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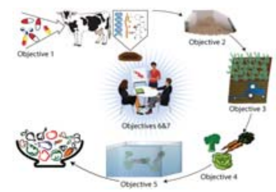
Competing priorities

Antibiotic use in a time of increasing antibiotic resistance

K. F. Knowlton & P. P. Ray
February 14, 2018

Today



Funding for this project has been provided by Virginia Ag Council & USDA NIFA award 2014-05280.

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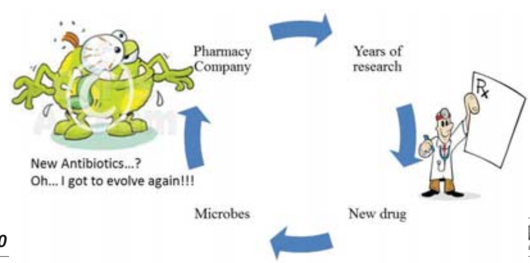
Antibiotic resistance a critical human health challenge, need "global strategy to contain resistance"

- 2 million Americans infected, 23,000 die/year



WHO, 2000

Development of Antibiotic Resistance

Antibiotic	Discovery / 1st clinical use	Resistance first observed
Penicillin	1940 / 1943	1940
Streptomycin	1944 / 1947	1947
Tetracylcine	1948 / 1952	1956
Erythromycin	1952 / 1955	1956
Vancomycin	1956 / 1972	1987
Gentamicin	1963 / 1967	1970

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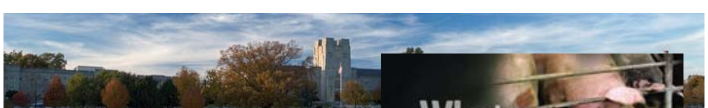

"Sen. Floats Bill to Combat Antibiotic-Res

Antibiotics Have Gone From Wonder Drugs to Wonder-If-They'll-Work Drugs

Antibiotic resistance 'crisis looms'
Superbug infections threaten 20th century's wonder drugs

Antibiotic resistance: The last resort
Health officials are watching in horror as bacteria become resistant to powerful carbapenem antibiotics — one of the last drugs on the shelf.

CDC Sounds Alarm on Antibiotic-Resistant Bacteria
Report cites overuse of antibiotics as key to the life-threatening problem

CDC Acknowledges Role of Farms in Antibiotic Resistance

FDA Underwhelms With Response to Super-Resistant Infections Rise

Disease resistance to antibiotics at tipping point, expert warns
Prof Jeremy Farrar says evolution of diseases will 'creep up on us ... affect patients in UK

Antibiotics Warning: Resistance 'Growing'

Is this criticism legit?

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It's the manure.

- Key questions:
  - Dose vs. excretion?
  - Degradation during storage, treatment?
  - Persistence in soil
  - Runoff
- Actual risk to humans?

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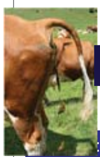
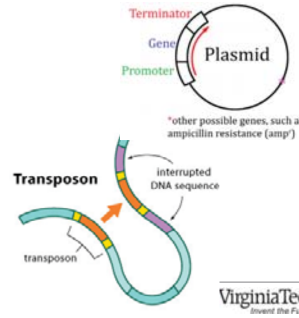
Coming right out the other end…



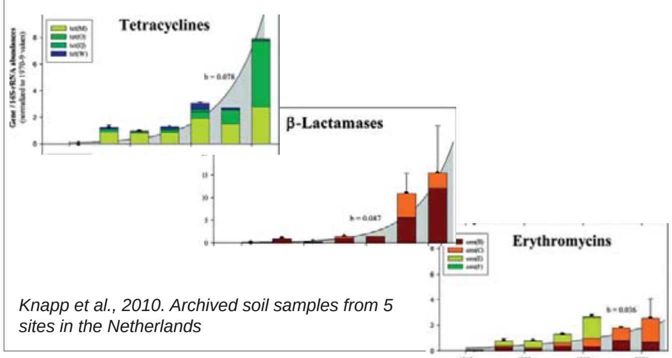

ic/class	% excreted
Beta lactams	Humans: 78-84%, urine *(Weidekamm, 1984)*
ceftiofur HCl	Beef cattle: 31% in feces, 55% in urine *(Beconi-Barker 1996)*
ceftiofur	Swine: 62% in urine, 11% in the feces *(Hornish 2002)*
Avilamycin (glycopeptide)	Swine: 95% in feces *(European Medicines Agency 2007)*

Antibiotic resistance genes (ARG)

- Spontaneous or induced
- Bacteria carrying ARG can survive exposure to that antibiotic.
- Genes can be **swapped**, can travel **together**, and **outlive** bacteria.



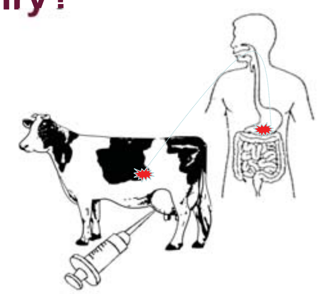
In soil? *The 70's vs. 2008*



Knapp et al., 2010. Archived soil samples from 5 sites in the Netherlands

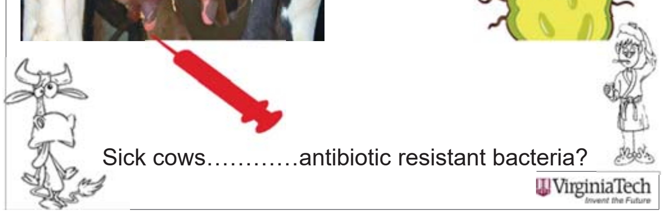
What about dairy?

- Growth promotion
  - ionophores
- Prophylactic
  - Milk replacers
  - Dry cow therapy
- Therapeutic use



Competing priorities



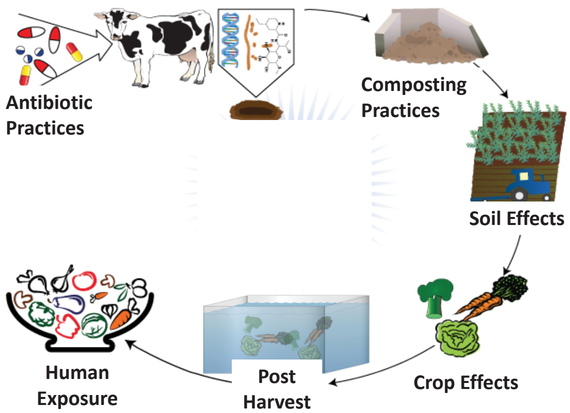


Sick cows…………antibiotic resistant bacteria?

Where we're going with this

- What cows?
- What manure?
- What days?
- Treated in what way?

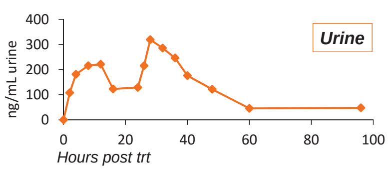
USDA "Farm to Fork" AR Mitigation

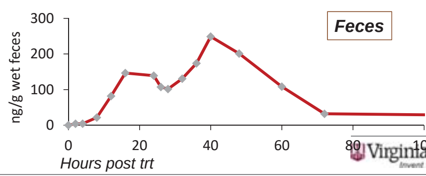


It's the manure.

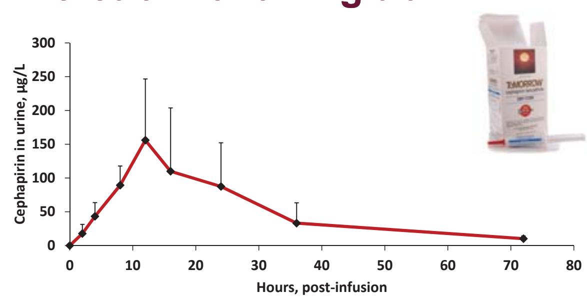
- Today:
  - **Dose vs. excretion?**
  - **Degradation during storage, treatment?**
  - Persistence in soil
  - Runoff
- Actual risk to humans?

Excretion following trt?



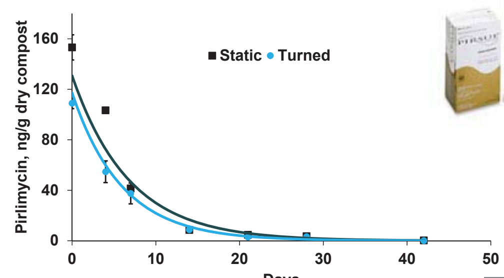


Excretion following trt?



Does excreted = environmental load?

Fate of pirlimycin w/composting



Fate of cephapirin w/composting

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ABX removal with composting

Manure	Drug	Removal	ref
Swine	CTC	100% by 21d	1
Swine	sulfadiazine	100% by 3d	1
Swine	ciprofloxacin	70-80% at 56d	1
Broiler	CTC	90% by 42 d	2
Layer	CTC	90% by 42d	2
Beef	CTC, OTC	99% by 30d	3
Broiler	OTC	84% at 20d	4
Dairy	**Sulfamethazine**	**>95% at 28d**	**5**

[1]Selvem et al, BRT 2012; [2]Bao et al, WM 2009; [3]Arakin et al., JHM 2009; [4]Ravindran et al., IJEST, 2017; [5]Mitchell et al., WASP, 2015

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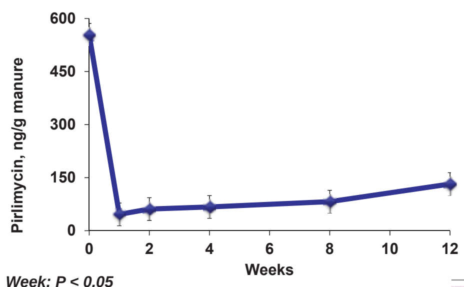
Fate of pirlimycin during liquid storage



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Recent Advances for Management of Fescue Toxicity in Beef Cattle Production

2018 Virginia State Feed Association Conference

Dr. Bain Wilson, Department of Animal and Poultry Sciences, Virginia Tech

The Fescue Problem

Endophyte-infected tall fescue (**E+**) is the dominant forage species in many parts of the southeastern United States. The dominant cultivar of endophyte-infected fescue is Kentucky 31 which is associated with excellent stand persistency, drought and pest resistance, high yield of moderate to high quality forage, and detrimental effects on animal performance (Hoveland, 1993). These negative effects on animal performance are known as the condition fescue toxicity; which results in: rough hair coats during summer, decreased blood flow to peripheral parts of the body, elevated body temperature, increased respiration rate, decreased milk production, reduced conception rates, reduced DMI, and poor ADG (Strickland et al., 2011). Industry-wide economic losses resulting from reduced growth and reproduction as a result of fescue toxicity were estimated to be over $3.2 billion (Kallenbach, 2015). Endophyte-infected fescue plants serve as hosts to ergot alkaloid-producing endophytes that live in the intercellular spaces in the plant. The effects of fescue toxicity are often greatest during late summer as plants accumulate greater ergot alkaloid concentrations (Belesky et al., 1988), and elevated environmental temperatures exacerbate the negative thermoregulatory effects of endophyte consumption (Hemken et al., 1981).

Pastures in what became known as the "fescue belt" were planted with E+ to stop soil erosion and take advantage of its desirable agronomic characteristics. It was only these E+ stands were established that negative effects on animal growth and performance were observed (Bacon, 1995). Beef producers are left with the challenge of managing sub-optimal animal performance when grazing cattle on E+ pastures because of the prevalence and high cost of replacing E+ pastures. Extensive research efforts have investigated how to best address the complex issue of fescue toxicity. Possible solutions are to renovate pastures with novel endophyte-infected fescue cultivars, utilize management strategies to decrease the symptoms of fescue toxicity, and select for cattle that less susceptible to fescue toxicity. A single best solution for fescue toxicity has yet to be discovered. This proceedings will outline current options for dealing with the problem of fescue toxicity.

Pasture Renovation with Novel Endophyte-Infected Fescue

Plant breeders have developed new cultivars of tall fescue that do not contain the ergot alkaloids known to cause fescue toxicity in grazing animals. Endophyte-free cultivars were developed in an attempt to completely remove the causative agent of fescue toxicity. Performance was dramatically improved when cattle grazed on endophyte-free pastures; however, endophyte-free stands had extremely low persistence and pastures reverted back to E+. Approximately 20 years ago, novel endophyte-infected fescue cultivars (**NE**) were developed to provide the positive agronomic attributes of E+ (Gunter and Beck, 2004) without negatively affecting animal performance (Parish et al., 2003). The first NE cultivar released commercially was MaxQ sold by Pennington Seed, Inc. (Madison, GA). MaxQ is the most heavily researched and widely-used NE cultivar. Improvements in growth and performance of cattle grazed on NE are because the ergot alkaloid-producing endophytes found in E+ are replaced with novel endophytes that do not produce ergot alkaloids.

Simply renovating E+ pastures with NE appears to be a straightforward solution to avoiding fescue toxicity. Yet, there are significant challenges to replacing E+ with NE in beef cattle operations. Converting E+ to NE comes at the significant costs of herbicide, seed, and fertilizer. Establishment costs of NE pastures have been estimated between $157.84 (Lacy et al., 2003) and $232.12 (Beck et al., 2008) per acre. Gunter and Beck (2004) and Beck et al. (2008) determined that renovating E+ pastures with NE takes between 3 to 7 yr to return profit to stocker operations. Additionally, renovation of a stand of E+ to NE requires 2 years before the new NE stand can be grazed. Pasture renovation requires that producers are able to graze other acreage during the renovation period. Renovation of E+ pastures is more practicable in areas with relatively flat terrain and good soils. Many areas in the "fescue belt" are located in Appalachia and have shallow, rocky soils and would be susceptible to soil erosion during pasture renovation. Understandably, there is great reluctance by many beef producers to renovate a large portion of their existing E+ pastures (Lacy et al., 2003).

An alternative to totally renovating a beef operation's pasture acreage to NE is the strategic renovation of only the acres most suitable for reseeding. The newly established NE pastures would then be grazed strategically during times of greatest risk of fescue toxicity during the operation's production cycle. This would mean grazing cows on NE pastures leading up to, during, and immediately after the breeding season. Young, growing cattle could be grazed on E+ pastures during the early summer and the switched to NE pastures during late summer when higher environmental temperatures would be expected to exacerbate the effects of fescue toxicity. Wilson et al. (2014) observed no differences in ADG of stocker calves that were either grazed on NE pastures during the entire summer or grazed on E+ from late spring through July 1 and grazed on NE from July 1 through late summer.

