The Future Is Here: Nucleotides, MOS, and β-Glucans in Ruminants

Melina Bonato

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The dairy production goal is to have healthy animals that can achieve the maximum genetic potential production with less cost and greater efficiency. Animal health is related to diseases caused by pathogenic agents, metabolic/nutritional/reproductive/physical problems, and stress factors (environmental conditions, handling, etc.). When talking about ruminants, in addition to thinking about the improvement of animal nutrition, we must think about rumen nutrition and health, considering that well-nourished, healthy, and properly stimulated rumen flora provide better productivity rates that are associated with better animal health. In this context, the use of functional ingredients that provide gains in performance and improvement in animal health tend to become required items in the diet of dairy cattle.

Yeast has been widely used in ruminants' nutrition as a functional feed additive, and there is extensive literature proving its benefits. Hilyses® (ICC Brazil Company) is pure *Saccharomyces cerevisiae* yeast originating from the sugarcane fermentation process for ethanol production. It undergoes autolysis (cell membrane disruption) where the intracellular content is released, and after this process, some specific enzymes are inserted for hydrolysis ("disruption") of the RNA chain into nucleotides and nucleosides (which form the nitrogenous basis of the RNA/DNA structure). This final product is highly digestible because it also contains amino acids, short chain peptides and polypeptides, glutamine, and the yeast cell wall, which is mainly composed of mannan oligosaccharides (MOS) and high levels of β-glucans.

The β-glucans are known as immune system modulators or stimulants. They are natural and effective stimulants of the innate immune system, and when they come in contact with the phagocytic cells, which recognize the β-1,3 and 1,6 bindings (Petravić-Tominac et al., 2010), these cells are stimulated and will produce cytokines that start a chain reaction inducing an immunomodulation and improving the response capacity of the innate immune system. Another benefit of using β-glucans is the binding capacity of mycotoxins by hydrogen bonds and by van der Waals bonds. These modes of action guarantee a wide range of adsorption on different mycotoxins because most of the adsorbents present in the world market are based on aluminosilicates, which are highly efficient in the adsorption of polar mycotoxins (such as aflatoxin) but can also bind to vitamins and minerals of the diet.

As mentioned above, MOS are also structural components of the yeast cell wall, and they are known for their pathogen (that has type 1 fimbria) agglutination capacity, such as diverse *Salmonella* and *Escherichia coli* strains. MOS offer a binding site for pathogens, preventing the colonization of the intestinal epithelium, and these agglutinated bacteria will be excreted together with the indigestible part of the fiber.

Thus yeast cell wall supplementation with high concentrations of MOS and β-glucans can be associated with the decrease of contamination by some pathogens and immune system modulation. This type of response is especially important in animals in initial growth and reproductive phases, stress periods, and environmental challenges. It even improves response to immunosuppressive diseases, acting as a prophylactic agent and increasing animal resistance while minimizing further damage (such as a drop in performance or high mortality rates).

The nucleotides and nucleosides present in Hilyses® can be readily absorbed by the enterocytes in the gut and are especially important in tissues of rapid cell proliferation and limited capacity of de novo pathway (major route of metabolism nucleotides production), as with intestinal epithelial cells, blood cells, hepatocytes, and cells of the immune system. So they can be used by the salvage pathway, where the body can synthesize nucleotides with less energy and nutrient consumption, because it will recycle the bases and nucleotides of metabolic degradation of nucleic acids in dead cells or from the diet. However, when the endogenous supply is insufficient, exogenous nucleotide sources become semi-essential or "conditionally essential" nutrients (Carver and Walker, 1995). This is especially important for animals during growth phases (early stages), reproduction, and stress and challenge periods.

Beyond intestinal health, which will reflect general animal health, the rumen flora must be considered as a complex factor in all dairy cow responses. Modulating and supporting the rumen flora to speed up the digestion of cellulose and hemicellulose, stabilizing the rumen pH under conditions of feed or caloric stress, and increasing the production of volatile fatty acids are the benefits expected with Hilyses® supplementation.

In the current context of the international dairy market, increasing milk production in terms of quantity is sometimes irrelevant due to low prices. Now more than ever, producing more milk fat and protein is a proven way to enhance herd profitability. The best way to boost milk fat and protein is to promote rumen fermentation with a particular focus on fiber digestion.

It is important to note that fat found in the milk originates from three sources: de novo fatty acids synthetized in the milk gland of the cow (short chain C4 to C14) that comprise about 20 to 30% of total milk fatty acids, preformed fatty acids (long chain C18:0, C18:1, and C18:3), which represent 35 to 40%, and the mixed group of fatty acids (C16) that makes up about 35%. The literature has shown that the percentage of de novo fatty acids in milk is positively correlated with the percentage of fat and true protein in the milk. It has also been indicated that these short chain fatty acids explain nearly 50% of the variation in milk fat percentage and as much as 68% of the variation in milk true protein. De novo fatty acids are crucial and can be used to monitor herd management. Indeed, milk fat and protein are two key drivers of dairy profitability positively related to net milk income over feed costs. The quantity of de novo fatty acids reflects rumen functioning, especially fiber fermentation, which produces acetate and butyrate, the building blocks of fatty acids. The relative proportion of de novo fatty acids in milk fat reflects how well the cow is being fed and managed for optimal rumen fermentation. Higher de novo fatty acids in the milk reflect healthier rumen conditions (Blezinger and Bonato, 2017).

The intrinsic digestibility of the forage fiber is a function of plant genetics, maturity at harvest, and growing environment, which determines the amount of lignin. Rumen pH has a large impact on fiber fermentation. Thus, poor feeding management can influence rumen pH and subsequent fiber digestion and microbial protein production. Furthermore, recent research has shown that feeding or management practices reducing pH result in accumulation of the CLA isomer that has a powerful milk fat depressing effect. Some management practices can enhance rumen conditions, such as avoiding overstocked pens, feeding more frequently, balancing the diet properly with fat and fiber requirements (and proper levels of physically effective NDF), and using feed additives/components to support rumen fermentation.

Several studies have shown that Hilyses® can increase milk production by 2 kg/cow per day, improve milk quality (fat and protein), decrease SCC and the incidence of disease, and also reduce mycotoxin contamination in the milk. The combination of proper rumen nutrition with the strengthening of the animals' immune systems means higher daily milk production, while also reducing to zero the concerns about any residues in the milk, a key factor to conquer an increasingly demanding consumer market.

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Blezinger, S. B., and M. A. Bonato. 2017. Optimising milk fat strengthens dairy profits. All About Feed, June 7. http://www.allaboutfeed.net/Feed-Additives/Partner/2017/6/Optimising-milk-fat-strengthens-dairy-profits-139561E/.

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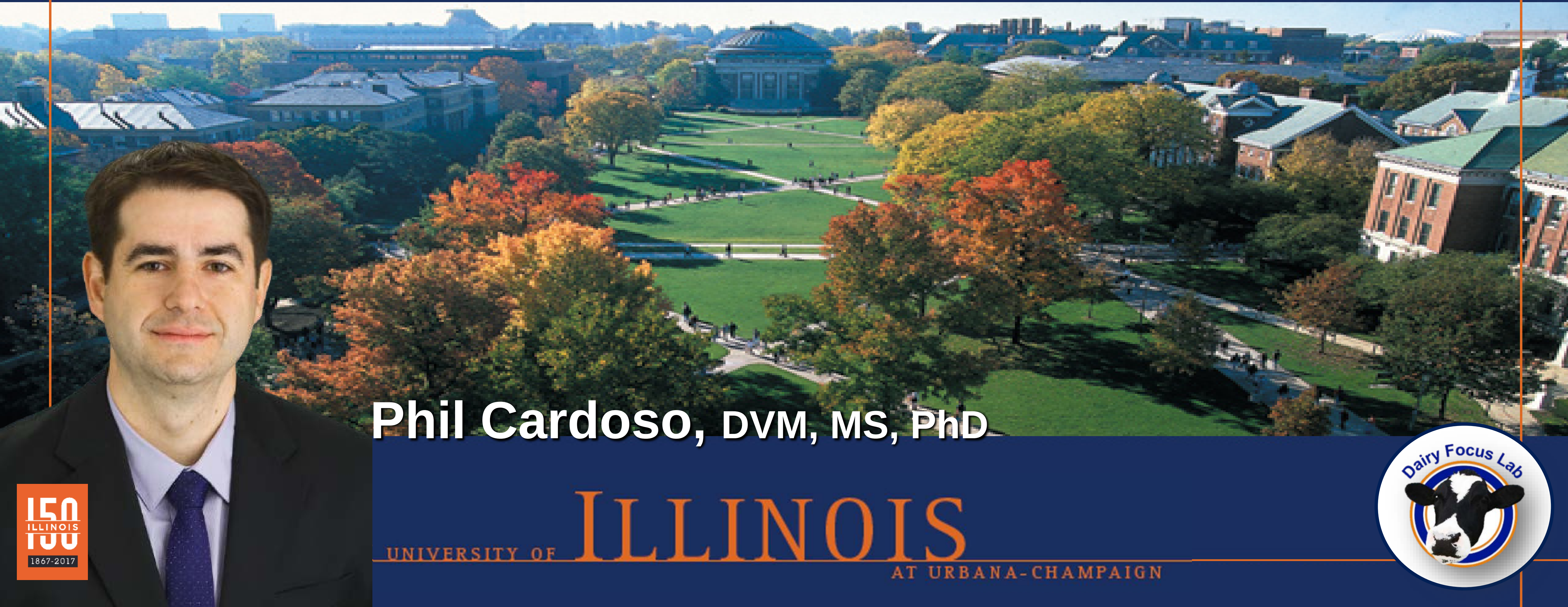
Applied Research into Amino Acid Nutrition



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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

ILLINOIS 150 1867-2017

Dairy Focus Lab

So, What do we want from this cow?


We should feed and manage dry and transition cows to:
1. minimize health disorders,
2. maximize production and reproduction
$$$
University of Illinois at Urbana-Champaign

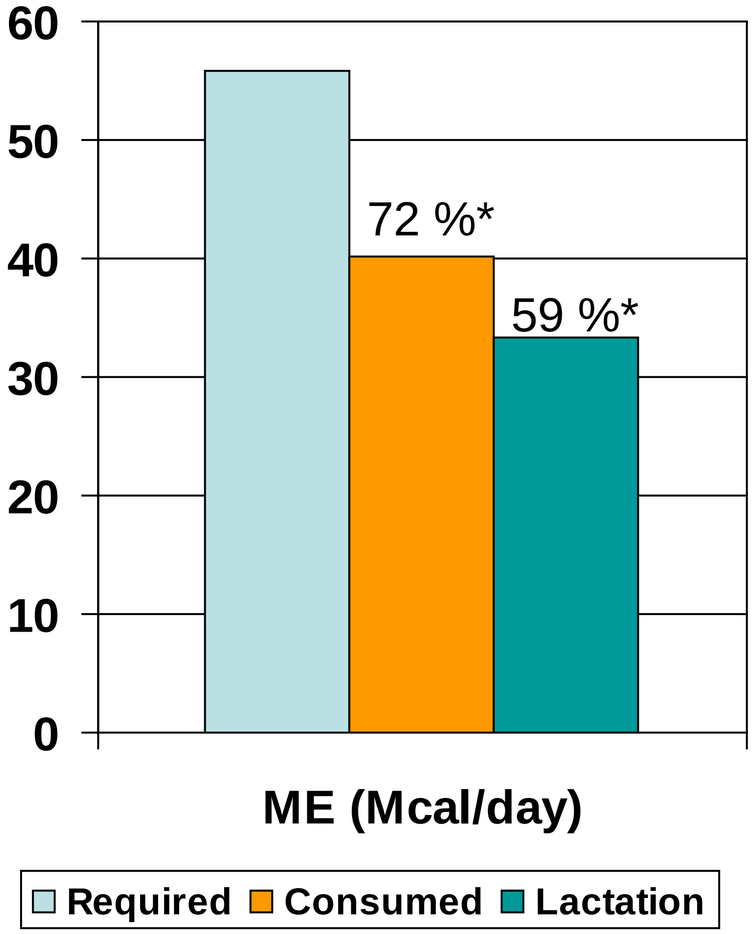
Net energy (NE_L) requirements 2 days before and 2 days after calving

Units	725-kg Cow		570-kg Heifer	
	Pre	Post	Pre	Post
Total (Mcal/d)	14.5	28.8	14.0	25.1
Typical intake	**14-17**	**19-21**		

Calculated from NRC (2001). Assumes milk production of 25 kg/d for cow and 20 kg/d for heifer, each containing 4% fat.

Courtesy of J.K. Drackley

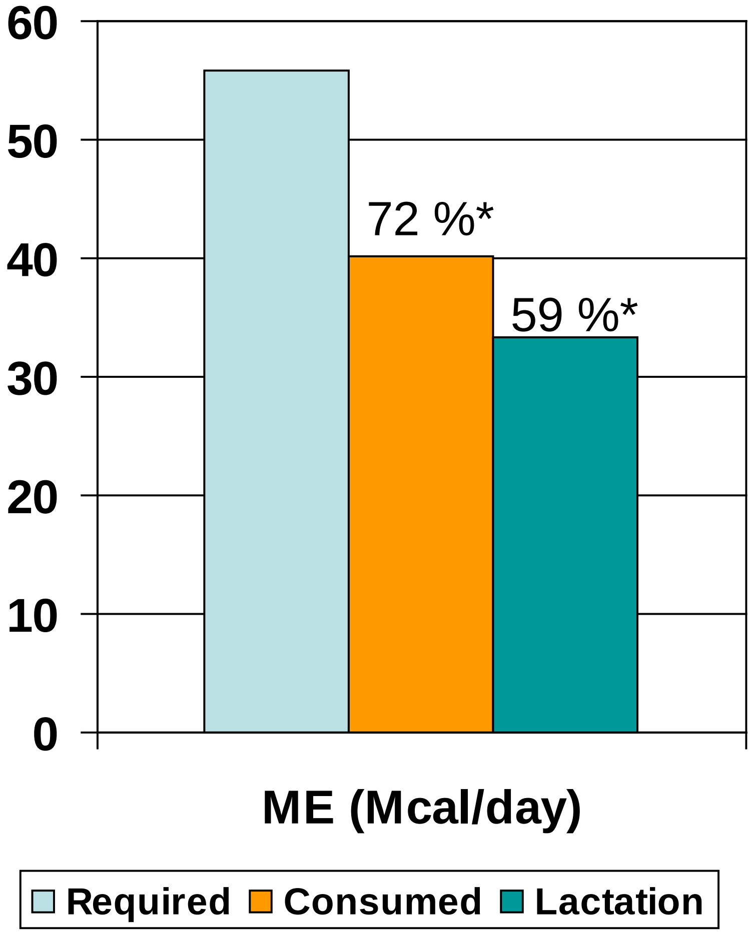
Metabolizable Energy (*ME*; Mcal/day) required and consumed at 7 days in milk

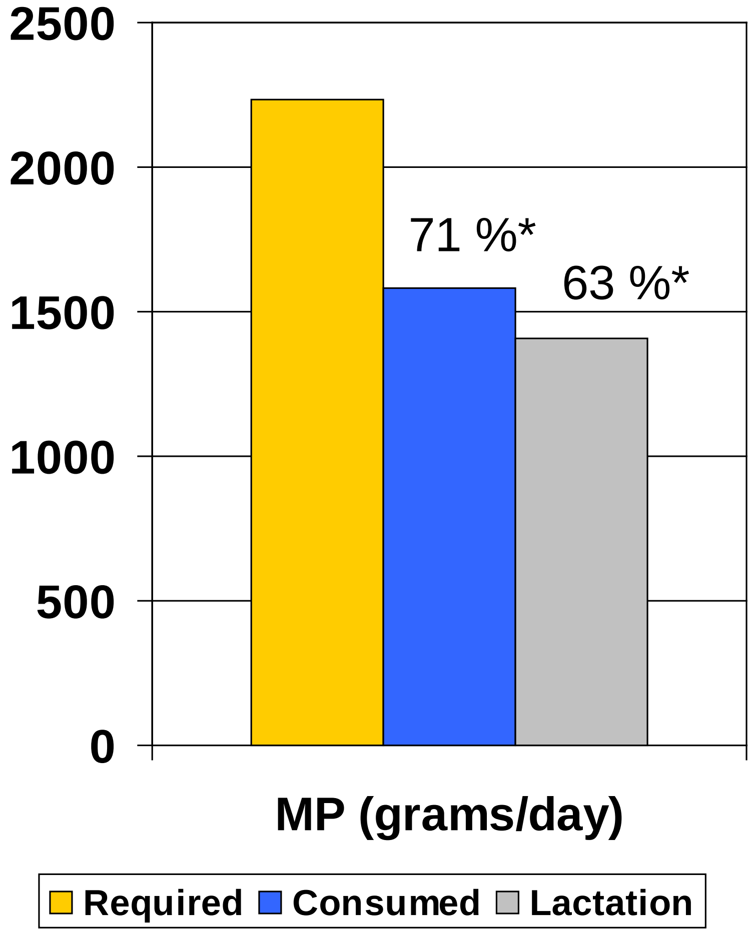


From CNCPS V6 – Assumes BW 700 kg, 15.5 kg DMI, 30 kg milk 3.8% fat, 3.2% prot.; * Percent of required; ** Percent of consumed

Adapted from J.K. Drackley

ME and metabolizable protein (MP; g/d) required and consumed at 7 days in milk





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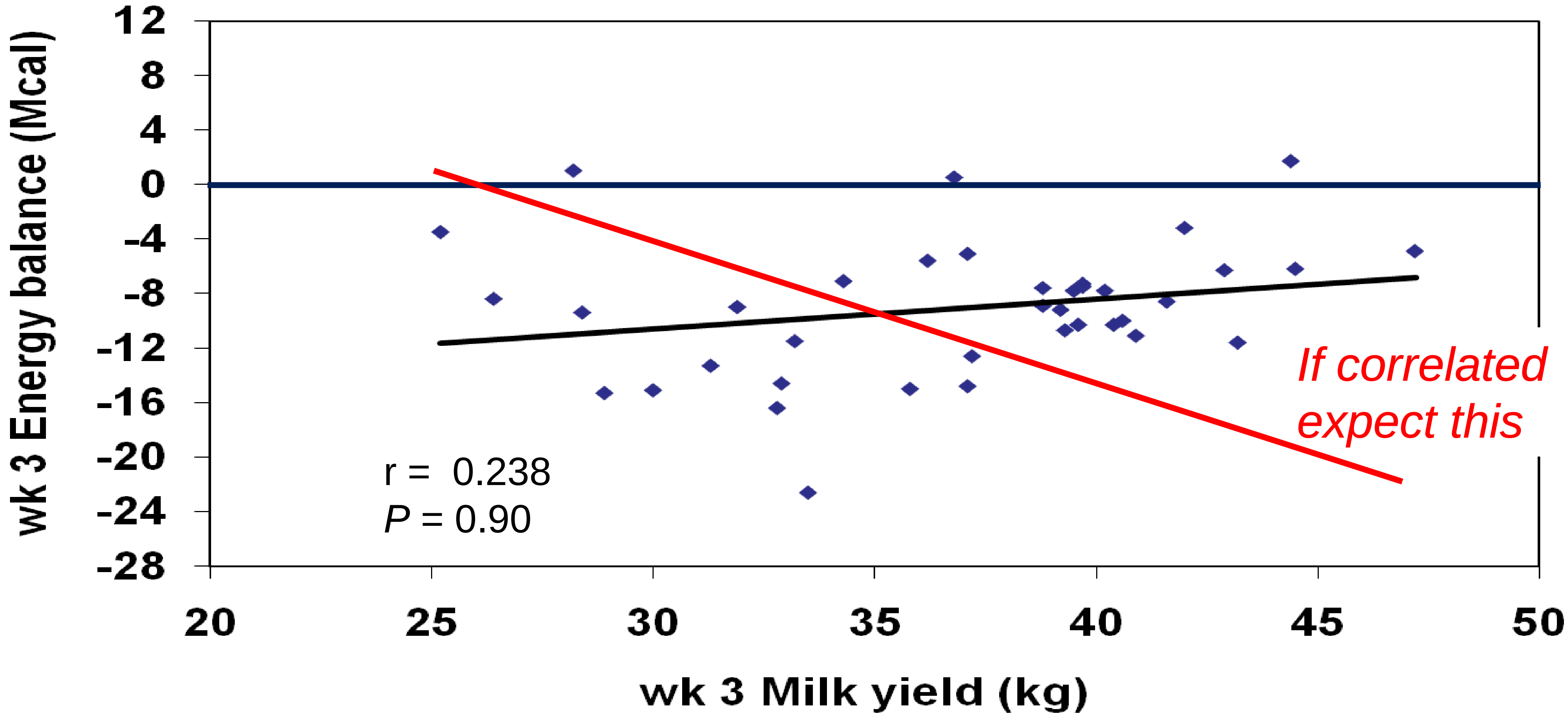
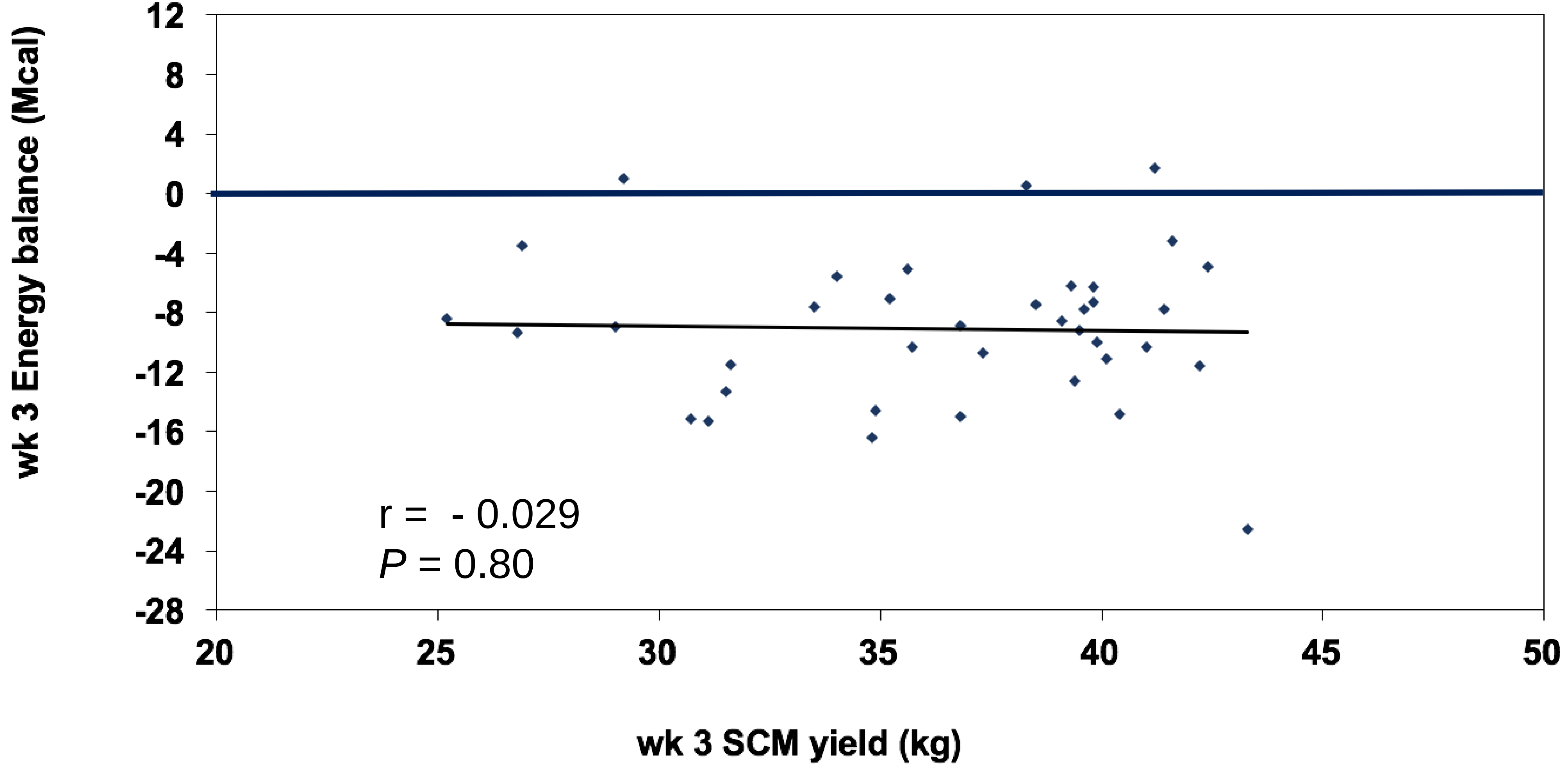
What drives negative energy balance?

Post-calving energy balance is not correlated with milk yield



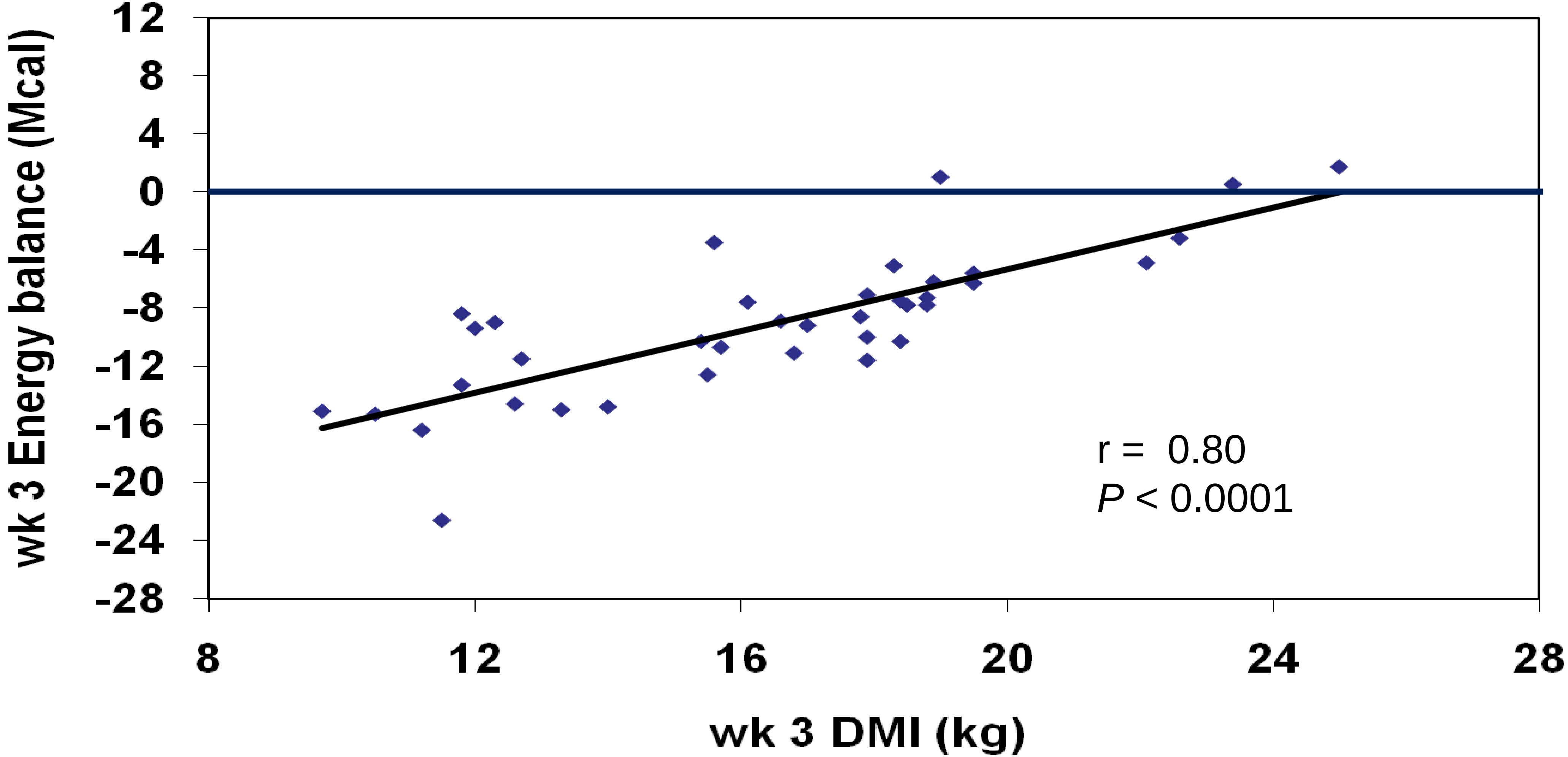
Drackley, 2006

Post-calving energy balance is not correlated with solids-corrected milk (SCM)



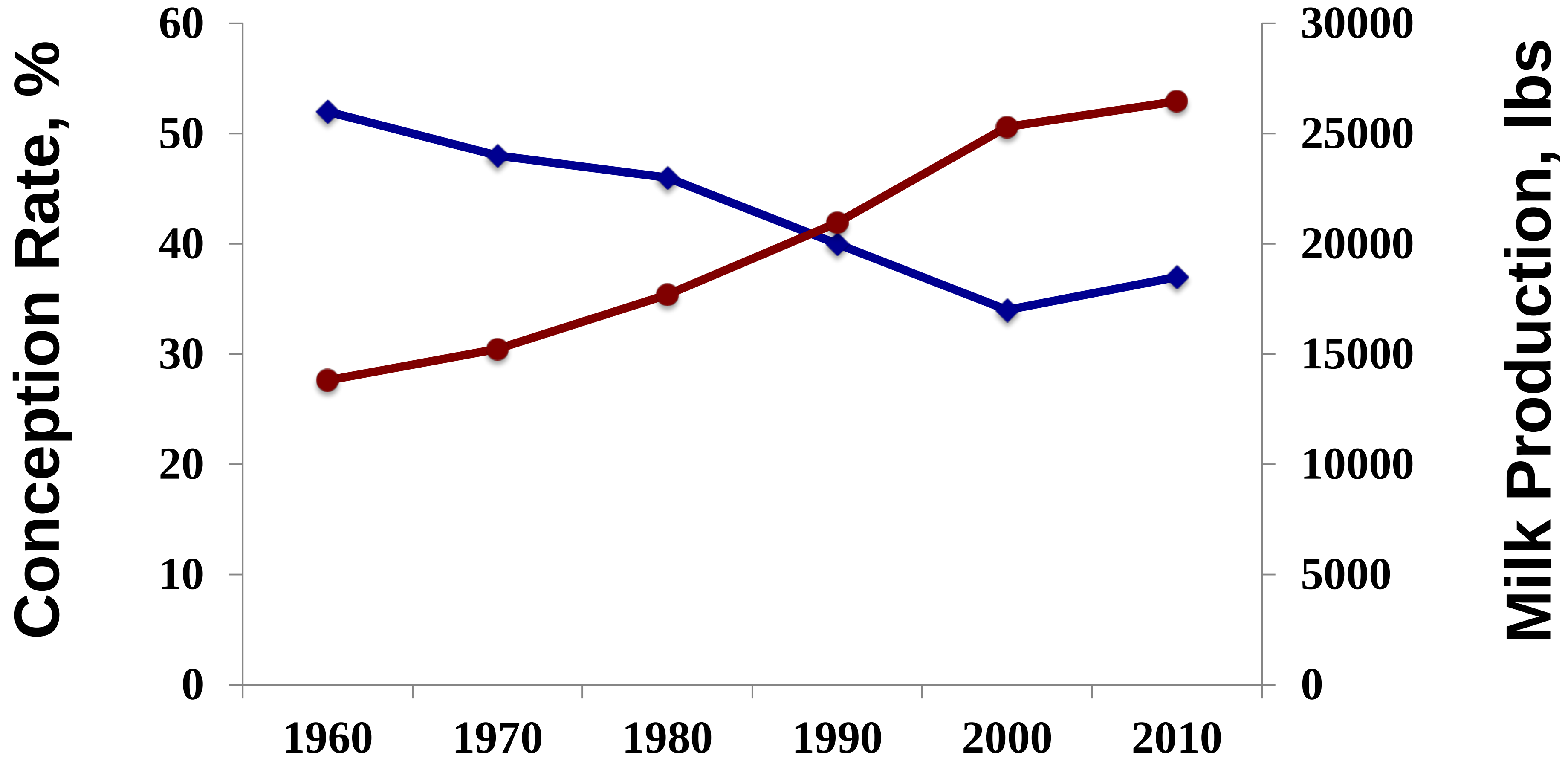
Drackley, 2006

Post-calving energy balance is highly correlated with DMI



Drackley, 2006

Evolution of Milk Production and Reproduction in the Last 50 years



Walsh,S.W. et al., 2011

Fertility and high milk production: Are they biologically compatible?

