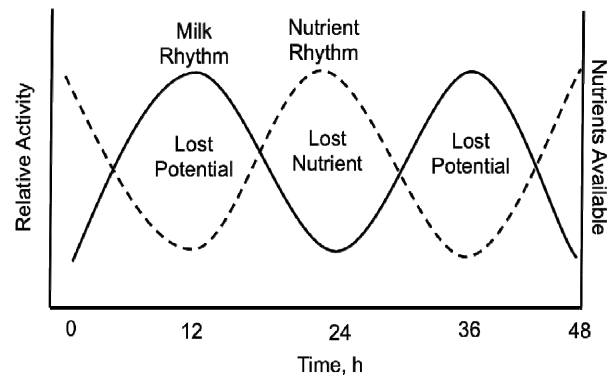
Milk Yield is Variable Over the Day

3x Milked Herds



Quist et al. 2008

Theoretical De-Synchronization of Intake and Mammary Metabolism



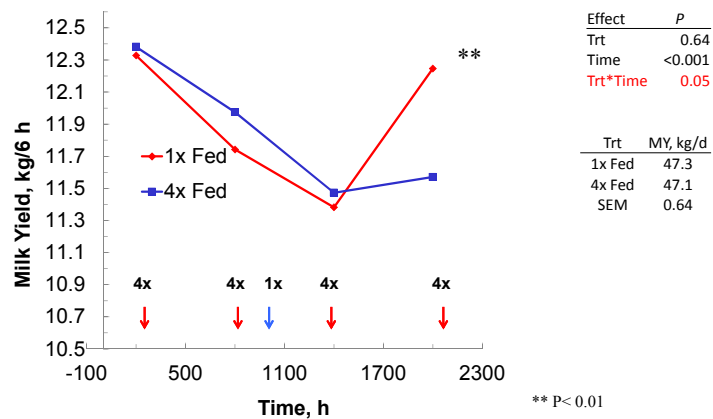
Interaction of Intake and Milk Synthesis

• Hypothesis

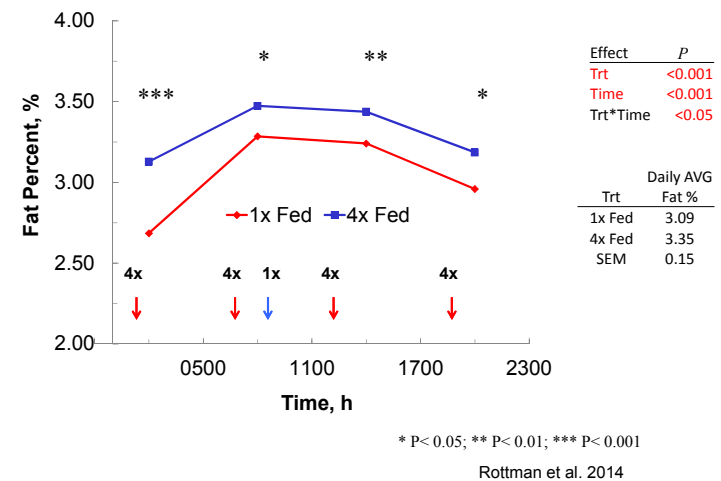
- The dairy cow has a circadian rhythm of milk synthesis that is dependent on the timing of nutrient absorption