Nutritional Management to Alleviate the Symptoms of Fescue Toxicity

Because complete replacement of E+ is often not possible, nutritional strategies to alleviate the symptoms of fescue toxicity include diluting dietary ergot alkaloid concentrations, managing pastures to maintain vegetative growth, and feeding novel feedstuffs. Interseeding E+ with legumes is a practice that has been recommended to dilute ergot alkaloid intake for several decades (Kallenbach, 2015). Clover species are the primary legume used because they can easily be frost seeded by broadcasting seed on E+ pastures during early spring when freezing and thawing of the ground works the seed into the ground. Clover provides an increase in nutritive value during spring and early summer; however, are typically not present in late summer because of poor drought resistance and early grazing pressure. Another method to dilute ergot alkaloid intake is supplementation of concentrates to cattle grazing E+ pasture (Aiken and Strickland, 2013). High fiber supplements such as soybean hulls, dried distillers grains plus solubles, and corn gluten feed are preferable to high starch supplements like corn to avoid negative associative effects in the rumen. This is because high fiber supplements will not trigger a shift in rumen microbial populations away from fibrolytic microbes needed to efficiently digest fiber (Russell et al., 2016). When interseeding legumes or supplementing concentrates in an attempt to dilute ergot alkaloid intake, the positive effect of ergot alkaloid intake is confounded by the increase in digestible nutrients provided by the added forage and supplement (Kallenbach, 2015).

Another strategy that is employed to alleviate the symptoms of fescue toxicity is to maintain the plant in a vegetative growth stage. It is in the interest of forage quality to manage all forages in the vegetative phase; yet, this strategy is of even greater importance in E+ pastures. Ergot alkaloids are present in all parts of the fescue plant; but are further concentrated in seedheads as the plant matures and transitions to the reproductive growth phase. Two methods that have been used to manipulate fescue growth stage are mowing seed heads and implementation of rotational grazing (Aiken and Strickland, 2013). Frequent grazing or clipping the tops of E+ pasture swards decreases concentration of ergot alkaloids by increasing the leaf to blade to stem ratio. Another option for preventing reproductive growth in E+ pastures is chemical seed head suppression. Chemical seed suppression slows maturation of fescue plants and had been demonstrated increase forage crude protein and digestibility (Aiken and Strickland, 2013). An example of a commercially available seed head suppressant is Chaparral from Dow AgroSciences (Indianapolis, IN). Goff et al. (2014) determined that timing of Chaparral application is ideal during late spring. One potential drawback to chemical seed head suppression is reduction in forage dry matter availability; however, it has not been determined if this reduction is associated with decreased vegetative growth, reduced seed and stem growth, or greater forage intake (Aiken and Strickland, 2013).

An additional strategy to alleviate fescue toxicity symptoms is to incorporate novel feedstuffs into the supplementation and mineral programs of cattle grazed on E+ pastures. The most effective delivery method for these novel feedstuffs is to incorporate them into mineral mixes because most cattle grazed on E+ pastures are not supplemented during the time of peak ergot alkaloid concentrations. Several feed companies market products specifically designed to combat fescue toxicity, such as the Fescue EMT mineral (Cargill, Minneapolis, MN) and Endo-Fighter feed additive (ADM Animal Nutrition, Quincy, IL). Other companies recommend the use of certain product to boost performance of cattle grazing E+ pastures; several examples include VitaFerm Heat (BioZyme, Inc., St. Joseph, MO) to reduce heat stress and Bio-Mos (Alltech, Nicholasville, KY) to improve gastrointestinal health. Evaluation of the novel feedstuffs is challenging because much of the data regarding the efficacy of these products at alleviating the effects of tall fescue toxicity is proprietary and not found in peer-reviewed literature.

A recent study was conducted by Hardin et al. (2017) at Virginia Tech to evaluate the effects of supplementing sodium bicarbonate to heifers fed endophyte-infected fescue seed on growth and reproductive development. It was hypothesized that sodium bicarbonate would buffer rumen pH, increase fiber digestion, and result increased growth and efficiency during a heifer development program. Hardin et al. (2017) observed positive trends for improved ADG and feed efficiency for the first 56 days of the treatment period when heifers consuming endophyte-infected fescue seed were supplemented with sodium bicarbonate relative to those offered no sodium bicarbonate. However, the benefits of sodium bicarbonate supplementation were not sustained through 84 days of sodium bicarbonate supplementation. It is thought that sodium bicarbonate may be an effective method to alleviate the effects of fescue toxicity if cattle are able to self-select their level of supplement intake in a pasture setting; however further research needs to evaluate this nutritional strategy.

Genetic Resistance to Fescue Toxicity

The beef industry has made rapid advances in the use of genomic technology in the last decade to select for production traits such as birth weight, weaning weight, yearling weight, and marbling. The increased use of genomics has increased interest in a genetic test for cattle that have varying levels of resistance to fescue toxicity. Cow/calf and seedstock producers in the southeast have inferred that there is a genetic component for several years. It is recognized that cows with long, rough hair coats in the summer or cows naïve to E+ often wean lighter calves and have reduced conception rates relative to cows with short, slick hair coats in the summer. Gray et al. (2011) demonstrated that cows who began shedding their winter coat before May had 11.1 kg heavier weaning weights than those that did not begin shedding their winter coat until after May. Poor shedding of winter coats has been correlated to suppression of serum prolactin concentration; as such, serum prolactin concentration has been used a biological indicator of the severity of fescue toxicity. Recent research findings have linked several single nucleotide polymorphisms to decreased serum prolactin concentrations. Campbell et al. (2014) linked genotype of dopamine receptor DRD2 to decreased serum prolactin concentrations and differences in hair coat shedding when cattle were grazed on E+. Bastin et al. (2014) related differences in genotype of dopamine receptor XKR4 with decreased serum prolactin concentrations in a herd grazed on E+ pastures. Overall, more research needs to be conducted to correlate genotypes at a limited number of single nucleotide polymorphisms with economically relevant traits like weaning weight, milk production, and conception rate.

One commercially available product to test for level of susceptibility to fescue toxicity is the T-Snip test by AgBotanica, LLC (Columbia, MO). The exact single nucleotide polymorphisms that make up this test are proprietary; but, tested cattle are given T-Snip score of 0 to 5 to indicate susceptibility to fescue toxicity. A T-Snip score of 0 represents an animal most susceptible to fescue toxicity and a score of 5 represents and animal least susceptible to fescue toxicity. Masiero et al. (2016) demonstrated that cow T-Snip score has a moderate, positive correlation with calf 205 day weaning weight. As cow T-Snip score increases from 0 to 5, 205 day weaning weight increased from 467 pounds to 542 pounds. It should be noted that the majority of cattle used in genomic tests for susceptibility to fescue toxicity have Angus or crossbreds with a high percentage of Angus genetics. More research need to be conducted to validate these tests in other British and continental breeds of *Bos taurus* cattle as well as *Bos indicus* breeds of cattle.

In summary, managing fescue toxicity has been a substantial and complex challenge for the beef industry in the southeastern United States. The symptoms of fescue toxicity have far-reaching and costly effects on animal growth and efficiency, reproduction, and cattle welfare. Alleviating the effects fescue toxicity often requires a multi-faceted approach that involves pasture renovation, forage management, nutritional interventions, and selecting for cattle less susceptible to fescue toxicity. Many management strategies have been around for several decades; however, new discoveries are increasing options to combat this endemic issue.

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Forage Quality: Fiber Digestibility

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Forage Quality

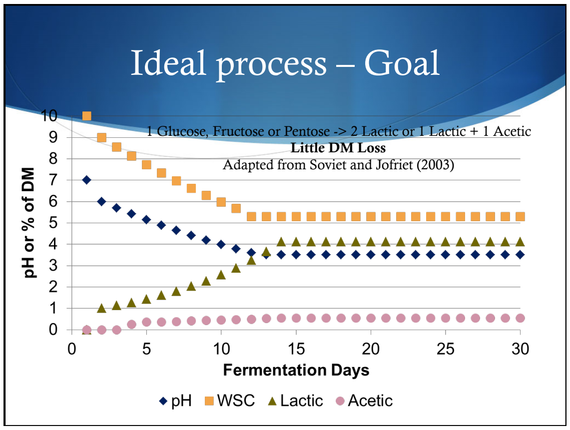
Preserving feed

Secondary Aim?

Where does Shrink happen?

Winning Fermentation

- **How do we preserve all 100 tons?**
- Grow the **right** bacteria, **quickly**
  - Convert only optimal amount of carbs into acid
- Produce effective acid amount in fastest possible time
- Avoid secondary fermentation
  - At all costs…


Ideal process – Goal
1 Glucose, Fructose or Pentose -> 2 Lactic or 1 Lactic + 1 Acetic
Little DM Loss
Adapted from Soviet and Jofriet (2003)
pH or % of DM
Fermentation Days
pH WSC Lactic Acetic

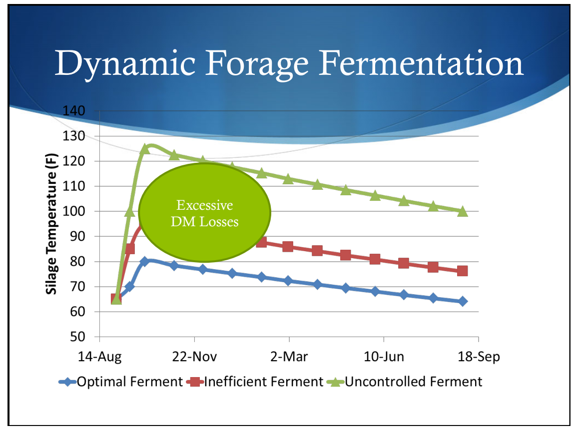
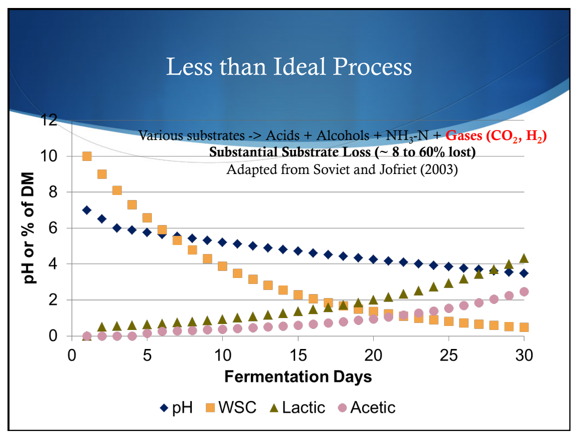
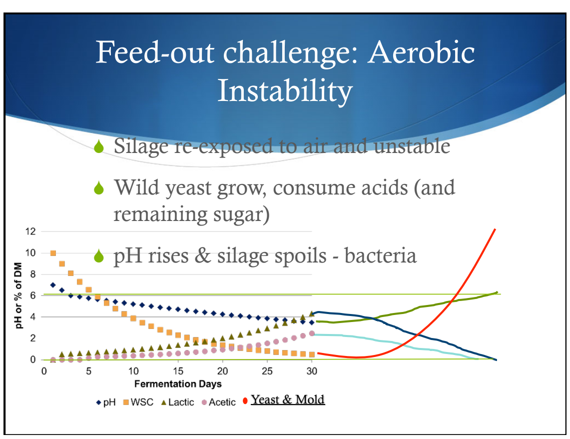

Dynamic Forage Fermentation
Silage Temperature (F)
Excessive DM Losses
14-Aug 22-Nov 2-Mar 10-Jun 18-Sep
Optimal Ferment Inefficient Ferment Uncontrolled Ferment


Image courtesy of Dr. Monty Belmer, DVM
Waupun Veterinary Service


Less than Ideal Process
Various substrates -> Acids + Alcohols + NH3-N + Gases (CO2, H2)
Substantial Substrate Loss (~ 8 to 60% lost)
Adapted from Soviet and Jofriet (2003)
pH or % of DM
Fermentation Days
pH WSC Lactic Acetic


Feed-out challenge: Aerobic Instability
Silage re-exposed to air and unstable
Wild yeast grow, consume acids (and remaining sugar)
pH rises & silage spoils - bacteria
pH or % of DM
Fermentation Days
pH WSC Lactic Acetic Yeast & Mold


Feed-out Opportunities
Limit aerobic exposure
At the feed-out face
Maintain density
Consider tools to improve forage stability or yield clean feed
Treatment/preservative

Goeser et al. (2015) Meta-Analysis

	Legume	Grass	Corn Silage	Small Grain
Fermentation Shrink (% of original DM)				
Mean	4.3	4.4	3.2	4.0
Median	3.0	3.0	2.4	3.0
Goal**	<2.0	<2.0	<1.5	<2.0
Max	35.0 and greater			

Fermentation Analysis Goals

Corn Silage	Published Means*	Typical***	Guideline	% RRL Met Goal?
pH	3.72	3.7 to 4.2	< 4.0	
Lactic	5.41	4 to 7	> 3.5	82.5%
Acetic	2.29	1 to 3	< 2.0	47.5%
Propionic	0.12	< 0.1	< 0.25	
EtOH	1.40	1 to 3	< 1.0	

Legumes\Grasses	Published Means**	Typical***	Guideline	% RRL Met Goal?
pH	4.63	4.3 to 4.7	< 4.5	
Lactic	6.84	2 to 10	> 3.0	70.0%
Acetic	2.01	0.5 to 3	< 1.5	61.5%
Propionic	0.04	< 0.5	< 0.25	
Butyric	0.07	< 0.5	< 0.25	

*, ** Published means were weighted by treatment number within a study and summarized from references cited. The numbers of treatments summarized from cited references were as follows: Corn Silage n = 159 and Legumes n = 36.

***Typical values adapted from those published by Kung and Shaver (2001).

Guidelines developed from Research Averages, Typical values, Rock River Laboratory means and from published references cited below.