Quartile	Milk yield (kg/d)	Estrual cyclic. by d 65, %	Pregnant at d 30 post-AI, %	Pregnant at d 58 post-AI, %	Pregnancy loss d 30 to 58, %
1	32.1	72.7	37.2	30.3	12.7
2	39.1	77.6	38.9	29.8	11.6
3	43.6	77.6	39.3	33.7	12.8
4	50.0	75.3	37.6	35.3	15.6
P		**0.002**	0.74	**0.008**	0.57

6,396 cows on 4 TMR-fed farms in California

Santos et al., 2009

Reproduction: Early Embryonic Loss

Reference	Cows	Days 1st Check	Days last Check	Days	Loss %	Loss/ Day %
Chebel et al., 2002a	195	28	42	14	17.9	1.28
Moreira et al., 2000a	139	27	45	18	20.7	1.15
Chebel et al., 2002b	1,503	31	45	14	13.2	0.94
Stevenson et al., 2000	203	28	45	17	15.8	0.93
Santos et al., 2002b	360	31	45	14	11.1	0.79
Santos et al., 2002a	220	27	41	14	10	0.71
Cerri et al., 2002	176	31	45	14	9.7	0.70
Juchem et al., 2002	167	28	39	11	11.4	1.03

Daily embryonic loss in the first 50 days of pregnancy = 0.9%

Reproduction is affected by events occurring earlier in lactation

Health problem	Pregnant at day 30, %	*P*-value
No clinical disease	**66.9**	--
Single clinical disease	**56.5**	<0.01
Multiple clinical disease	**40.8**	<0.01
No subclinical disease	**68.0**	--
Single subclinical disease	63.6	0.36
Multiple subclinical disease	**52.2**	<0.01

Multiple factors affecting development of pre-antral follicles

957 multiparous cows in 2 farms

Adapted from Ribeiro et al., *J Dairy Sci* 2013

Factors Affecting Pregnancy in Dairy Cows

1. Minimize BCS loss & resolve postpartum uterine infection

2. Detect heat & inseminate at the correct time (Day 0)

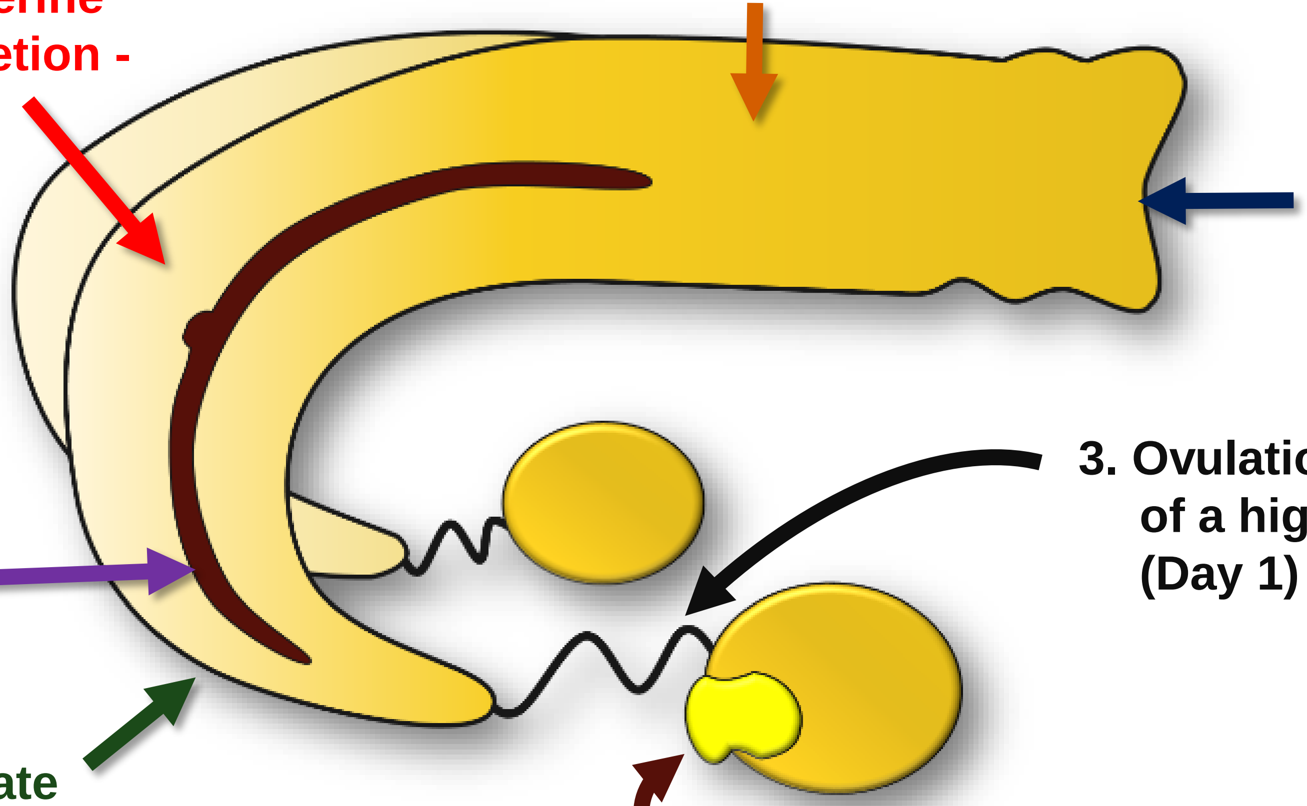
3. Ovulation & fertilization of a high quality oocyte (Day 1)

4. Have an early increase in P4 secretion (Day 3 to 7)

5. Have early & appropriate uterine histotroph production (Day 6 to 13)

6. Have a large embryo producing adequate quantities of Interferon tau (Day 14 to 18)

7. Maternal recognition of pregnancy (alter uterine prostaglandin secretion - Day 16 to 18)



Walsh et al., 2011

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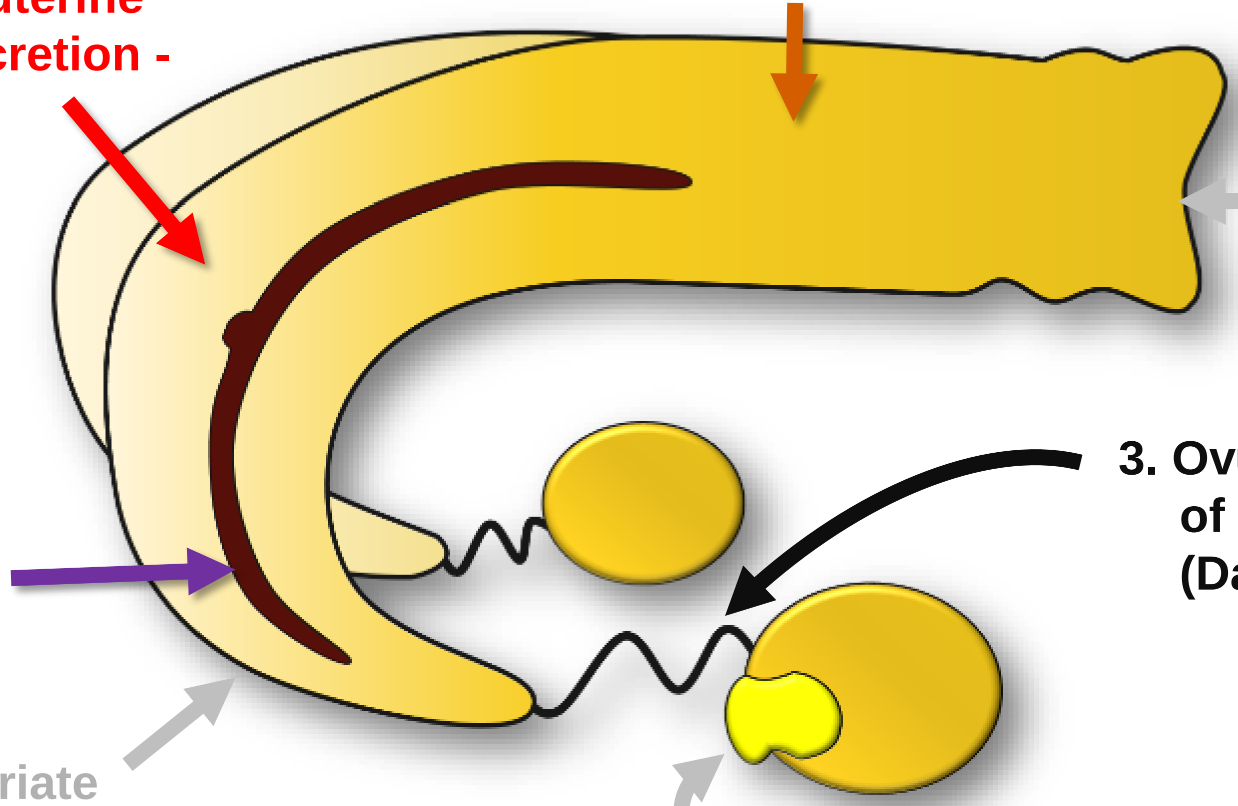

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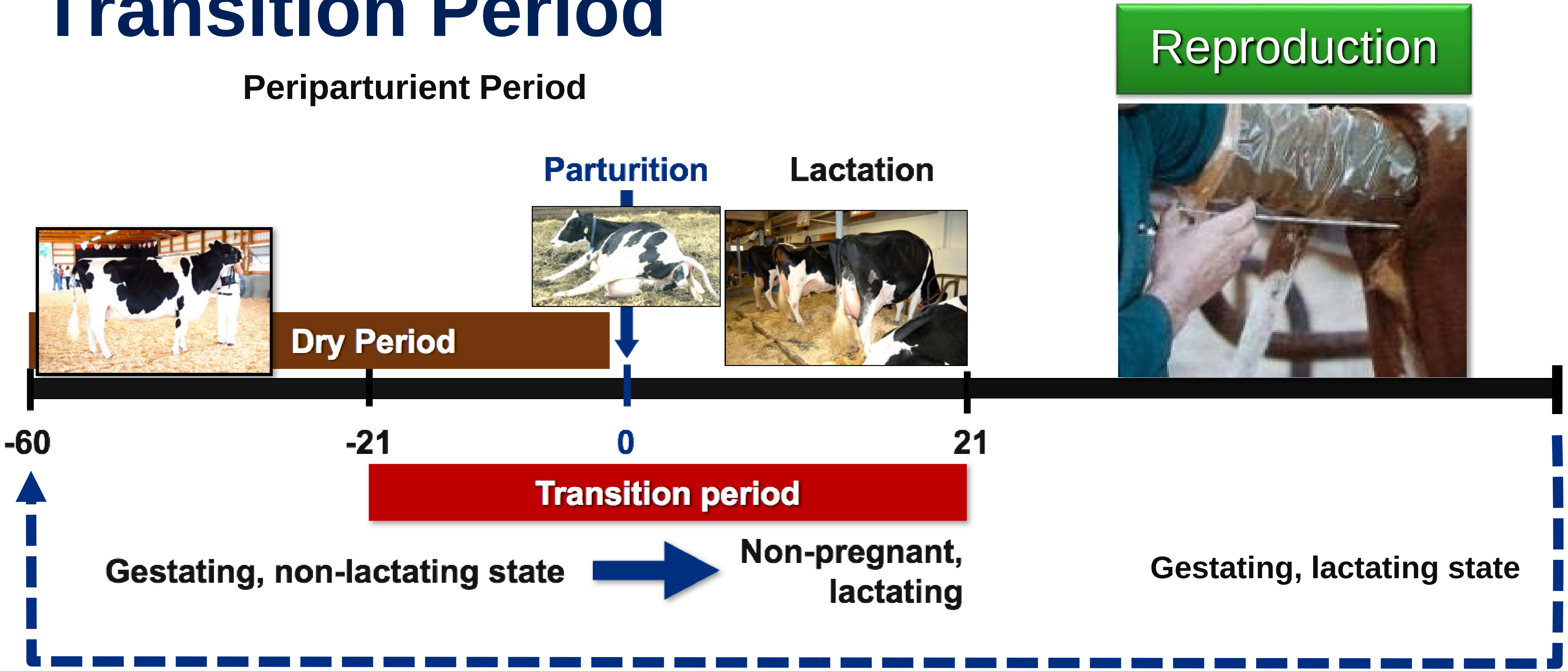
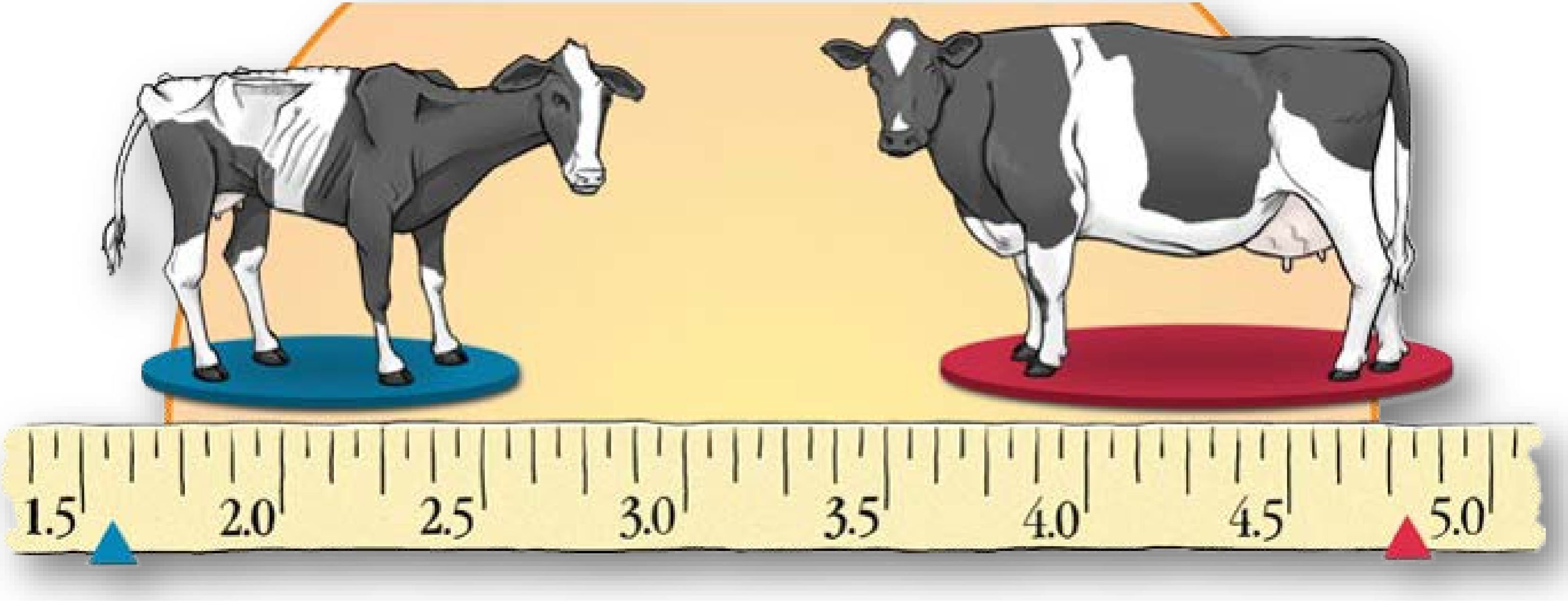
Walsh et al., 2011

Transition Period



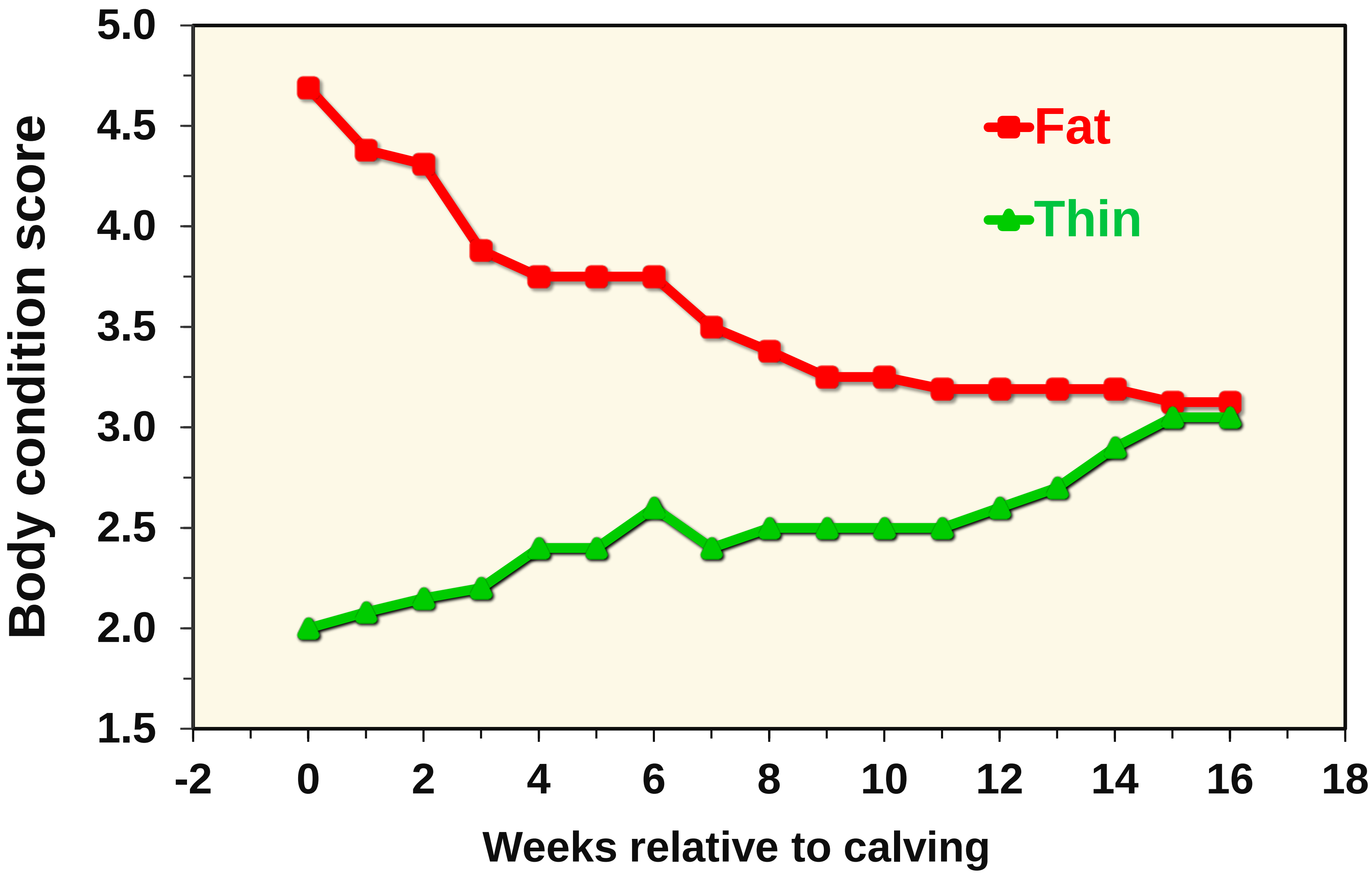


BCS at drying off: _______________

BCS at calving: _______________

BCS at breeding: _______________

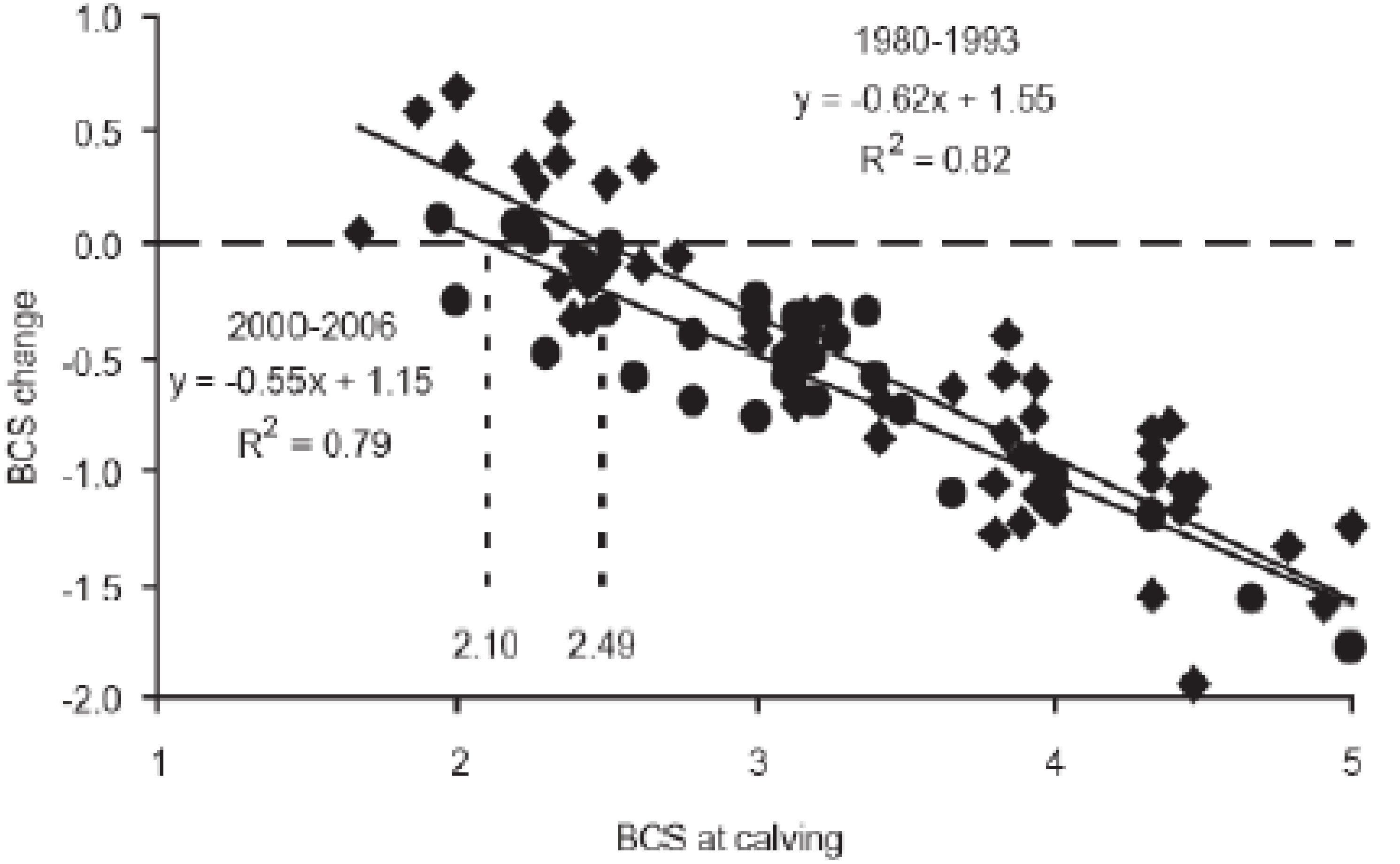
Changes in BCS in cows fed to be fat or thin at calving



*Thin cows had greater DMI and milk production

Redrawn from Garnsworthy, 1990

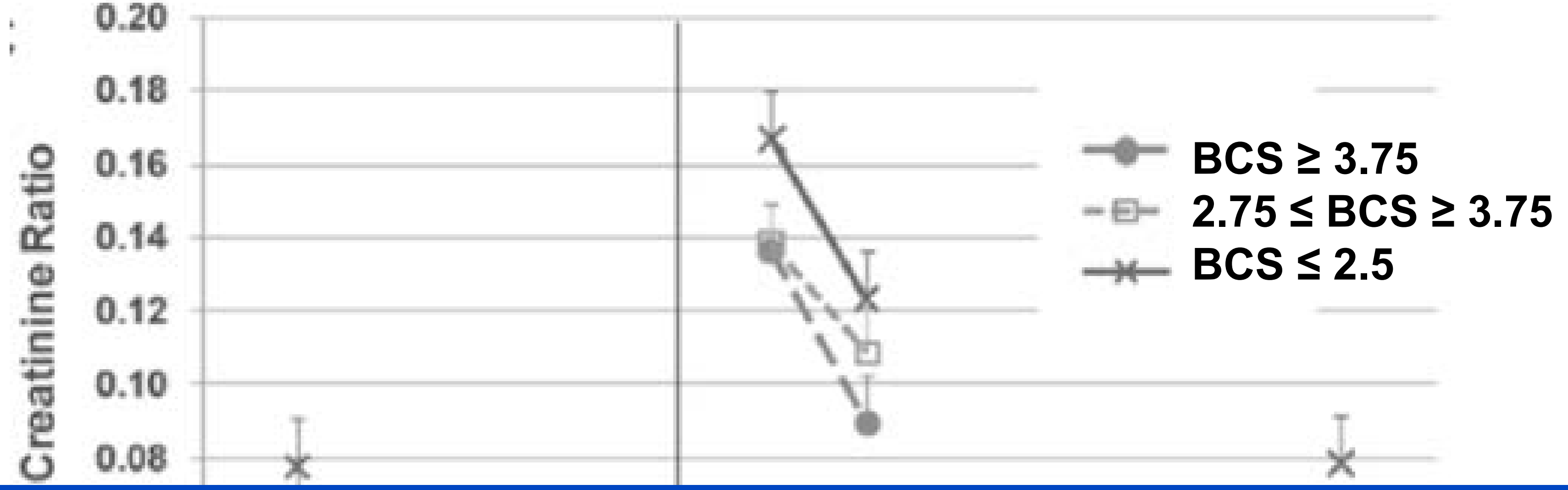
BCS at calving for neutral BCS change over the first 10 – 12 weeks of lactation was greater in older studies



- ♦ studies 1980 – 1993
- ● studies 2000 – 2006

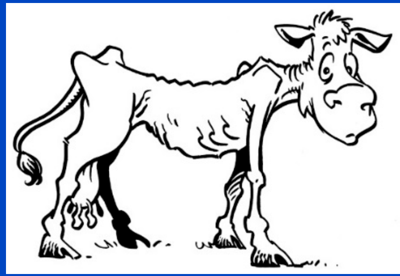
Redrawn from Garnsworthy, 1990

Thin cows before calving mobilize more protein after calving

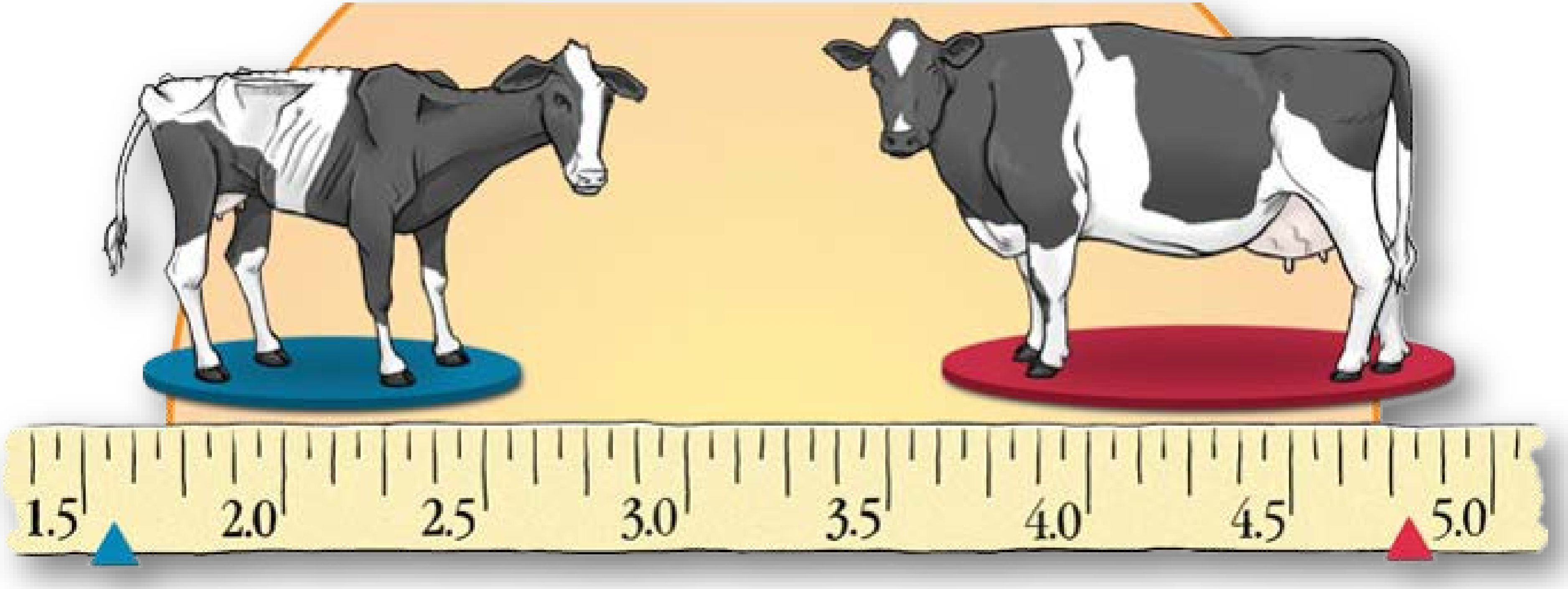


Thin cows mobilized less body fat but had more intense muscle protein catabolism.

- Need more protein for thin cows?



Pires et al., 2013



BCS at drying off: ______________

BCS at calving: ______________

BCS at breeding: ______________

Hoards Dairyman
May 10, 2015

“It’s the change that matters”

It’s the change that matters

A cow’s body condition score at calving may not be as important as the change in body weight she experiences in early lactation.

by Phil Cardoso

NUTRIENT demand for milk synthesis climbs quickly in early lactation. If no compensatory intake of nutrients is provided to cope with such a requirement, physiological functions like synthesis and secretion of hormones, immune response and embryo development may be compromised. Since milk production rises faster than dry matter intake (DMI) in the first four to six weeks after calving, cows are likely to experience negative energy balance (NEB).

CARDOSO

The author is an assistant professor in the department of animal sciences at the University of Illinois.

Energy balance during late gestation is largely a factor of DMI, as the variation in energy requirements is relatively small; an exception may be cows carrying twins. Even after calving, research indicates that the extent of early lactation energy balance is still more highly correlated with DMI than with milk yield.

The role of excessive body condition in transition difficulties has been studied for many years but remains a problem in many dairy herds. It is more prevalent in modern TMR-fed dairy herds, particularly with the growing reliance on corn silage as a primary forage. High serum beta-hydroxybutyrate (BHBA) and nonesterified fatty acid (NEFA) concentrations before and after calving can lower DMI, lead to hepatic lipid accumulation and ketosis, negatively affect the immune system, and can cause oxidative stress and inflammation.

How about thin cows? Researchers from the French National Institute for Agricultural Research (INRA) showed that cows that were thin (body condition score (BCS) less than 2.5) before calving mobilized more protein after calving than cows that were classified as fat (BCS greater than 3.75). Those cows mobilized less body fat but had more intense muscle protein catabolism. Therefore, if thin cows don’t have high serum concentrations of BHBA or NEFA, it does not mean they are not at risk. Instead, perhaps the method we are using to try to assess their “sickness” is not adequate.

Cows have their own target

Recommendations for optimal BCS at calving have trended downward over the last two decades. A score of about 3.0 (on a 5-point scale) represents a good goal at present.

Researchers from the University of Nottingham (UK) showed that, over the first 12 weeks of lactation, cows that were fat at calving lost 0.9 to 1.0 BCS units; cows that were thin at calving gained 0.4 to 0.5 BCS units (see figure). For both groups of cows, BCS tended to converge at 2.5 in Weeks 12 to 15 of lactation, suggesting that cows have a target BCS that they try to achieve and maintain. Fat cows reached maximum DMI at Week 15, whereas thin cows reached maximum DMI at Week 9. It seems body fat had a direct effect on DMI.

If a cow’s BCS is above this genetically-programmed target, DMI is reduced, and she loses condition; if a cow’s BCS is below this target, DMI goes up, and she gains weight. Therefore, it seems that the theory of getting a cow to a “good condition” (BCS 3.50 to 3.75) at calving is counterproductive, as it will only reduce DMI and exacerbate NEB. We believe that more important than looking only at BCS at calving is to observe the BCS change from calving to about 12 weeks after calving.

Changes in BCS in cows fed to be fat or thin at calving

Manage with nutrition

The ability of the cow to maintain a reasonable BCS change is affected by diet composition. Our group showed that cows fed high-energy (0.72 Mcal NEL/lb. DM) diets during the last four weeks before calving lost more BCS in the first six weeks postpartum than those fed controlled energy (0.60 Mcal NEL/lb. DM) diets (-0.43 and -0.30, respectively).

Cows fed even moderate-energy diets (0.67 to 0.72 Mcal NEL/lb. DM) will easily consume 40 to 80 percent more energy than required during both the far-off and close-up periods. Allowing dry cows to consume more energy than required, even if they do not become noticeably overconditioned, results in responses that would be typical of overly fat cows. Because energy consumed in excess by cows must either be dissipated as heat or stored as fat, we speculate that, at least in some cows, the excess is accumulated preferentially in internal adipose tissue depots.

Our group recently demonstrated that moderate overconsumption of energy by nonlactating cows for 57 days leads to greater deposition of fat in abdominal adipose tissues than in cows fed a high-bulk diet to control energy intake to meet requirements. The NEFA and signaling molecules released by the visceral adipose tissues travel directly to the liver, which may cause fatty liver, subclinical ketosis and secondary problems with liver function.

The effect of BCS change on cows’ fertility is also clear. Recently, researchers from the University of Wisconsin found that cows that either gained or maintained BCS from calving to 21 days after calving had higher pregnancy rates (83.5 and 38.2 percent, respectively) per A.I. at 40 days than cows that lost BCS (25.1 percent) during that same period.

And previously, researchers from the University of Florida found that cows that had greater than 1.0 BCS unit change from calving to A.I. at approximately 70 days postpartum had lower pregnancy per A.I. (28 percent) than cows that lost less than 1.0 BCS unit (37.3 percent) or did not have a BCS change (41.6 percent).

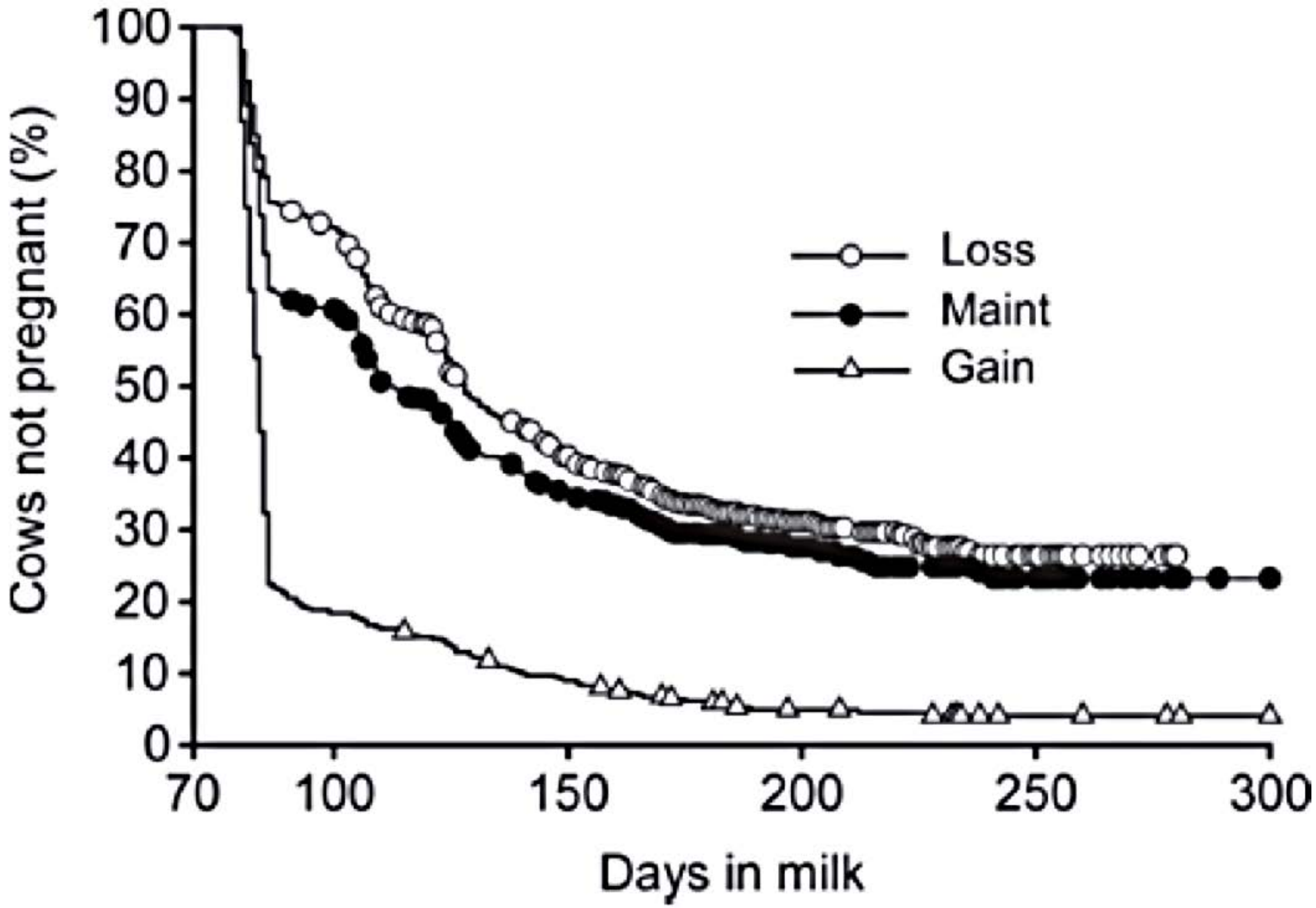
Two simple letters

Ideally, BCS would be measured in every cow in the herd every month. If that is an unachievable commitment, we recommend that farmers measure individual cow’s BCS at least three times per lactation: at dry-off, calving and breeding. With these numbers in hand, you will be able to calculate BCS change and maintain the goal for a loss of no more than 0.5 to 0.75 BCS units.

The variation between individuals assigning BCS to cows can be another challenge. To make it simple, train yourself and your team the two letters of BCS: “V” and “U.” This is the shape of the dip between a cow’s hips and pins. It is easy to visualize and can be used to determine when to move cows from the fresh/high pen to the next group.

If a cow has a BCS of “V,” consider letting her stay a little bit longer in the fresh/high group. Whenever a cow achieves a BCS of “U,” she is ready to be moved to the next nutritional group. This strategy will most likely help your cows to achieve the right BCS at dry-off, allowing for a minimal and more ideal BCS change when she calves in again.

Calving-to-pregnancy interval for cows that gained, maintained, or lost BCS between calving and 21 d postpartum



Carvalho et al., 2014

Dietary Recommendations for Dry Cows

- **NEL:** Control energy intake at 14 to 16 Mcal daily [diet ~ 1.30 Mcal/kg (0.60 Mcal/lb) DM] for mature cows
- **Crude protein:** 12 – 14% of DM
- **Metabolizable protein (MP):** > 1,200 g/d
- **Starch content:** 12 to 16% of DM
- **NDF from forage:** 40 to 50% of total DM or 4.5 to 5 kg per head daily (~0.7 – 0.8% of BW). Target the high end of the range if more higher-energy fiber sources (like grass hay or low-quality alfalfa) are used, and the low end of the range if straw is used (2-5kg).
- **Total ration DM content:** <55% (add water if necessary)
- **Minerals and vitamins:** follow guidelines (For close-ups, target values are 0.40% magnesium (minimum), 0.35 – 0.40% sulfur, potassium as low as possible, a DCAD of near zero or negative, 0.27% phosphorus, and at least 1,500 IU of vitamin E)

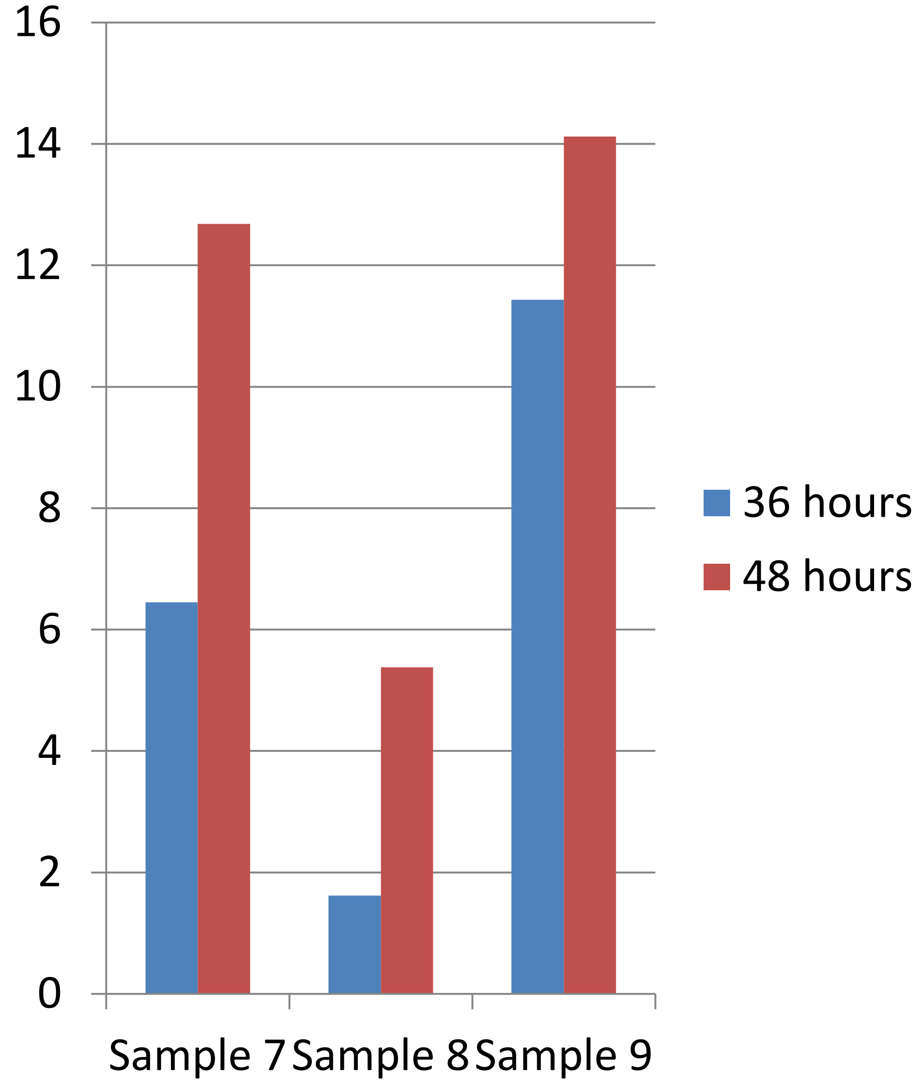
Crude Fiber… remember?

#	Almond hull variety	DM	CF	NDF	ADF	Ash
7	Cal 66%, HS 34%	91.3	22.3	36.5	25.1	5.9
8	B/P 50%, HS 50%	87.7	22.2	33.7	24.6	5.2
9	B/P 66%, HS 34%	88.3	21.8	32.4	23.8	5.5

- Conclusion

  Breaking fiber into ADF and NDF gives better understanding of what happens to fiber.