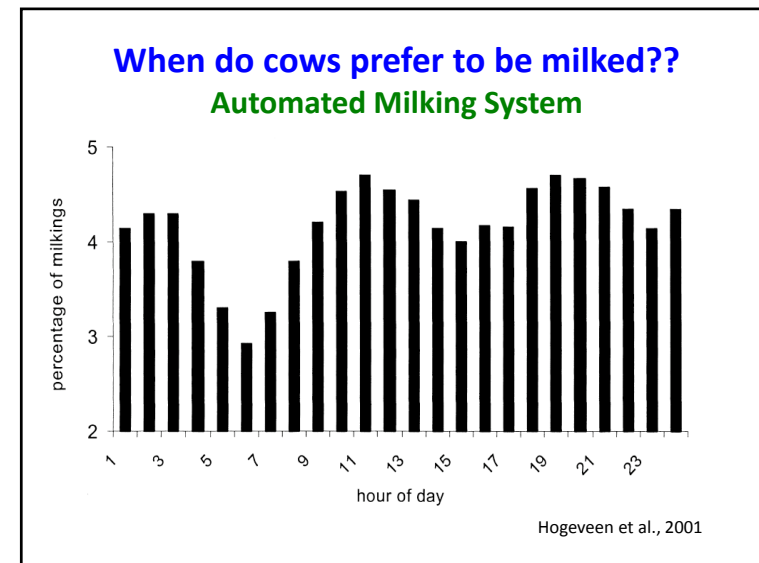
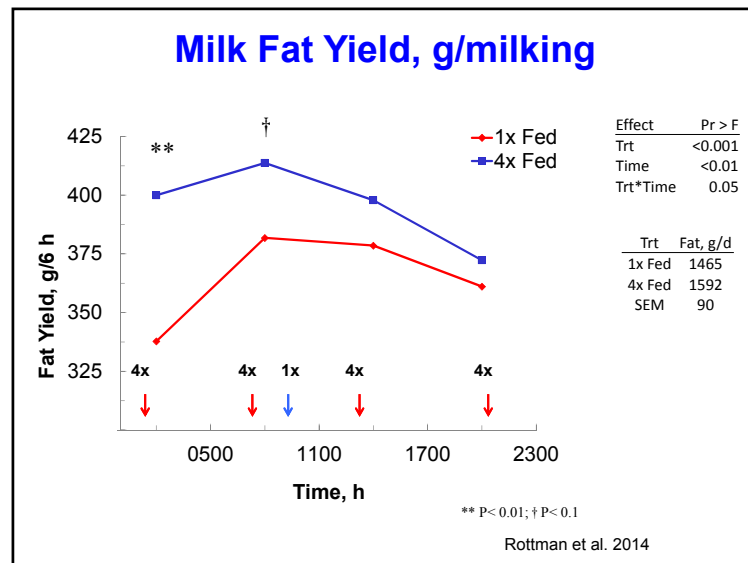
- Fed cows 1 x/d or 4 x/d in equal meals
- Milked 4 x/d

Milk Yield, kg/milking



Milk Fat Percent, %





How Can We Use This Information??

“Circadian Feeding Strategies”

Match the timing of delivery and diet composition to the temporal requirements of the rumen and the cow

1st... Think of the rumen

- Can we stabilize the amount of fermentable organic matter entering the rumen over the day?
- Feeding a single TMR does not provide this since there is high and low periods of intake over the day

Feeding Multiple TMRs over the Day

- Three diets were used

- Control (Con): 30.1% NDF
- High fiber (H): 31.8% NDF
- Low fiber (L): 26.9% NDF

70% of H &
30% of L = Control

- Three Treatments

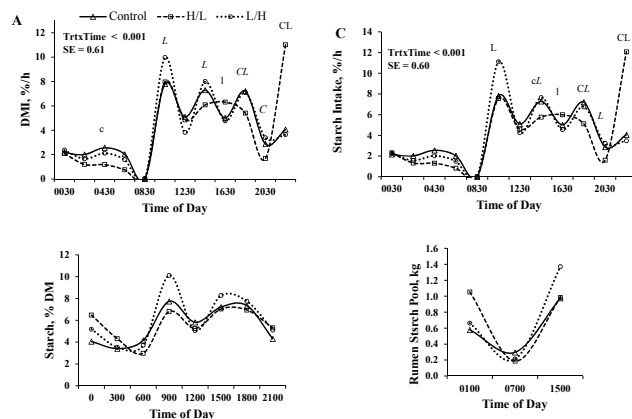
- Fed control TMR once per day at 0900
- High-Low Treatment (HL)
 - 70% of feed fed as High Fiber Diet at 0900 h
 - 30% of feed fed as Low Fiber Diet at 2200 h
- Low-High Treatment (LH)
 - 30% of feed fed as Low Fiber Diet at 0900 h
 - 70% of feed fed as High Fiber Diet at 1300 h