Fermentation Analysis Goals

High Moisture Corn Grain	Published Means*	Typical**	Guideline	% RRL Met Goal?
pH	4.22	4 to 4.5	< 4.5	
Lactic	1.07	0.5 to 2.0	> 1.75	40.0%
Acetic	0.51	< 0.5	< 0.5	61.0%
Propionic	0.05	< 0.1	< 0.25	
EtOH	0.84	0.2 to 2.0	< 0.25	

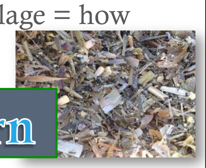
* Published means were weighted by treatment number within a study and summarized from references cited. The numbers of experimental treatments summarized from cited references were 32 for High Moisture Corn Grains

**Typical values adapted from those published by Kung and Shaver (2001).

Guidelines developed from Research Averages, Typical values, Rock River Laboratory means and from published references cited below.

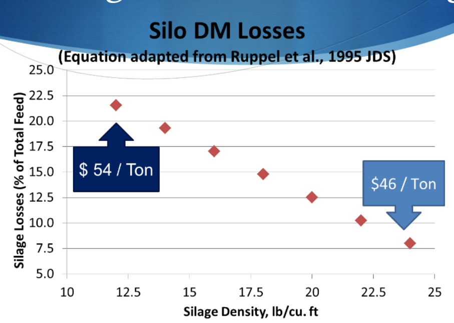
What is Fermentation Shrink?

- High quality water soluble carbohydrate (Sugar and starch)
- Must be replaced with corn or similar energy value ingredient
- 3% Shrink with 1 ton Silage = how many bushel???



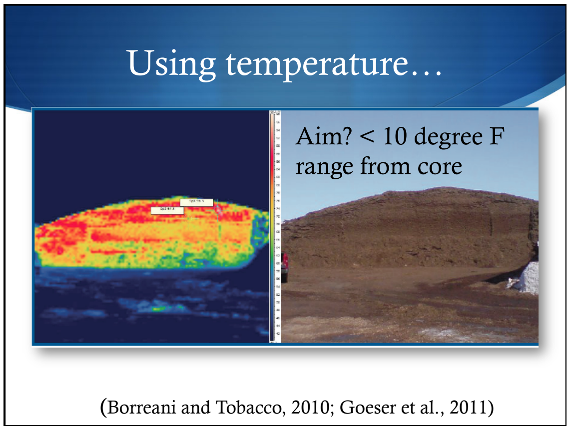
½ Bushel Corn

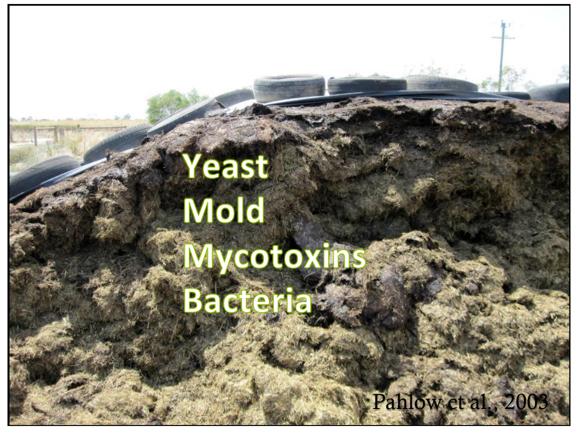
Limiting shrink losses: Packing

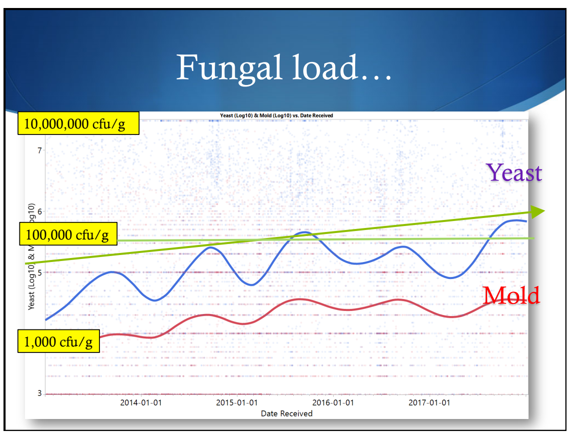


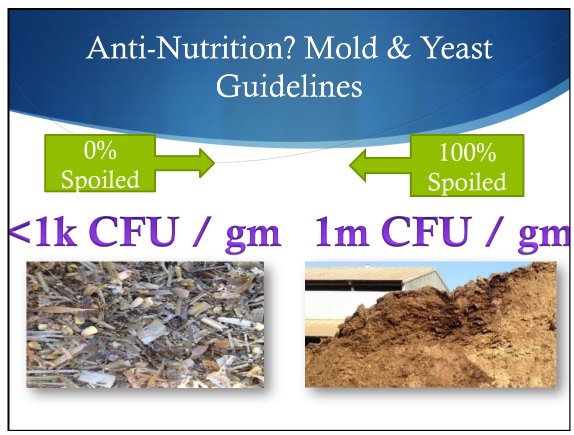
Keys to Limit DM Loss

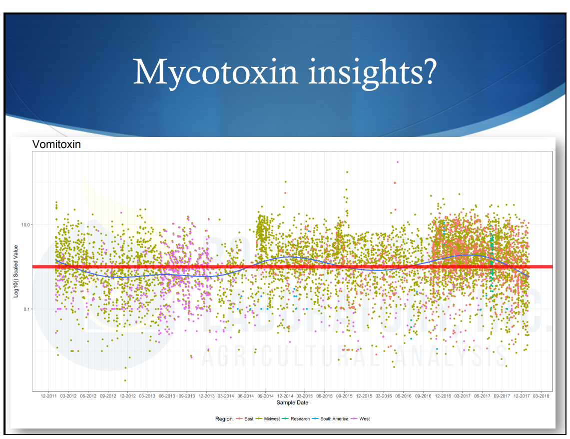
- Harvest a high quality crop & avoid rain
- Chop at the correct moisture
  - Moisture also excludes oxygen, don't go dry
- Put your decision maker on the Pack Tractor, Silo or Bagger
  - Watch the crop coming in and make key decisions
- Use a *research proven* inoculant at the chopper
  - Insulate the tank, mix at correct ratios and keep fresh supply
- ***Manage oxygen – keep O_2 out!***
- ***Get the pH < 5.0 ASAP!!!***

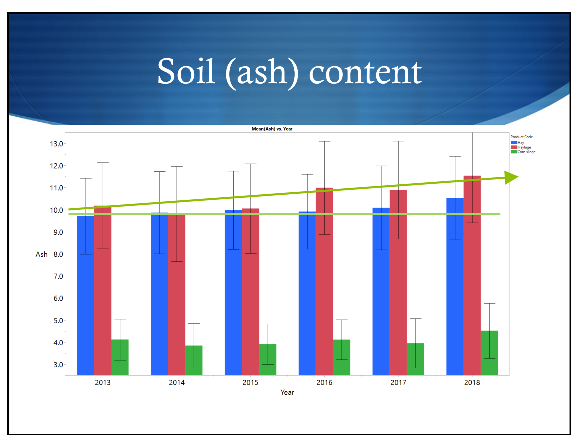

Using temperature…
Aim? < 10 degree F range from core
(Borreani and Tobacco, 2010; Goeser et al., 2011)


Yeast
Mold
Mycotoxins
Bacteria
Pahlow et al., 2003

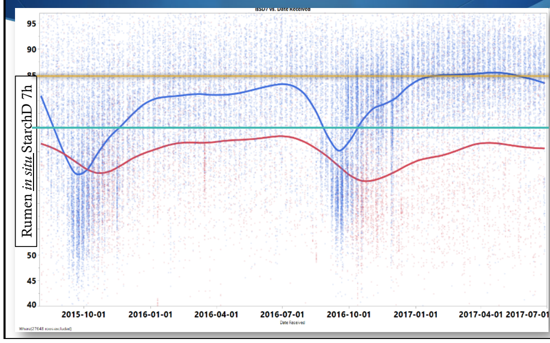

Fungal load…
10,000,000 cfu/g
100,000 cfu/g
1,000 cfu/g
Yeast
Mold
2014-01-01
2015-01-01
2016-01-01
2017-01-01
Date Received


Anti-Nutrition? Mold & Yeast Guidelines
0% Spoiled
100% Spoiled
<1k CFU / gm
1m CFU / gm

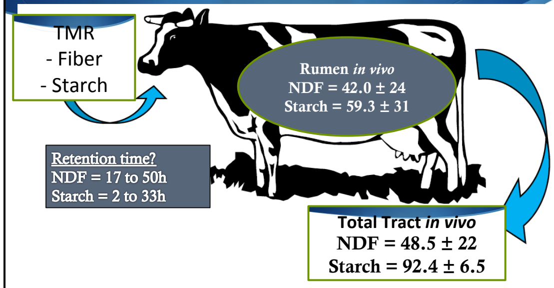

Mycotoxin insights?
Vomitoxin
Sample Date


Soil (ash) content
Ash
2013
2014
2015
2016
2017
2018
Year

Corn silage & Grain starch potential?

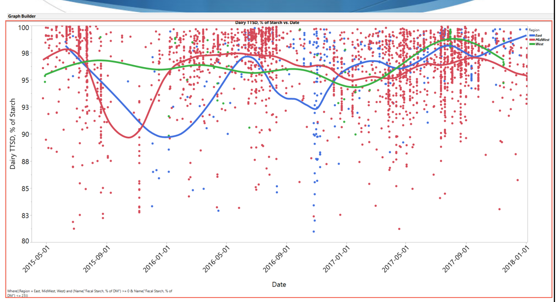


What do Cows have to say?

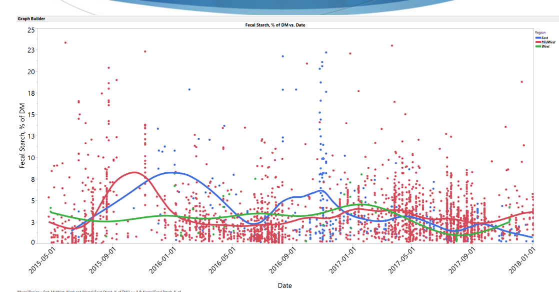


(Goeser, 2014)

Total Tract Starch Digestibility



Fecal Starch



Rock River Laboratory, Inc.
P.O. Box 169
Watertown, Wi 53094-0169
920.261.0446

TMR-D Enhanced Report
Reference: Schalla, Meyer, Meyer, Onetti, Schultz and Goeser. 2012, J Dairy Sci.

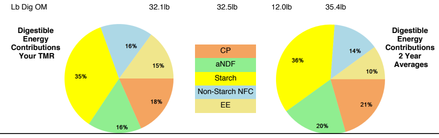
2013 Certified Chemistry by NFTA

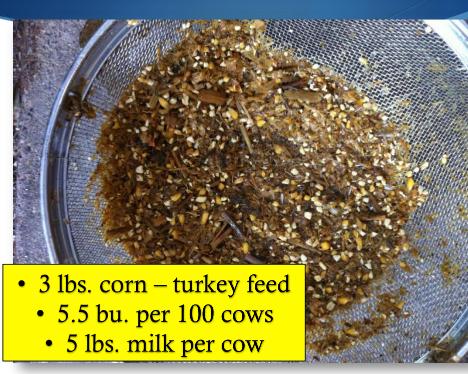
Sample # 1 LOT8 TMR
Lab # **Sampled on** 4/9/2013 **Received on** 4/10/2013
Farm

Dry Matter 48.3% **Avg. DMI** 56.4

TMR Nutrient Analysis	Your TMR, % of DM	Avg TMR, % of DM (Prior 2 Yr Data)
Crude Protein (CP)	16.1%	17.3%
aNDF	30.2%	33.8%
Fat (EE)	6.3%	4.3%
Starch	24.0%	25.1%
Organic Matter (OM)	92.7%	92.1%
Non-Starch NFC	16.0%	11.7%

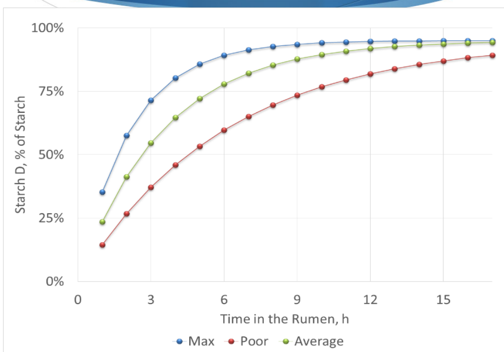
TMR-D in vivo results	Your TMR, % Digested	Benchmarks (Prior 2 Year Data)		
		Avg	Min	Max
OM-D	61.4%	62.6%	46.1%	79.2%
NDF-D	34.3%	37.1%	13.8%	60.4%
Starch-D	94.9%	92.4%	83.1%	99.0%
CP-D	57.7%	59.3%	39.1%	79.6%
Fat (EE)-D	68.4%	67.3%	38.3%	96.4%
Lb Dig OM	32.1lb	32.5lb	12.0lb	35.4lb





- 3 lbs. corn – turkey feed
- 5.5 bu. per 100 cows
- 5 lbs. milk per cow

Starch Digestibility



StarchD developments: Commercial feed analysis

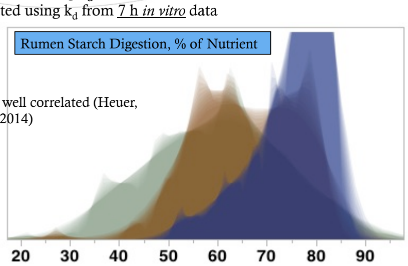
- Lab bench versus a live rumen?
  - *In vitro* starch digestion **not related** to commercial dairy TTSD
    - (Powell-Smith et al., 2015; Schuling et al., 2016)
  - Rumen *in situ* **Agrees with cows** (Schuling et al., 2016)
    - isSD7 significantly related to on-farm rumen starch digestion
    - Improved ration milk prediction (R^2 from .69 to .76)
- ***Go to the Rumen!***

Focus on the rumen…

Rumen Starch D – results summary

- **Green** = TMR reality based on *in vivo* meta-analysis
- **Brown** = predicted using k_d from 7 h *in situ* data
- **Blue** = predicted using k_d from 7 h *in vitro* data

In vitro & in situ not well correlated (Heuer, MS Thesis; Goeser, 2014)



Rumen *in situ* Starch Digestion Guidelines - RRL

Feed	Goal	Avg	Min
TMR	>75	60-70	<50
Corn Silage	>85	75-80	<60
HMSC	>80	60-65	<40
Dry Corn	>70	55-60	<40

In situ Rumen Starch Disappearance

Feed		*in situ* Rumen Starch Disappearance		
	h	Average	Goal	Low
Corn Silage	3	60 - 70	> 80	< 45
	7	70 - 80	> 85	< 60
	16	85 - 95	> 95	< 75
Ear Corn/Snaplage	3	60 - 70	> 75	< 45
	7	75 - 85	> 85	< 65
	16	85 - 95	> 95	< 85
High Moisture Corn	3	50 - 55	> 70	< 35
	7	65 - 70	> 80	< 55
	16	80 - 85	> 90	< 75
Dry ground corn	3	30 - 40	> 40	< 30
	7	50 - 60	> 65	< 45
	16	70 - 75	> 80	< 65
TMR	3	45 - 55	> 60	< 40
	7	60 - 70	> 80	< 50
	16	NA	NA	NA

Intestinal Digestion?!?