NDF Disappearance



Pate et al., *unpublished*

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→ Methionine
Lysine

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A summary of some early lactation cow rumen-protected Lys and Met supplementation experiments

7 experiments that measured production responses to increasing Met, Lys, or both in MP *after* calving

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+ 0.70 kg/d milk

+ 0.16% units milk protein

+ 79 g/d milk protein

+ 0.02% units milk fat

+ 48 g/d milk fat

5 experiments that measured production responses to increasing Met, or Met + Lys in MP starting *before* calving

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+ 2.30 kg/d milk

+ 0.09% units milk protein

+ 112 g/d milk protein

+ 0.10% units milk fat

+ g/d milk fat

Garthwaite et al., 1999

Can AA Prevent Embryonic Losses?

Whole Rat Embryos Require Methionine for Neural Tube Closure when Cultured on Cow Serum[1–4]

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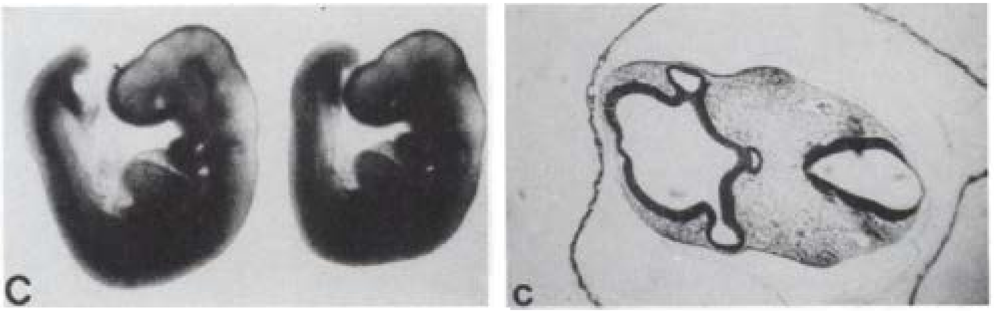
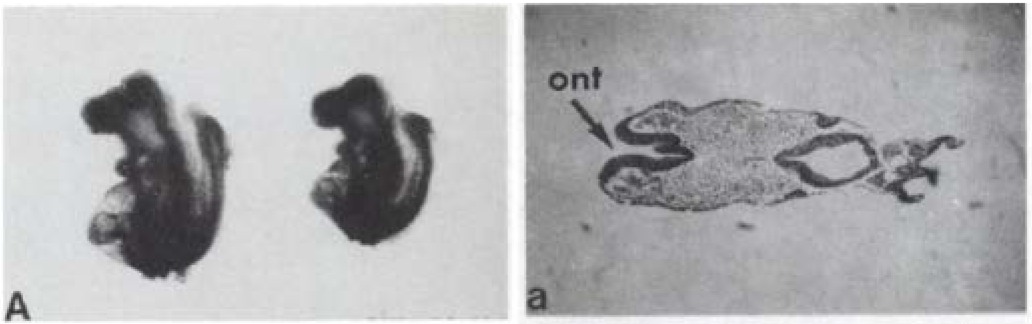


Culture in Rat Serum



Culture in Bovine Serum

Cow serum with:	Embryo Protein	% Abnormal
None	73.7 ± 8.6[a]	100%
Amino acids + vitamins	**130.0 ± 7.7[b]**	**0%**
Amino acids	**117.1 ± 8.5[b]**	**0%**
Vitamins	56.6 ± 5.76[a]	100%
Amino acids w/o methionine	82.9 ± 8.7[a]	100%
Methionine	**133.7 ± 5.5[b]**	**0%**

Coelho et al., 1989

Nutritional Effects from Pre-fresh to Early Pregnancy on Embryo Development and Fertility

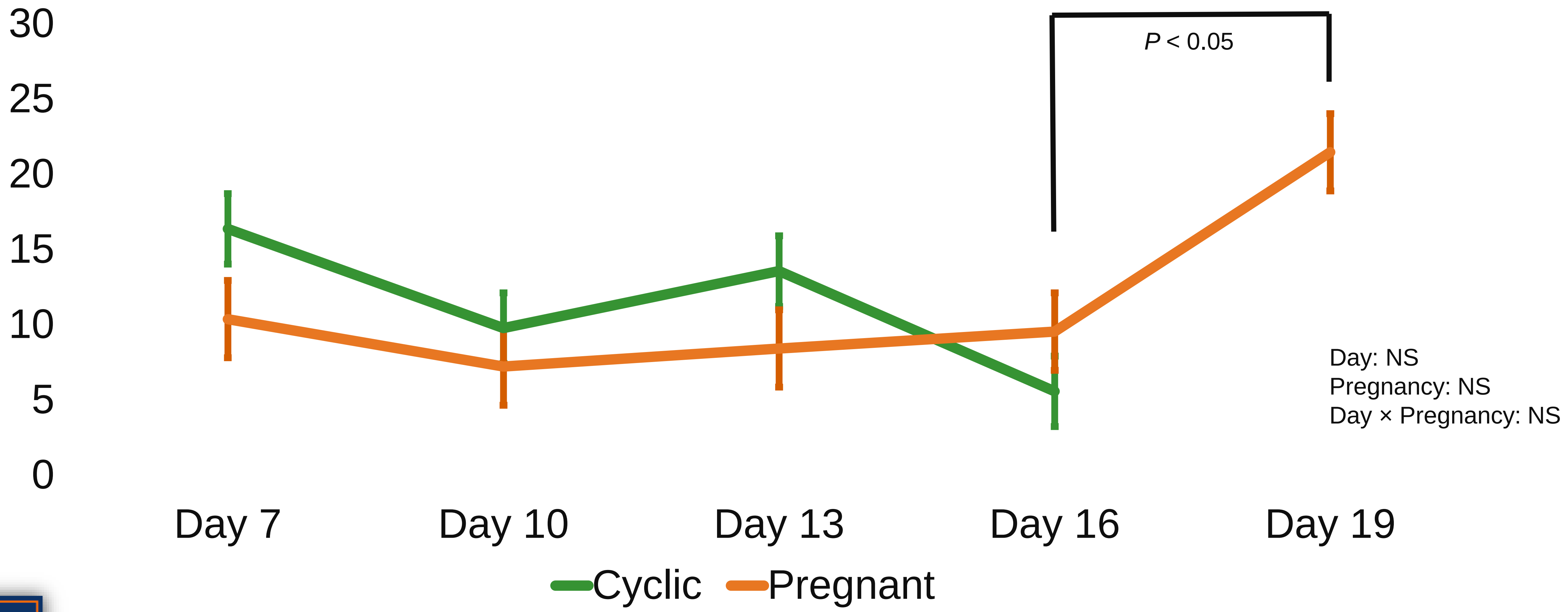
It is now evident that nutritional effects on oocyte quality can originate when ovarian follicles emerge from the primordial pool and become committed to growth (approx. three to four months in cows). Undernutrition at this time reduces the number of follicles that emerge and therefore the number available to ovulate.

Ashworth et al. 2009

Methionine enriched diets impact on embryo quality? → Improved Fertility?

Adapted from Wiltbank et al., 2014

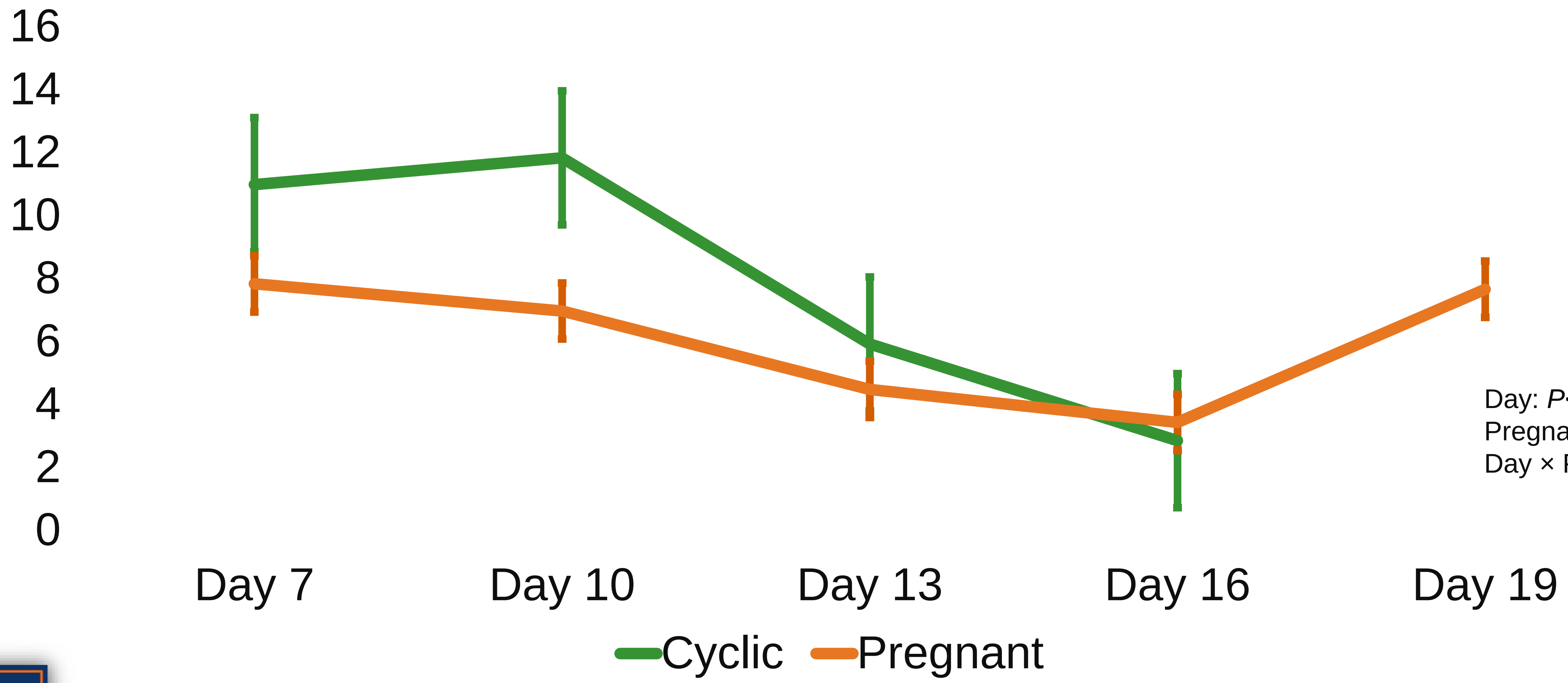
Lysine concentration (µ*M*) in uterine luminal fluid of cross-bred beef heifers



n = 5 per treatment per time-point

Forde et al., 2014

Methionine concentration (μ*M*) in uterine luminal fluid of cross-bred beef heifers

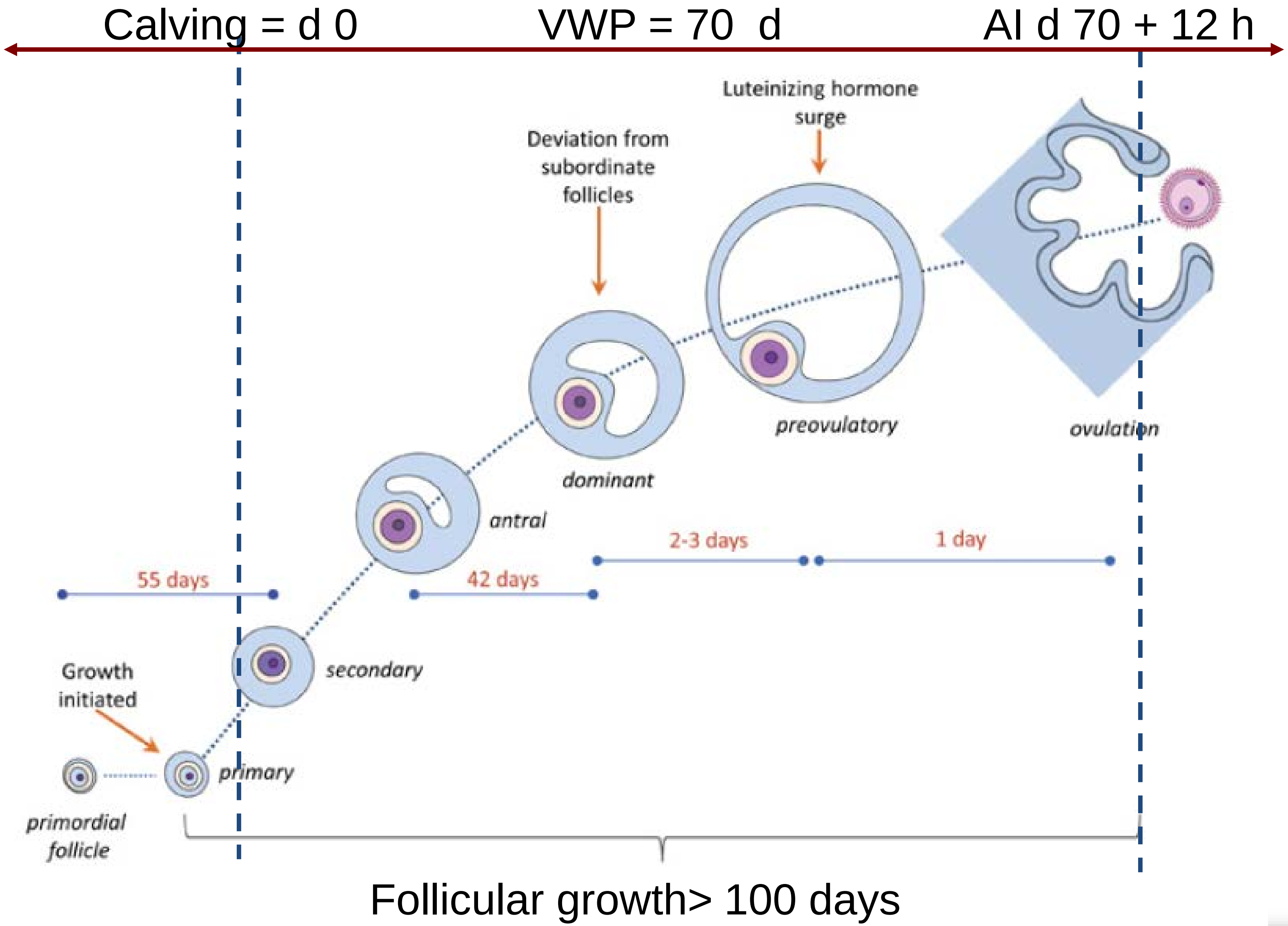


Day: *P*<0.001
Pregnancy: *P*<0.05
Day × Pregnancy: NS

n = 5 per treatment per time-point

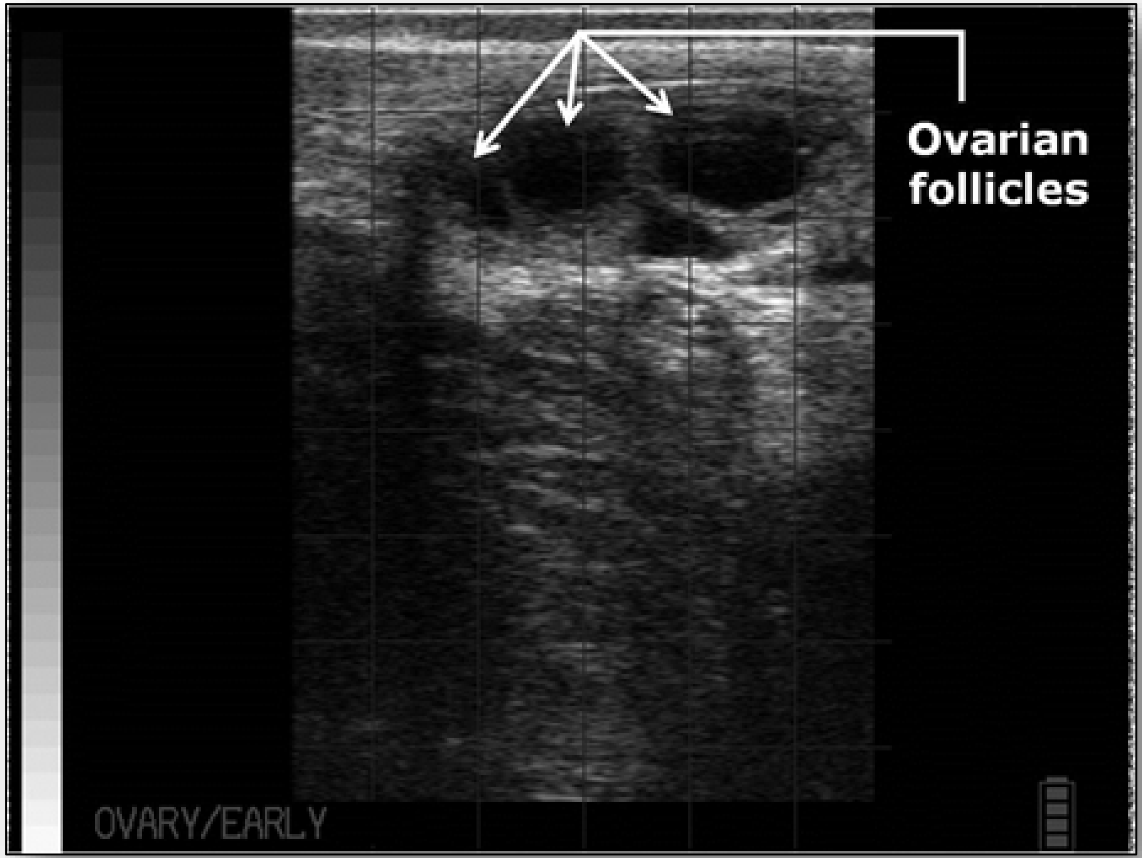
Forde et al., 2014

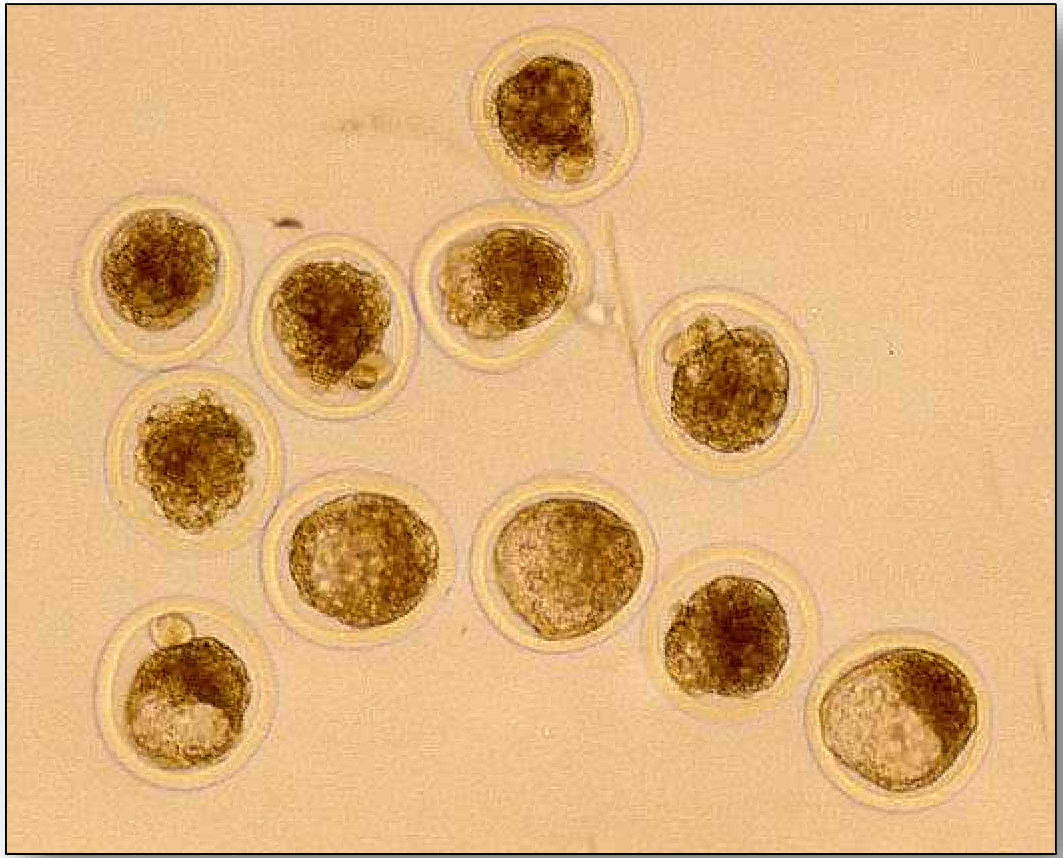
The Growth of the Follicle Starts Prior to Calving



University of Illinois at Urbana-Champaign

Hansen, 2013


Ovarian
follicles
OVARY/EARLY



Effects of Rumen-Protected Methionine or Choline Supplementation on the First Dominant Follicle

- 72 Holstein cows entering 2nd or greater lactation
- Experimental design was a randomized block design
- Housed in tie stalls with sand bedding
- Milked 3x per day
- Fed same basal TMR to meet but not exceed 100% of the energy requirements as outlined by NRC, 2001
  - From -34 d to calving: prepartum diet
  - From 0 to 30 DIM: fresh cow diet
  - From 31 to 72 DIM: high cow diet
- Treatments were given as top-dress

Acosta et al., 2016

Effects of Rumen-Protected Methionine or Choline Supplementation on the First Dominant Follicle

1. Rumen-protected methionine
   (**MET**; n = 20, received 0.08% of the DM of the diet/d as methionine, Smartamine M®, Adisseo, Alpharetta, GA, USA, to a Lys:Met = 2.9:1)

2. Rumen-protected choline (**CHO**; n = 17, received 60 g/d choline, Reassure, Balchem Corporation, New Hampton, NY)

3. Both rumen protected methionine and choline
   (**MIX**; n = 19, received 0.08% of the DM of the diet/d as methionine to a Lys:Met = 2.9:1 and 60 g/d choline)

4. No supplementation to serve as control
   (**CON**; n = 16, fed TMR with a Lys:Met = 3.5:1)

Acosta et al., 2016

Diets

Ingredients	Pre-Fresh -21 d to calving	Fresh Calving to 30 DIM	High 31 to 73 DIM
	% DM		
Alfalfa silage	8.35	5.07	6.12
Alfalfa hay	4.29	2.98	6.94
Corn silage	36.40	33.41	35.09
Wheat straw	15.63	2.98	---
Cottonseed	---	3.58	3.26
Wet brewers grain	4.29	9.09	8.16
Soy hulls	4.29	4.18	4.74
Blood meal	0.86	1.50	1.43
Concentrate mix	25.89	37.21	34.26

Acosta et al., 2016

Diets; chemical composition

Item	Pre-Fresh -21 d to calving	Fresh Calving to 30 DIM	High 31 to 73 DIM
	% DM		
DM, %	47.1	47.9	47.1
CP, % of DM	18.0	17.6	18.3
ADF, % of DM	22.7	24.4	23.2
NDF, % of DM	35.6	37.3	36.3
Lignin, % of DM	4.53	4.00	3.80
Starch, % of DM	22.3	21.4	23.6
Crude fat, % of DM	5.23	4.70	4.57

Acosta et al., 2016

Milk Yield and Components

Parameter	MET With	MET Without	SEM	P-value MET	P-value Parity	P-value Time	P-value M × T
Milk composition (%)							
Fat	3.72	3.74	0.11	0.92	-	<0.01	0.58
Protein	3.32[a]	3.14[b]	0.05	<0.01	-	<0.01	0.67
SCC	1.86	1.81	0.07	0.55	-	<0.01	0.85
Lactose	4.70	4.69	0.03	0.79	<0.01	<0.01	0.90
Total solids	12.65	12.39	0.12	0.13	-	<0.01	0.24
Other solids	5.62	5.60	0.03	0.58	<0.01	<0.01	0.82
MUN	12.80	12.94	0.30	0.75	-	0.50	0.92
Milk production (kg/day)							
Milk yield	44.32[a]	40.32[b]	1.29	0.03	-	<0.01	0.60
Milk fat yield	1.67[a]	1.53[b]	0.05	0.04	-	<0.01	0.47
Milk protein yield	1.51[a]	1.33[b]	0.05	<0.01	-	<0.01	0.73
ECM	44.81[a]	40.25[b]	1.05	<0.01	-	<0.01	0.16

Zhou et al., 2016

Milk Yield and Components

Parameter	MET With	MET Without	SEM	P-value MET	P-value Parity	P-value Time	P-value M×T
Milk composition (%)							
Fat	3.72	3.74	0.11	0.92	-	<0.01	0.58
Protein	3.32[a]	3.14[b]	0.05	<0.01	-	<0.01	0.67
SCC	1.86	1.81	0.07	0.55	-	<0.01	0.85
Lactose	4.70	4.69	0.03	0.79	<0.01	<0.01	0.90
Total solids	12.65	12.39	0.12	0.13	-	<0.01	0.24
Other solids	5.62	5.60	0.03	0.58	<0.01	<0.01	0.82
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Milk production (kg/day)							
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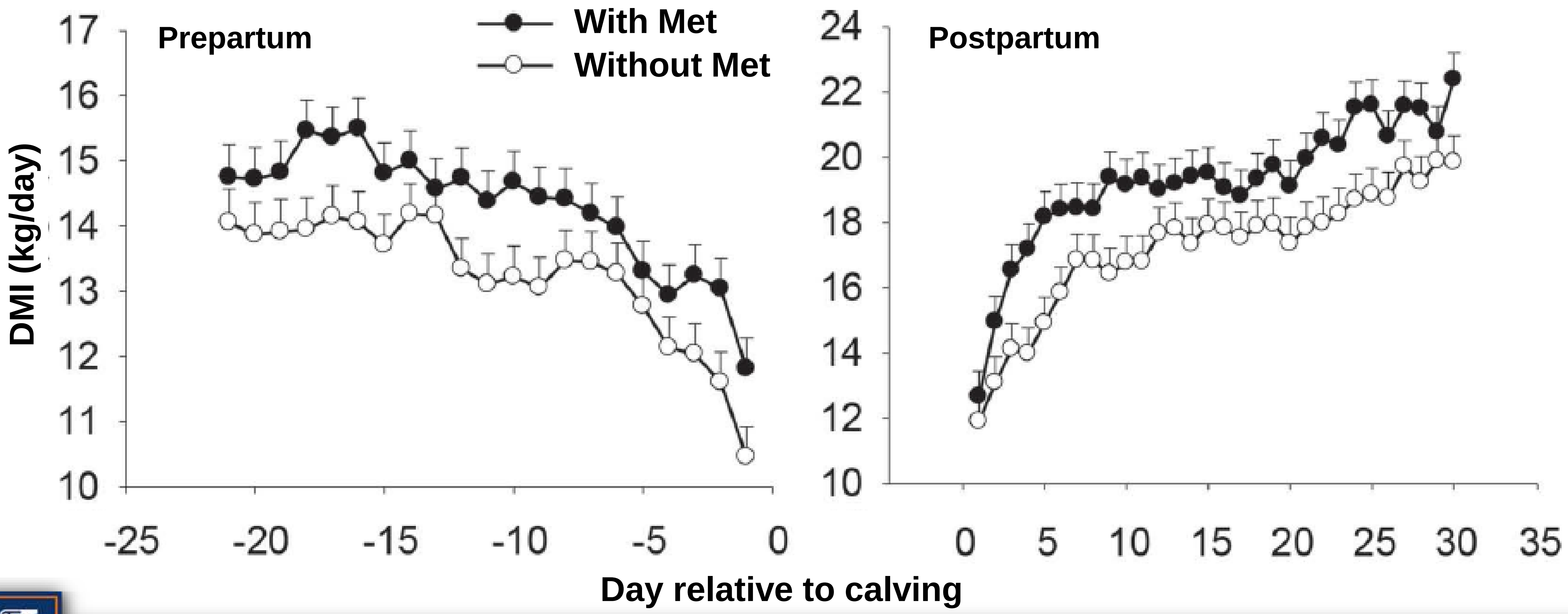
Milk protein yield	1.51[a]	1.33[b]	0.05	<0.01	-	<0.01	0.73
ECM	44.81[a]	40.25[b]	1.05	<0.01	-	<0.01	0.16

Zhou et al., 2016

Improved postpartal performance in dairy cows supplemented with rumen-protected methionine during the peripartal period



Zhou et al., 2016

Theriogenology 96 (2017) 1–9

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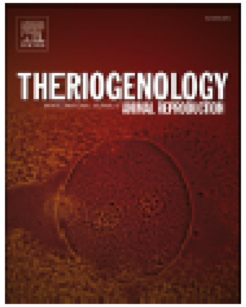


Effects of rumen-protected methionine and choline supplementation on steroidogenic potential of the first postpartum dominant follicle and expression of immune mediators in Holstein cows

CrossMark

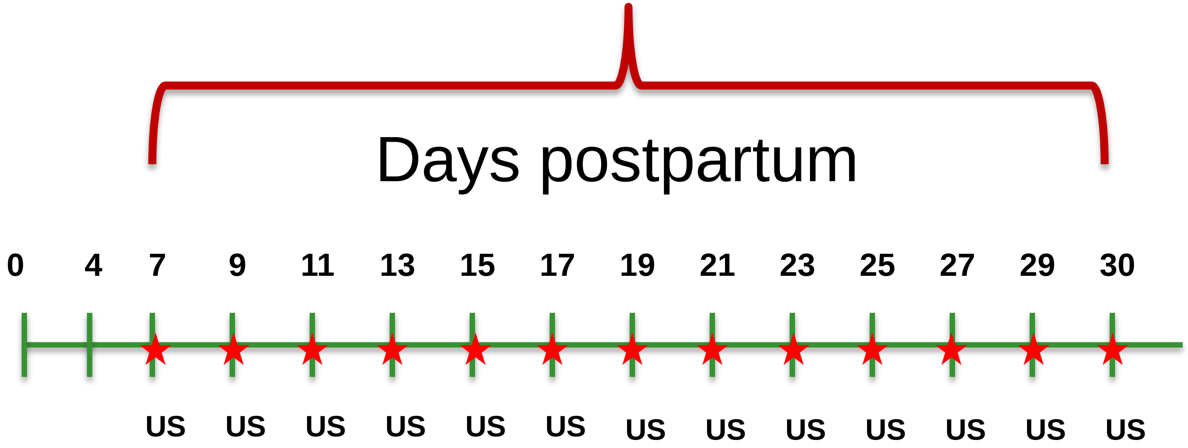
D.A.V. Acosta [a, b, e], M.I. Rivelli [a], C. Skenandore [a], Z. Zhou [a], D.H. Keisler [c], D. Luchini [d], M.N. Corrêa [e], F.C. Cardoso [a, *]

[a] *Department of Animal Sciences, University of Illinois, Urbana, IL, USA*
[b] *The Colombian Corporation for Agricultural Research (CORPOICA), Bogotá, Colombia*
[c] *Division of Animal Sciences, University of Missouri, Columbia, USA*
[d] *Adisseo, Alpharetta, GA, USA*
[e] *Department of Clinics, Faculty of Veterinary Medicine, Universidade Federal de Pelotas, Pelotas, RS, Brazil*

University of Illinois at Urbana-Champaign

Ovulation, first dominant follicle (n = 40)

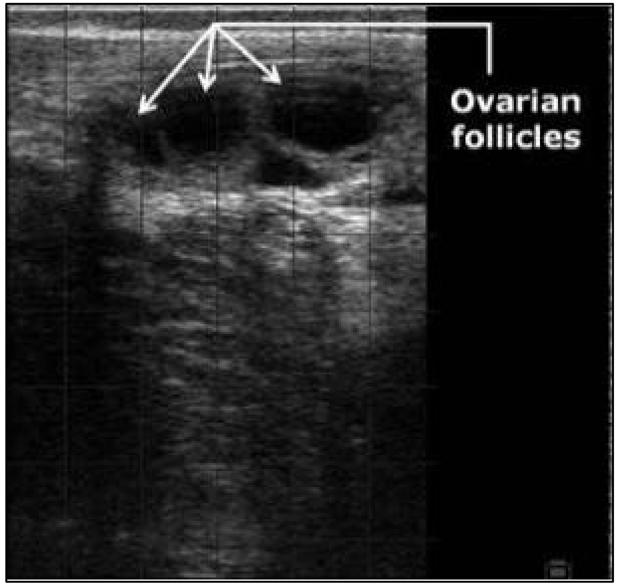
Follicular Aspiration, 16mm (n = 40)