Rottman et al. 2015; Ying et al. 2015

Milk Yield and Composition

| | Treatment | | | P-value | |
|--------------|-----------|--------------------|------|---------|------|
| | CON | HL | LH | SEM | Trt |
| DMI, lbs/d | 58.0 | 53.7 ^c | 56.0 | 2.4 | 0.01 |
| Milk, lbs/d | 87.3 | 84.9 | 90.2 | 5.3 | 0.14 |
| Milk Fat | | | | | |
| Percent | 3.44 | 3.39 | 3.45 | 0.25 | 0.73 |
| Yield, lbs/d | 2.99 | 2.82 ^{LH} | 3.10 | 0.11 | 0.07 |
| Milk Protein | | | | | |
| Percent | 3.08 | 3.10 | 3.10 | 0.09 | 0.86 |
| Yield, lbs/d | 2.68 | 2.64 | 2.79 | 0.15 | 0.19 |

Pattern of Intake and Rumen Digesta Composition



Rumen Observations

- No Change in

- Average pH or time under pH 5.8 or 5.6
- No change in daily average rumen VFA's
- No change in DM or OM digestibility

What Did We Learn?

- Its complicated!
- Have to be very careful with the effect of timing of feed delivery changing feeding behavior
- Demonstrates we don't have to have the same TMR across the day and there are times that feeding different diets might be advantageous

Summary of Circadian Feeding Strategies

- Feed delivery is a strong signal for feeding which can be used to increase intake during low intake periods of the day
- Make sure feed is available when return from parlor....., but
 - Delivery of feed 2-3 h before or after milking may spread intake more across the day??

Is he crazy or can "Circadian Feeding" concepts be applied in the field?

- Some products may be most effective during a certain time of day (Both ruminally and post-ruminally)
- Multiple rations may not be that more complex
 - Feed same ration to entire herd in morning
 - Return to "top-off" high groups

Interesting Call From the Field

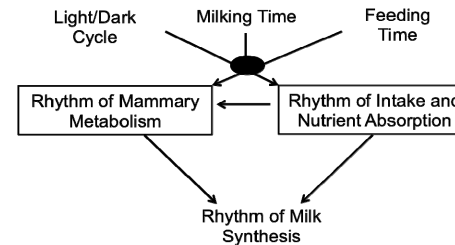
- One pen of cows on a large farm consistently 0.3 to 0.5 units lower in milk fat than peer pen in another barn fed same diet
- Moved fifteen cows from the pen to another pen and they increased milk fat
- Normal MFD troubleshooting turned up no clues
- Cows being fed later in the day (11:30 AM)
- Switched milking and feeding order so feed delivered earlier and before milking.
- Milk fat increased equal to peer pen

Herd Management Associations

- Herds feeding 2x/d had 3.1 lbs higher DMI and 4.4 lb higher milk yield
 - Sova et al. 2013
- Increasing feeding frequency increased number of meals at high stocking rates
 - Crossley et al. 2018
- High milk de novo fatty acid herds were five time more likely to feed more than once per day
 - Woolpert et al. 2017

Summary: Spreading intake across the day is probably better for the rumen and milk yield

- Timing and frequency of feeding and milking most important. Smaller effect of pushing up feed.
- Watch the cows to see how things work on that farm.
- Don't be afraid of different rations across the day!



Lab Members:

Isaac Salfer, Cesar Matamoros, Elle Andreen, Elaine Brown, Beckie Bomberger, Chengmin Li, Reilly Pierce, Ahmed Elzennary

Previous Lab Members:

Dr. Daniel Rico, Dr. Michel Baldin, L. Whitney Rottman, Mutian Niu, Dr. Natalie Urrutia, Richie Shepardson, Andrew Clark, Dr. Liying Ma, and Jackie Ying

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Thank You