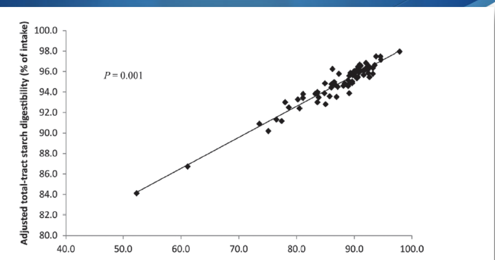


Figure 5. Relationship between postruminal starch digestibility as a percentage of duodenal flow and total-tract starch digestibility adjusted for the random effect of trial. Prediction equation: $y = 68.287 + (0.304 \times \text{postruminal percentage of flow}) + (0.013 \pm 0.574)$; $n = 72$, root mean square error (RMSE) = 0.58.

Adapted from Ferraretto et al., 2013

Forage Analysis Structure – StarchD

Received: 3/15/2017 **Sampled:** 3/15/2017
Rep: Craig Goeser
GOESER DAIRY / 2 SLG BD

Comprehensive Nutrition Analysis Report
Moisture: 69.11
Dry Matter: 30.89

ROCK RIVER LABORATORY, INC. AGRICULTURAL ANALYSIS

Protein & Amino Acid	%DM	60d	4 yr
Crude Protein	8.33	8.16	7.65
Total Amino Acid	6.50		
Sol. CP, % of CP	63.51		46.88
NH3-N CP Equivalent	0.94	1.00	
NH3-N, % of CP	11.25	12.30	11.96
ADICP	0.91	0.70	0.66
NDICP	1.14		1.19
ADICP, % of CP	10.92		
Available CP	7.42		
Nitrate-N			
Calculated Amino Acids			
Lysine, % of CP	2.49		
Methionine, % of CP	1.57		
Histidine, % of CP	1.83		
Minerals & Ash			
Ash	3.96	4.21	4.13
Calcium	0.23	0.20	0.23
Phosphorus	0.23	0.21	
Magnesium	0.22	0.15	
Potassium	0.88	0.94	0.92
Sodium	0.00	0.01	0.04
Sulfur	0.08	0.10	0.11
Chloride	0.19	0.25	0.37
Aluminum	79.84		
Boron	4.01		
Copper	4.93		7.53
Iron	102.47		296.71
Manganese	19.12		27.59
Molybdenum			
Zinc	17.38		25.56

Carbohydrates	%DM	60d	4 yr
ADF	23.91	23.05	
aNDF	38.63	37.02	44.40
aNDFom	37.40	35.64	40.41
Lignin	3.39	3.45	2.77
Starch	31.96	33.85	32.57
Sugar (ESC)	0.26	1.23	1.35
Sugar (WSC)	2.76		3.05
Glucose			
Fructose			
Sucrose			
Lactose			
Mannitol			
Crude Fiber			
Fermentation Products			
pH	3.87		4.36
Lactic Acid	4.87	4.02	4.49
Acetic Acid	2.82	2.07	1.94
Butyric Acid	0.00	0.06	0.07
Propionic Acid			
Succinic			
Formic			
Ethanol			
1,2 Propanediol			
1 Propanol			
2,3 Butanediol			
2 Butanol			
2 Propanol			
Total Acids			
Total Alcohols			
Fermentation Shrink	3.34		3.15

Fat	%DM	60d	4 yr
Ether Extract	3.10	2.79	2.12
Total Fatty Acid	1.99		
	% of FA	**60d**	**4 yr**
Myristic (C14:0)	0.30		
Palmitic (C16:0)	13.02		
Stearic (C18:0)	1.99		
Oleic (C18:1 c9)	21.57		
Linoleic (C18:2 c9,12)	49.51		
Linolenic (C18:3 c9,12,15)	3.85		
RUFAL	74.93		
Nutrient Digestion, % of nutrient **Prefixes: s=standard, t=traditional*			
tNDFD30	54.80	54.09	54.06
tNDFD48	66.14	62.21	64.29
tNDFD120	67.19	64.00	77.10
tNDFD240	76.34		80.50
tNDFD30om	58.11		
tNDFD120om	69.88		
tNDFD240om	78.58		
sNDFD24	18.59	21.54	21.09
sNDFD30	21.72	25.40	29.08
sNDFD48	46.78	46.71	47.29
uNDF30, % DM	17.46		
uNDF240, % DM	9.14		8.64
uNDF30om, % DM	15.67		
uNDF240om, % DM	8.01		
in situ rumen starchD 0h	34.40		
in situ rumen starchD 3h	81.05		65.00
in situ rumen starchD 7h	90.78		75.00
in situ rumen starchD 16h	94.24		90.00
in situ RUP 16h			
RUP intest. dig., % RUP			

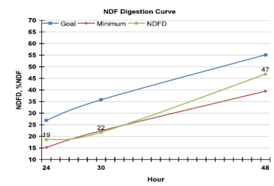
Forage Analysis Structure

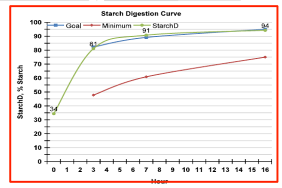
Comprehensive Nutrition Analysis Report

Calculations	%DM	60d	4 yr
Dynamic NDF kd, %/h	3.99	4.18	3.72
Dynamic Starch Kd, %/h	33.19		
RFV			
RFQ			
TTNDFD, % of NDF	40.93	40.61	42.84
Total Tract Starch Dig			
NFC	47.12		
DCAD	12.02	11.08	7.97
Salt			

Energy Calculations		NEG	NEM
ADF (PA) TDN	70.08	0.514	0.796
ADF (PA) NEL	0.728		
OARDC TDN	73.06	0.559	0.847
OARDC NEL	0.757		
NRC2001 TDN			
NRC2001 NEL			
TDN, Milk2006	73.68	0.568	0.858
NEL 3x, Milk2006	0.729		
Milk/Ton, Milk2006	3478		
California TDN 90% DM			

Anti-Nutrients
Mold
Yeast
Vomitoxin, ppm
Aflatoxin, ppb
Zearalenone, ppb
Fumonisin, ppm
T-2, ppb
Ochratoxin-A, ppb
Clostridium perfringens
Salmonella & Enterococcus





Minerals by ICP

Corn Silage Kernel Processing Score (KPS) Guidelines and Benchmarks

Rock River Lab Data summarized by Dr. John Goeser; March 2017

% Corn Silage Starch that Passes through a 4.75mm Screen

Industry Guidelines

Industry Guidelines		Rock River Lab % of Samples in Each Range
Optimum	>70	22.5%
Average	50 to 70	55.0%
Below Average	<50	12.5%

Rock River Lab Results

Rock River Laboratory Database	
All Years	
Average	64.4
Min	51.9
Goal	>76.0

2016 Crop Year	
Average	66.0
Min	55.5
Goal	>76.4

2015 Crop Year	
Average	65.8
Min	52.4
Goal	>77.5

The Alphabet Soup

aNDFom

aNDFom

Cleans up the "contaminates" that skew the NDF analysis results

aNDFom—Nitrogen and starch contamination

- removed by treatment with sodium sulfite and amylase

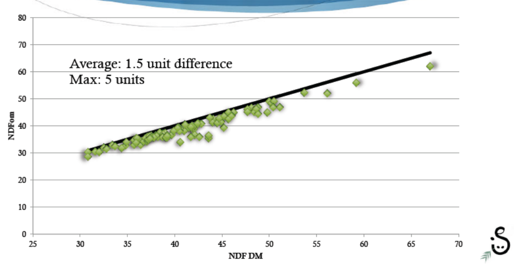
aNDFom—Ash contamination

- firing post-boiling to subtract out dirt, non-organic particles

Source of Ash Contamination

- Modern Methods of Hay making
  - Discbind hay mowers act as a vacuum
- Flood Irrigation
- Soil and dirt does not solubilize in NDF solution and if not corrected for will inflate values

Alfalfa hay/haylage aNDFom



Bottomline

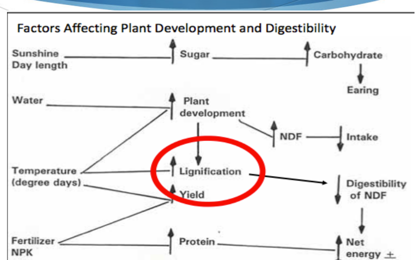
NDF content of diets, in some cases, will DROP 2-5 units

On specific forages:

May see as high as a 8-10 point drop in NDF!

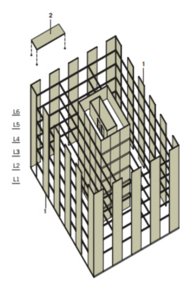
Keep in mind that this will affect the NDFD value as well!

Fiber Digestibility



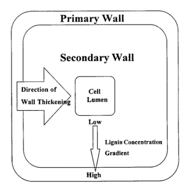
From Van Soest, 1996

Fiber Digestibility – Maturity Impact



https://diagram+of+tall+building+structures

- Lignin highest in primary wall & moves into secondary wall as plant matures
  - ML and 1° wall often indigestible (for fiber particles)



Lignin is not Lignin is not Lignin Feedtype/Hybrids Impact

2.4 factor to calculate CHO C is NOT constant

- BMR corn silage hybrids, 3 to 5
- Conventional hybrids 2 to 7
- Alfalfa 1.9 to 3.2

  (with 80% between 2.2 and 2.8)
- Grasses 1.5 to 5.5

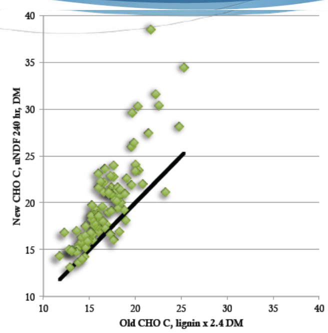
  (with immature grasses varying from 1.9 to 7.5).

uNDF

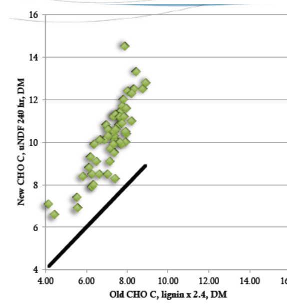
Some papers call it iNDF to represent indigestible NDF

- Mertens has pushed for us to call it uNDF for undigestible NDF and uNDF is becoming the *de facto* standard term

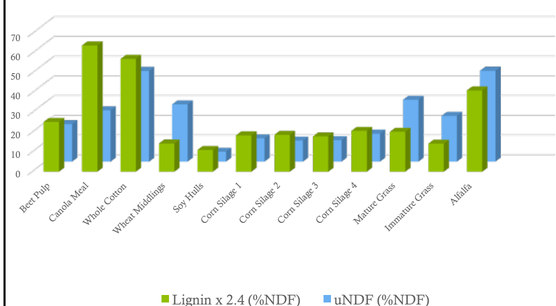
New Data Alfalfa



New Data Corn Silage



uNDF vs Lignin x 2.4 in Select Feeds

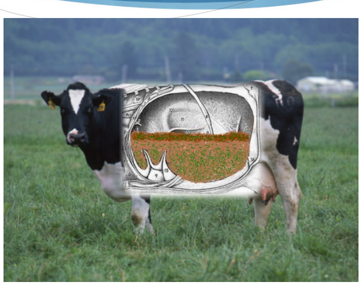


Who's got the time?