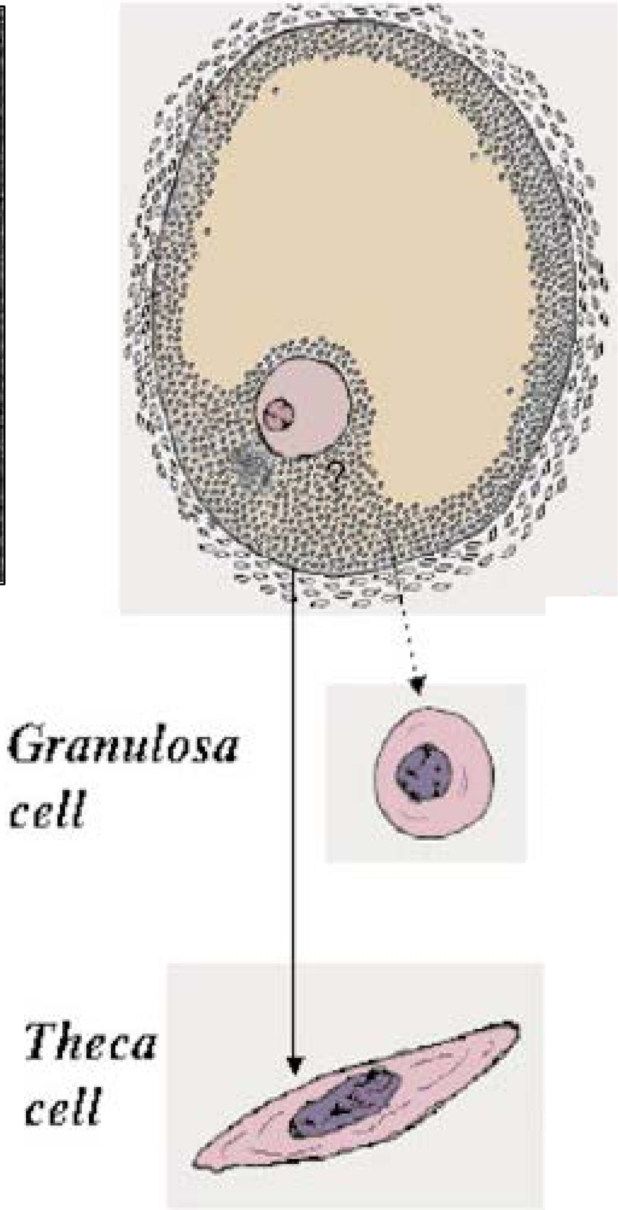


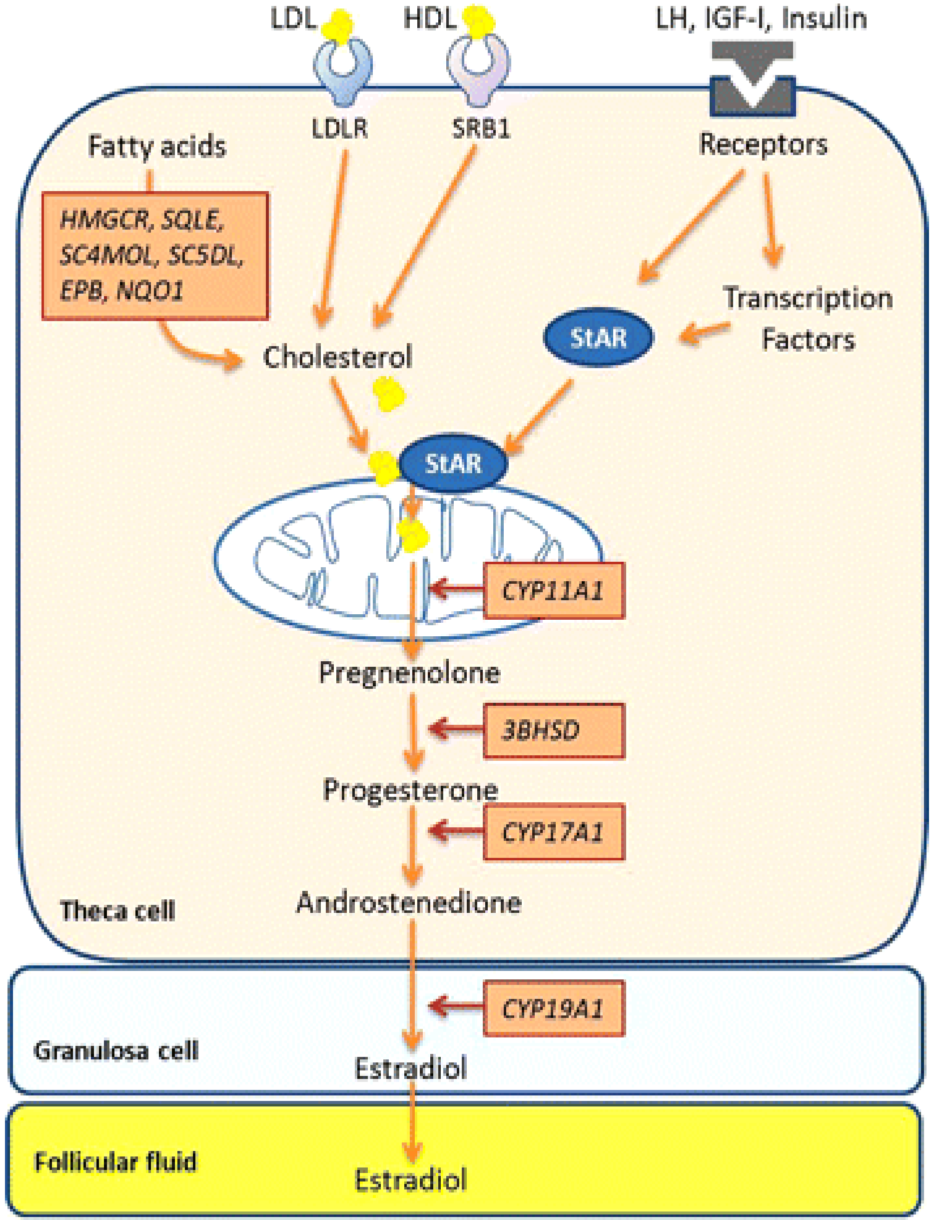
★ Blood Samples

US: Ultrasonography

Acosta et al., 2017

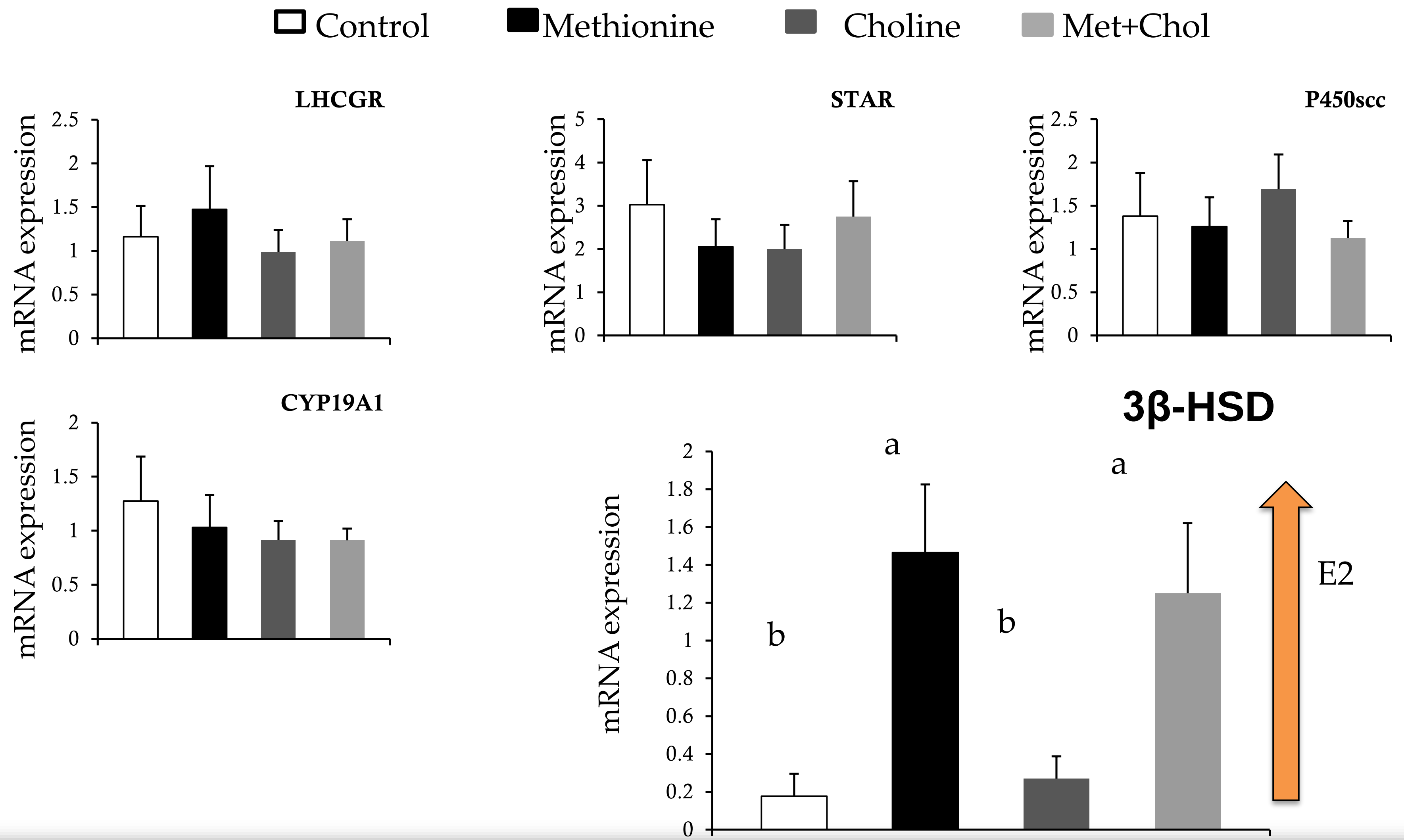






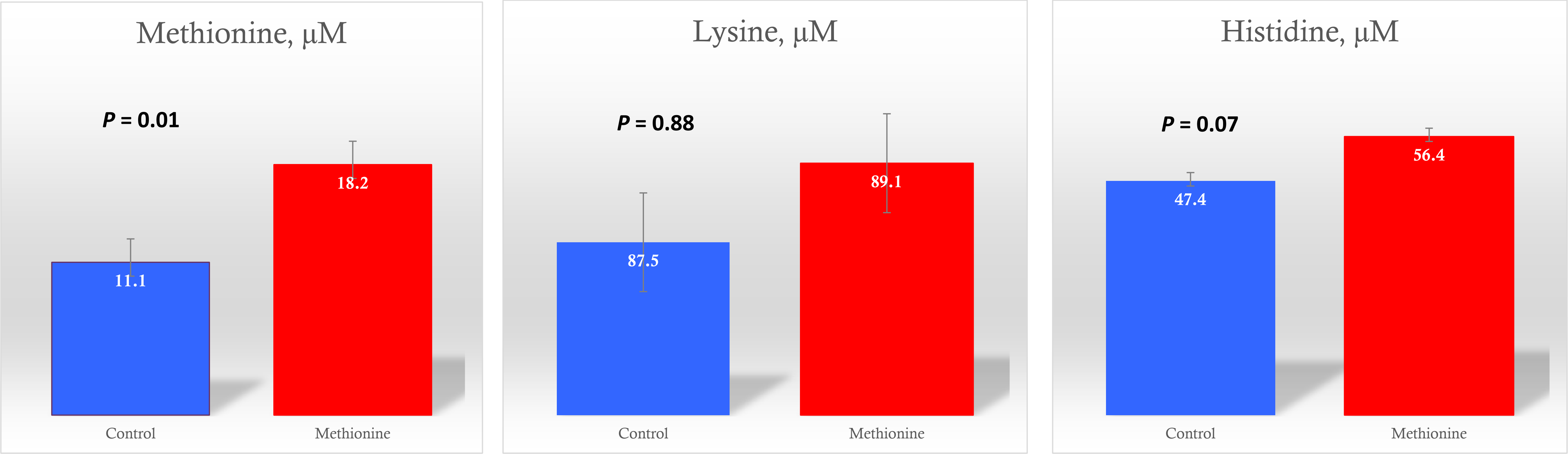
Walsh et al., 2012

Steroidogenesis Pathway



Acosta et al., 2017

Follicular Fluid AA Concentration from Cows at the Day of Follicular Aspiration of the Dominant Follicle of the 1st Follicular Wave Postpartum (~16 mm)

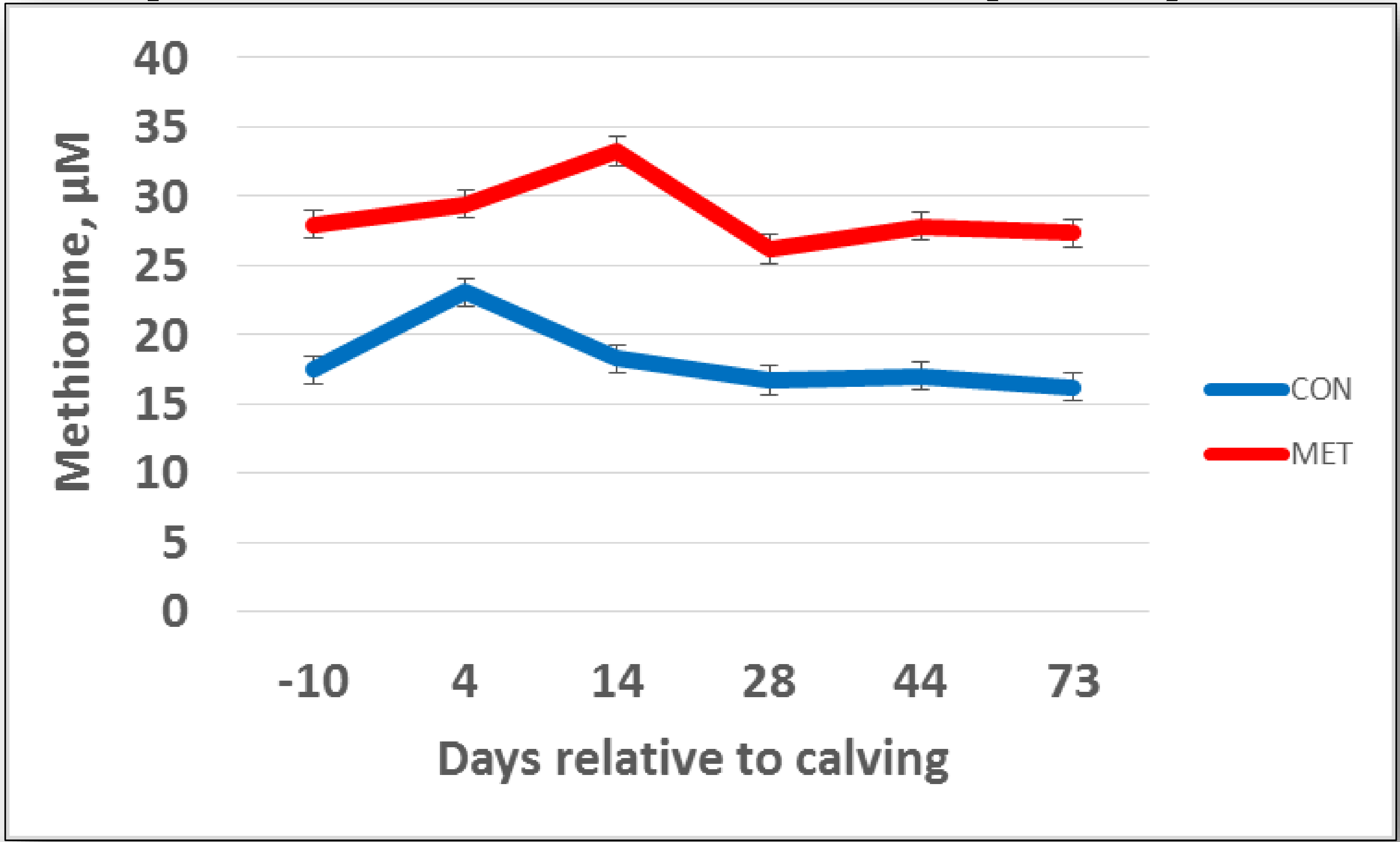


University of Illinois at Urbana-Champaign

Control: n = 7; Methionine: n = 8

Acosta et al., 2017

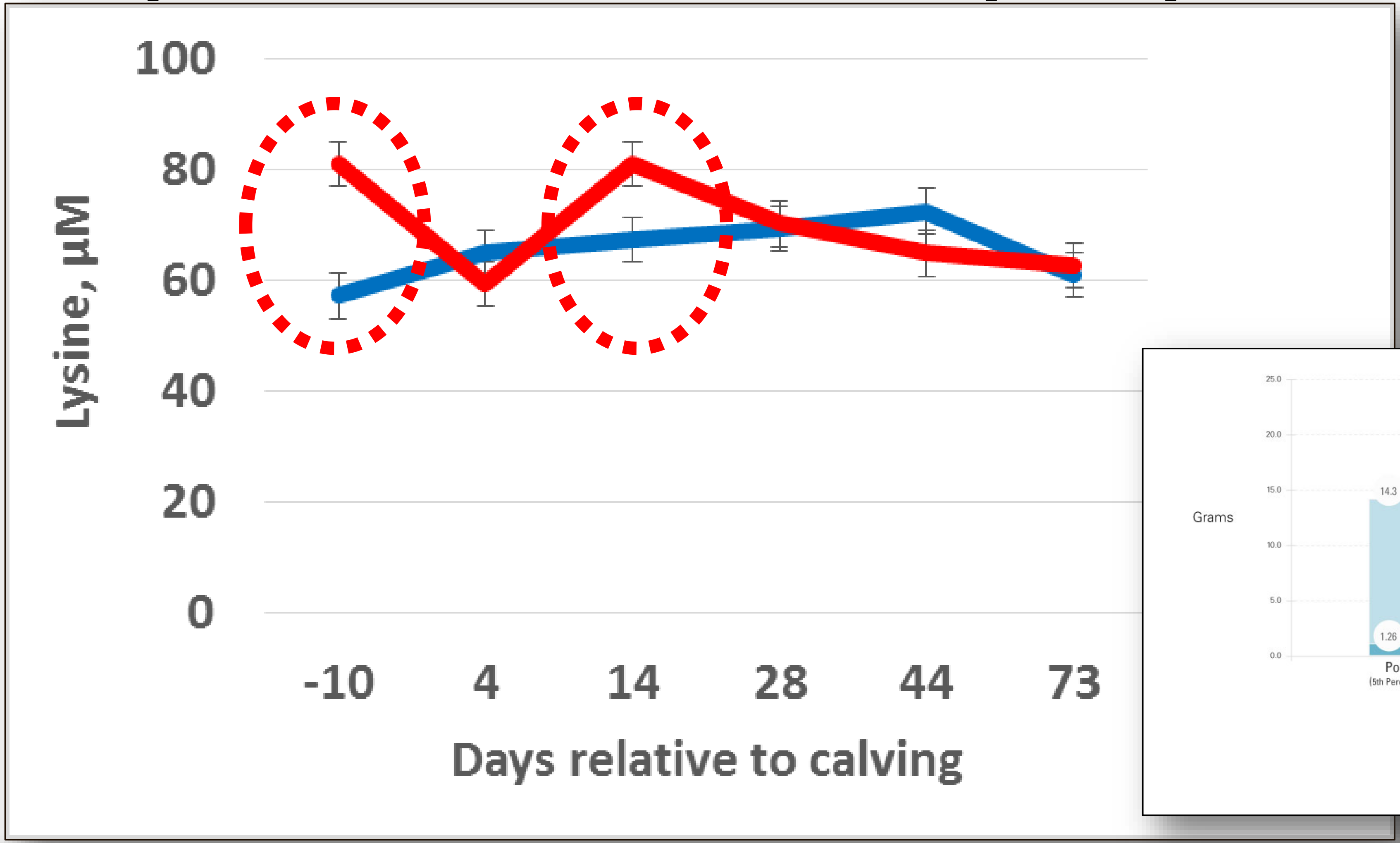
Serum Methionine Concentration from Cows Fed rumen-protected methionine (MET) or not (CON)

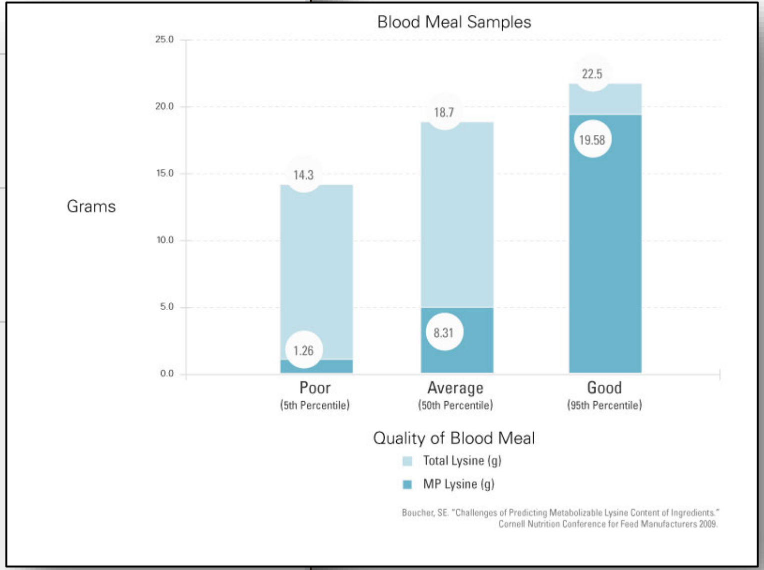


Control: n = 7; Methionine: n = 10

Stella et al., *unpublished*

Serum Lysine Concentration from Cows Fed rumen-protected methionine (MET) or not (CON)

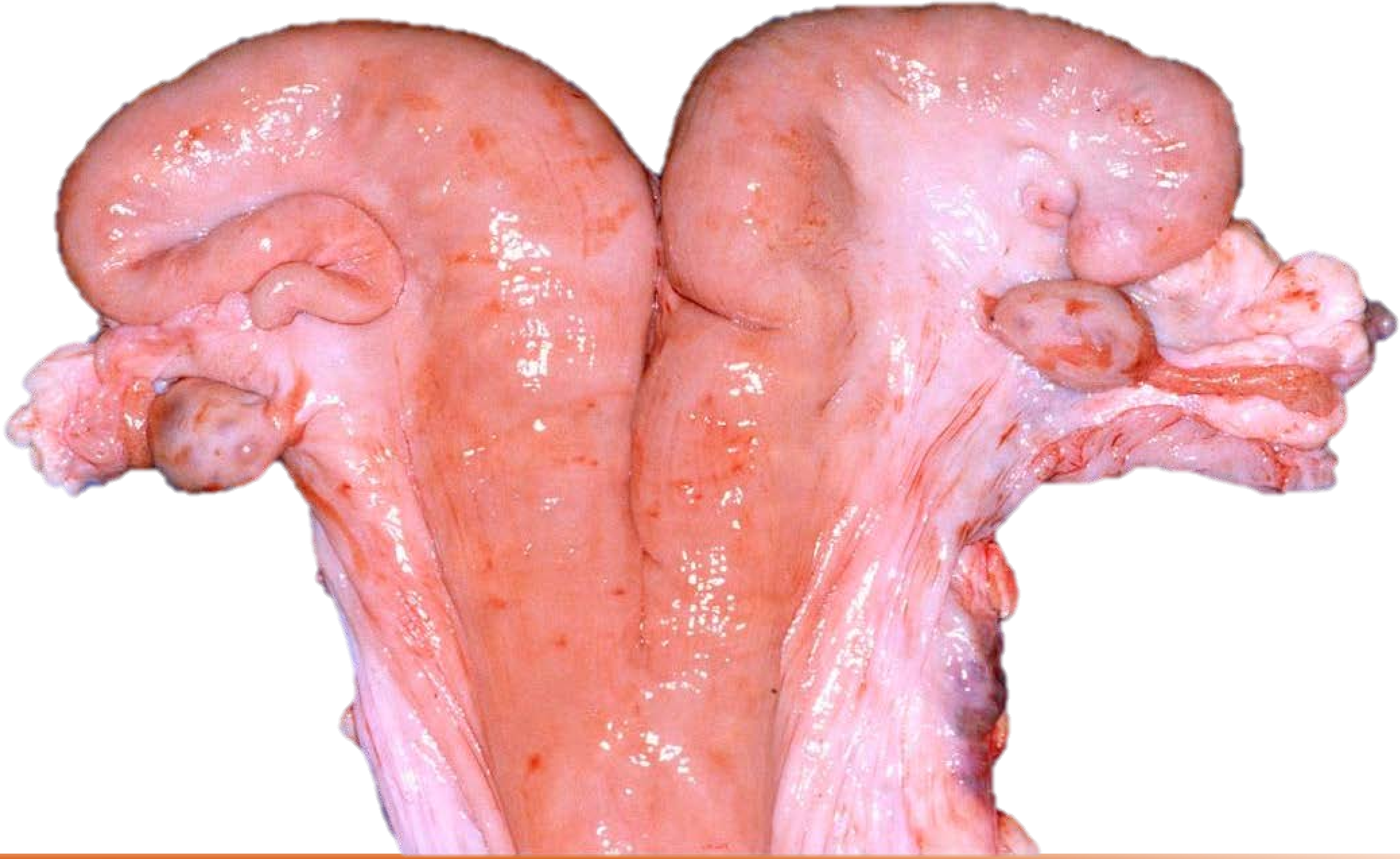




University of Illinois at Urbana-Champaign

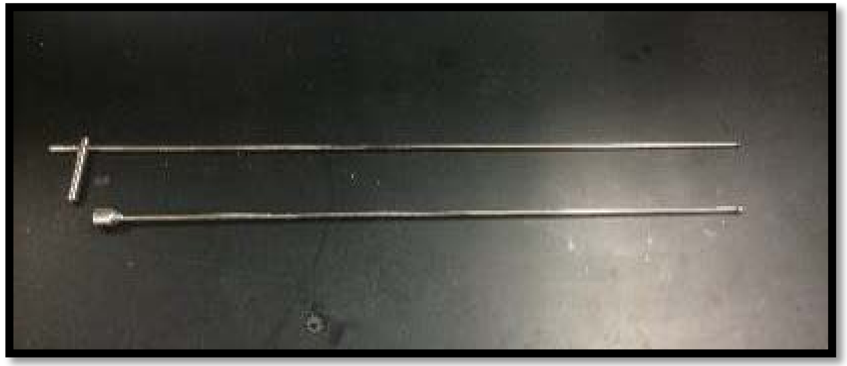
Control: n = 7; Methionine: n = 10

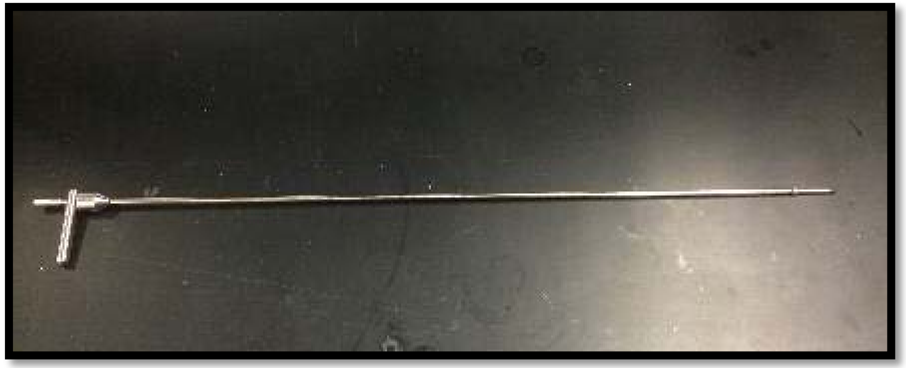
Stella et al., *unpublished*

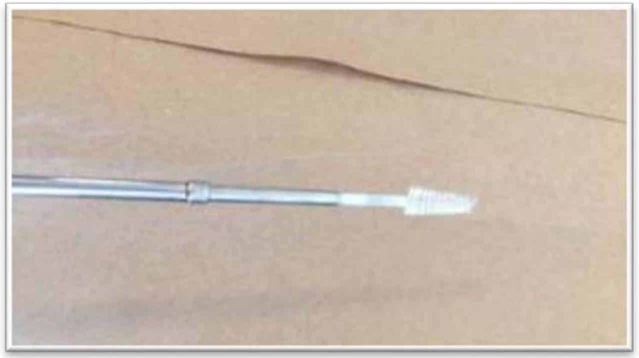


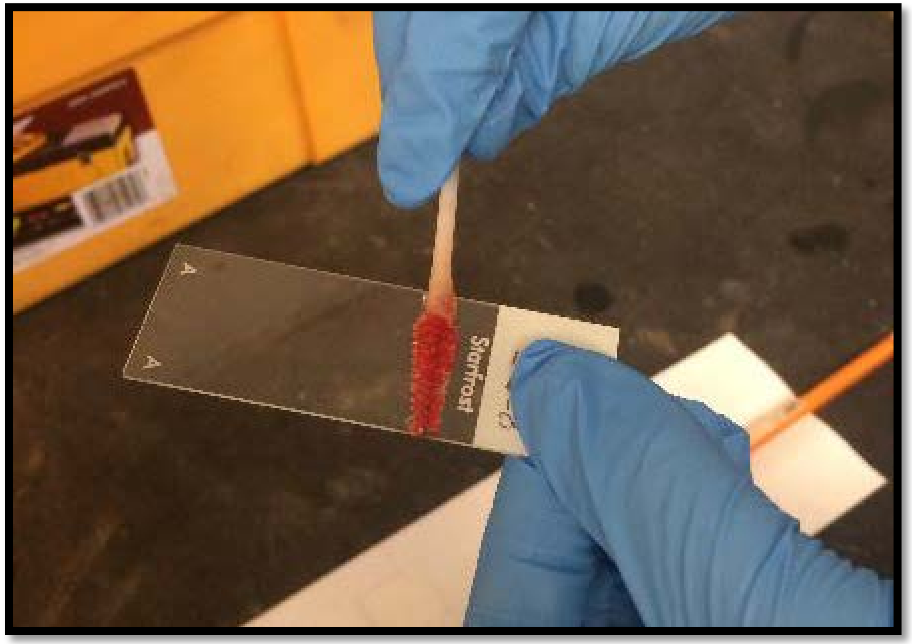
http://loribovinesection.blogspot.com/2013_07_01_archive.html

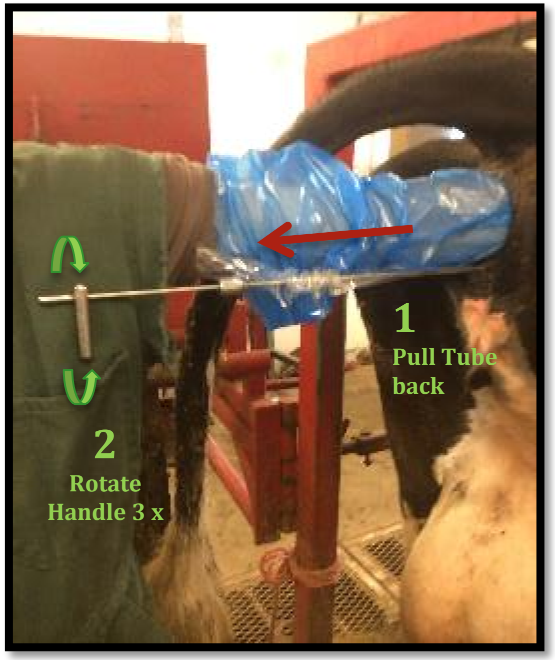
Uterine Cytology



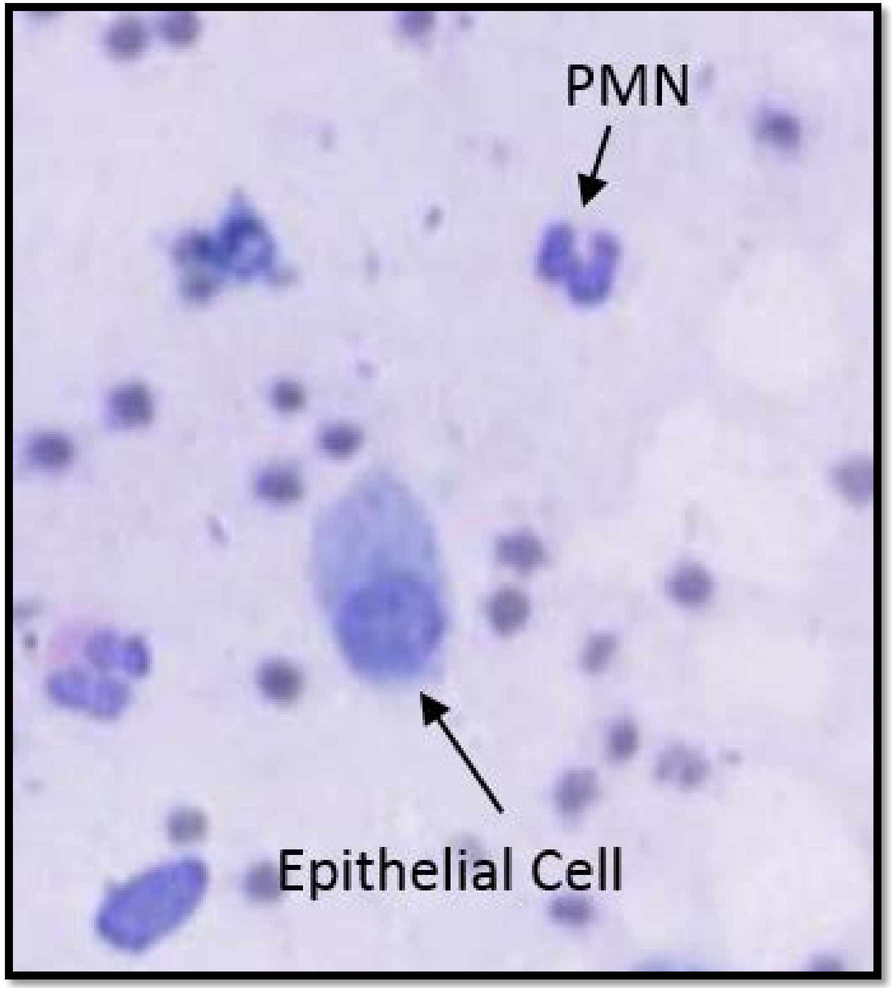




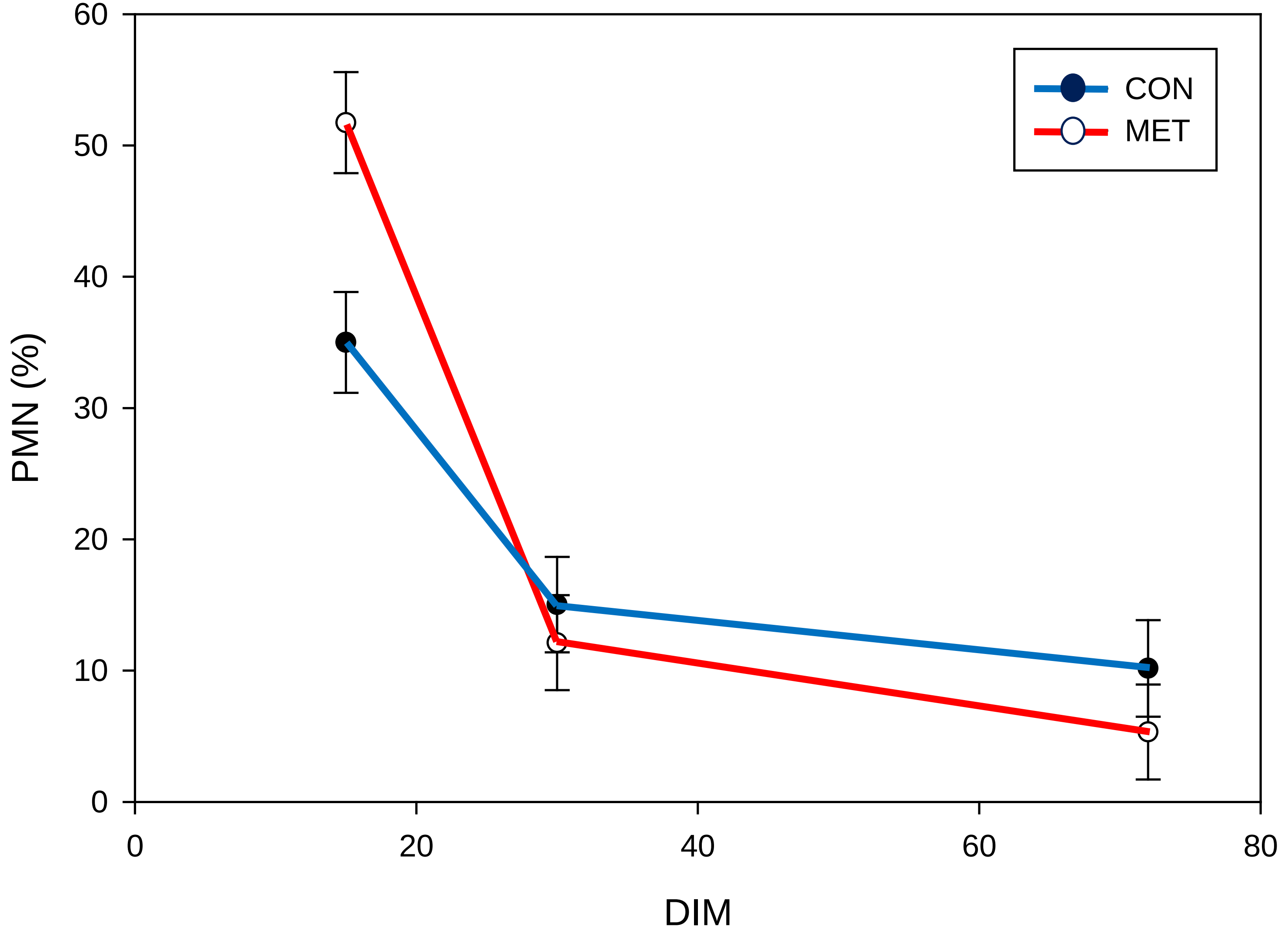




Uterine Cytology – Polymorphonuclear (PMN)



PMN in Uterus of Cows Fed rumen-protected methionine (MET) or not (CON)



Effect	*P*-Value
TRT	0.93
DIM	<0.001
TRT*DIM	0.01

Control: n = 36; Methionine: n = 36

Skenadore et al., 2017

Animal (2014), 8:s1, pp 54–63
doi:10.1017/S1751731114000524

animal

Reproductive tract inflammatory disease in *postpartum* dairy cows

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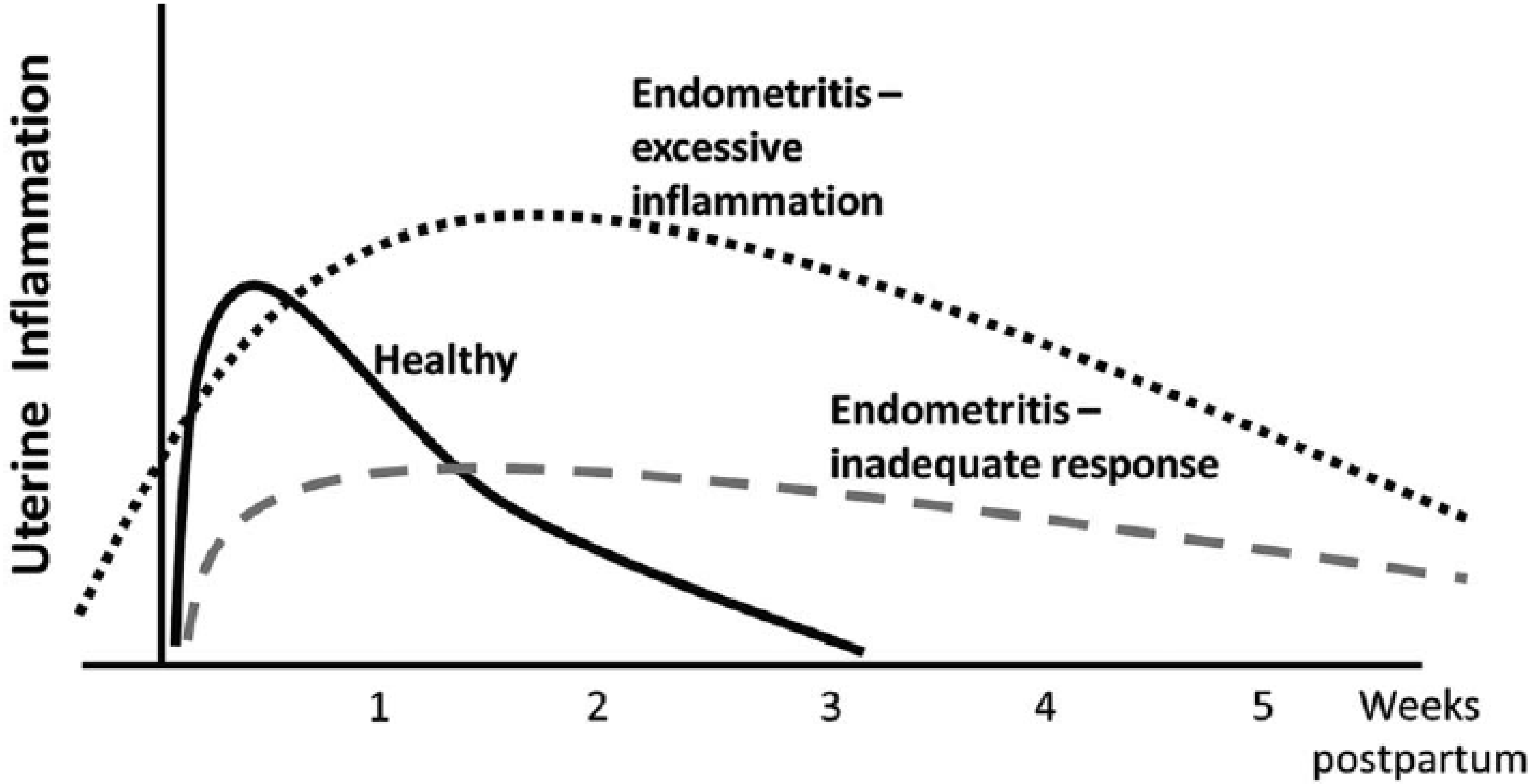
Department of Population Medicine, University of Guelph, Guelph, ON, Canada N1G 2W1