Digestibility values for forages: 30, 120, and 240

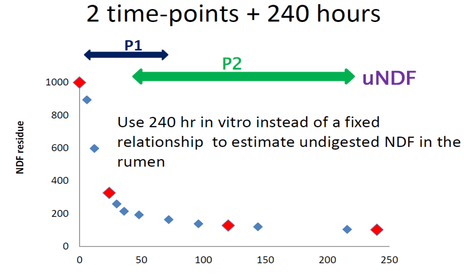
Digestibility values for non-forages: 12, 72, and 120

NDF Rates and Digestion

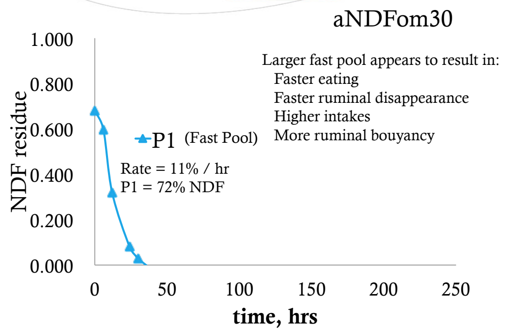


NDF kd

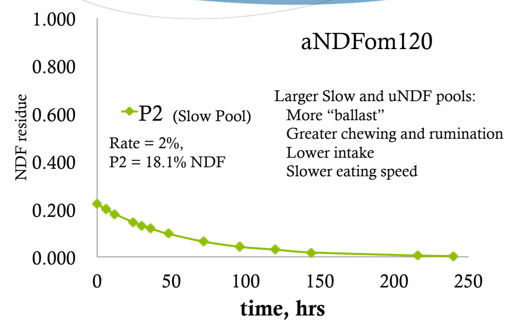
2 time-points + 240 hours



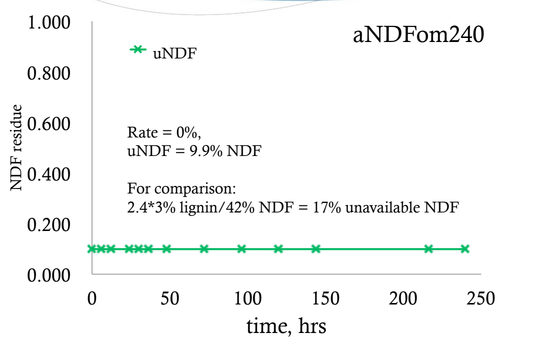
Corn silage example: fast pool



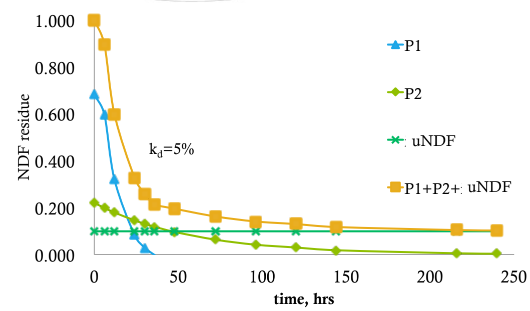
Corn silage example: slow pool



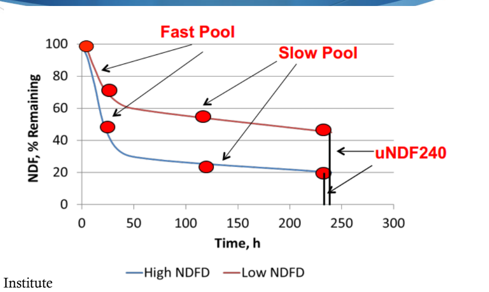
Corn silage example: uNDF



Corn silage example: P1+P2+uNDF



Using the Data



Miner Institute

Study Data—Miner Institute

Project	% of BW	Diets			
% Forage		53% 40%CS:13% HCS	67% 54%CS:13% HCS	49% 36%BMR:13% HCS	64% 51%BMR:13% HCS
2011	Intake	0.36[ab]	0.39[a]	0.30[c]	0.33[bc]
	Rumen	0.57[a]	0.62[a]	0.48[b]	0.52[ab]
	Intake: Rumen	0.625	0.632	0.633	0.637

While the $uNDFom_{240}$ intake and rumen $uNDFom_{240}$ (% BW) varied, the ratio was fairly constant

NDF Guidelines (at ~59# DMI, 99# SCM)

- Max NDFom 1.47 % BW (Range 1.26 – 1.47)
- Max Rumen NDFom 19# or 1.28 % BW
- Range of intake $uNDFom_{240}$ 0.30 to 0.48 % BW
- Range of $uNDFom_{240}$ mass in rumen is 0.48 to 0.62 % BW
- Range of $uNDFom_{240}$/ intake $uNDFom_{240}$ is 1.60 regardless of diet
- This equates to a $uNDFom_{240}$ rate of passage of about 2.64 %/ hr.

Miner Institute

Take Home…

uNDF and intake appear to be very highly correlated

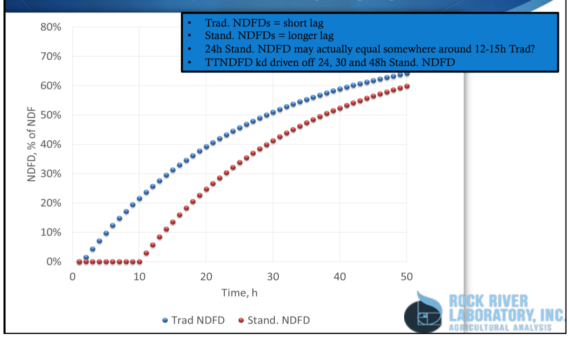
- It appears in Holsteins that the cow will reach a steady-state uNDF rumen level **4-5 kg or 8.8 to 11 lbs.**

For her to consume more feed, an equal amount of uNDF must escape the rumen first.

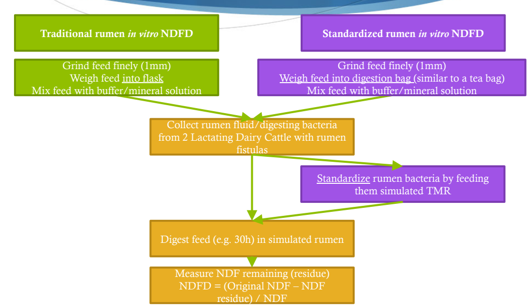
- uNDF has 0 kd so completely regulated by passage rate and reduction of particle size.

This has massive potential impact on formulation, procurement of feeds and management for crop quality.

Traditional vs RRL Standardized NDFD Methods



Traditional vs RRL Standardized NDFD



TMR-D Enhanced Report

Rock River Laboratory, Inc.
P.O. Box 169
Watertown, Wi 53094-0169
920.261.0446

Reference: Schalla, Meyer, Meyer, Onetti, Schultz and Goeser. 2012, J Dairy Sci.

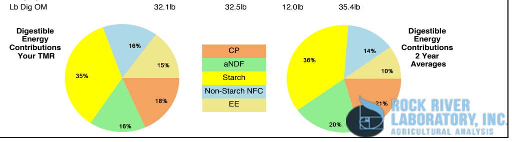
2013 Certified Chemistry by NFTA

Sample # 1 LOT8 TMR
Lab # **Sampled on** 4/9/2013 **Received on** 4/10/2013
Farm

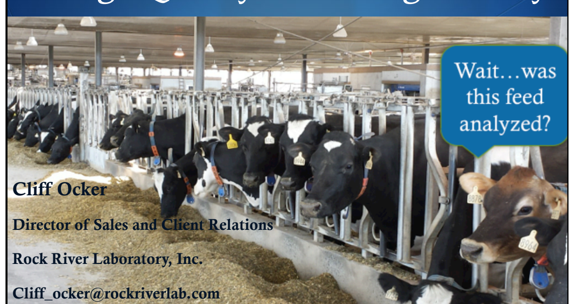
Dry Matter 48.3% **Avg. DMI** 56.4

TMR Nutrient Analysis	Your TMR, % of DM	Avg TMR, % of DM (Prior 2 Yr Data)
Crude Protein (CP)	16.1%	17.3%
aNDF	30.2%	33.8%
Fat (EE)	6.3%	4.3%
Starch	24.0%	25.1%
Organic Matter (OM)	92.7%	92.1%
Non-Starch NFC	16.0%	11.7%

TMR-D in vivo results	Your TMR, % Digested	Benchmarks (Prior 2 Year Data) Avg	Min	Max
OM-D	61.4%	62.6%	46.1%	79.2%
NDF-D	34.3%	37.1%	13.8%	60.4%
Starch-D	94.9%	92.4%	83.1%	99.0%
CP-D	57.7%	59.3%	39.1%	79.6%
Fat (EE)-D	68.4%	67.3%	38.3%	96.4%
Lb Dig OM	32.1lb	32.5lb	12.0lb	35.4lb



Forage Quality: Fiber Digestibility



Cliff Ocker

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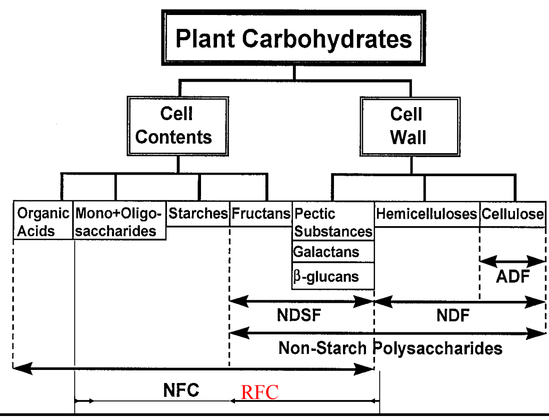
Impact of Post Harvest Forage on the Rumen Function

Gbenga Ayangbile, Ph.D.

Established Facts

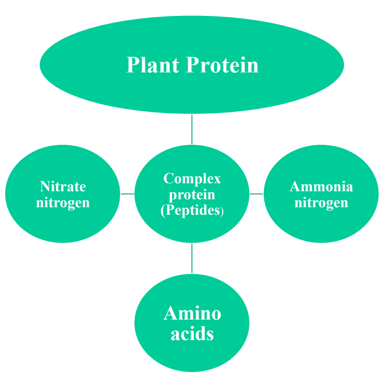
- Most nutrients in fresh forages before harvesting are more available and efficiently utilized for productive purposes in livestock production.
- However post harvesting with or without a form of preservation is known to reduce the availability and quality of these nutrients.



Known Facts

- Forage Cell Contents with their natural organic acids, mono and oligosaccharides, starches, fructans usually do not improve in nutrient qualities after harvesting.
- However, post harvesting of the forage followed by some forms of conservation methods; are known to improve the nutrient qualities of the Cell Wall contents such as NDF pectic substances e.g galactans,beta-glucans, hemicellulose and ADF celluloses.

Protein qualities in Pre-harvest forages



Known Facts

- Proteins in pre-harvest forages are of greater qualities; and are sensitive to various forms of degradation or biochemical transformation after harvesting.
- Depending on methods of conservation at harvest, most of the non-protein nitrogen may be converted to utilizable proteins for the Rumen Function.

Benefits from Pre Harvest Forages

- Ensuring availability of forage to the animals post forage growing season.
- Improved palatability to the animals.
- Improved digestibility and nutrient qualities of cell wall carbohydrates and non-protein nitrogen through effective post harvest conservation methods.

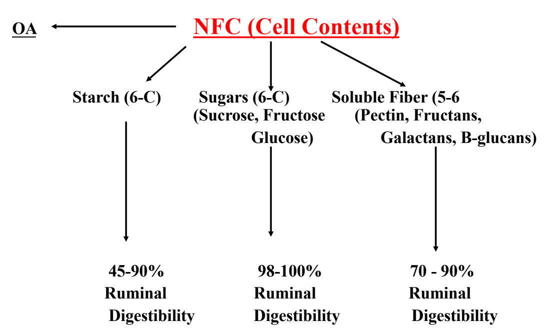
Comparing the Benefits from the Pre and Post Harvested Forages

CELL CONTENTS

VS

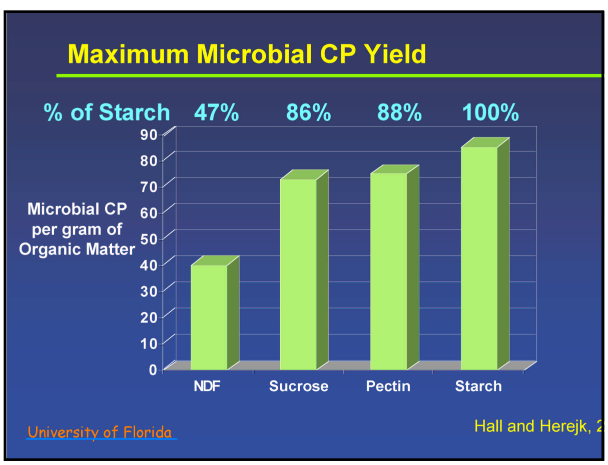
CELL WALLS

Constituents of forage carbohydrates



Percent DM of Sugars in fresh Pastures and other harvested forages (averages < 500 samples)

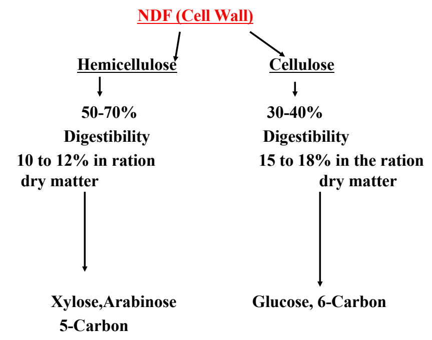
Items	Arabinose	Fructose	Glucose	Sucrose	Xylose	NFC	Starch
Pasture	2.56	4.37	2.74	1.23	7.75		0
Hay	1.4	2.77	1.45	0.76	8.8	26.15	0
Balage	1.43	5.05	1.98	0.959	5.95	29.1	0
Haylage	1.3	2.59	1.14	1.26	5.7	29.06	0
Grass silage	1.37	1.93	0.49	0.67	10.17	20.28	0
CS	0	0.233	0.248	0.71	12.6	43.84	31.93



Chemical changes in Forages Post Harvest

- Most post harvested forages are matured and high in fiber contents as Sugar level decreases.
- As plant matures, 5 carbon sugars such as arabinose are converted to Hemicelluloses.
- And 6 carbon sugars such as glucose are converted to starch and cellulose.
- In corn forage and others, glucose is converted to starch.
- With maturity, LIGNIN strongly binds the hemicelluloses and cellulose, thus reduce animal digestibility.

Constituents of forage cell wall carbohydrates



Percent DMD and Cell wall contents in fresh Pastures and harvested forages (averages < 500 samples)

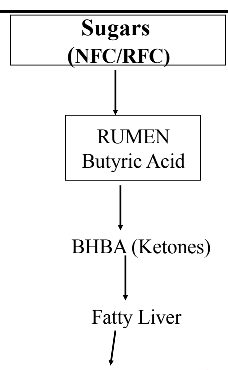
Items	IVDMD	CWD	NDF	ADF	HEM	CP	SP
Pasture	82.26	79.54	41.62	22.26	19.37	24.5	40.2
Balage	73.78	56.99	42.64	28.85	13.79	19.71	51.43
Haylage	75.02	60.38	40.03	28.35	11.68	21.92	58.97
Grass silage	66.49	53.47	58.04	35.54	22.5	13.08	60.13
Hay	67.14	57.29	50.39	33.02	17.37	17.64	33.17
CS	73.25	51.91	42.23	24.83	17.4	7.93	57.36

Cell contents vs Cell walls sugars in the Rumen

The profile and ratio of energy metabolites produced in the rumen when Cell Contents and Cell walls fractions are fed to the animals may help diet formulators on how to formulate more efficiently.

In Vitro Rumen Microbial VFA Production from the Sugars in Pre and Post harvest Forages

Sugars	Types of chain	% Acetate	% Propionic	% Butyric	Total VFA, um/ml	Acetate+Butyric/Propionate ratio
Starch	6	56.23	16.93	26.61	25.27	4.89
Galactose	6	47.18	10.46	40.71	22.14	8.40
Fructose	6	52.49	7.54	39.54	20.51	12.21
Glucose	6	51.06	10.45	38.08	24.67	8.53
Pectin	5	86.03	6.12	7.86	25.98	15.34
Xylose	5	71.69	13.66	14.65	24.12	6.32
Arabinose	5	71.87	13.39	14.69	27.93	6.46



Inhibits TCA cycle = Increases anaerobic glycolysis, blood glucose and blood lactate. Reduction in Propionate conversion to Glucose

Since the season of harvest affect the nutrients profile, how much impact does the nutrient change played on the Rumen function?

Distribution of sugars (%) in Grasses

Item	Sucrose (6 C)	Fructose (6 C)	Glucose (6 C)	Ribose (5 C)	Xylose (5 C)
BTR9 1st	0.774	3.70	3.67	16.23	52.19
BTR9 2nd	0.284	3.23	2.83	11.03	49.35
BTR9 3rd	0.538	7.15	5.90	10.27	43.16

Comparison of %sugars to NDF, NFC and CWD in Grasses

Item	5 Carbon Sugars	NDF	Sol. 5 and 6 Carbon Sugars	NFC	CWD
BTR9 1st Cut	60.53	53.38	16.03	18.04	56.84
BTR9 2nd Cut	53.72	55.26	13.01	18.04	54.81
BTR9 3rd Cut	46.48	46.11	20.54	27.62	51.54

Distribution of sugars (%) in Grasses

Item	Sucrose (6 C)	Fructose (6 C)	Glucose (6 C)	Ribose (5 C)	Xylose (5 C)
Barfest 1st Cut	0.936	5.52	5.27	12.15	31.57
Barfest 2nd Cut	0.476	1.46	2.35	15.28	49.67
Barfest 3rd Cut	0.371	8.50	7.02	11.31	33.8

Comparison of sugars to NDF, NFC and CWD in Grasses

Item	5 Carbon Sugars	NDF	Sol. 5 and 6 Carbon Sugars	NFC	CWD
Barfest 1st Cut	35.44	44.78	20.02	21.55	67.9
Barfest 2nd Cut	57.94	58.76	11.29	16.32	58.62
Barfest 3rd Cut	38.17	40.52	22.83	32.78	57.38

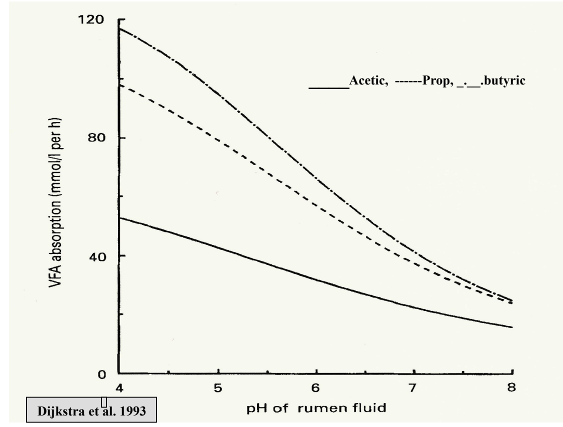
VFA Profile of Grasses as affected by Sugars Composition

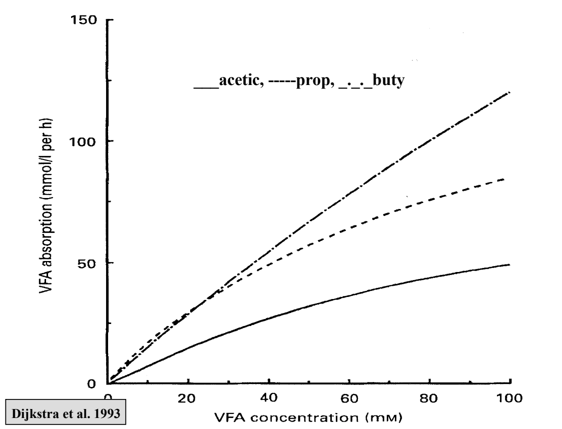
Item	% Acetate	% Propionic	% Butyric
Barfest 1st Cut	63.7	14.1	15.9
Barfest 2nd Cut	69.7	15.2	12.7
Barfest 3rd Cut	57.6	17.5	21.4

Effect of Types of sugars in feedstuffs on the Production of Energy for Cows

Sugar Type	Type of ingredient	Acetic%	Prop. %	Buty. %	Total VFA, um/ml
Starch	CS, Corn	56.23	16.93	26.61	25.27
Fructose	Hay	52.49	7.54	39.54	20.51
Glucose	Hay	51.06	10.45	38.08	24.67
Arabinose	Pastures	71.87	13.39	14.69	27.93
Pectin	Alf., Soy hull	86.03	6.12	7.86	25.98
Xylose	Hay, Hlg	71.69	13.66	14.65	24.12

When there is excessive concentration of **BUTYRIC** acid in the RUMEN as a result of overproduction, this excess may cause low performance and initiation of metabolic problems especially in pre and post fresh cows.





The Graphs show:

a) absorption of VFA when rumen pH is <6.3 is in the order of Butyrate>Propionate>Acetate

b) absorption of VFA into the blood decreased as rumen pH increased

c) as the total VFA concentration in the rumen increased, absorption of acetate and propionate decreased but butyrate is not affected

Protein qualities in Post-harvest forages

- Depending on methods of conservation at Post harvest, most of the non-proteinous nitrogen may be converted to efficient utilizable proteins for the Rumen Function.
- While others are transformed from quality complex proteins to soluble proteins.
- Excess Soluble Proteins in an unbalanced rations may be toxic to cows.

Impact of Post-Harvest on Transformation of Nitrogen in Fresh Alfalfa.

Items	% CP	%SP	Ammonia, ppm
Fresh chopped Alfalfa	25.12	32.7	133.83
Alfalfa Balage @ 60 d	25.3	67.9	2494

Fate of Ammonia ingested in Post Harvested forages

- Approximately 1/3rd of Rumen Bacteria required ammonia with other cofactors to synthesize microbial protein (70% bypass).
- Excess dietary ammonia is toxic if the animal's liver is limited in detoxify it.

Fate of Ammonia ingested in Post Harvested forages

- MUN is a great indicator of how much dietary ammonia is produced and detoxified.
- Accumulated ammonia changes the acid-base balance of the cells (metabolic problems especially post calving).

Soluble protein

↓

Elevated Rumen Ammonia

↓

Blood ammonia toxicity

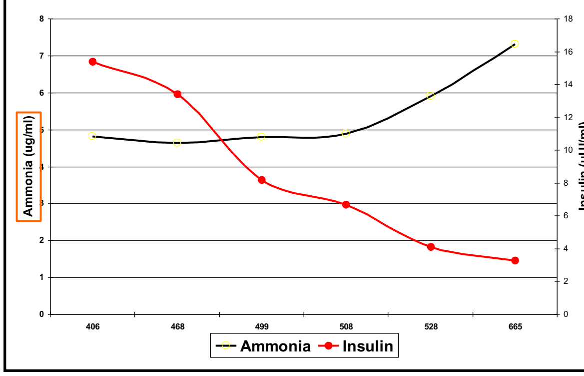
↓

Over worked Liver

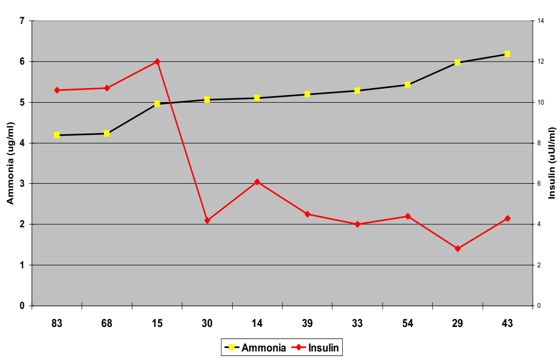
↓

Inhibits TCA cycle = Increases anaerobic glycolysis, blood glucose and blood lactate. <u>Reduction in Propionate conversion to Glucose</u>

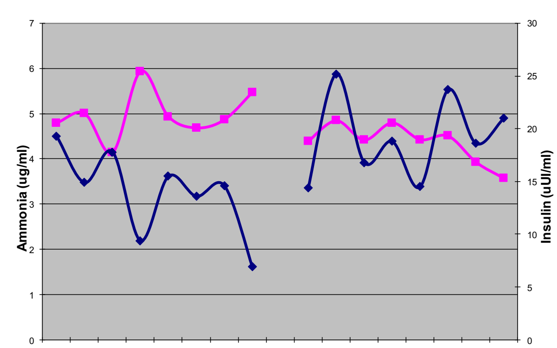
Impact of Blood Ammonia on Insulin concentration in Milking Cows



Impact of Blood Ammonia on Insulin Concentration in Milking Cows



Impact of Blood Ammonia on Insulin Concentration



Conclusion

Nutrients in forages pre harvest are naturally of greater quality for animal production.

Post harvesting of forages is necessary to meet the feed demands and quality needed for animal production.

Many studies showed that a form of preservation is needed during harvesting to control spoilage, improve palatability and digestibility to the animals.

Conclusion

The sugar types in the cell contents and cell wall varied according to the season, maturity and preservation methods.

It would be a great benefit to formulate rations according to the ways the Rumen Bacteria see these sugars.

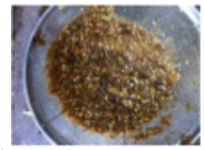
Understanding how to combine these sugars in the diet with variable forms of forage proteins will help maximize Rumen microbial functions.

Thank You

How Fiber Digestibility Affects Forage Quality and Milk Production

Dr. Dave Combs
Professor
Dept of Dairy Science
University of Wisconsin-Madison

What causes performance swings in dairy diets? **MOST OF THE TIME ENERGY**



- ✓ Diet Energy is impacted largely by carbohydrates
  - ✓ Fiber
  - ✓ Starch
- ✓ Fiber is always lower energy than starch (grain)
- ✓ 2-3 unit drop in Fiber or Starch digestibility will decrease milk by about one pound

New Technologies and Innovations in Forage Feeding Programs for Livestock
Digestibility!

Corn Silage
- Shredlage (↑ starch digestibility)
- BMR (↑ fiber digestibility)

Alfalfa
- Reduced lignin (↑ NDF digestibility)

Grasses
- Improved grasses for high producing dairy cows (Higher fiber digestibility than alfalfa or corn silage)

Forage testing/analysis
- Indigestible fiber ($uNDF_{240}$)
- Total Tract NDF digestibility (TTNDFD)

Topic #1. What makes a better forage?

- ✓ High digestibility
  - ✓ Fiber (-)
  - ✓ Fiber digestibility (+)
- ✓ High intake potential
  - ✓ Fiber (-)
  - ✓ Fiber digestibility (+)

BOTH NDF and NDF digestibility are needed to assess forage quality

Forage Fiber Tests

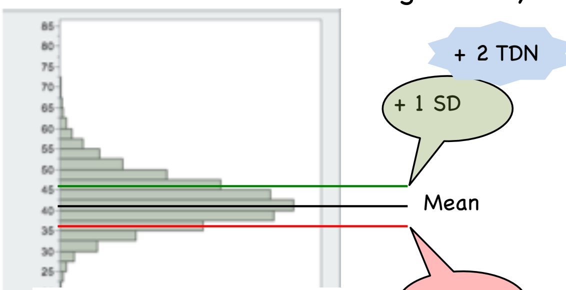
Test	Rumen Fill	TDN Estimation	Diet Formulation	Herd Diagnostics	Quality Index
NDF_{OM}	X	X	X	X	
$NDFD_{(30 \text{ or } 48)}$	X/?	X			X/?
TTNDFD	X	X	X	X	X
$uNDF_{240}$	X				?
NDF kd			X		
RFV/RFQ					X
Milk/ton					X

Fiber digestibility varies in forages

TTNDFD	Range in % of NDF
Alfalfa hay and silage	25-70
Corn silage	25-80
Grass hay and silage	15-80

Two units increase in diet TTNDFD can potentially increase milk yield by 1 lb

How variable is alfalfa fiber digestibility?



1/3 of alfalfa forages at the same NDF will vary by more than 2 units of TDN from average

Why is fiber digestibility important?

Oba and Allen (1999)
A 1% change in vitro or in situ NDF digestibility (primarily 30-h or 48-h NDFD) was correlated with:

- ✓ 0.4 lb increase in dry matter intake
- ✓ 0.5 lb increase in 4% fat corrected milk yield

Why does fiber digestibility vary? 1: Maturity

	NDF % of DM	Lignin % of DM	TTNDFD % of NDF
Immature	33	5.4	54
Vegetative	37	6.2	50
Mid-maturity	43	7.3	47
Mature	50	8.4	46

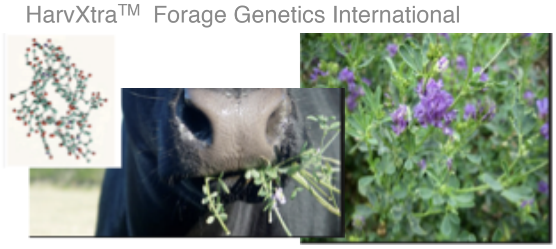
Why does fiber digestibility vary? 2: Growing conditions/environment

- ✓Moisture
- ✓Temperature
- ✓Sun intensity

2/3 or more of variation in fiber digestibility is likely due to growing conditions/environment

Why does fiber digestibility vary? 3: Genetics: Reduced Lignin Alfalfa

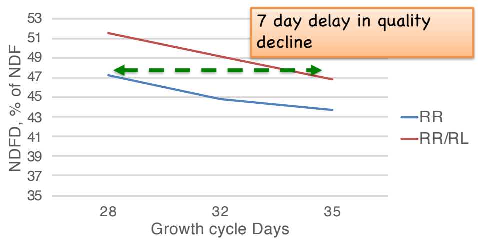
HiGest™ Alforex
HarvXtra™ Forage Genetics International



Why does fiber digestibility vary? 2: Genetics

Variety	Lignin Reduction	Unit reduction (assuming 7% lignin)
HiGest™ (Alforex)	7 to 10%	0.49 to 0.7
HarvXtra™ (FGI)	10 to 15%	0.7 to 1.05

Effect of harvest delay on NDFD, average of 4 cuttings (HarvExtra Alfalfa)