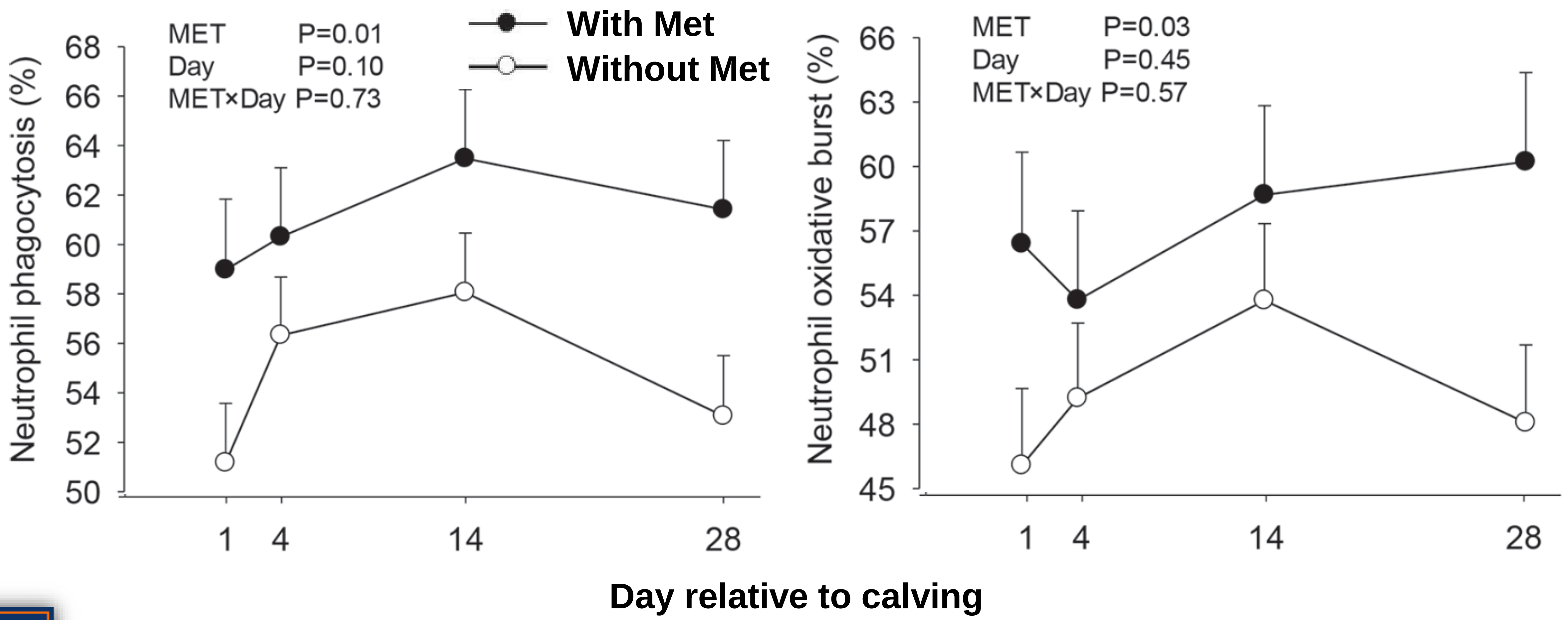
(Received 23 October 2013; Accepted 10 February 2014; First published online 28 March 2014)

Schematic Representation of Concepts of the Patterns of Immune and Inflammatory Response in Dairy Cows in the Postpartum Period

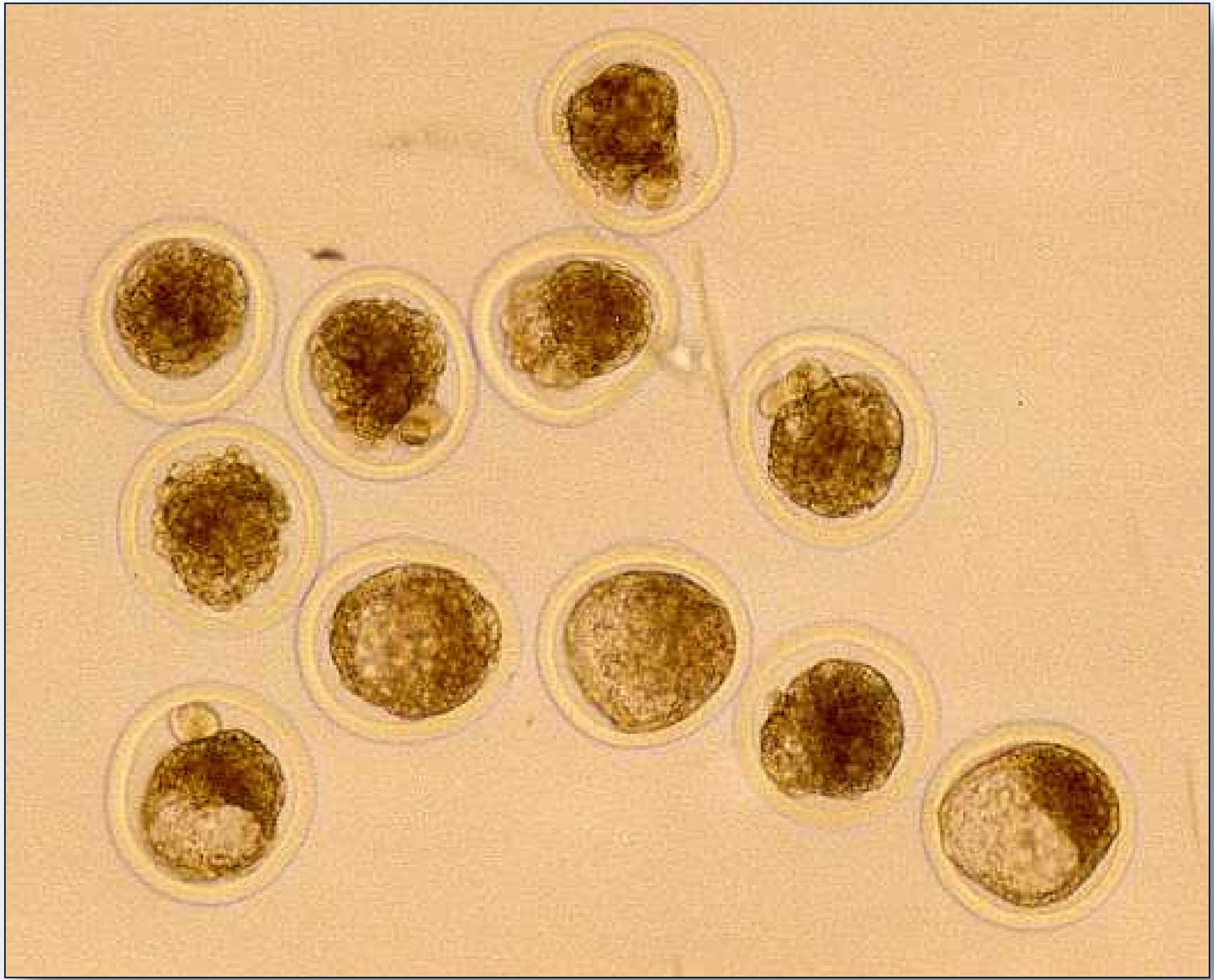


LeBlanc, 2014

Rumen-protected methionine improves immunometabolic status in dairy cows during the peripartal period



Zhou et al., 2016



Theriogenology 85 (2016) 1669–1679

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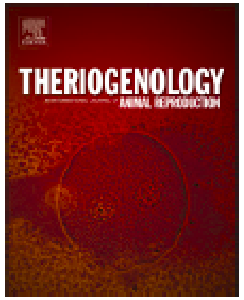


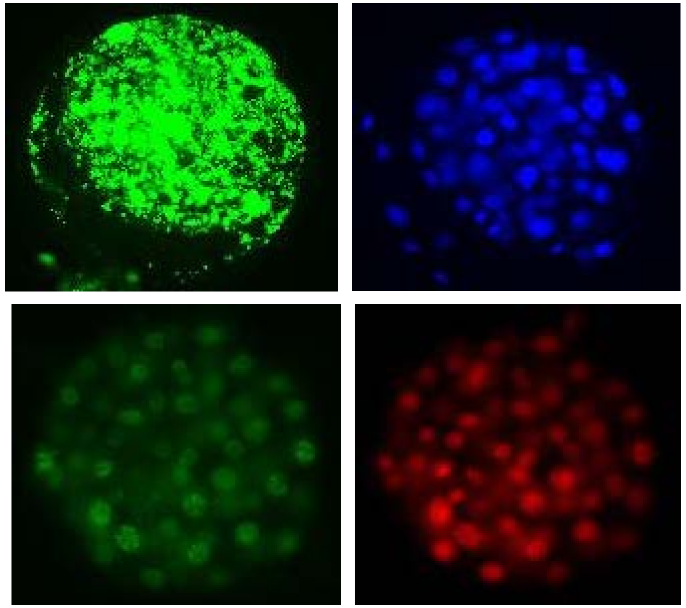
Effects of rumen-protected methionine and choline supplementation on the preimplantation embryo in Holstein cows

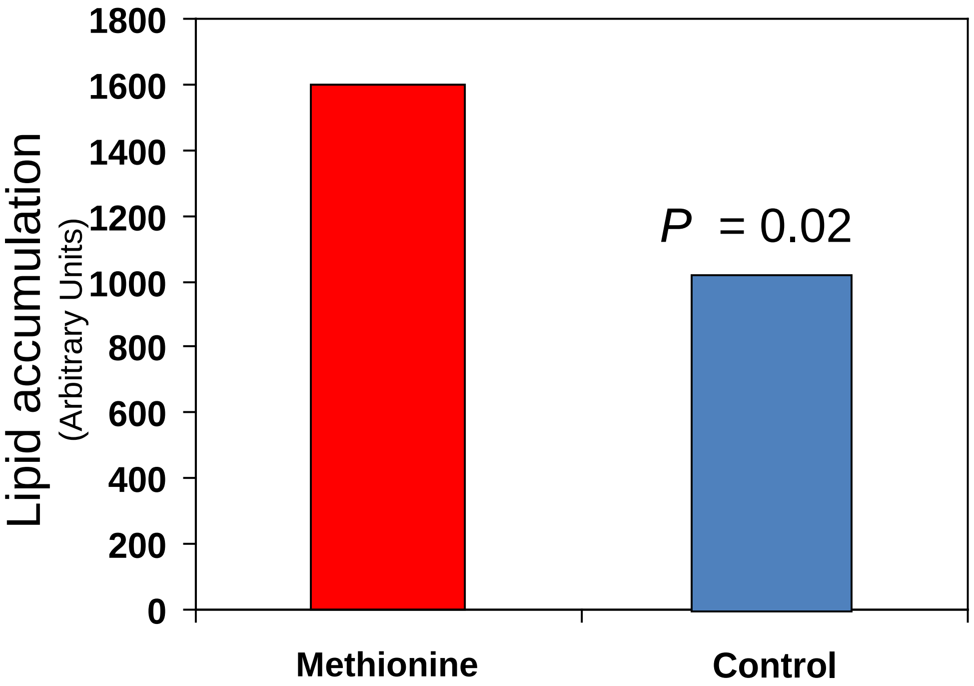
D.A.V. Acosta [a,b], A.C. Denicol [c,d], P. Tribulo [d], M.I. Rivelli [a], C. Skenandore [a], Z. Zhou [a], D. Luchini [e], M.N. Corrêa [b], P.J. Hansen [d], F.C. Cardoso [a,*]

[a] Department of Animal Sciences, University of Illinois, Urbana, Illinois, USA
[b] Faculty of Veterinary Medicine, Department of Clinics, Universidade Federal de Pelotas, Pelotas, Rio Grande do Sul, Brazil
[c] Department of Biology, Northeastern University, Boston, Massachussets, USA
[d] Department of Animal Science, University of Florida, Gainesville, Florida, USA
[e] Adisseo NACA, Alpharetta, Georgia, USA

Effect of Methionine Supplementation from -21 DIM to 72 DIM on Lipid Accumulation of Preimplantation Embryos

Embryos (n= 37) harvested 7 d after timed AI at 63 DIM from cows fed a control diet or the control diet enriched with rumen-protected methionine.





Fluorescence intensity of Nike Red staining

Acosta et al., 2016

OPEN ACCESS Freely available online

PLOS | ONE

Effect of Maternal Methionine Supplementation on the Transcriptome of Bovine Preimplantation Embryos

Francisco Peñagaricano[1], Alex H. Souza[2], Paulo D. Carvalho[2], Ashley M. Driver[1], Rocio Gambra[1], Jenna Kropp[1], Katherine S. Hackbart[2], Daniel Luchini[3], Randy D. Shaver[2], Milo C. Wiltbank[2]*, Hasan Khatib[1]*

1 Department of Animal Sciences, University of Wisconsin, Madison, Wisconsin, United States of America, 2 Department of Dairy Science, University of Wisconsin, Madison, Wisconsin, United States of America, 3 Adisseo USA Inc., Alpharetta, Georgia, United States of America

Penagaricano et al., 2013

OPEN ACCESS Fre

PLOS ONE

Effect of ... ion on the Transcri... bryos

Francisco Peña... Rocio Gambra[1],
Jenna Kropp[1], ... Wiltbank[2*],
Hasan Khatib[1*]

1 Department of Animal ... University of Wisconsin, Madison,
Wisconsin, United States

Table 3. Top 30 most significant genes that showed differential expression between control and methionine-rich treatment.

Gene	Name	log2 FC	FDR
LAPTM5	Lysosomal protein transmembrane 5	−14.9	4.7×10^{-9}
NKG7	Natural killer cell group 7 sequence	−13.6	4.4×10^{-8}
VIM	Vimentin	−13.8	1.8×10^{-7}
TYROBP	TYRO protein tyrosine kinase binding protein	−13.2	3.2×10^{-6}
IFI6	Interferon, alpha-inducible protein 6	−12.6	1.5×10^{-5}
CUFF.2147.1	*Novel transcript unit*	−8.2	1.5×10^{-5}
LOC505451	Olfactory receptor, family 1, subfamily J, member 2-like	−13.0	1.5×10^{-5}
SLAMF7	Signaling lymphocyte-activating molecule family 7 family member 7	−10.4	3.5×10^{-5}
LOC788199	Olfactory receptor 6C74-like	−10.4	7.6×10^{-5}
LCP1	Lymphocyte cytosolic protein 1 (L-plastin)	−9.9	1.1×10^{-4}
LOC100849660	*Uncharacterized*	11.9	2.2×10^{-4}
BLA-DQB	MHC class II antigen	−11.1	2.2×10^{-4}
SHC2	SHC (Src homology 2 domain containing) transforming protein 2	−11.5	3.4×10^{-4}
NT5C3	5′-nucleotidase, cytosolic III	−11.5	3.5×10^{-4}
LOC510193	Apolipoprotein L, 3-like	7.8	4.3×10^{-4}
LOC100848815	SLA class II histocompatibility antigen, DQ haplotype D alpha chain-like	−11.4	4.3×10^{-4}
CUFF.606.1	*Novel transcript unit*	−5.6	4.3×10^{-4}
LOC100850656	*Uncharacterized*	−11.2	4.8×10^{-4}
SLC11A1	Solute carrier family 11 (proton-coupled divalent metal ion transporters), member 1	−10.7	6.9×10^{-4}
LOC100852347	Beta-defensin 10-like	−11.2	7.3×10^{-4}
LOC100297676	C-type lectin domain family 2 member G-like	−6.8	9.2×10^{-4}
BCL2A1	BCL2-related protein A1	−7.1	1.2×10^{-3}
INSR	Insulin receptor	−5.1	1.3×10^{-3}
NOVA1	Neuro-oncological ventral antigen 1	−10.6	1.5×10^{-3}
TBX15	T-box 15	−11.2	2.2×10^{-3}
TMEM200C	Transmembrane protein 200C	−6.6	2.2×10^{-3}
GPNMB	Glycoprotein (transmembrane) nmb	−7.5	2.3×10^{-3}
ARHGAP9	Rho GTPase activating protein 9	−5.7	2.7×10^{-3}
EIF4E1B	Eukaryotic translation initiation factor 4E family member 1B	−11.3	3.1×10^{-3}
LOC100295170	Protein BEX2-like	−9.3	3.5×10^{-3}

A negative log2 Fold Change (FC) value means that the gene showed higher expression in control treatment while a positive value means that the gene showed higher expression in methionine-rich treatment.

doi:10.1371/journal.pone.0072302.t003

University of

Penagaricano et al., 2013

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Effect of ... ion on the Transcri... bryos

Francisco Peña ... Rocio Gambra[1], Jenna Kropp[1] ... Wiltbank[2*]

PLOS ONE

Table 3. Top 30 most significant genes that showed differential expression between control and methionine-rich treatment.

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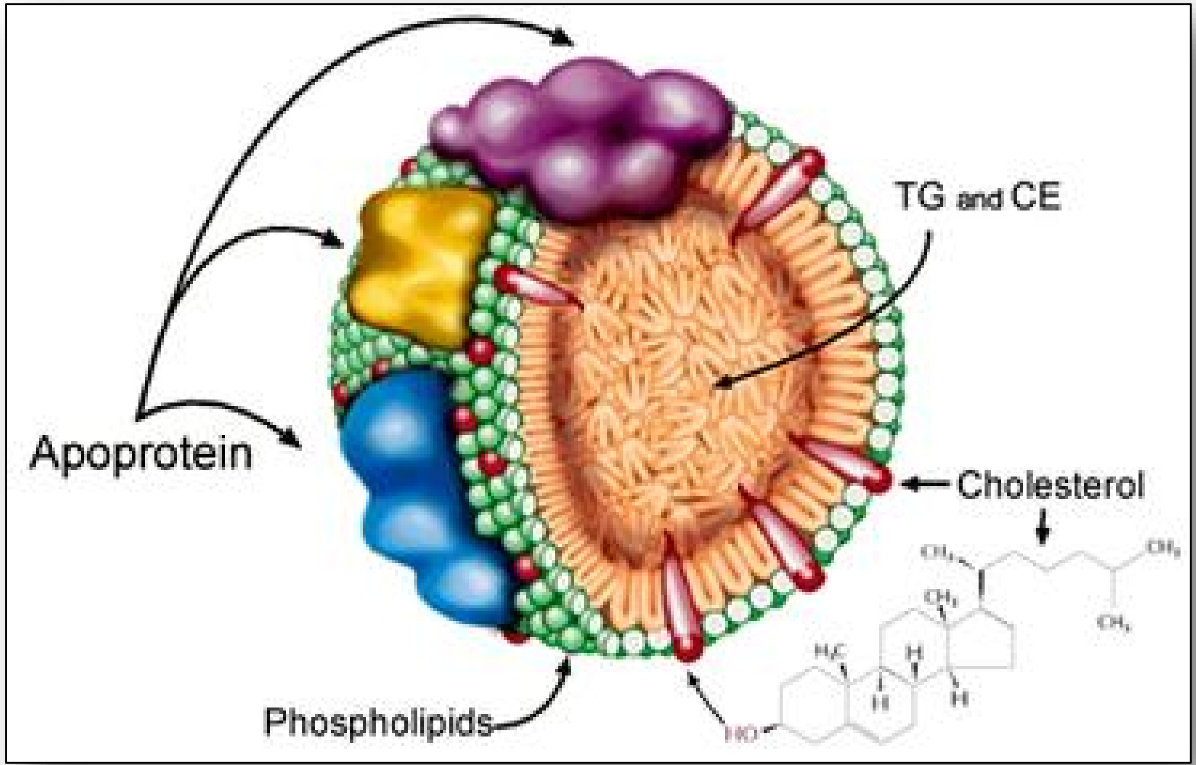
NKG7	Natural killer cell group 7 sequence	−13.6	4.4×10^{-8}
VIM	Vimentin	−13.8	1.8×10^{-7}
TYROBP	TYRO protein tyrosine kinase binding protein	−13.2	3.2×10^{-6}
IFI6	Interferon, alpha-inducible protein 6	−12.6	1.5×10^{-5}
CUFF.2147.1	*Novel transcript unit*	−8.2	1.5×10^{-5}
LOC505451	Olfactory receptor, family 1, subfamily J, member 2-like	−13.0	1.5×10^{-5}
SLAMF7	Signaling lymphocyte-activating molecule family 7 family member 7	−10.4	3.5×10^{-5}
LOC788199	Olfactory receptor 6C74-like	−10.4	7.6×10^{-5}
LCP1	Lymphocyte cytosolic protein 1 (L-plastin)	−9.9	1.1×10^{-4}
LOC100849660	*Uncharacterized*	11.9	2.2×10^{-4}
LOC510193	Apolipoprotein L, 3-like	7.8	4.3×10^{-4}
CUFF.606.1	*Novel transcript unit*	−5.6	4.3×10^{-4}
LOC100850656	*Uncharacterized*	−11.2	4.8×10^{-4}
SLC11A1	Solute carrier family 11 (proton-coupled divalent metal ion transporters), member 1	−10.7	6.9×10^{-4}
LOC100852347	Beta-defensin 10-like	−11.2	7.3×10^{-4}
LOC100297676	C-type lectin domain family 2 member G-like	−6.8	9.2×10^{-4}
BCL2A1	BCL2-related protein A1	−7.1	1.2×10^{-3}
INSR	Insulin receptor	−5.1	1.3×10^{-3}
NOVA1	Neuro-oncological ventral antigen 1	−10.6	1.5×10^{-3}
TBX15	T-box 15	−11.2	2.2×10^{-3}
TMEM200C	Transmembrane protein 200C	−6.6	2.2×10^{-3}
GPNMB	Glycoprotein (transmembrane) nmb	−7.5	2.3×10^{-3}
ARHGAP9	Rho GTPase activating protein 9	−5.7	2.7×10^{-3}
EIF4E1B	Eukaryotic translation initiation factor 4E family member 1B	−11.3	3.1×10^{-3}
LOC100295170	Protein BEX2-like	−9.3	3.5×10^{-3}

A negative log2 Fold Change (FC) value means that the gene showed higher expression in control treatment while a positive value means that the gene showed higher expression in methionine-rich treatment.

doi:10.1371/journal.pone.0072302.t003

University of

Penagaricano et al., 2013



Apolipoproteins are involved in the transport and metabolism of lipids, including cholesterol, and allow the binding of lipids to organelles

Methionine influences lipid metabolism in the preimplantation embryo

Penagaricano et al., 2013

Effect of Supplementation with Smartamine M on Reproduction of Lactating Dairy Cows

Cows were fed a basal TMR (6.9% Lys of MP and 1.87% Met of MP) from 30 ± 2 to 128 ± 2 DIM and assigned to two treatments:

RPM: Basal TMR top dressed daily with Smartamine M

CON: Basal diet top dressed daily with DDG

Toledo et al., *unpublished*

Effect of Supplementation with Smartamine M on Reproduction of Lactating Dairy Cows

RPM cows were top dressed with 50 g (29 g DDG and 21 g of Smartamine M)
CON cows were top dressed with 50 g of DDG

RPM

CON

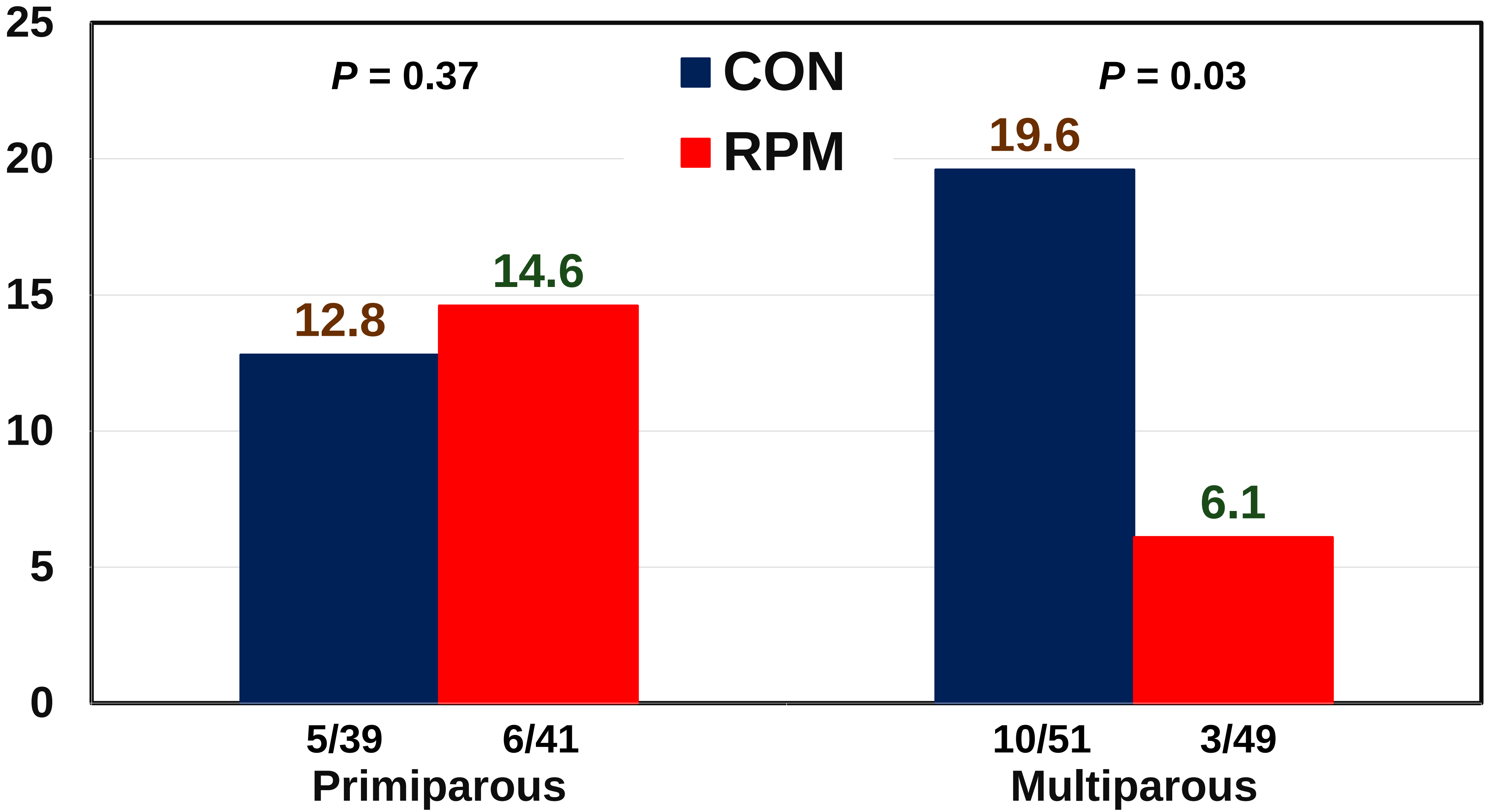
Toledo et al., *unpublished*

Animals

	CONTROL	RPM	TOTAL
Primiparous	68	70	138
Multiparous	85	86	171
TOTAL	153	156	309

Toledo et al., *unpublished*

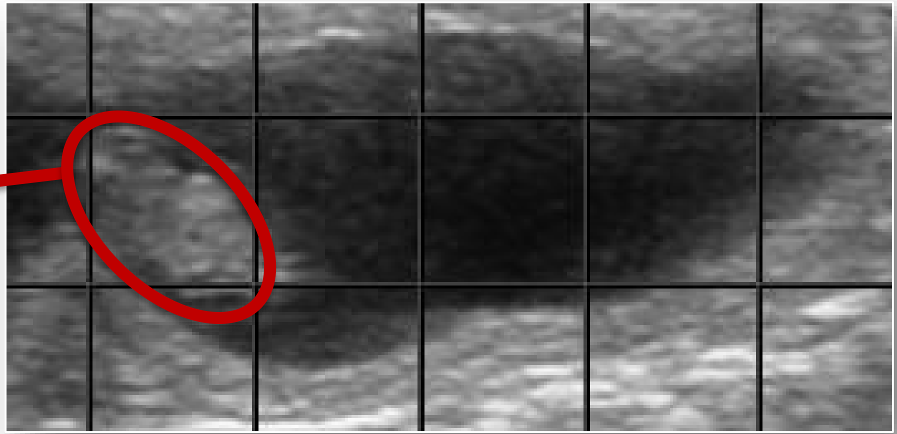
Pregnancy Losses (%) from 28 to 61 days after AI



Toledo et al., *unpublished*

Amniotic vesicle size

Ellipsoid Volume



Day 33	n	Volume (mm^3) ± SEM
Primiparous		
Control	31	**610.6** ± 38.6
RPM	36	**596.0** ± 36.9
P-value		**0.71**
Multiparous		
Control	35	**472.3** ± 28.6
RPM	45	**592.1** ± 46.0
P-value		**0.05**

Toledo et al., *unpublished*

Is *Increased* Embryo Lipid Composition Associated with Lower Embryonic Death in Dairy Cows?

Is *Increased* In-Utero Lysine Concentration (d 16 – 19) Associated with Lower Embryonic Death in Dairy Cows?

Summary

- Promote high DMI immediately after calving.
- Rumen-protected methionine increased methionine concentration in serum and follicular fluid of dairy cows.
- The cow's pregnancy success starts during the transition phase.
- Amino acid balancing (methionine and lysine) from pre-fresh to confirmed pregnancy may not only improve milk production and composition, it may also improve embryo quality and reduce early embryo losses.

- Manage dietary ingredients for
  - Manage for adequate CP (~13% Dry & 16% Lactation)
  - Metabolizabe methionine in TMR (30 g/d Dry & 46 g/d Lactation)
    - ~ 15 g/d Dry & 20 g/d Lactation of rumen-protected methionine
  - Metabolizabe lysine in TMR (84 g/d Dry & 129 g/d Lactation)
    - ~ 26 g/d Dry & 36 g/d Lactation rumen-protected lysine
    - Balanced for the ratios: Met 2.6% MP; Lys, 7.0% MP (LYS:MET ratio of 2.8:1)
    - Methionine supply relative to energy is ~ 0.97-1.0 g/Mcal ME
    - Lysine supply relative to energy is ~ 2.72-2.78 g/Mcal ME
- Pregnancy rate > 20% (go for > 25%; conception rate at first AI > 40%)
- Embryonic death < 15% (go for < 10%)

Dairy Focus Lab

THANK YOU

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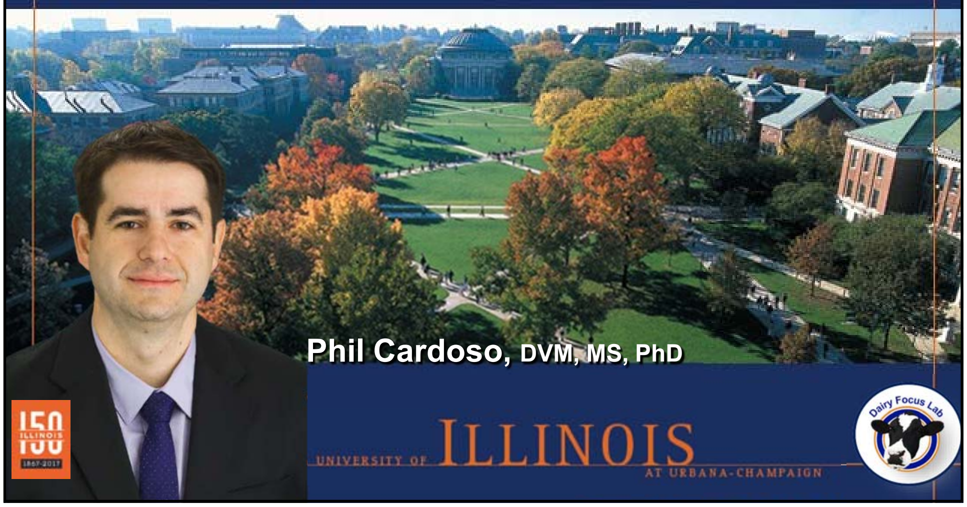
Foliar fungicide application on corn can enhance dairy cow performance



Phil Cardoso, DVM, MS, PhD

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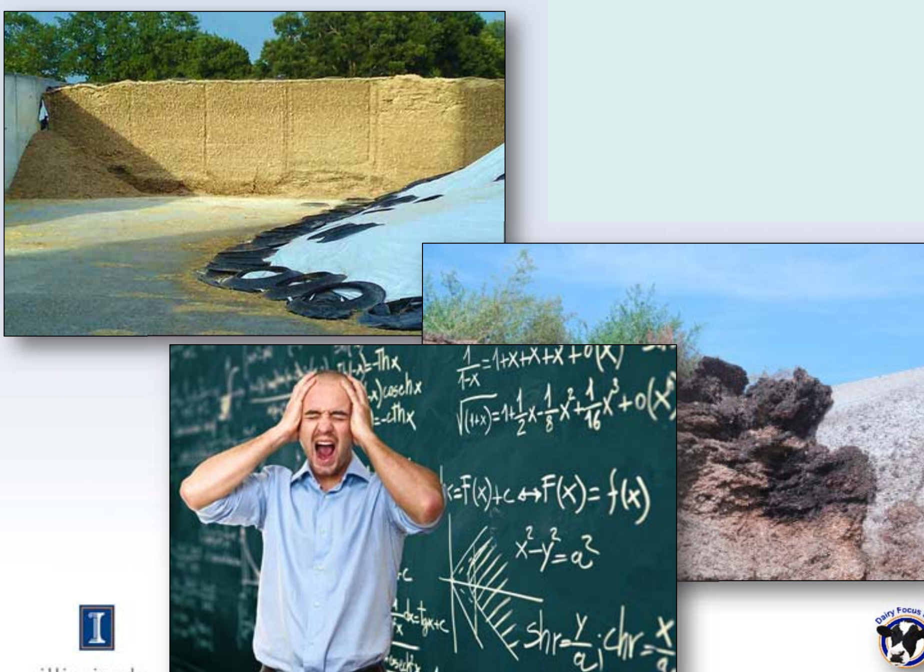

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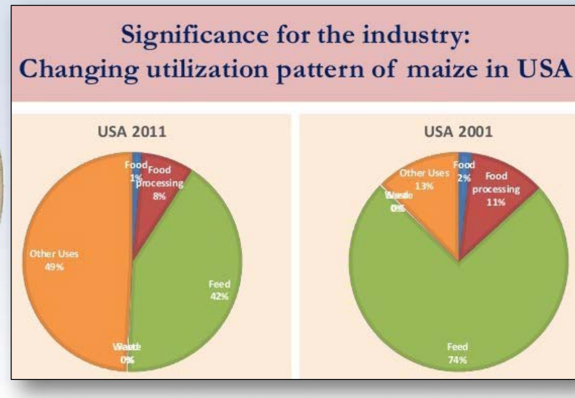
Source: FAOSTAT 2015



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Source: FAOSTAT 2015

Outline

- Introduction
- Effects of corn silage treated with various applications of foliar fungicide on
  - corn silage quality and cow performance
  - *in situ* digestibility in Holstein cows
- Economic considerations and concluding remarks

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Introduction

- Fungus…
  – Very diverse kingdom of organisms including yeasts and molds
  – May be beneficial
    - Recent research done shows that fungi may be a useful tool in helping to decrease the spread of malaria
    - Ergot may help plant growth
  – May be (
    - Fungu … n CCD i
    - May b … ed by h … nimals



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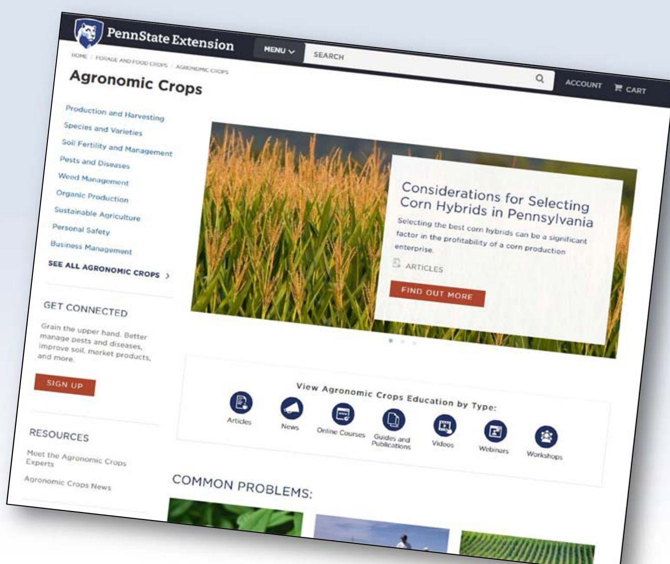
Corn Varieties



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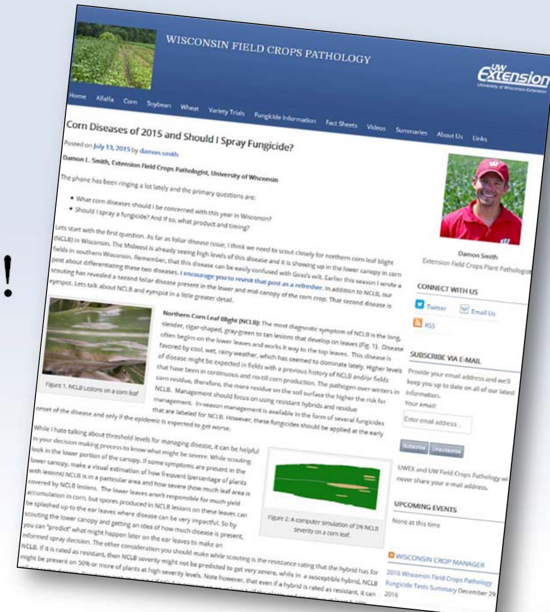
https://extension.psu.edu/forage-and-food-crops/agronomic-crops

Fungus in Corn – Scout!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Corn Diseases of 2015 and Should I Spray Fungicide?

Posted on July 13, 2015 by damon.smith

Damon L. Smith, Extension Field Crops Pathologist, University of Wisconsin

The phone has been ringing a lot lately and the primary questions are:

- What corn diseases should I be concerned with this year in Wisconsin?
- Should I spray a fungicide? And if so, what product and timing?

Lets start with the first question. As far as foliar disease issue, I think we need to scout closely for northern corn leaf blight (NCLB) in Wisconsin. The Midwest is already seeing high levels of this disease and it is showing up in the lower canopy in corn fields in southern Wisconsin. Remember, that this disease can be easily confused with Goss's wilt. Earlier this season I wrote a post about differentiating these two diseases. I encourage you to revisit that post as a refresher. In addition to NCLB, our scouting has revealed a second foliar disease present in the lower and mid-canopy of the corn crop. That second disease is eyespot. Lets talk about NCLB and eyespot in a little greater detail.

Figure 1. NCLB Lesions on a corn leaf

Northern Corn Leaf Blight (NCLB): The most diagnostic symptom of NCLB is the long, slender, cigar-shaped, gray-green to tan lesions that develop on leaves (Fig. 1). Disease often begins on the lower leaves and works it way to the top leaves. This disease is favored by cool, wet, rainy weather, which has seemed to dominate lately. Higher levels of disease might be expected in fields with a previous history of NCLB and/or fields that have been in continuous and no-till corn production. The pathogen over-winters in corn residue, therefore, the more residue on the soil surface the higher the risk for NCLB. Management should focus on using resistant hybrids and residue management. In-season management is available in the form of several fungicides that are labeled for NCLB. However, these fungicides should be applied at the early onset of the disease and only if the epidemic is expected to get worse.