Undersander, 2015

Effect of Low Lignin Trait on Alfalfa ADF and NDF Digestion

Item	Harvest interval	Roundup Ready	Roundup Ready + Low Lignin*	P Value Forage	Harvest interval	
ADF	28d	26.6	26.5	NS	NS	
	33d	27.2	26.6			
	35d	27.8	26.5			
TTNDFD	28d	52.1	56.3	0.05	0.01	+ 8%
	33d	46.3	51.9			+12%
	35d	46.8	51.1			+ 9%

* HARVXTRA® Forage Genetics International
Li, Li, Undersander and Combs, 2015, ADSA abstract

Nutrient composition of corn silage stalk hybrids

Item	BMR	CONS	HFD	LFY	SEM	P-value
DM, % as fed	33.7	34.5	35.1	33.2	0.9	0.45
CP, %DM	8.0	7.8	8.1	8.0	0.2	0.20
NDF, %DM	42.3	42.6	45.0	42.3	0.8	0.09
Lignin, %DM	2.0^{b}	2.8^{a}	2.9^{a}	2.6^{a}	0.2	0.001
Starch, %DM	28.7^{ab}	30.1^{a}	26.7^{b}	30.0^{ab}	1.1	0.02

Ferraretto and Shaver, 2013

DMI & Milk Yield greater in BMR/HFD

Item	BMR	CONS	HFD	LFY	SEM	P-value
DMI, kg/d	25.1^{a}	24.0^{b}	24.6^{a}	23.0^{b}	0.5	0.001
Milk, kg/d	38.6^{a}	37.2^{b}	38.1^{a}	37.4^{b}	0.8	0.001
Fat, %	3.55	3.62	3.61	3.64	0.08	0.25
kg milk/kg DMI	1.52	1.54	1.55	1.55	0.03	0.61

Why does fiber digestibility vary? 4: Harvest management

- ✓Moisture (leaf shatter)
- ✓Rain damage
- ✓Respiration losses due to slow dry-down

Fiber in leaves is higher in digestibility than fiber in stems

Using forage analysis to assess quality

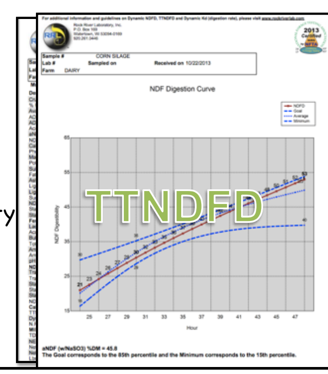
Reading Forage Analyses

✓ Dave's Quick List:

1. NDF and Starch
2. Protein
3. Ash Content

✓ Evaluate Digestibility

- ✓ TTNDFD
- ✓ StarchD



TOPIC # 2: Assessing fiber digestion

Poor digestion < 40%

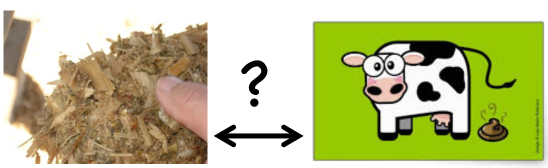
Excellent digestion > 50%

A 2-3 unit change in fiber digestibility corresponds to 1 lb change in milk yield.

Forage Quality Indicators for High-Producing Dairy Herds

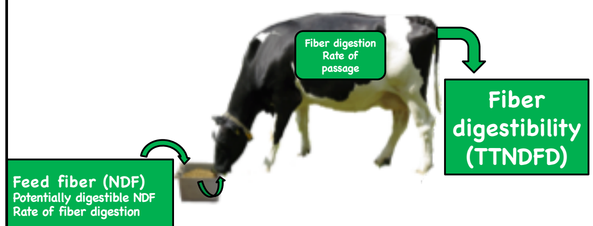
Parameter	Indicates Better Quality	Primary Reason
NDF	↓	↓ Rumen Fill Limitation of DMI Potential for production response or feeding of higher-forage diets
Lignin	↓	
$uNDF_{240}$	↓	
$NDFD_{30}$	↑	
TTNDFD	↑	
NFC	↑	↑ Energy Density Potential for production response or feeding less corn grain
CP	↑	↓ Supplemental Protein
Ash	Minimal Soil Contamination	↑ Energy Density
RFV; RFQ	↑	Quality Index for Ranking

How Can We Equate Feed Fiber Measurements to Animal Utilization of NDF



The Process of fiber digestion is described with the TTNDFD assay

Feed and cow factors both affect fiber digestion



Fiber digestion is affected by:

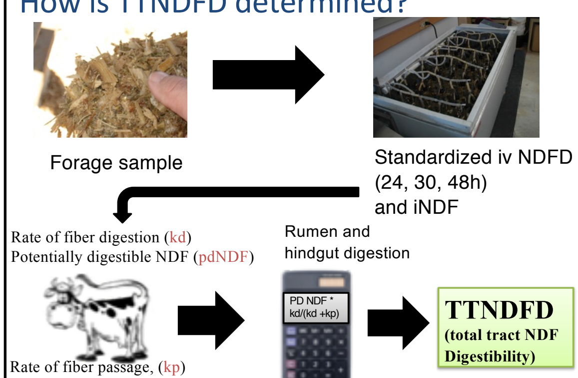
Feed characteristics

- ✓ The amount of fiber (NDF)
- ✓ Potentially digestible fiber (pdNDF)
  (pdNDF = NDF-$uNDF_{240}$)
- ✓ Rate of fiber digestion (kd)

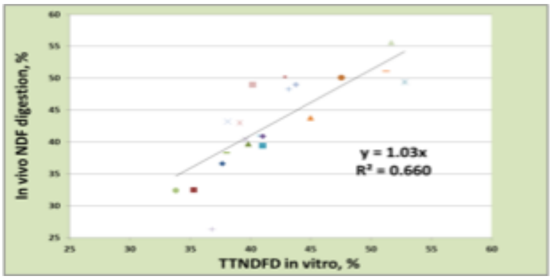
Animal and diet

- ✓ Intake affects rate of fiber passage (kp)
- ✓ Approx. 90% of NDF digestion is in rumen

How is TTNDFD determined?



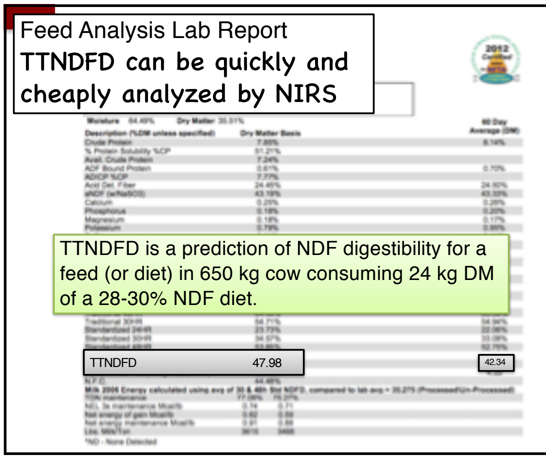
TTNDFD combines *in vitro* rate of NDF digestion with *iNDF* to improve the prediction of *in vivo* fiber digestion

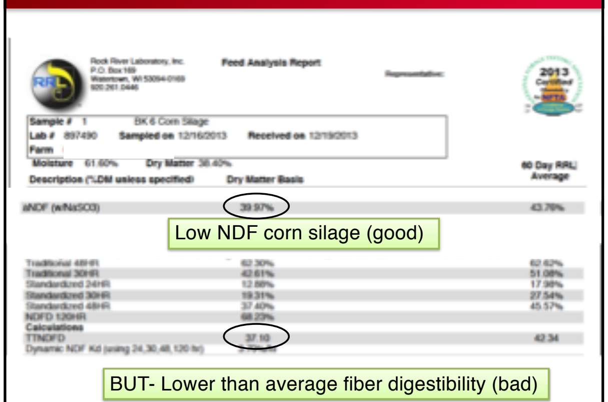


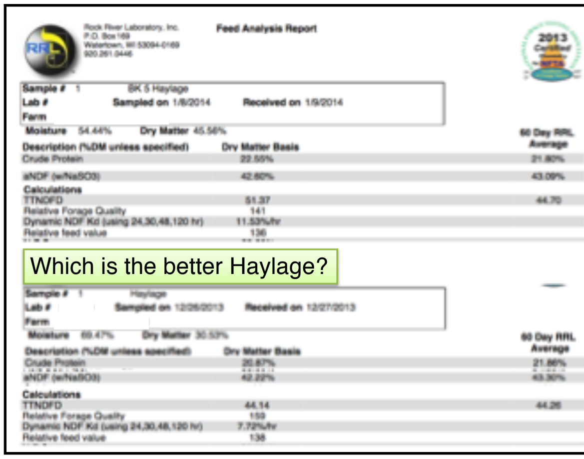
Lopes et. al. 2015 JDS

Feed Analysis Lab Report

TTNDFD can be quickly and cheaply analyzed by NIRS







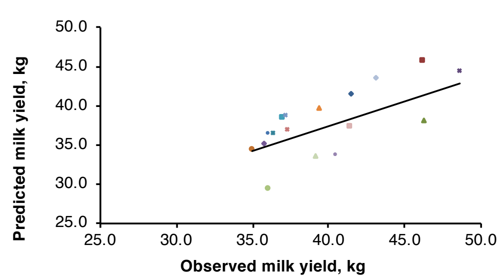
Typical NDF and TTNDFD values

	NDF	Average TTNDFD	High TTNDFD	Low TTNDFD
Alfalfa	< 40%	42%	> 48%	< 36%
Corn Silage	< 40%	42%	> 48%	< 36%
Grasses	< 45%	42%	> 48%	< 36%

Dairy quality alfalfa and corn silages will be < 40% NDF with a TTNDFD value of at least 42%

A 2-3 unit change in ration TTNDFD corresponds to a one pound change in milk yield.

Milk predictions from a model based on NRC equations and TTNDFD as the coefficient for NDF digestibility



The Take Home Message

1. Fiber digestibility has a big impact on milk yield.

   A 2-3 unit change in ration TTNDFD corresponds to a one pound change in milk yield.

2. The TTNDFD test was developed to predict fiber digestibility in high producing dairy cattle

   Can be used across forage types and byproduct feeds
   Can be used in ration balancing and evaluation

Thank You!

Visit our Web sites:
http://dysci.wisc.edu/
http://fyi.uwex.edu/forage/

Transition cow management: calcium health and diagnostics

Jessica A. A. McArt, DVM, PhD
Department of Population Medicine and Diagnostic Sciences, College of Veterinary Medicine
Cornell University, Ithaca, NY 14853

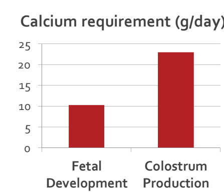
Cornell Dairy Center of Excellence

Overview

- Background of hypocalcemia
- Classification of subclinical hypocalcemia – is it abnormal?
- Measurement methods
- Current testing recommendations

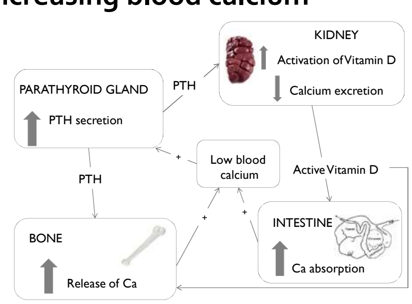
Large demand for calcium

- Sudden increase in requirements
  - Need ~24 g for colostrum
  - Only 2-4 g in plasma pool
- Adaptation requires coordination of several hormones and tissues
- Daily calcium requirement for 100 lbs milk = 50 g



Courtesy: Brittany Leno

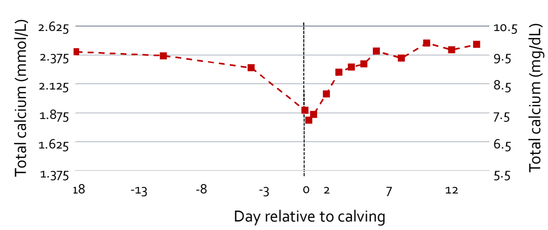
Increasing blood calcium



Goff et al., 2008

Courtesy: Brittany Leno

Periparturient change in blood calcium

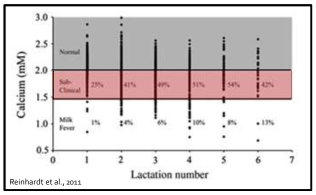


Sweeney et al., 2015. J. Dairy Sci 98 (Suppl. 2):128

Courtesy: Brittany Leno

Today's hypocalcemia

- Clinical disease has been well addressed, focus now on subclinical disease



Reinhardt et al., 2011

- Milk fever incidence <5% on dairies
- Subclinical hypocalcemia (SCH) incidence up to 50%

Classification of SCH at calving

J. Dairy Sci. 101:547–555
https://doi.org/10.3168/jds.2017-13313

Association of immediate postpartum plasma calcium concentration with early-lactation clinical diseases, culling, reproduction, and milk production in Holstein cows

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*Department of Population Medicine and Diagnostic Sciences, College of Veterinary Medicine, and
†Department of Animal Science, Cornell University, Ithaca, NY 14853
‡Dairy Health and Management Services LLC, Lowville, NY 13367

- *Objective*: to determine the association of plasma total calcium (tCa) collected soon after parturition with:
  - Health outcomes (RP, metritis, DA, clinical mastitis)
  - Culling risk within 60 DIM
  - Pregnancy risk to 1st service
  - Milk production across the first 9 DHIA tests

Neves et al.: materials and methods

- Prospective cohort study in 5 dairy herds in NY
  - Part of a large randomized clinical trial
  - Control cows only

- Enrolled cows that calved between February-November, 2015

	Farm				
	A	B	C	D	E
Milking cows, n	1,474	567	1,282	1,677	1,222
Milk production, kg	38.4	38.9	37.0	37.3	36.8
Prepartum DCAD, mEq/100 g DM	-6.9	-2.8	-5.5	7.3/14.1	-2.8

Neves et al.: results

- n = 1,416 included in the final analysis
  - Primiparous, n = 350
  - Multiparous, n = 1,066
- Mean time from calving to blood collection = 3 h

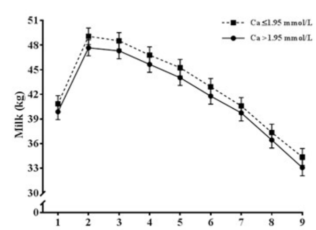
	Primiparous	Multiparous
Retained placenta	6.0%	9.2%
Metritis	13.0%	8.9%
Displaced abomasum	0.3%	3.7%
Clinical mastitis	4.6%	10.0%
Culling	2.6%	4.9%
Pregnancy to 1st service	44.5%	37.3%

Neves et al.: results

- Primiparous cows: tCa at calving meant nothing!
- Multiparous cows:
  - tCa **not** associated with: risk of RP, metritis, clinical mastitis, or pregnancy to 1st service
  - tCa ≤1.85 mmol/L:
    - More likely to develop a DA
    - RR = 2.8 (95% CI = 1.35 to 5.85; $P = 0.006$)
  - Higher Ca associated with increased culling risk
    - Every 0.1 mmol/L increase, RR = 3.4 (95% CI = 0.95 to 12.0; $P = 0.06$)

Neves et al.: results

- Multiparous cows with tCa ≤1.95 mmol/L:
  - Made more milk: 42.9 vs. 41.8 kg per test-day, $P < 0.001$



Neves et al.: conclusions

- Caution in classifying SCH based on a single time-point collected within 12 h of calving
- Are our cut-points for SCH too high?
- Is it the duration of SCH, not the value that is important?