While I hate talking about threshold levels for managing disease, it can be helpful in your decision making process to know what might be severe. While scouting look in the lower portion of the canopy. If some symptoms are present in the lower canopy, make a visual estimation of how frequent (percentage of plants with lesions) NCLB is in a particular area and how severe (how much leaf area is covered by NCLB lesions. The lower leaves aren't responsible for much yield accumulation in corn, but spores produced in NCLB lesions on these leaves can be splashed up to the ear leaves where disease can be very impactful. So by scouting the lower canopy and getting an idea of how much disease is present, you can "predict" what might happen later on the ear leaves to make an informed spray decision. The other consideration you should make while scouting is the resistance rating that the hybrid has for NCLB. If it is rated as resistant, then NCLB severity might not be predicted to get very severe, while in a susceptible hybrid, NCLB might be present on 50% or more of plants at high severity levels. Note however, that even if a hybrid is rated as resistant, it can

Figure 2: A computer simulation of 5% NCLB severity on a corn leaf.

Damon Smith
Extension Field Crops Plant Pathologist

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Provide your email address and we'll keep you up to date on all of our latest information.

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UWEX and UW Field Crops Pathology wi never share your e-mail address.

UPCOMING EVENTS

None at this time

WISCONSIN CROP MANAGER

2016 Wisconsin Field Crops Pathology Fungicide Tests Summary December 29 2016

http://fyi.uwex.edu/fieldcroppathology/2015/07/13/corn-diseases-of-2015-and-should-i-spray/

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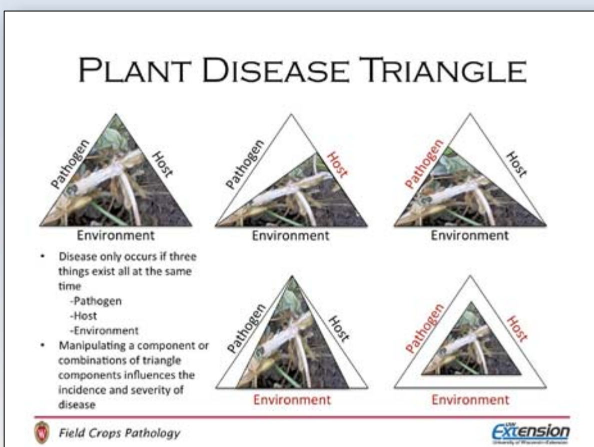
Fungus in Corn



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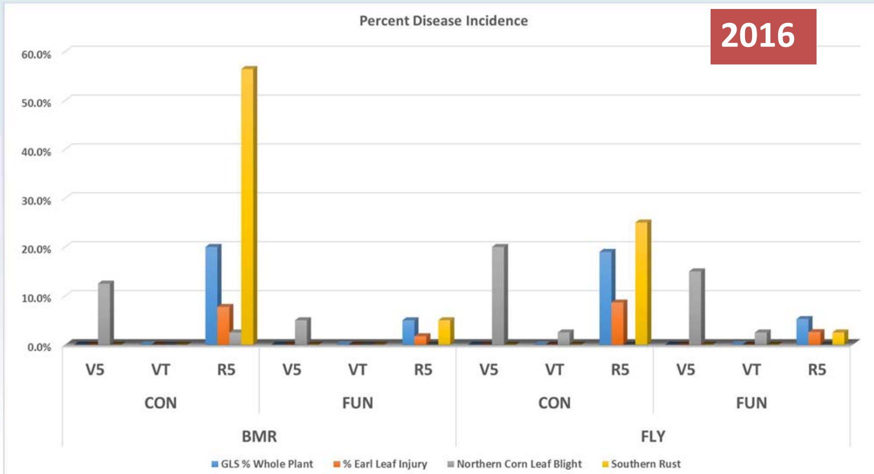
Fungus in Corn



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Weatherly et al., *unpublished*

Corn Silage

- Process dates back thousands of years
- Popularity has increased since the 60's when the forage harvester was invented (Wilkinson et al., 2003)
- Popular due to its ability to keep nutritive value, and increase digestibility over time
- NASS estimates that in 2014 corn silage production was
  - 128 million tons
  - 20.1 tons/acre (as fed)

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Fungicide Use in Corn

- Common practice on modern farms
  - Disease scoring done to determine need for application
  - May be applied once twice or none
  - In 2007 it was estimated that 16% of corn planted was sprayed with foliar fungicide (Bradley and Ames, 2009)
- Most common fungicides are
  - Strobilurin
  - Triazole

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Fungicide Use in Corn: Plant Yield Effect

- Foliar fungicide (Pyraclostrobin) may increase crop yield by 255 kg/ha (5 bu/acre) (Paul et al., 2011)
  - Due to control of infection (Blandino et al., 2012)
  - Physiological effects caused by foliar fungicide (Kohle et al., 2002)
- 46% of trials conducted using a Quinone outside inhibitor (QoI) found a significant yield increase
  - Disease severity < 5% : 1.5 bu/acre increase
  - Disease severity >5%: 9.6 bu/acre increase (Wise & Mueller, 2011)

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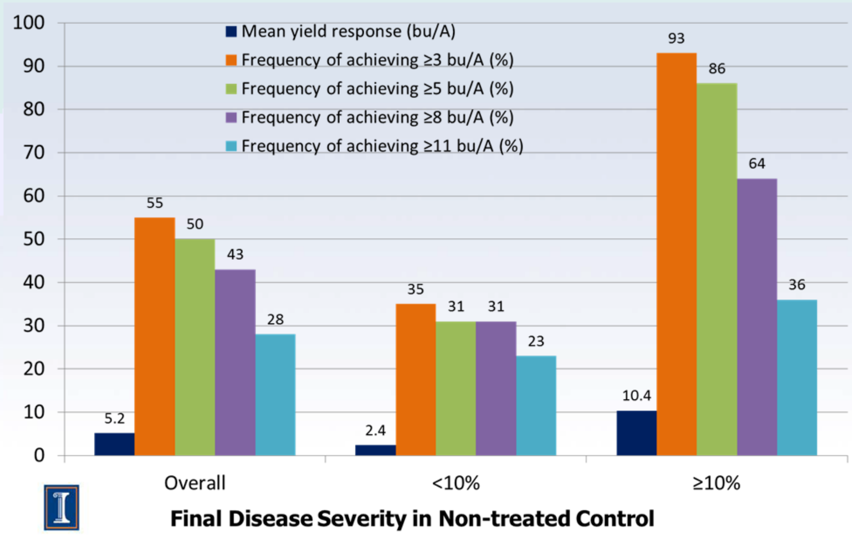
Fungicide Use in Corn: Plant Yield Effect



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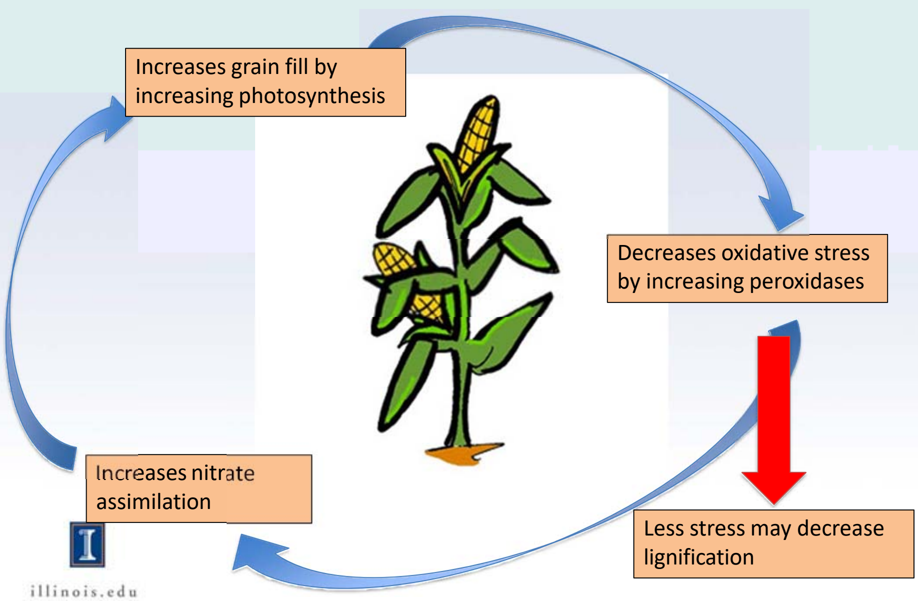
Adapted from Carl Bradley

Pyraclostrobin: Plant Health Effects



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Pyraclostrobin: Grain Fill

- Decreased leaf senescence in upper canopy
  - Area under green leaf incidence curve greater for corn treated with fungicide (Byanukama et al., 2013)
- Linear decrease in yield response to defoliation
  - 11% decrease in yield when leaves dropped prior to silking
- Leaf dropping may be due to
  - Decrease in disease severity

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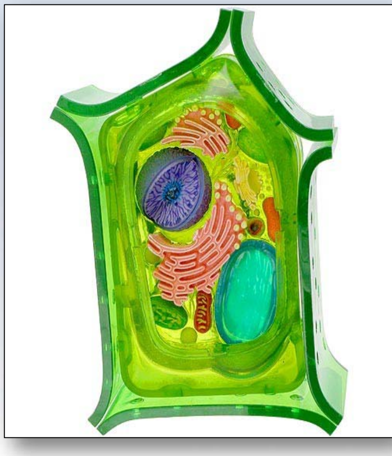
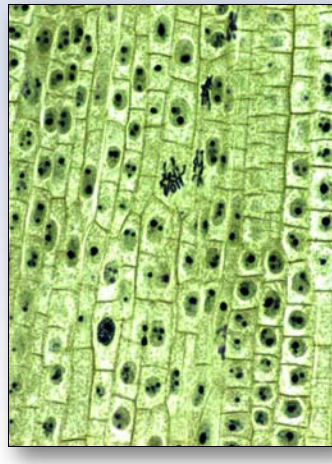
Key Forage Quality Factors





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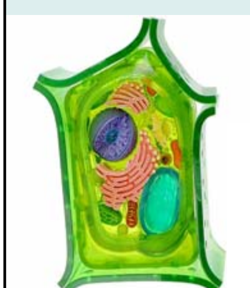
Key Forage Quality Factors



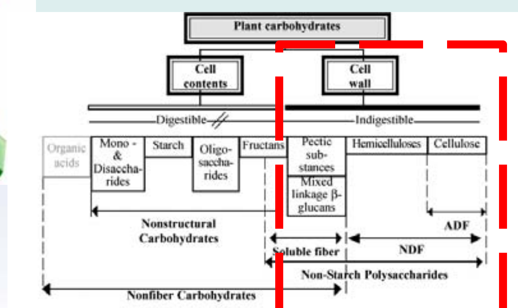
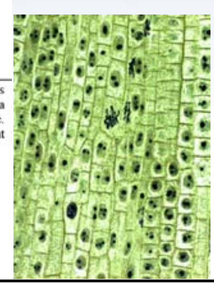


Figure 1 - Carbohydrates in plants. *Digestible or Indigestible* refer to potential for digestion by enzymes in the small intestine; all carbohydrates shown are potentially fermentable. Organic acids are not a carbohydrate, but their mass is included in the nonfiber carbohydrate value that is calculated by difference. As shown, soluble fiber includes only non-starch polysaccharides not in NDF. NDF = neutral detergent fiber, ADF = acid detergent fiber.



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Cell wall fraction makes up approximately 70% of corn silage

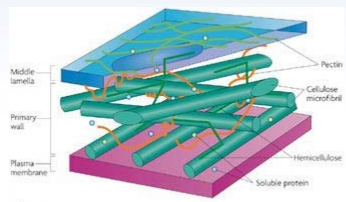
Key Forage Quality Factors

NDF

- Cellulose, hemicellulose, lignin
- Going from low to high NDFD can increase milk 11 lb/d (Grant et al, 1995)
- Plant stress can cause more lignin content and decrease NDFD (Yates et al., 1997)
  - Cold stress
  - Drought stress
  - Infection stress

ADF

- Cellulose, lignin
- Related to plant cell wall digestibility
- Negative correlation between ADF and DMI (Van Soest, 1965)
- Negative correlation with *in vitro* NDFD (Allen et al, 2003)



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Other Forage Quality Factors

- Mycotoxins
  - Produced by secondary metabolism of *Aspergillus*, *Penicillium*, *Fusarium*, and *Alternaria* (Keller et al., 2013)
  - Field disease scoring for infection may not be adequate to determine mycotoxin content (Eckard et al., 2011)
  - Can lead to loss of nutrients, dry matter, and palatability, can also decrease rumen function and decrease reproductive performance (Scudamore & Livesy, 1998)

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Mycotoxins

Fusarium

- Responsible for production of fumonisin
  - Deoxynivalenol, HT-2, T-2, and zearalenone
- May reduce nutritive value of plant
- Ruminants are more resistant to zearalenone
- May alter immune mediated responses

(Keller et al., 2003, Miller et al.,1983)

Aspergillus flavus

- Spores of *A. flavus* are spread through soil & insects
- Develops pre-harvest and thrives in mild temperatures and drought conditions
- Responsible for production of aflatoxins
  - B1 is carcinogenic and can be passed into milk

(Keller et al., 2003,Diener et al.,1987)

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Fungicide Effects on Corn Silage

- Corn treated with Headline® (pyraclostrobin) and harvested for silage when compared to control
  - Increased yield by 0.7 tons DM/acre
  - Decreased NDF content while increasing NDFD content
  - Predicted increase of 75 lbs milk/ton and 2,500 lbs milk/acre using MILK 2006

(Esker & Blond, 2007)

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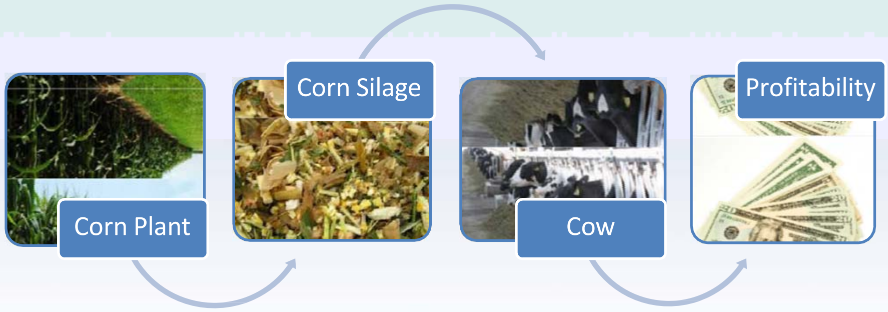

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J. Dairy Sci. 98:8962–8972
http://dx.doi.org/10.3168/jds.2015-9887

Corn silage from corn treated with foliar fungicide and performance of Holstein cows

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†Departamento de Zootecnia, Universidade Federal de Lavras, Lavras, MG, Brazil 37200-000
‡BASF Corporation, Research Triangle Park, NC 27709

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Objective

- To determine if corn treated with foliar fungicide and ensiled has increased nutrient density, digestibility, and

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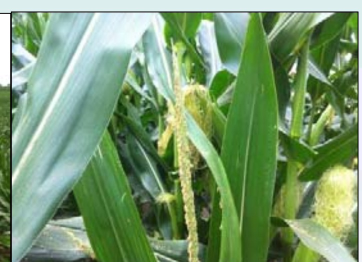
The Effect of Corn Treated with Various Applications of Foliar Fungicide on Corn Silage Composition and Cow Performance



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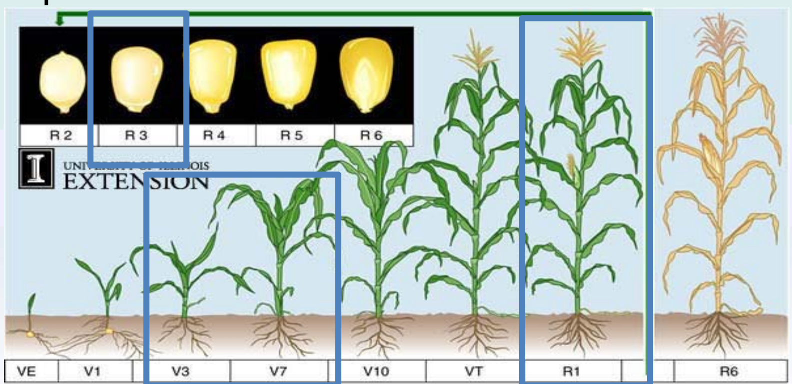
Materials and Methods

- 4 Treatments



CON: No Applications of foliar fungicide	1X: 1 Application of Headline® at V5	2X: 1 Application of Headline® at V5, 1 Application of Headline® AMP at R1	3X: 1 Application of Headline® at V5, 1 Application of Headline® AMP at R1 and R3

Active ingredient in Headline®: Pyraclostrobin
Headline® AMP: Pyraclostrobin + Metconazole

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Materials & Methods

- Corn
  - Variety: LG seeds/ CPS variety LG2636 VT3P RIB
  - Planting date: June, 5 2013
  - Harvest date: September 27, 2013
    - DM: 33, 30, 30, & 32.5% for CON, 1X, 2X, and 3X
  - Disease scoring at silk emergence and kernel milk stage (August 2nd and August 16th)
    - **No Evidence of plant disease**
  - Theoretical length of chop
    - ¾ inch

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Materials & Methods

- Cows
  - 64 multiparous and primiparous Holstein cows (DIM 161 ± 51)
  - Housed in tie stall barn
  - Fed at 3PM
  - Milked 3x at 4 AM, 12 PM, and 8 PM
  - Fed diet to meet NRC requirements

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Diet Composition

Ingredient	% DM
Alfalfa hay	6.90
Corn silage	34.9
Alfalfa silage	6.09
Cottonseed	3.25
Wet brewers grain	8.12
Soy hulls	4.87
Concentrate mix	45.7

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Materials & Methods

- **Aerobic Stability**
  - A representative sample of corn silage was obtained and aerated in a bucket
  - 3 loggers were put into each treatment and temperature after 38 h was considered aerobic stability
  - Environmental temperature was used as a covariate
  - Replicated 3x
- **Density**
  - Taken 2x per week using master forage probe
  - Samples taken from 5 different locations & depth was recorded
  - DM was then taken to calculate DM density

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Statistical Analysis

- Contrasts
  - CON *vs* TRT:
    - Control vs the average of 1X, 2X, and 3X
  - Linear
  - Quadratic
- Significance declared at $P \leq 0.05$
- Tendencies at $0.05 < P \leq 0.10$

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Corn silage yield did not change

- No symptoms of foliar disease
- Yield
  - CON: 61.12 Mg/ha or 9 tons/ acre (DM)
  - 1X: 59.70 Mg/ha or 8.0 tons/ acre (DM)
  - 2X: 63.99 Mg/ha or 9.2 tons/ acre (DM)
  - 3X: 61.22 Mg/ha or 9 tons/ acre (DM)

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Dry matter intake decreased with fungicide application

CON vs TRT: *P* = 0.08
Linear: *P* = 0.01
Quad: *P* = 0.11

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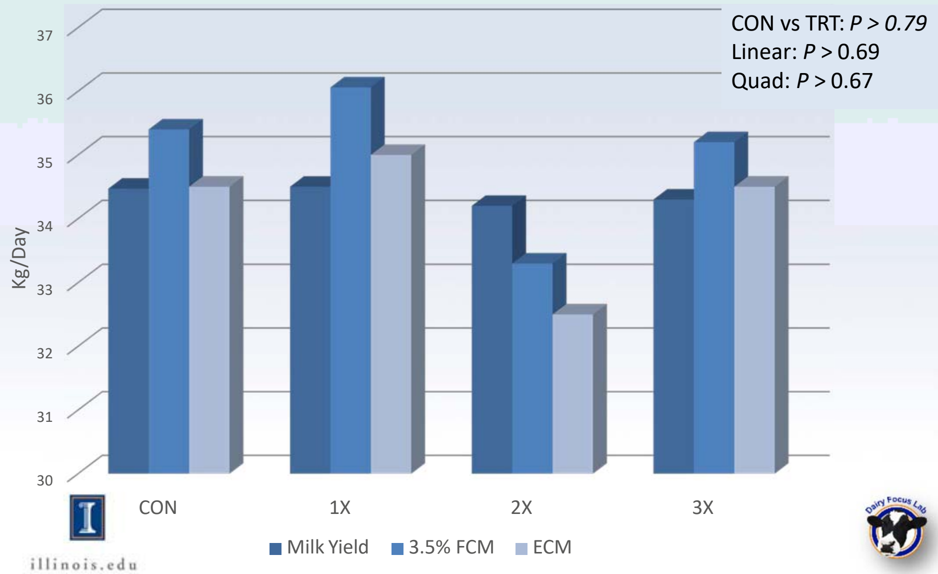
Milk yield kept the same



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So…

- The diet had the same analyzed energy content but cows fed treated corn silage tended to eat less than cows eating CON
- However milk production remained the same

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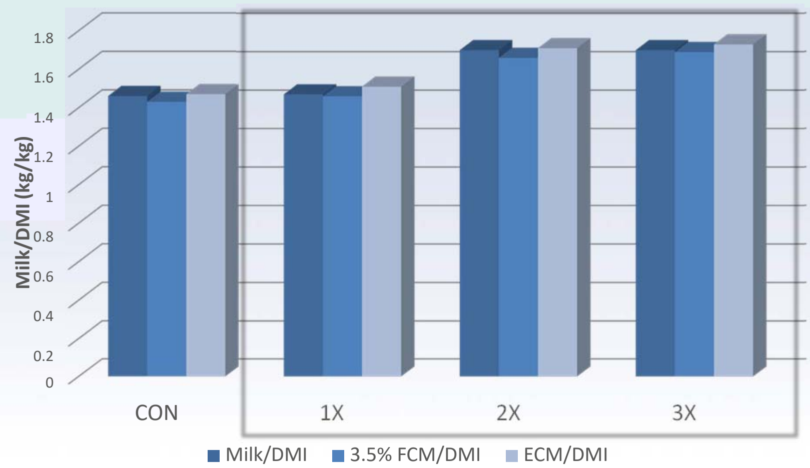
Feed efficiency increased with fungicide application



CON vs TRT: *P = 0.14*
Linear: *P* = 0.03
Quad: *P* = 0.95

CON vs TRT: *P = 0.09*
Linear: *P* = 0.01
Quad: *P* = 0.94

CON vs TRT: *P = 0.08*
Linear: *P* = 0.02
Quad: *P* = 0.99

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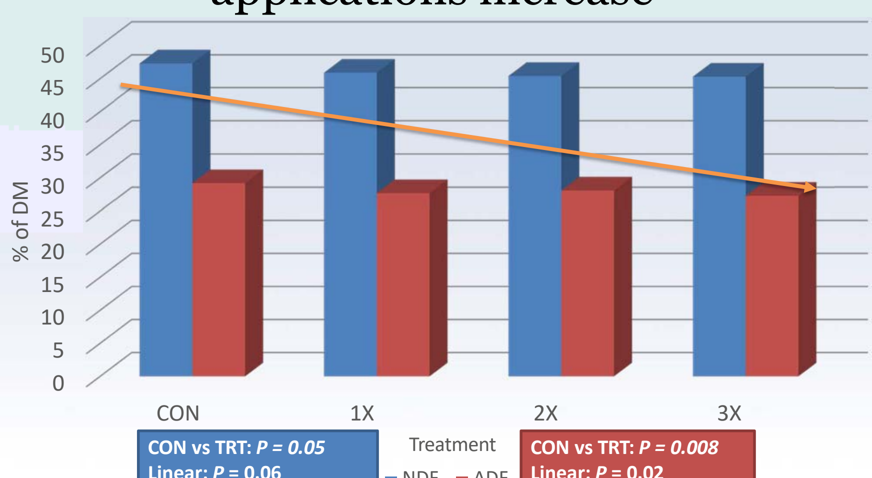
Fiber content decreases as amount of applications increase



CON vs TRT: *P = 0.05*
Linear: *P* = 0.06
Quad: *P* = 0.39

CON vs TRT: *P = 0.008*
Linear: *P* = 0.02
Quad: *P* = 0.43

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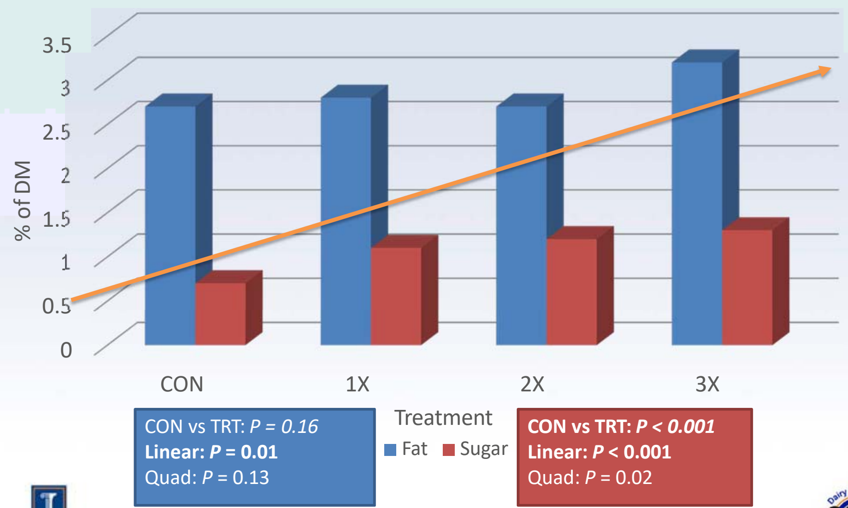
Sugar content increases as application number increases



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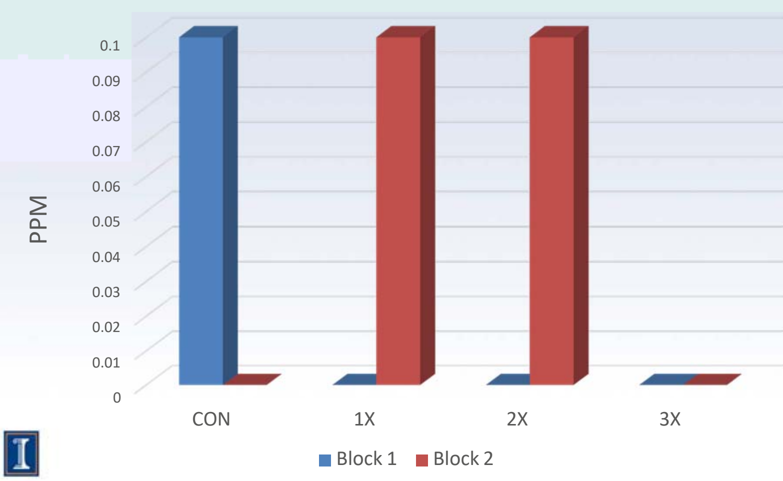
Mycotoxins

- 15-acetyl Deoxynicalenol



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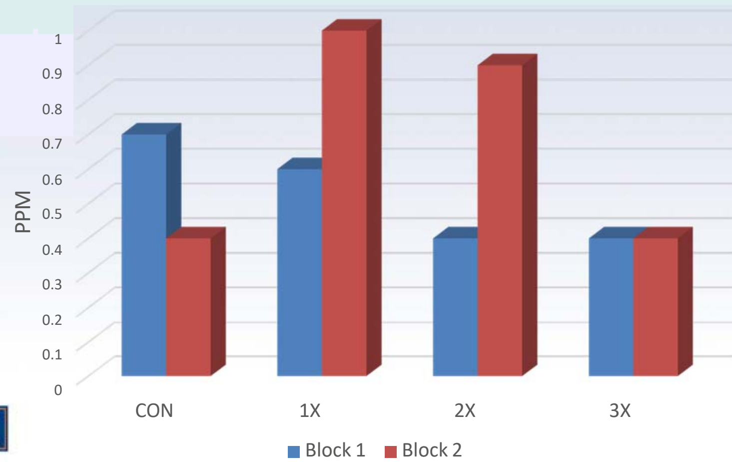
Mycotoxins

- Deoxyscirepenol



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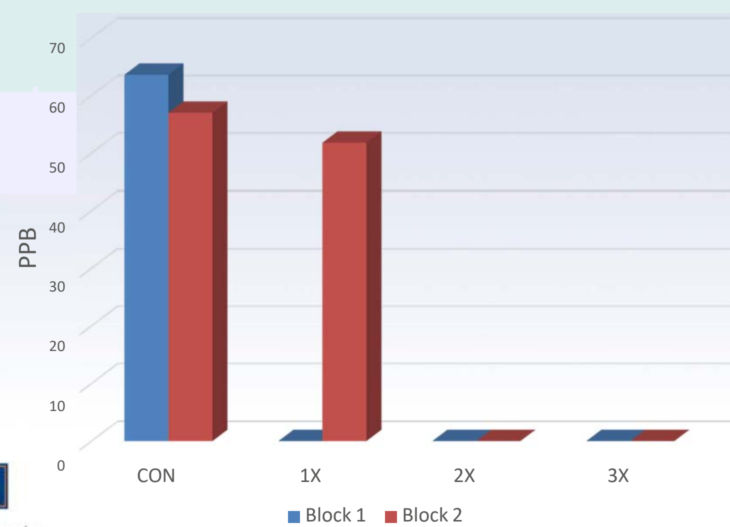
Mycotoxins

- Zearalenone



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- Toxins were lower in treated silage, but even CON had no visible sign of infections, and relatively low concentrations of toxins

Potentially Harmful Toxin Levels for a Total Diet (DM)					
	Dairy	Feedlot	Swine	Poultry	Equine
Toxin	Values listed in blue are PPM, all other listed in PPB				
Aflatoxin	20	20	20	20	20
Deoxynivalenol (DON or Vomitoxin)*	0.5 to 1.0	10	1	2	500
Fumonisin	2	7	10	20	500
T-2 Toxin	100	500	100	100	NA
Zearalenone	400	5	300	10	50
Ochratoxin	5	5	700	700	35
Ergot toxins (combined)	500	500	500	750	300

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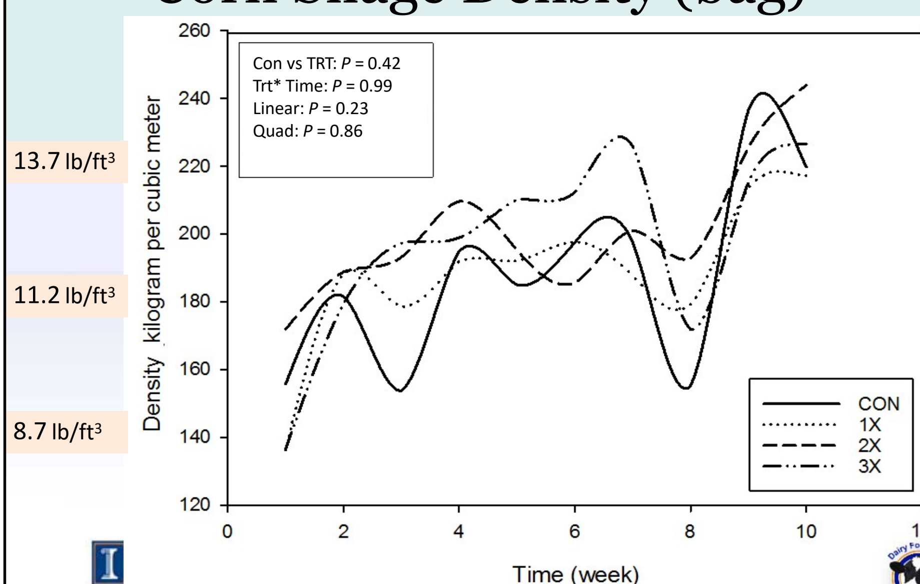
Corn Silage Density (bag)



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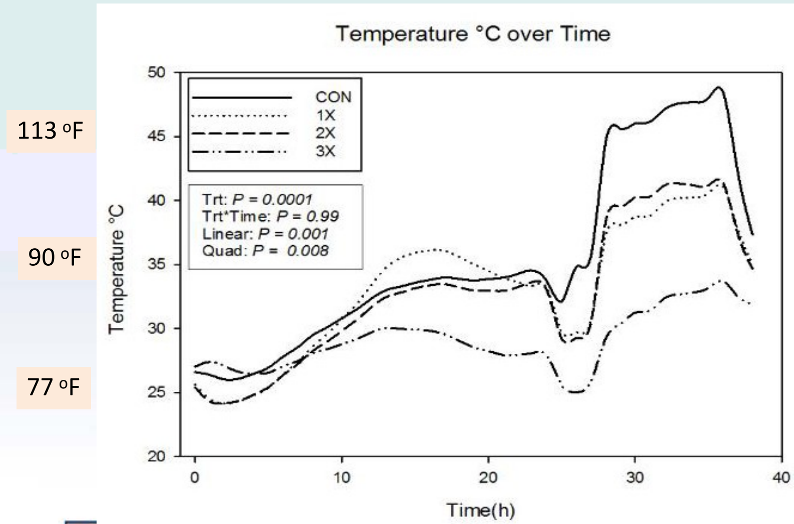
Aerobic Stability



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Summary

- Differences in
  - DMI
  - Feed conversion
  - Silage NDF, ADF, Sugar
  - Aerobic Stability

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- Even though DMI decreased, because milk production did not decrease, overall efficiency increased

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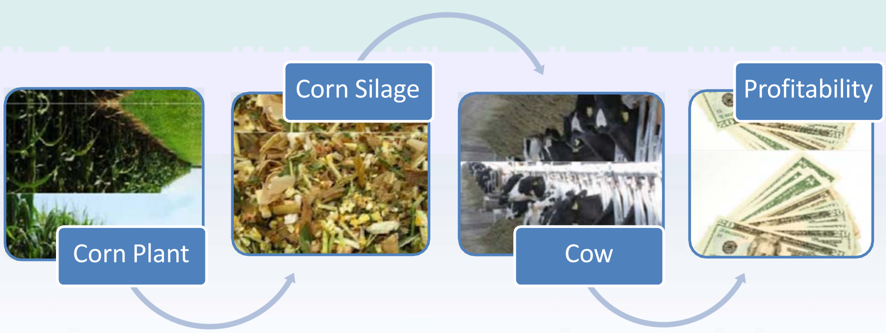
Project Outline



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Effects of Corn Treated with Various Applications of Foliar Fungicide on *in situ* Corn Silage Degradability in Holstein Cows

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Animal Feed Science and Technology 222 (2016) 149–157

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

ELSEVIER

Research Paper

Effects of corn treated with foliar fungicide on in situ corn silage degradability in Holstein cows

K.J. Haerr[a], A. Pineda[a], N.M. Lopes[a,b], J.D. Weems[c], C.A. Bradley[c], M.N. Pereira[b], M.R. Murphy[a], G.M. Fellows[d], F.C. Cardoso[a,*]

[a] Department of Animal Sciences, University of Illinois, Urbana, IL 61801, USA
[b] Departamento de Zootecnia, Universidade Federal de Lavras, Lavras, MG 37200-000, Brazil
[c] Department of Crop Sciences, University of Illinois, Urbana, IL 61801, USA
[d] B.A.S.F. Corporation, Research Triangle Park, NC 27709, USA

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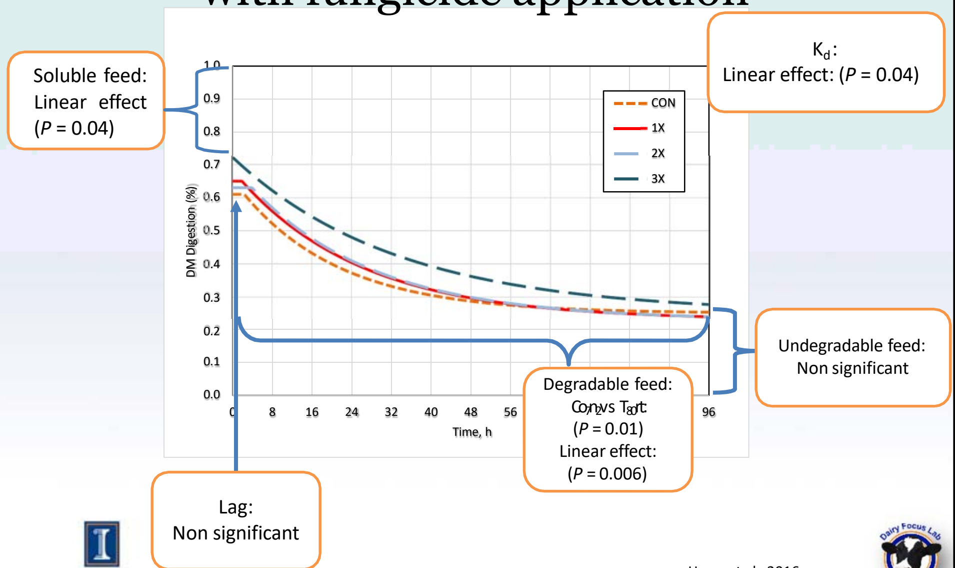
Dry matter degradability is increased with fungicide application



Haerr et al., 2016

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Economic Considerations

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MILK 2006 Predictions

http://shaverlab.dysci.wisc.edu/spreadsheets

- Developed by the University of Wisconsin
  - Relative quality of a forage based on energy value which is predicted from ADF, and potential intake using NDF and NDFD.

	Milk Per Ton			Milk per Acre		
Treatment	Estimated	Calculated	Difference	Estimated	Calculated	Difference
CON	2952	2898	-53	26567	26090	-476
1X	3010	3006	-4	24062	24050	-11
2X	3016	3506	490	27563	31907	4344
3X	3057	3222	165	27540	28996	1456

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Cost of Fungicide

- Cost of fungicide per acre
  - 1X: $ 30.00
  - 2X: $ 60.00
  - 3X: $ 90.00
- Cost per pound of silage
  - CON: $ 0.044
  - 1X: $ 0.046
  - 2X: $ 0.047
  - 3X: $ 0.049

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It seems to pay off…

Income over feed cost (IOFC)*

	$/lb DM	Feed Cost (consumed)	Milk Income	IOFC*
CON	$ 0.121	$ 6.30	$ 13.65	$ 7.34
1X	$ 0.121	$ 6.11	$ 13.66	$ 7.54
2X	$ 0.122	$ 5.23	$ 13.54	$ 8.31
3X	$ 0.122	$ 5.79	$ 13.62	$ 7.83

CON vs TRT: $ 7.34 vs $7.89

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* Income over feed cost calculated as IOFC= milk income - total feed cost

Animal Feed Science and Technology 225 (2017) 38–53

Contents lists available at ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

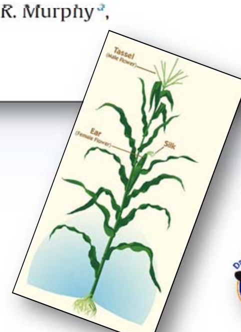
ELSEVIER

Foliar fungicide (pyraclostrobin) application effects on plant composition of a silage variety corn

CrossMark

C.C. Kalebich[a], M.E. Weatherly[a], K.N. Robinson[a], G.M. Fellows[b], M.R. Murphy[a], F.C. Cardoso[a,*]

[a] Department of Animal Sciences, University of Illinois, Urbana, IL 61801, USA
[b] B.A.S.F. Corporation, Research Triangle Park, NC 27709, USA



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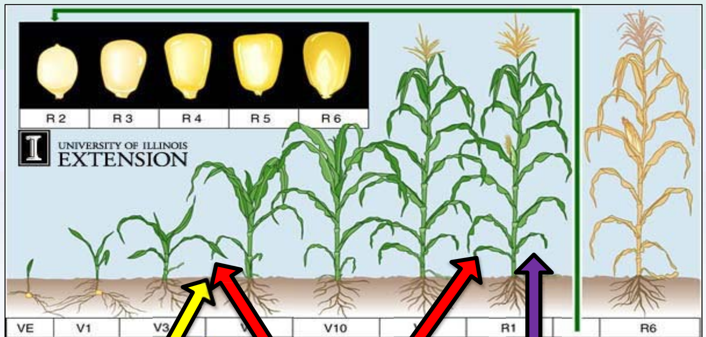
Material and Methods

During summer 2015:

4 Treatments



CON: no application of fungicide

V5: one application of Priaxor ® at V5

V5+R1: one application of Priaxor ® at V5 and one of Headline AMP ® application at R1

R1: one application of Headline AMP ® at R1

Active Ingredient in Priaxor ® : Pyraclostobin + Fluxapyroxad
Active Ingredient in Headline AMP ® : Pyraclostobin + Metaconzole

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Material and Methods

- Corn:
  - Seed: 1417 AMXRR, Pioneer
  - Type: Silage
  - Planted: April 30, 2015 at 32,000 plants/acre
  - Disease Evaluation:
    - July 11, 2015 – R1
    - August 13, 2015 – R3
  - Removed stalks from field at R1 and R3
    - July 12, 2015 – R1
    - August 18, 2015 – R3

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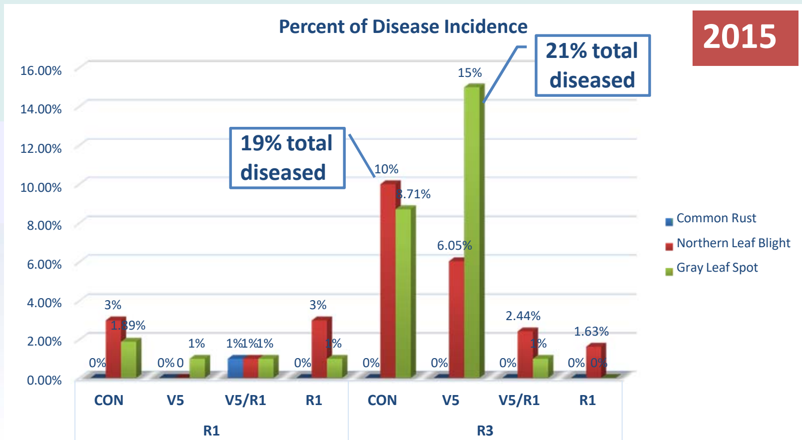
Fungus in Corn



Kalebich et al., 2017

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Plant parts collected

Collection at each R1 and R3

Sampling as full plant:
- Weight of full plant
- Height of full plant
- Number of leaves
- Number of green leaves
- Number of yellow leaves

1. Flag Leaf
- Composited

2. Leaves
- Composited

3. Ears = cobs + kernels
- Weight of ears
- Composited

4. Stalks
- Composited

Kalebich et al., 2017

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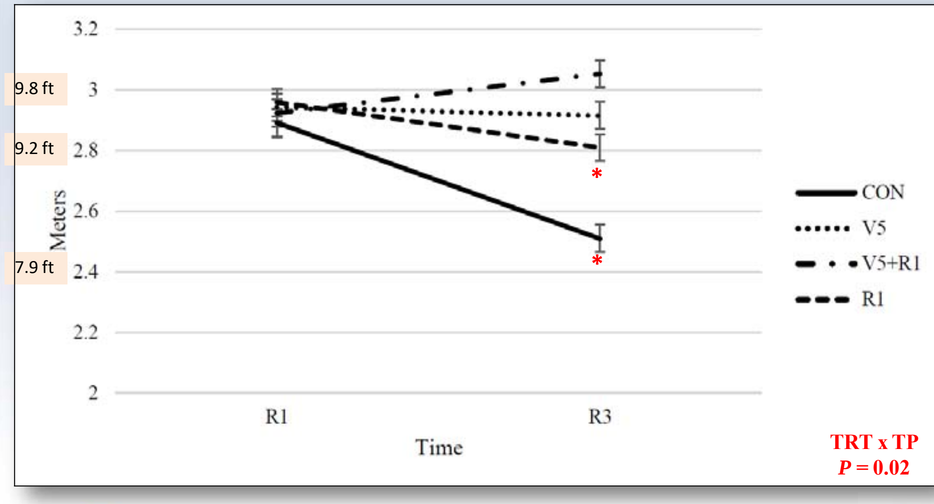
Height of corn stalk



Kalebich et al., 2017

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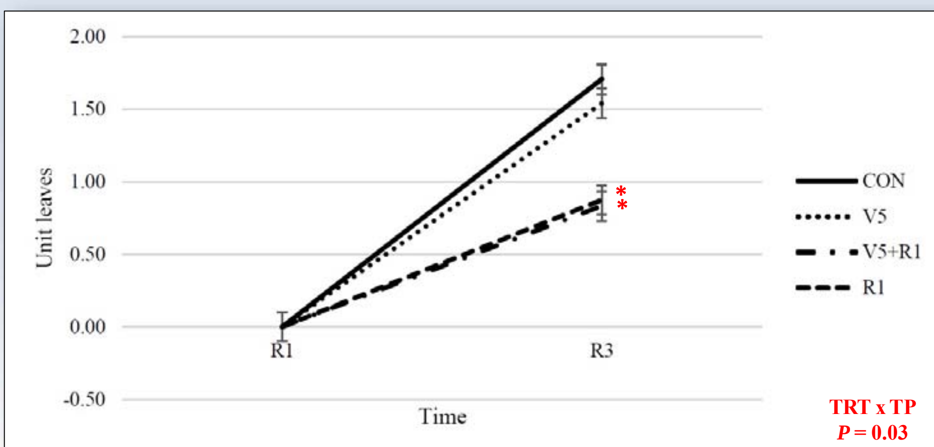
Number of yellow leaves



Kalebich et al., 2017

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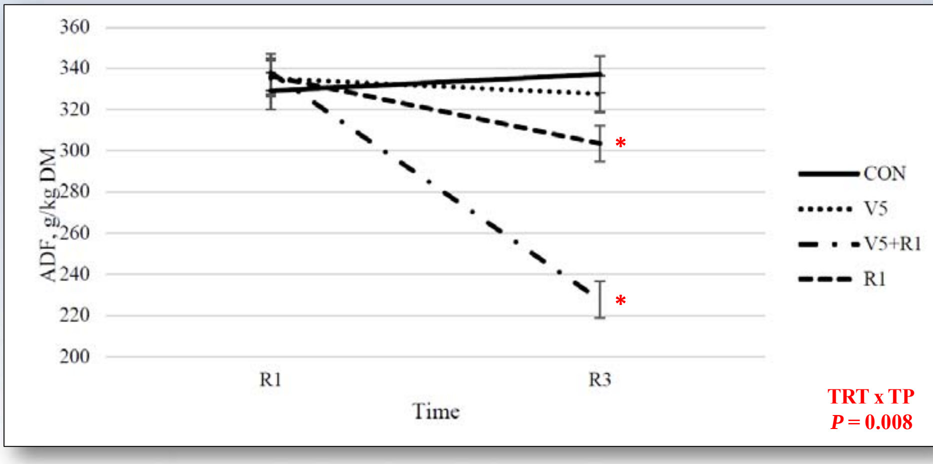
Leaves fiber content



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Kalebich et al., 2017

Corn Plant Conclusions

- Applications of fungicide on corn resulted in
  - Less yellow leaves
  - Taller plants
- Applications at both V5 and R1
  - Reduced NDF and ADF content in leaves
  - Increased lignin in stalks
- Implication:
  - Fungicide on corn may reduce stress impacts from disease and reduce the fibrous content in the leaves, while improving stalk strength

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journal homepage: www.elsevier.com/locate/anifeedsci

ELSEVIER

Foliar fungicide (pyraclostrobin) application on corn and its effects on corn silage composition

CrossMark

C.C. Kalebich[a], M.E. Weatherly[a], K.N. Robinson[a], G.M. Fellows[b], M.R. Murphy[a], F.C. Cardoso[b,*]

[a] Department of Animal Sciences, University of Illinois, Urbana, IL, 61801, USA
[b] B.A.S.F. Corporation, Research Triangle Park, NC 27709, USA

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Material and Methods

Harvest:

- August 25, 2015 for CON, V5, V5+R1, R1
  - 26.5%, 34.4%, 27.7% and 33.2%, respectively
- 1.9 cm theoretical length of chop
- Kernel Processor

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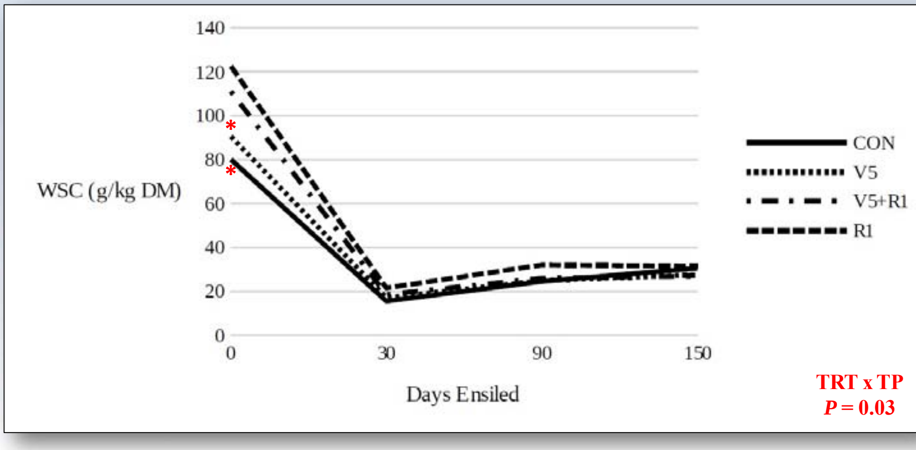
Water soluble carbohydrates (WSC) in corn silage



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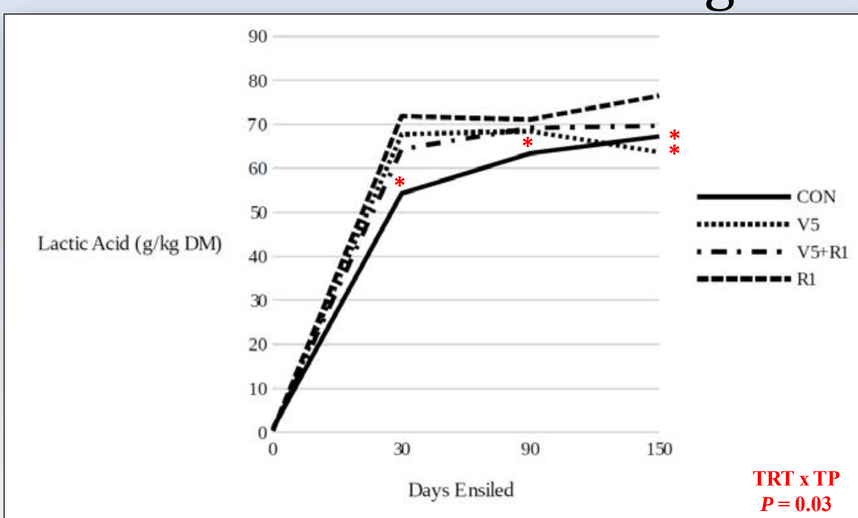
Kalebich et al., 2017

Lactic acid in corn silage



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Kalebich et al., 2017

Corn Silage Conclusions

- Applications of fungicide on corn resulted in
  - Greatest water soluble carbohydrate (WSC) content
  - Greatest lactic acid content
- Implication:
  - Applications at V5 or R1 may reduce the fibrous content of corn silage, increase the fermentation products during ensiling, and yield greater milk when fed to dairy cattle

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Kalebich et al., 2017

TAKE HOME MESSAGE

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Conclusions & Implications

- Corn treated with foliar fungicide had
  - Less fiber, more sugar and fat
  - Better aerobic stability
  - Higher DM digestibility
  - Improved corn plant and corn silage quality
- Cows fed silage receiving foliar fungicide had
  - Lower DMI
  - Higher feed efficiency
  - Higher IOFC

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For the road…

- **Scout corn at V5**
  - **If diseased (> 5%) apply fungicide at V5 and R1**
- **Scout corn at R1** **(may be too late ☹)**
  - **If diseased (> 5%) apply fungicide at R1**
- **ONE Fungicide application at VT/R1, even if corn is not diseased, seems to improve corn silage quality and milk production**

How tall can you go?

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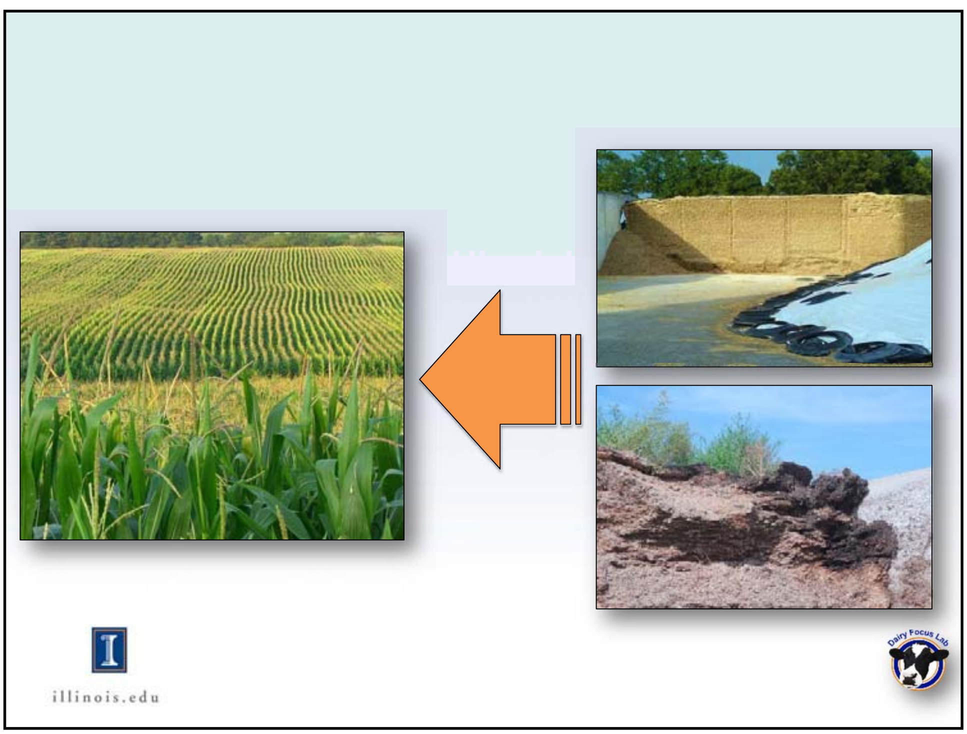
Remember!
DON'T FORGET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www.dairyfocus.illinois.edu

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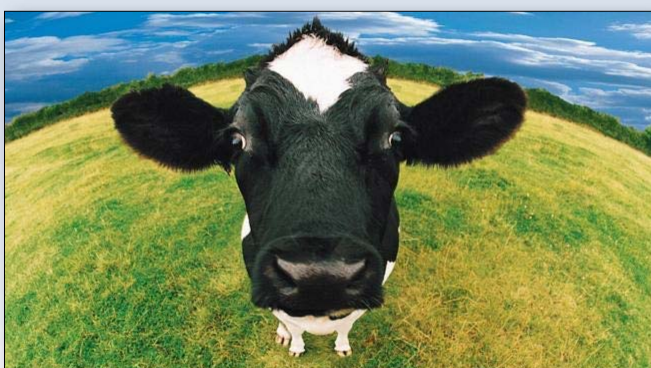
Thank you!



Questions?

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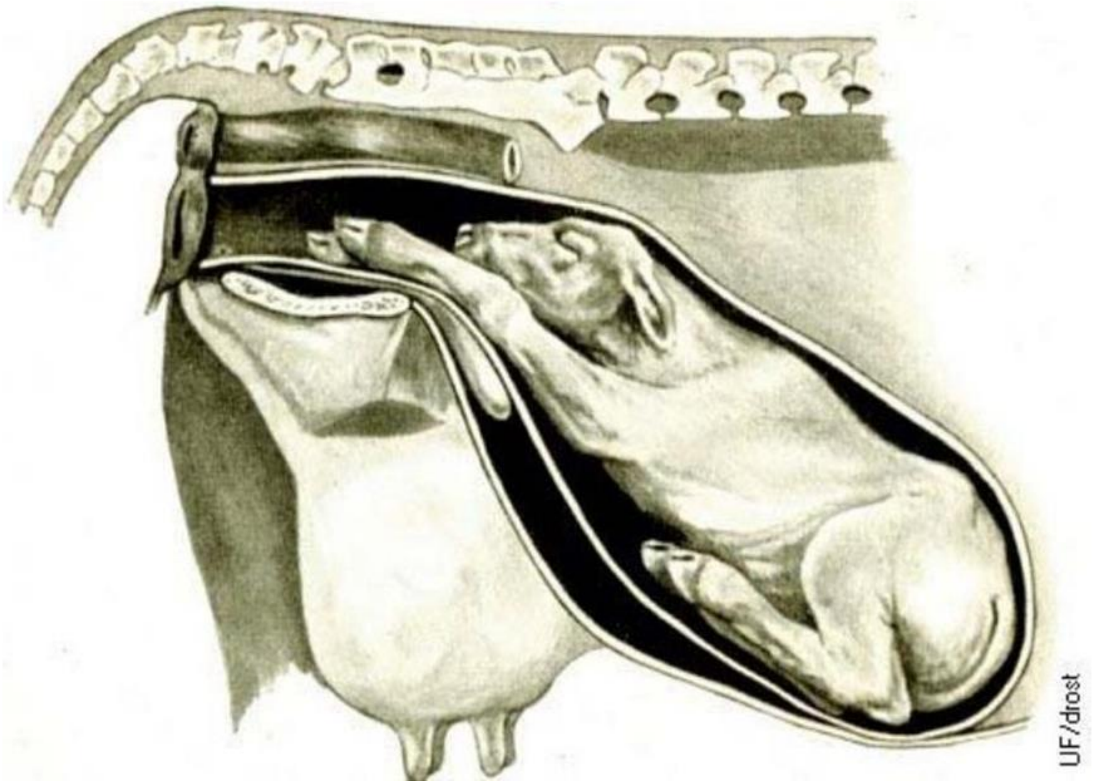
Dairy Reproduction

Devin Cunningham
Dauphin County 4-H Educator
dmc49@psu.edu
717-921-8803

Topics to Cover

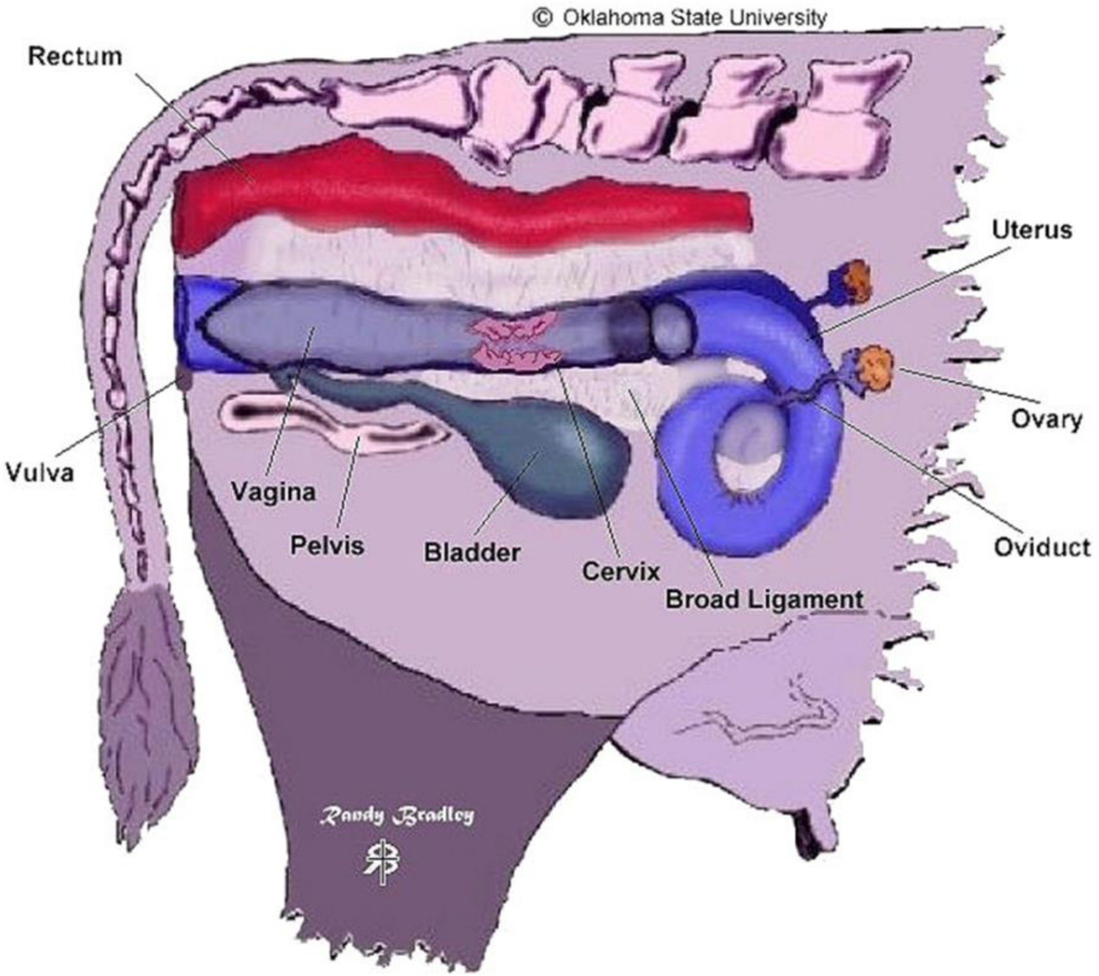
- Basic Anatomy
- Physiology of Uterus
- Pregnancy
- Dissection



moocall.com

Anatomy of Female Repro Tract

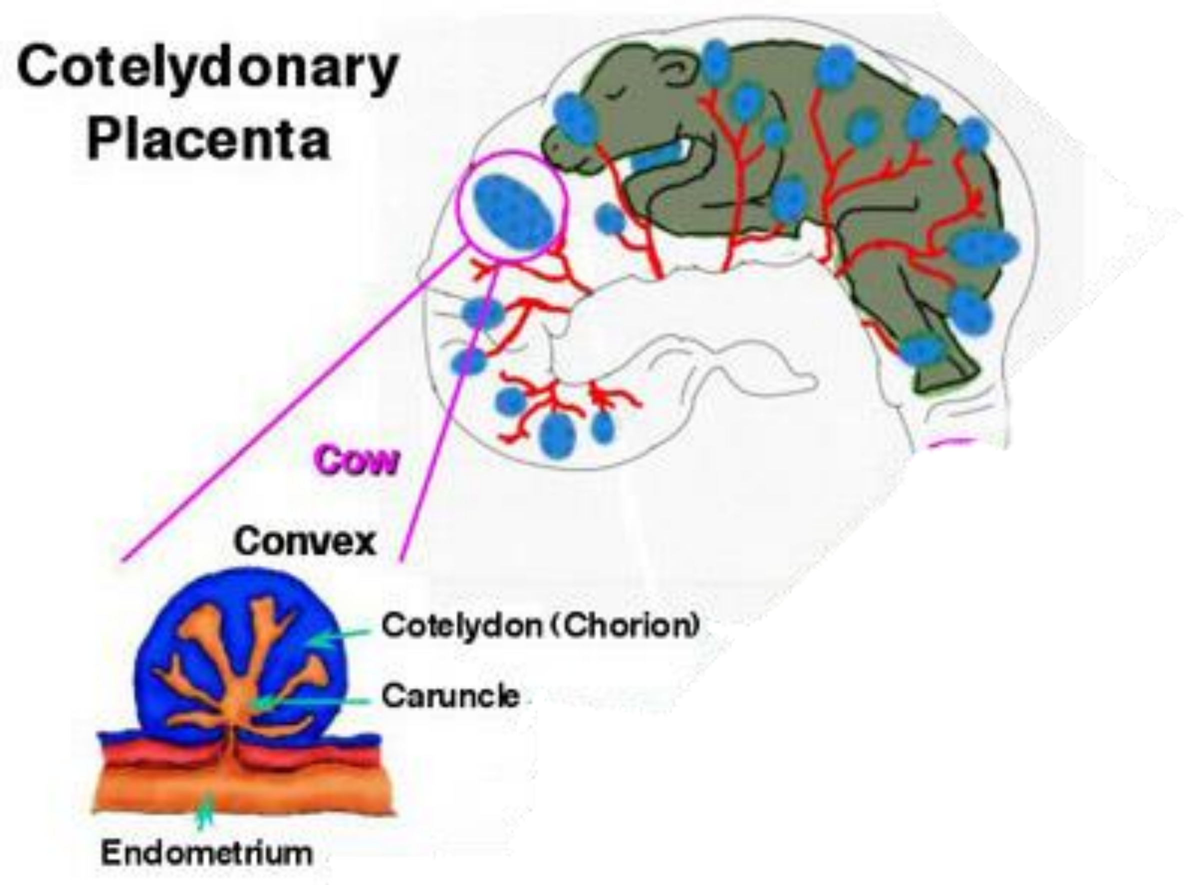
- Vulva
  - External opening
- Vagina
  - Tough plastic walls
- Cervix
  - Thick, fibrous, ridges
- Uterus
  - 2 horns & body, deposit semen
- Oviducts
  - End of horn, sperm travels to
- Ovaries
  - Contains eggs



http://www.angusjournal.com

Physiology of Uterus

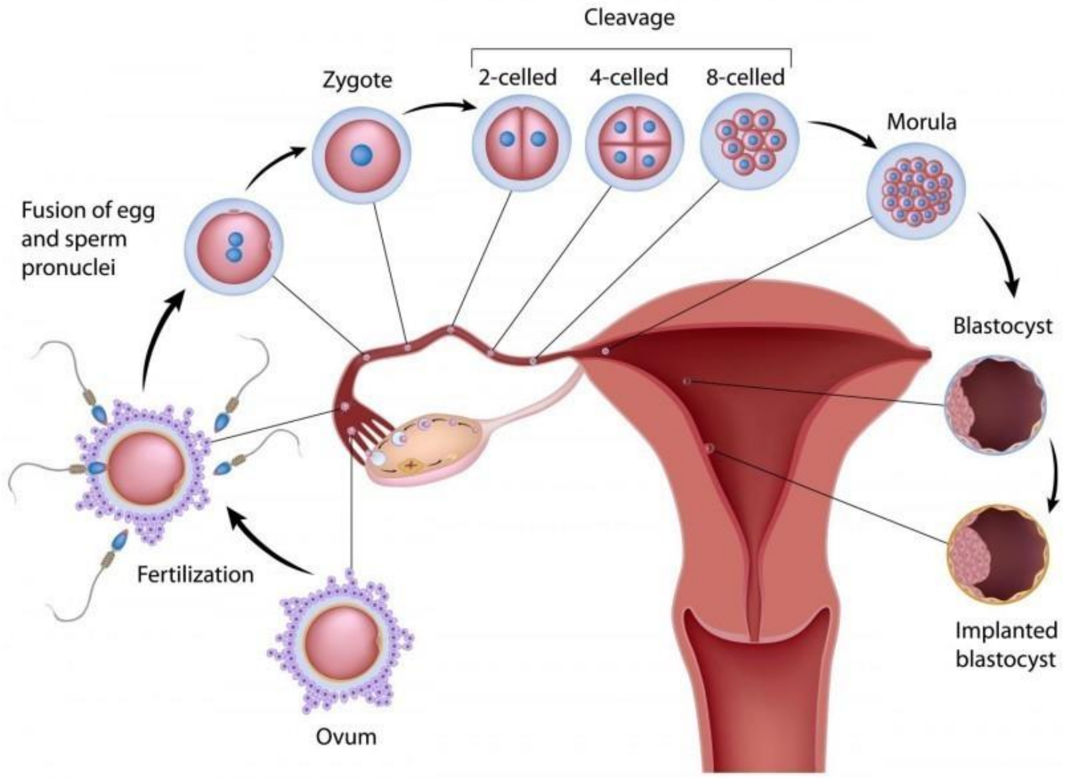
- Ovulation
- Sperm Motility
- Environment for embryo
  - Thicken uterine walls
  - Angiogenesis
  - Placenta Development
- Hormonal communication



http://www.ansci.wisc.edu/

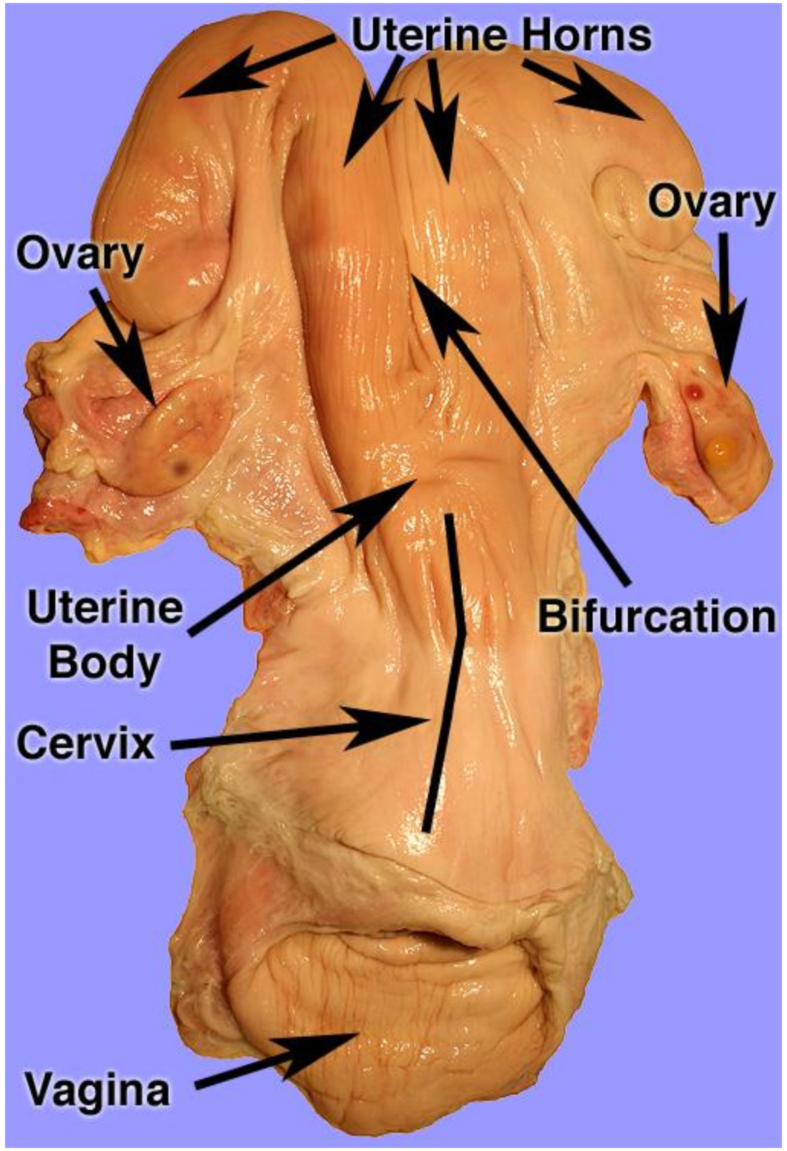
Pregnancy

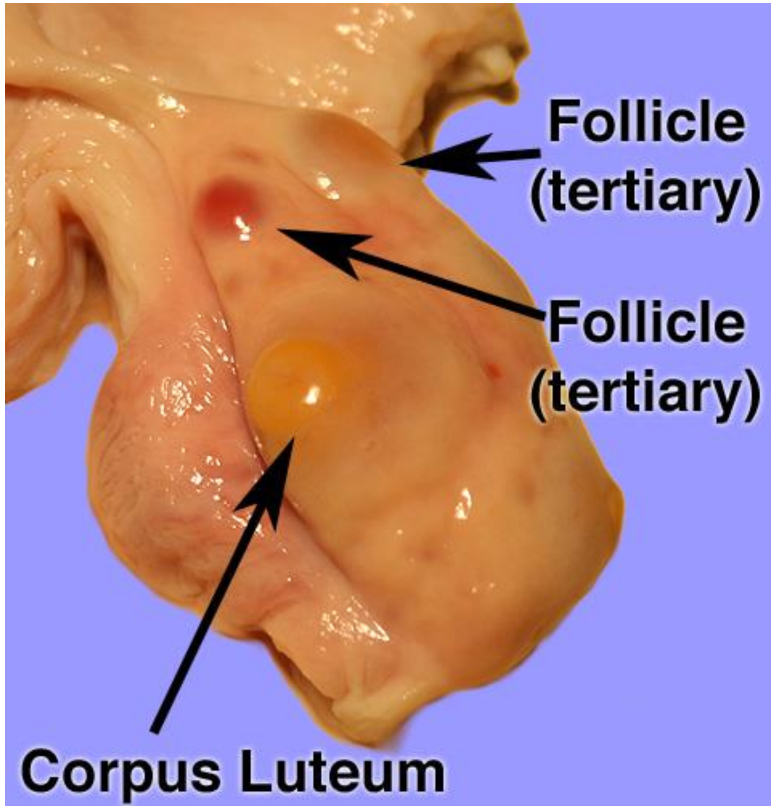
- Rapid cell growth
- Increase in progesterone
  - Inhibits estrous
- Placenta Role
  - Acts as fetal gut, lungs, kidneys & endocrine gland



http://www.pinkfamilies.com/fertilization/

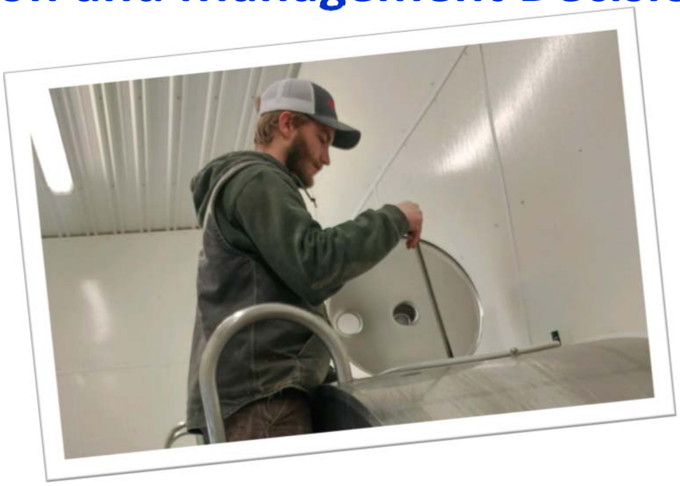
Dissection





www.ansci.wisc.edu

Use of Milk Fatty Acid Metrics to Make Nutrition and Management Decisions

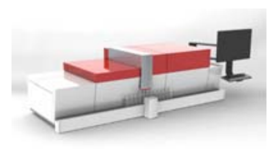


Heather Dann, Rick Grant, & Dave Barbano

Penn State Dairy Cattle Nutrition Workshop – November 16, 2017

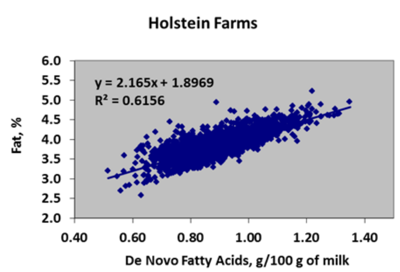
Used world-wide to measure fat, protein, and lactose for payment and dairy herd improvement programs

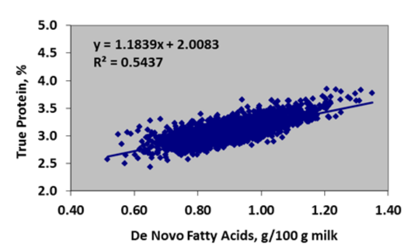
Develop new tools in milk analysis for bulk tank using mid infrared technology to provide information to support decision making for feeding and general management of the herd



Key Findings from Monitoring 430 Farms over a 15-Month Period with Milk Fatty Acid Metrics

- **Milk fat and protein increased when de novo fatty acids in milk increased**
- **Occurred for both Holstein and Jersey herds**





Barbano, 2016

Bulk Tank Milk Report for Farmer

TRANS_DATE	TANK	POUNDS	BFAT	PROT	LACT	TSOL	SNF	OSOL	CELL	MUN	DEN	MIX	PREF	DBOND	RAW	PAST	PI	CRYO
07-MAR-2017	1		4.13	3.17	4.86	13.05	8.92	5.75	140	12.86	0.99	1.44	1.63	0.282				550
05-MAR-2017	1	15480	4.17	3.19	4.85	13.12	8.95	5.76	180	11.56	1.00	1.37	1.76	0.280				536
04-MAR-2017	1	15674	4.27	3.19	4.88	13.25	8.98	5.79	190	11.9	1.03	1.40	1.84	0.285				548
03-MAR-2017	1	15932	4.19	3.19	4.85	13.13	8.94	5.75	180	12.95	1.00	1.38	1.77	0.285				546
02-MAR-2017	1	15846	4.04	3.15	4.88	12.97	8.93	5.78	110	13.16	0.98	1.29	1.76	0.289				536
01-MAR-2017	1	15824													3	5	15	
28-FEB-2017	1	16018	4.13	3.16	4.87	13.03	8.9	5.74	110	12.85	0.96	1.44	1.58	0.282				538
27-FEB-2017	1	15695	4.1	3.21	4.88	13.12	9.02	5.81	100	13.28	1.04	1.33	1.79	0.268				544
26-FEB-2017	1	15889	4.16	3.17	4.9	13.12	8.96	5.79	140	13.04	0.97	1.49	1.58	0.285				543
25-FEB-2017	1	15738	4.2	3.17	4.88	13.13	8.93	5.76	120	13.17	0.94	1.54	1.55	0.283				544
24-FEB-2017	1	15824	4.16	3.15	4.88	13.08	8.92	5.77	130	13.9	0.94	1.53	1.51	0.293				542
23-FEB-2017	1	16039	4.12	3.16	4.89	13.04	8.92	5.76	120	13.04	0.92	1.54	1.46	0.292				547
22-FEB-2017	1	16104	4.22	3.16	4.85	13.11	8.89	5.73	90	13.09	0.92	1.52	1.55	0.295				544
21-FEB-2017	1	15588	4.28	3.17	4.85	13.17	8.89	5.72	120	13.95	0.94	1.61	1.47	0.284				545
20-FEB-2017	1	16125	4.2	3.17	4.85	13.08	8.88	5.71	110	13.42	0.92	1.56	1.49	0.291				544
19-FEB-2017	1	15996	4.26	3.16	4.83	13.1	8.84	5.68	150	11.61	0.92	1.64	1.46	0.277				544

Testing Facilities For Milk Fatty Acid Metrics

(MIR Spectroscopy)

What are Milk Fatty Acid Metrics?