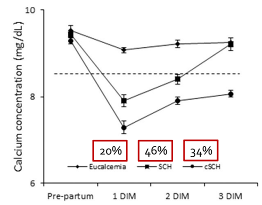
Chronic subclinical hypocalcemia (cSCH)

Theriogenology. 2017 May;94:1-7. doi: 10.1016/j.theriogenology.2017.01.039. Epub 2017 Jan 25.

Association between subclinical hypocalcemia in the first 3 days of lactation and reproductive performance of dairy cows.

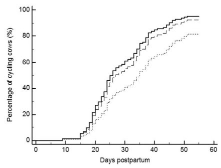
Caixeta LS[1], Ospina PA[1], Capel MB[2], Nydam DV[3].

- 2 dairy farms, 97 cows
- Definitions:
  - SCH = serum tCa ≤2.15 mmol/L (8.6 mg/dL)
  - cSCH = SCH at 1, 2, and 3 DIM
- Incidence cSCH:
  - Parity 1 = 20%
  - Parity 2 = 32%
  - Parity ≥3 = 46%



Caixeta et al.: chronic SCH on reproduction

- Return to cyclicity:
  - Eucalcemic cows were more likely to return to cyclicity by end of VWP than cSCH cows
  - HR = 1.8 (*P* = 0.06)



- Pregnancy at first service:
  - cSCH cows had lower odds of pregnancy compared to eucalcemic cows
  - OR = 0.27 (*P* = 0.04)

Is subclinical hypocalcemia bad?

- When to test?
  - Not at calving
  - Need more longitudinal studies with lots of cows
- What cut-point to use?
  - Large, epidemiological studies to define "normal"
  - Based on health and production outcomes
- How do we test cows?

Determining Calcium Status

Cold ears?

J. Dairy Sci. 99:6542–6549
http://dx.doi.org/10.3168/jds.2015-10734
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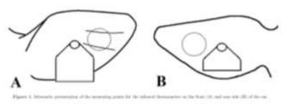
Evaluation of ear skin temperature as a cow-side test to predict postpartum calcium status in dairy cows

P. L. Venjakob,*† S. Borchardt,* G. Thiele,† and W. Heuwieser*[1]
*Clinic for Animal Reproduction, Faculty of Veterinary Medicine, Freie Universität Berlin, Koenigsweg 65, 14163 Berlin, Germany
†Veterinary practice G. Thiele, Baruth, Germany

- 7 herds
- 251 cows, 0-48 hr postpartum

- Manual scoring
- Rectal temperature
- Infrared thermometer
- Blood calcium



- Hypocalcemia defined as blood calcium < 2.0 mmol/L

Calcium threshold, mmol/L	Prevalence, %	Temperature variable[1]	Threshold, °C	Sensitivity	Specificity	AUC[2]	P-value
2.0	29.6	STEar	27.0	49.3	73.8	0.641	0.001
		STCox	30.0	52.2	78.7	0.668	0.001
		RT	39.0	75.4	42.7	0.606	0.009

- Decrease in ear temp of 0.39°C associated with decrease of 0.1 mmol/L in calcium
- Ambient temp was a major confounder
- Conclusions: ear temperature cannot be recommended for diagnosis of subclinical hypocalcemia

Direct measurement of calcium

- Calcium is differentiated into 3 forms in blood:
  - Free or ionized (50-60%)
  - Bound to proteins (30%)
  - Complexed (10%)
- 2 options:
  - Total calcium (tCa)
  - Ionized calcium (iCa)

Total calcium

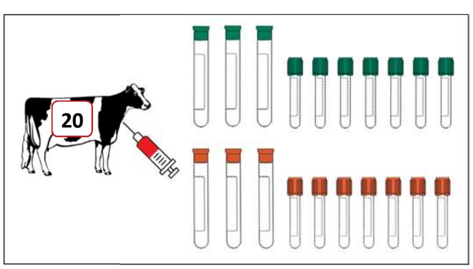
- Collect in green or red top tubes
- Fairly stable
- Methods of analysis:
  - Benchtop analyzer in laboratory @ $5-15/sample
  - Analyzer in vet clinic @ $5-7.50/sample

Stability of total calcium measurement: best practices for bovine practitioners

AABP-L: *I'm working with a dairy client on some transition cow issues and we'd like to do some hypocalcemia screening of fresh cows. This dairy has herd check every two weeks and is an hour away. They are taking blood after first milking and storing red top tubes in fridge until next herd check. Thus when I collect them, the samples will be 1-14 days old. The dairy does not have a centrifuge. How should the red tops be stored--fridge or freezer or other?*

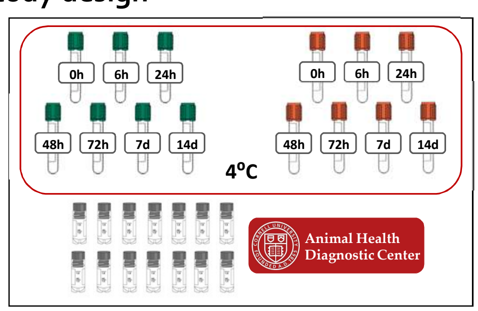
Responses (paraphrased):
- Use serum separator tubes, let them clot in a refrigerator for few hours, the wax plug will separate the serum from red cells. These tubes should be stable for some time in the fridge.
- The best solution is to collect in a red top tube and turn the red top tube upside down in the fridge for at least 8 hours. Set them upside down at a slight angle in the fridge so the clot forms in the depression of the red rubber top. Once the clot is completely formed, hold the tube so the rubber top can be removed gently, and pull the entire clot out while keeping the serum in the tube. Serum may be frozen or kept in a fridge if it will be picked up in a few days.
- In my opinion, there isn't a huge effect by age of sample on Ca assay. Store the samples in the fridge upside down, and after a couple of days, gently turn the vials upright and pull the stopper. The clot should stick to the stopper and can be discarded. Re-stopper the sample.

Study design



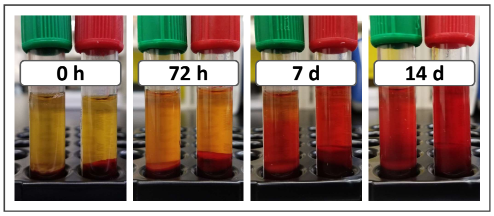
Courtesy: Kathryn Bach

Study design



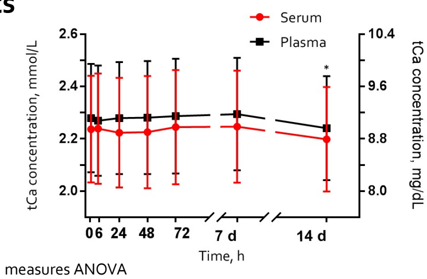
Courtesy: Kathryn Bach

Results



Courtesy: Kathryn Bach

Results



- n = 13
- Repeated measures ANOVA
  - Time, P <0.001
  - * = different from Time 0, P < 0.05
  - Sample type, P = 0.64

Ionized calcium

- iCa thought to have greater biological relevance than tCa
- Ion-selective electrode technology is largely employed for clinical use (blood-gas analyzers)
- Measurement of iCa is expensive, special handling procedures
  - Heparin salts bind calcium
  - Use of electrolyte-balanced syringes
  - Exposure to air changes blood pH

Ionized calcium – methods of analysis

- Cowside = not practical
- Machines targeted for on-farm use:
  - iSTAT, VetScan, Nova Stat
  - $5,000-$15,000 + sample costs
- Fast, accurate, and inexpensive tools that measure iCa are currently non-existant
- Why not just measure tCa?
  - Relationship between tCa and iCa varies following parturition (Leno et al., 2017)

Optimization of commercial meter

Dr. Rafael Neves

- Software changes: units and resolution
- Modification of calibration set-points
- Temperature sensor adjustments

Final prototype

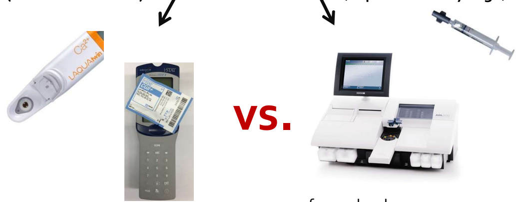
- 2 calibration solutions: 1.25 mmol/L, 5.0 mmol/L
- 15 sec sample contact time
- 0.7 mL blood

On-farm vs. in-lab comparison

Blood collected into a plain vacutainer tube

Results obtained on-farm (fresh whole blood)

Results obtained in the lab (hep-balanced syringe)



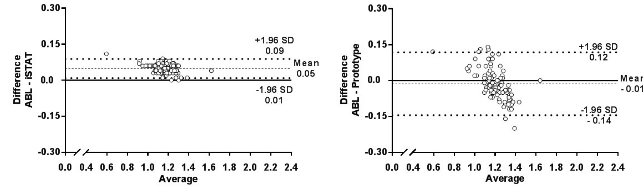
101 cows from 3 herds

Courtesy: Rafael Neves

On-farm vs. in-lab comparison

i-STAT

Prototype



Bland-Altman plots

Courtesy: Rafael Neves

On-farm vs. in-lab comparison

Method	SCH cut-point (mmol/L)					
	≤0.95		≤1.00		≤1.05	
	Se (%)	Sp (%)	Se (%)	Sp (%)	Se (%)	Sp (%)
Prototype	100	98	100	96	100	97
i-STAT	100	97	100	97	100	93.5

- SCH based on the heparinized-balanced syringe sample analyzed in the ABL-800 FLEX
- Wide Se confidence intervals - few low iCa samples

Precision

- Coefficient of variation: 10 consecutive measurements
- Below, within, and above normal iCa range

iCa concentration	Coefficient of variation
0.72 mmol/L	3.9%
1.29 mmol/L	2.1%
2.0 mmol/L	1.0%

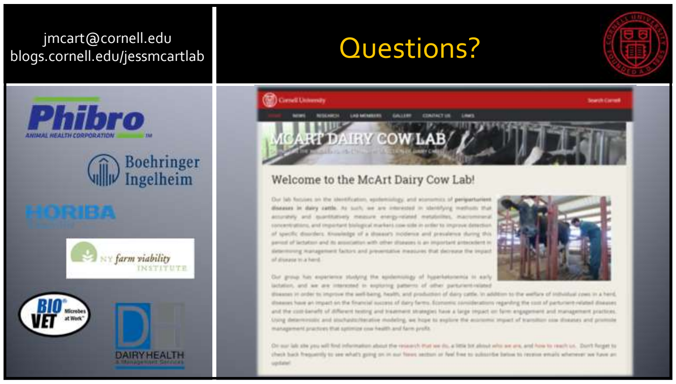
On-farm Horiba iCa meter?

- Not a good quantitative meter: mmol/L
- Solid qualitative meter: yes/no
- Future:
  - Release date by Horiba unknown
  - Develop quality-control check
  - Need to streamline on-farm use

Dr. Rafael Neves & Dr. Kathryn Bach

Current testing recommendations

- Wouldn't it be great if I could tell you this …
- We need better on-farm measurement tools
  - Who
  - When
  - What
- Improve monitoring of our preventative methods
- Improve and target treatment methods


jmcart@cornell.edu
blogs.cornell.edu/jessmcartlab
Questions?
Phibro
Boehringer Ingelheim
HORIBA
NY farm viability INSTITUTE
BIO VET
DAIRY HEALTH
MCART DAIRY COW LAB
Welcome to the McArt Dairy Cow Lab!

Why Robotics?

COTY GOODWIN

About me

- 5th generation dairy farmer
  - Grandview Farm, Gordonsville, VA
- 2015 Virginia Tech graduate
  - CSES & Agronomy
- Recently married

About Grandview

- Milk over 100 cows mixed herd
  - Jerseys, Holsteins, Crossbreeds
- Compost bedded pack, retrofitted two Lely A4s
  - Automatic calf feeder
- Family owned & operated

Why robots?

- Milking in a stanchion barn prior to robots
  - Labor, time, production
- People management vs. equipment management
- All that data without DHIA

But do they work?

- With the right cows & right management robots are better than a traditional parlor
- Cell count, cleanliness
  - Make highest premium, visually not as clean
  - Learning curve on identifying robot sanitation issues

All that DATA!!

- Learning what to look at
- How to look at it
- When to look at it
- What to do when you identify a problem?

DATA continued

- Training
  - Courses offered through Lely
- Technicians
  - Lely invested in their product and customers
- Trends
  - Cow problems vs. herd problems

What's not good?

- Cold Weather!!!!
  - Everything can and will freeze
- T4C not user friendly
  - Reports limited, creating reports
- Limited research on robots
  - Canada

Opportunities to Increase Success

- Increase profits with better feeding system
- Homegrown feeds in robot/less feed
  - Roasted beans, HMSC, fabba beans, field peas

Opportunities Continued…

- Rumen health
  - Protocols for low rumination (off feed cows)
- More cows/more milk per stall
  - Attachment time
  - Milk speed
  - Milkings per cow

Do over?

- Changes
  - Barn, drainage, retro-fit stanchions, platforms, heating
- Timing?
- Planned growth of herd better

Conclusion

- Best decision we've ever made
  - Time spent wisely
- Better quality of life
  - Freedom from milk schedule, flexibility with chores
- More aligned with consumers' views


Questions?