De Novo Fatty Acids

Relative %

Mixed Fatty Acids

g/100 g milk

Double Bonds per Fatty Acid

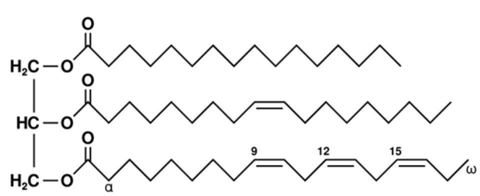
Unsaturation Index

Performed Fatty Acids

Milk Fat Composition

Most Variable Component of Milk

- 98% triglycerides

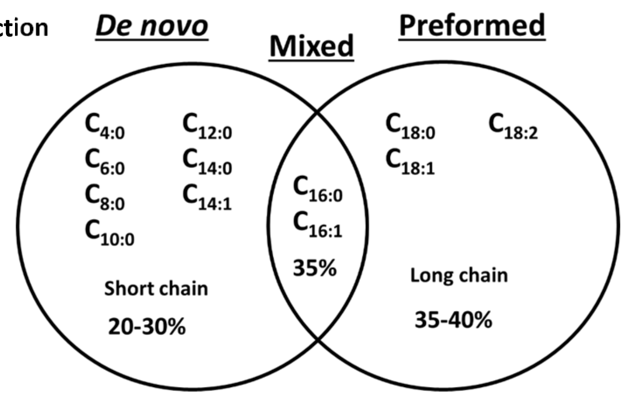


- More than 400 unique fatty acids (FA) in milk
- About 20 FA make up the majority
  - Broadly grouped into 3 subcategories

Jensen et al., 2002; Palmquist, 2006; Moate et al., 2007

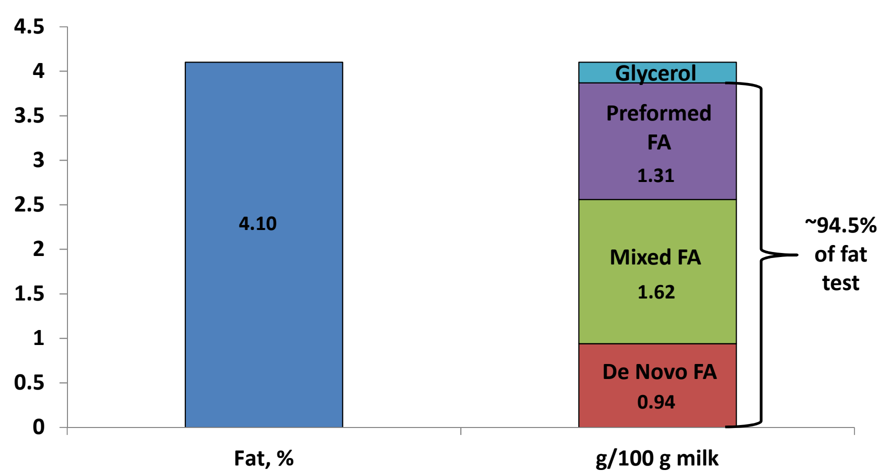
Milk Fatty Acid (FA) Groups

- **De novo FA - < C16**
  - Made in the mammary gland
  - Influenced by rumen fermentation/function
  - 18-30 relative % (21-26)
- **Preformed FA - > C16**
  - From fat the diet
  - From body fat mobilization
  - 32-42 relative % (35-42)
- **Mixed origin FA - C16**
  - From fat the diet (preformed)
  - Made in the mammary gland (de novo)
  - 30-40 relative % (35-42)



Courtesy of M. Woolpert

Fat and Fatty Acid Groups – Relationship in Bulk Tank Milk



Milk Fatty Acid Profiles Provide Insight: Performance and Health of Cow/Herd

- Profile of de novo, mixed, and preformed fatty acids reflect:
  - Diet and dietary changes
    - CHO fermentability, RUFAL, forages…
  - Management environment
    - Behavior, rumen pH, turnover
  - Physiological state of cow
    - Risk of milk fat depression
    - Energy balance
    - Stage of lactation

Research Conducted on St. Albans Coop Herds

Better Understand Management and Nutrition Differences between Herds with High and Low De Novo Fatty Acids

	High	Low
2014 – Holstein, Jersey, mixed		
Fat, %	4.55	3.90
True protein, %	3.50	3.16
De novo FA, g/100 g milk	1.13	0.90
Mixed FA, g/100 g milk	1.65	1.36
Preformed FA, g/100 g milk	1.52	1.43
2015 – Holstein		
Fat, %	3.96	3.75
True protein, %	3.19	3.10
De novo FA, g/100 g milk	0.92	0.81
Mixed FA, g/100 g milk	1.53	1.41
Preformed FA, g/100 g milk	1.27	1.30

Woolpert et al., 2016; Woolpert et al., 2017

Focus on De Novo Fatty Acids…

- De novo fatty acids reflect rumen function – especially fiber fermentation
  - Acetate and butyrate are building blocks
- Rumen conditions that enhance microbial fermentation stimulate microbial protein production and increase milk protein content
- De novo fatty acids in milk fat tells us how well the cow is being fed and managed for optimal rumen fermentation conditions

What Factors were Most Related to De Novo Fatty Acid Content?

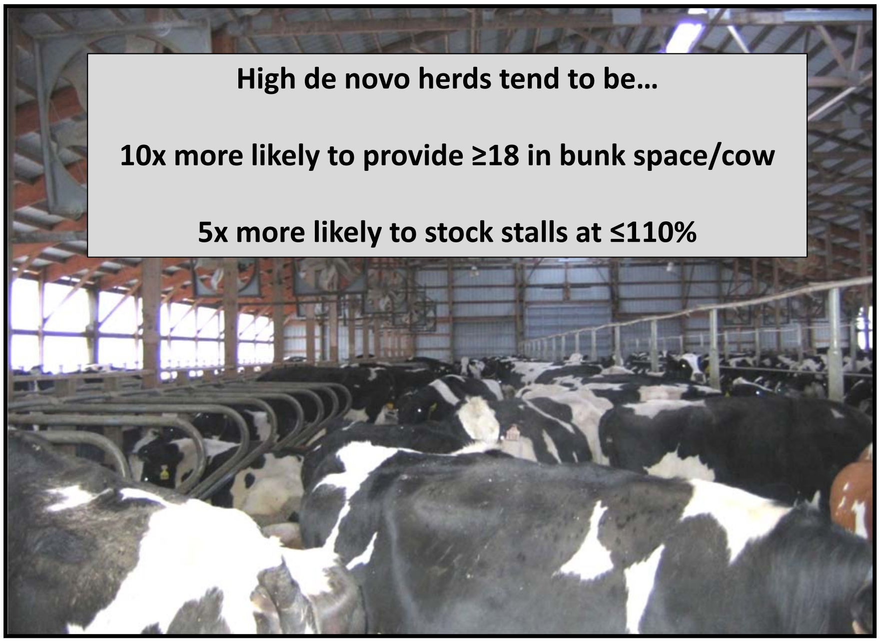
Woolpert et al., 2016; Woolpert et al., 2017

High de novo herds tend to be…

5x more likely to delivery feed 2x/d in freestall

11x more likely to delivery feed 5x/d in tiestalls

Woolpert et al., 2016; Woolpert et al., 2017



Woolpert et al., 2017

Need to Get the Diet and the "Dining Experience" Right

Must focus on

diet formulation

&

management environment

How Should We Use Milk Fatty Acid Metrics?

- Herd "snapshot" and troubleshooting
- Evaluating changes over time
- Need to understand natural variation
- Place in context of season and stage of lactation

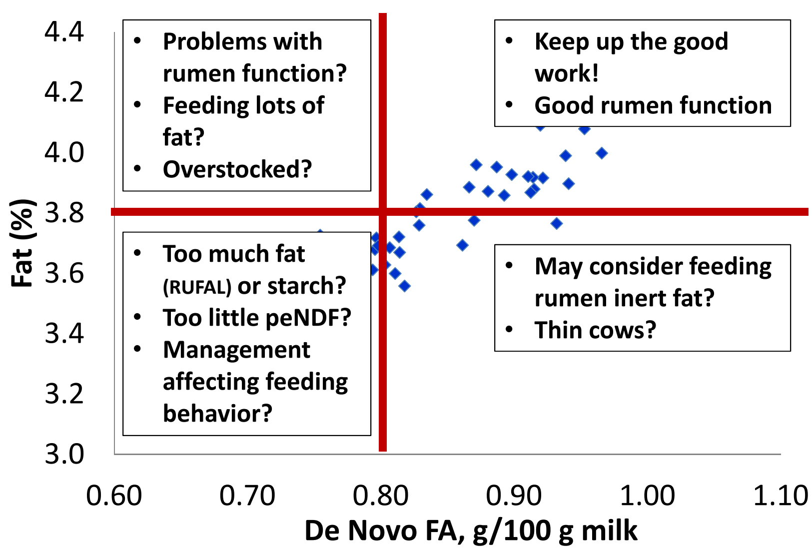
Observed Variation in Milk Composition and Fatty Acid Metrics of 167 Holstein Herds

	True Protein	Fat	De novo	Mixed	Preformed	FA Unsat
	g/100 g of milk					DB/FA
Mean	3.02	3.59	0.80	1.27	1.30	0.32
Min	2.76	3.01	0.59	0.98	1.06	0.26
Max	3.34	4.35	1.08	1.62	1.75	0.37

Bulk Tank "Alarms" for Holstein Herds that Want >3.8% Milk Fat

Milk Component	Units	Alarm Value
Fat	%	<3.8
De Novo FA	g/100 g milk	<0.8
Mixed FA	g/100 g milk	<1.3
Preformed FA	g/100 g milk	<1.3
FA Unsaturation	double bonds/FA	>0.31

Can We Use Milk Fatty Acid Metrics to Make Decisions On-Farm?



Soybeans, RUFAL, and Low Milk Fat

- **Snapshot: ~3.4 to 3.5% fat**
  - 0.77 g de novo FA/100 g milk
  - 1.09 g mixed FA/100 g milk
  - 1.30 g preformed FA/100 g milk
  - 0.35 double bonds/FA
- **Problem: Diet too high in RUFAL**
  - Use of home grown roasted soybean
  - Ground extremely fine with hammer mill
- **Solution: ↑ grind size**

- **Outcome: ≥ 3.7% fat**
  - 0.94 g de novo FA/100 g milk
  - 1.18 g mixed FA/100 g milk
  - 1.56 g preformed FA/100 g milk
  - 0.31 double bonds/FA

Example courtesy of M. Carabeau

Factors Associated with Increased Risk of Milk Fat Depression

Diet Factors

- **Fermentable carbohydrates**
  - **Starch**
  - **Forage fiber**
  - **peNDF**
- **Fats (RUFAL)**
  - **C18:1 + C18:2 + C18:3**
  - **< 3.5% of diet DM**
- **Feed additives (+/-)**
- **Yeasts/molds**

Cow/Environment/Management Factors

- **Genetics**
- **Parity**
- **Days in milk**
- **Season**
- **Time budget (behavior)**
  - **Stocking density**
- **Feeding strategy**
  - **TMR vs. PMR vs. component**
  - **Frequency of feed delivery/push up**

Jenkins, 2013; Bauman, 2017 AMTS webinar

Milk Fat Depression Timeline When Feeding "High Risk" Diets

Induction

- When did the problem start?
- After a diet change – 7 to 10 day lag
- Consider diet PUFA, CHO fermentability, rumen modifiers, feeding management

Recovery of Milk Fat

- When should it improve?
- After a diet change – 10 to 14 days

Rico and Harvatine, 2013; Harvatine, 2015

How Should We Use Milk Fatty Acid Metrics?

- **Herd "snapshot" and troubleshooting**
- **Evaluating changes over time**
- **Need to understand natural variation**
- **Place in context of season and stage of lactation**

Monitor Fatty Acid Metrics in Bulk Tank Milk for Changes Over Time

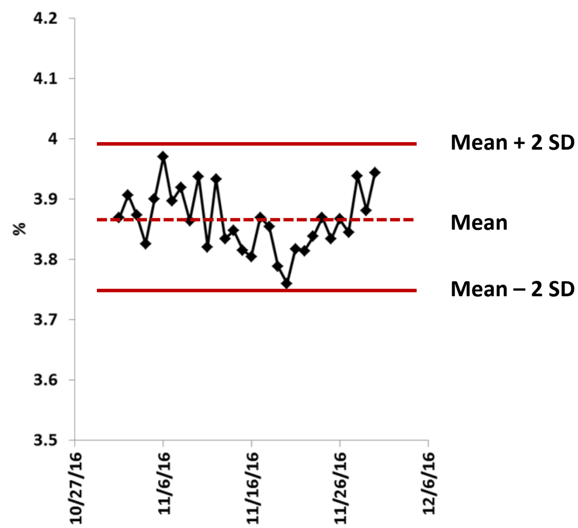
Fatty Acid Metric	Increases	Decreases
De novo FA	• Positive impact on milk fat and/or protein • Response to improved rumen function and/or feed quality	• Evaluate management and nutrition • Did an unexpected change occur?
Mixed FA	• Response to increased dietary fat • Possible response to de novo synthesis	• Evaluate management and nutrition • Did an unexpected change occur?
Preformed FA	• Response to more body fat mobilization or increased dietary fat	• Milk fat may decrease • Energy partitioning change
Unsaturation Index	• Greater risk for milk fat depression	

Need to Know the Herds's Typical Variation

	Mean	Standard Deviation (SD)	Coefficient of Variation (CV) (SD/mean x 100)
Fat, %	3.84	0.06	1.52
FA, g/100 g milk			
De Novo	0.86	0.02	2.19
Mixed	1.43	0.03	2.37
Preformed	1.39	0.05	3.63

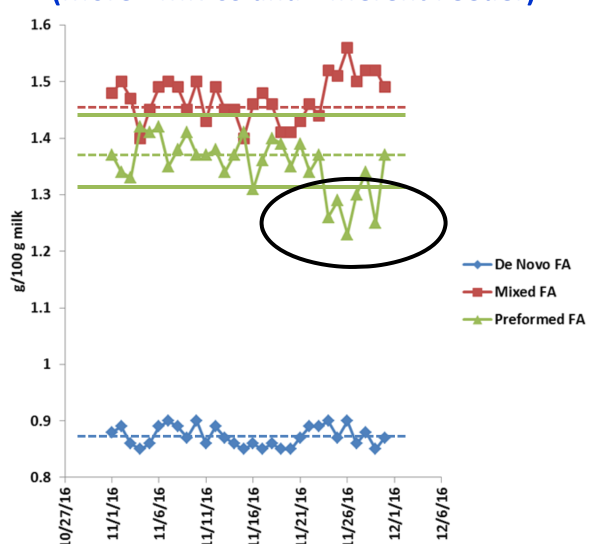
1 tank, 305 samples from 13 month period

Fat %

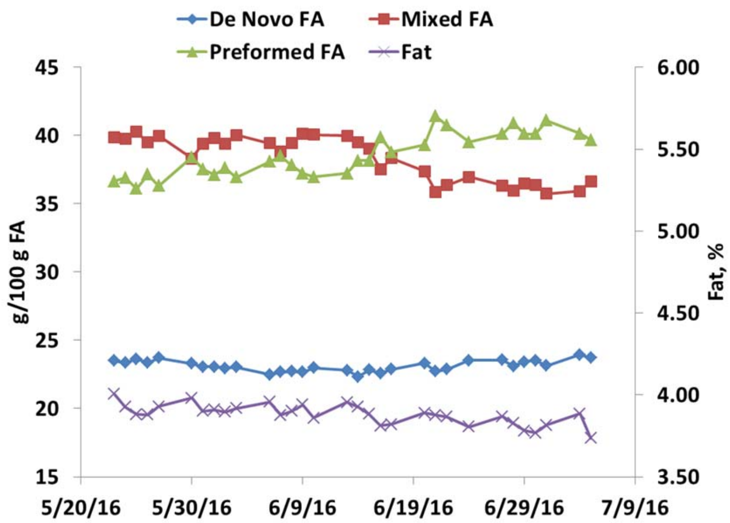


Variation in November… Diet Changed

(More BMR CS and Different Feeder)



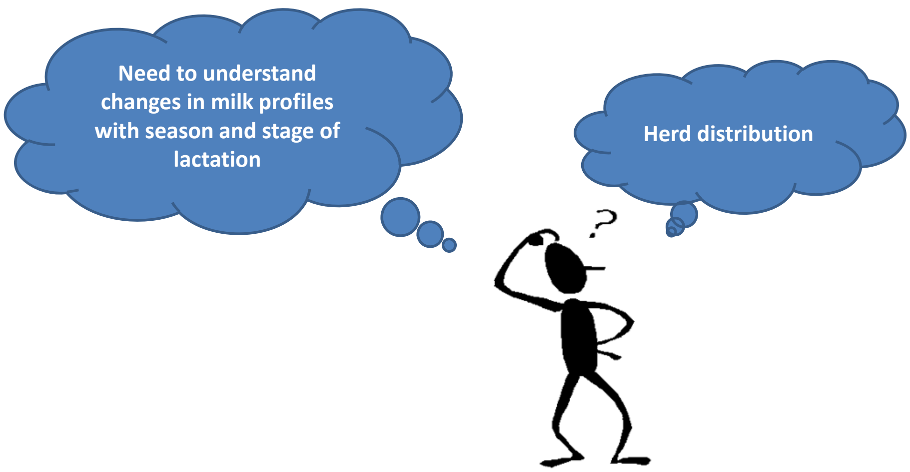
Forage Quality Changed Unexpectedly



Factors Affecting Variation Within & Between Herds

- **Management related to feeding, housing, and milking of cows**
- **Diet and feed quality**
- **Consistency in day to day routine**
  - **Affects time budget of cow**
- **Days off and vacations**
- **Weather changes**
- **Filling sequence of multiple tanks**

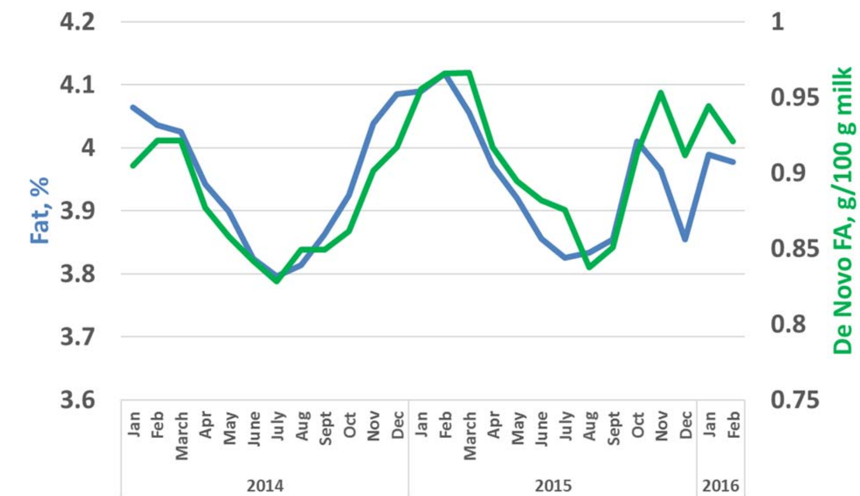
What Else is Needed to Interpret Milk Fatty Acid Metrics?



Seasonal Changes in Milk Composition

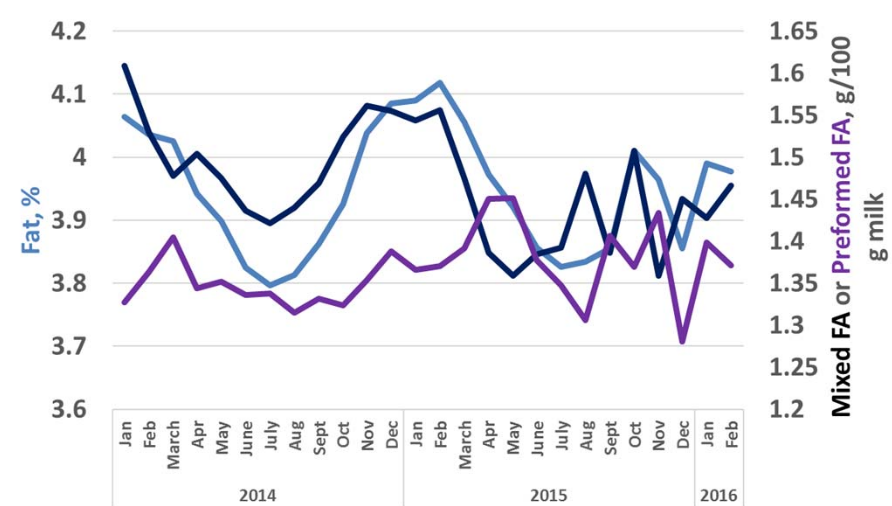
40 St. Albans Coop herds

Seasonal Changes in Milk Composition



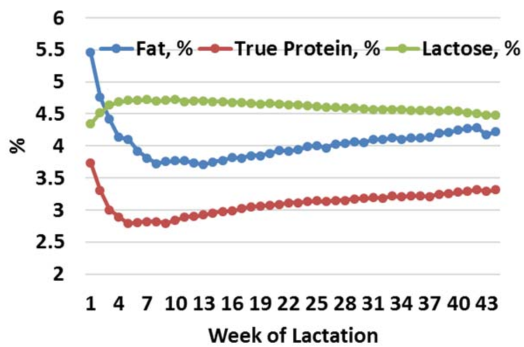
40 St. Albans Coop herds

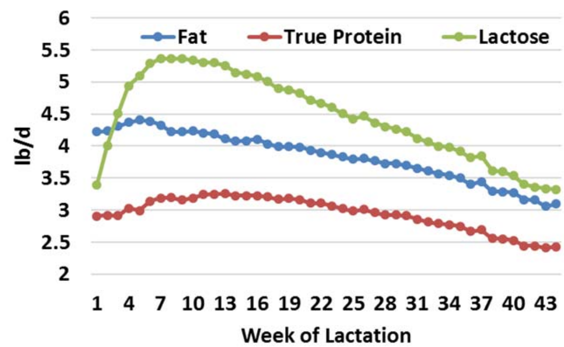
Seasonal Changes in Milk Composition



40 St. Albans Coop herds

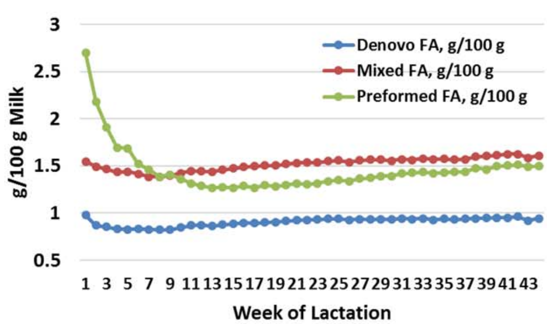
Stage of Lactation Affects Milk Components

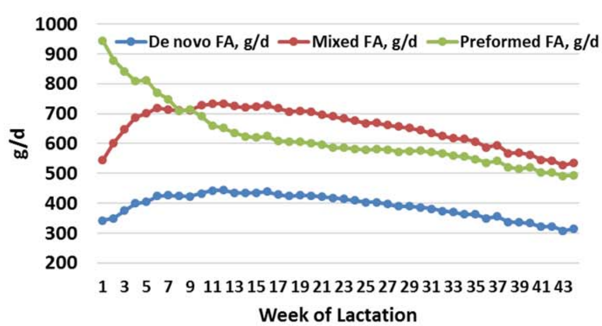




Holstein herd, ~90-95 lb milk/d, TMR feeding system

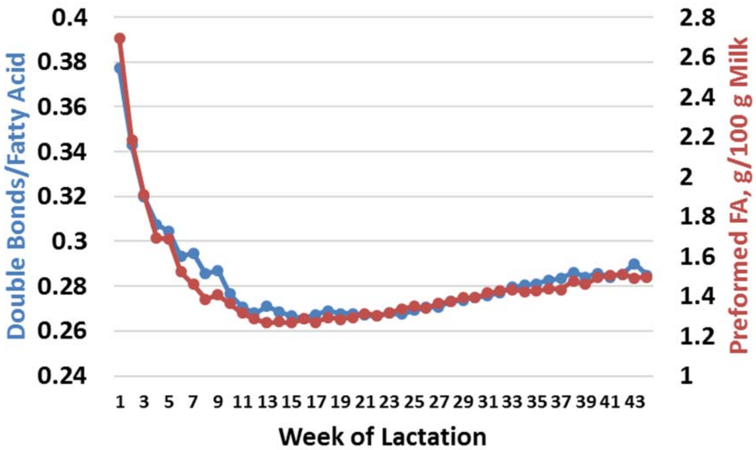
Stage of Lactation Affects Milk Fatty Acid Metrics





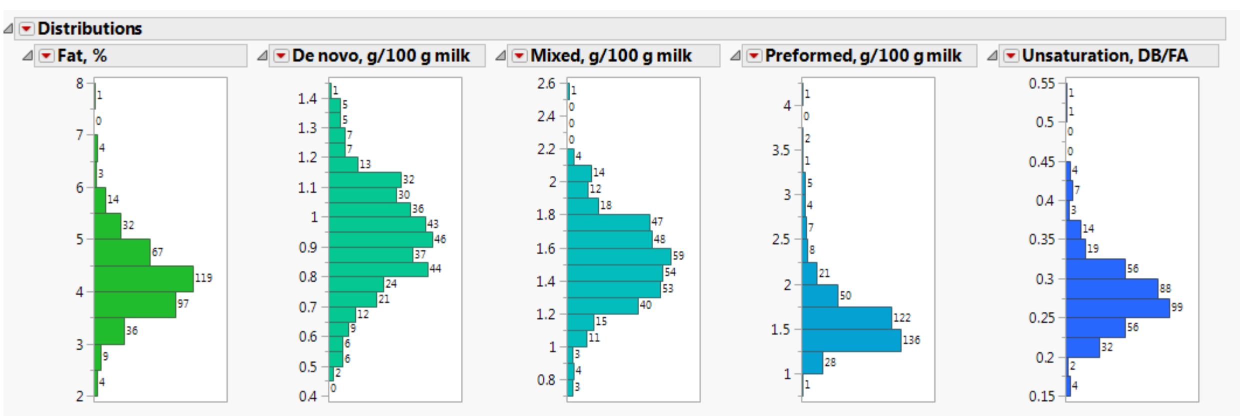
Holstein herd, ~90-95 lb milk/d, TMR feeding system

Unsaturation Index Changes Similar to Preformed Fatty Acid Concentration

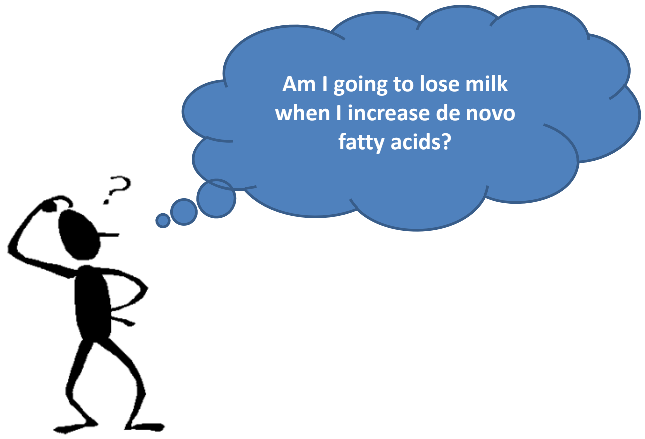


Holstein herd, ~90-95 lb milk/d, TMR feeding system

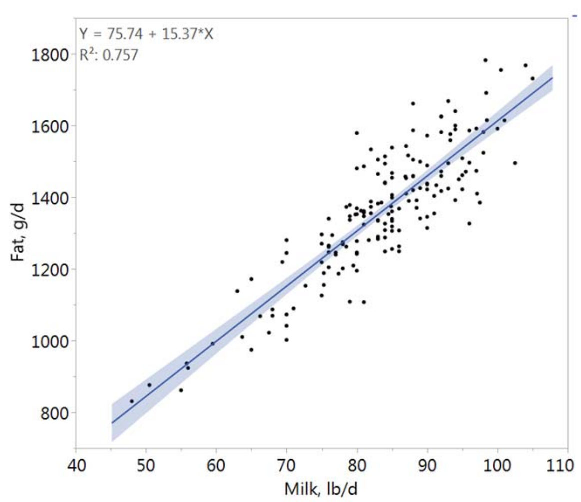
Herd Distribution

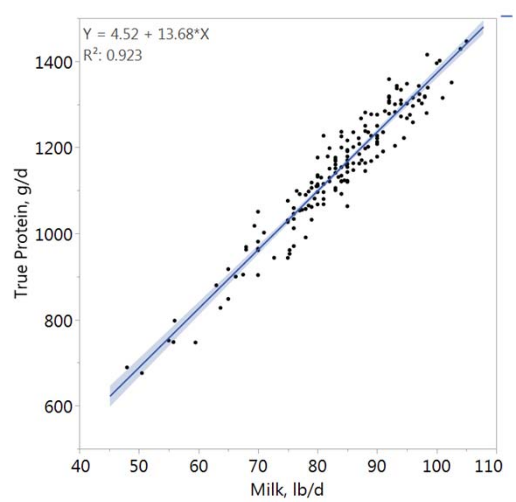


What are the Relationships among Milk, Fat and Fatty Acid Metrics?



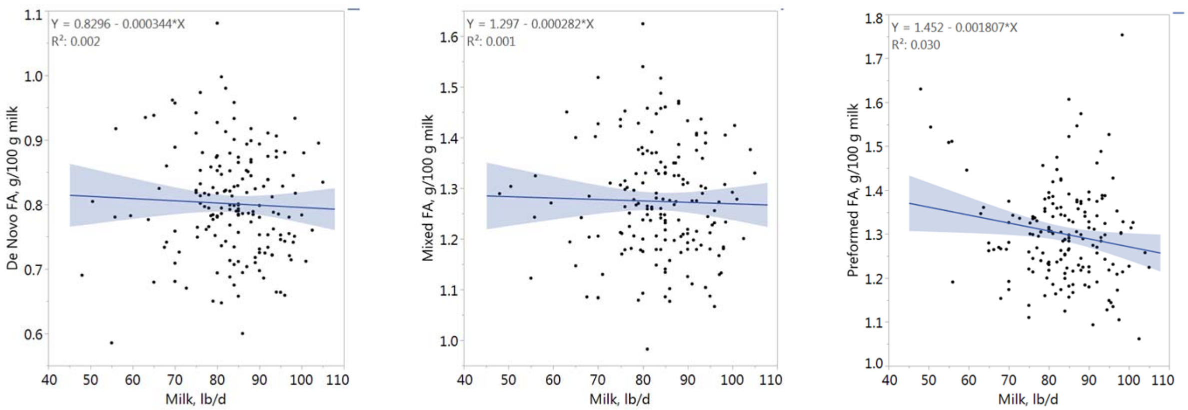
Milk Fat and Protein Yield Increase





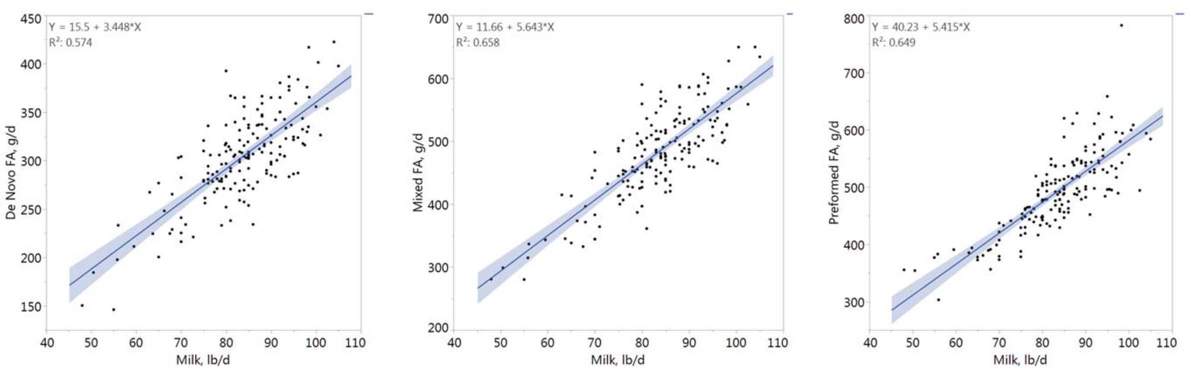
167 Holstein herds (Aug. 2017 dataset)

Fatty Acid Group Concentration Not Affected by Milk Yield

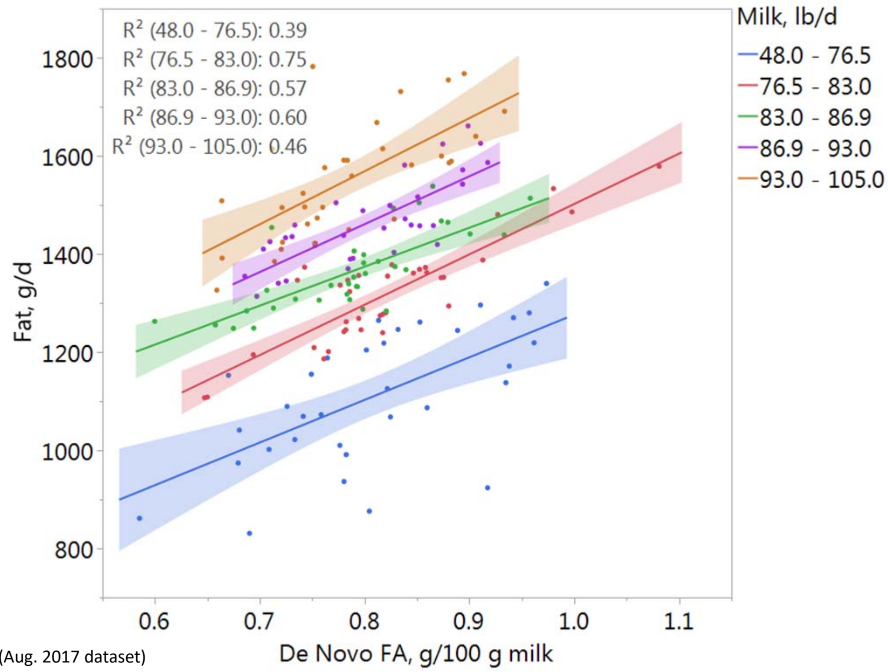


167 Holstein herds (Aug. 2017 dataset)

Fatty Acid Group Yield is Affected by Milk Yield



167 Holstein herds (Aug. 2017 dataset)



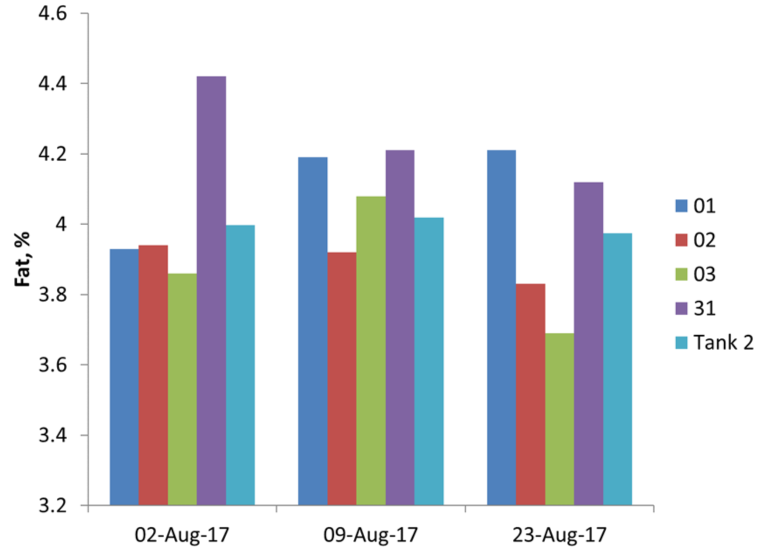
167 Holstein herds (Aug. 2017 dataset)

What's Next? What are the Challenges?

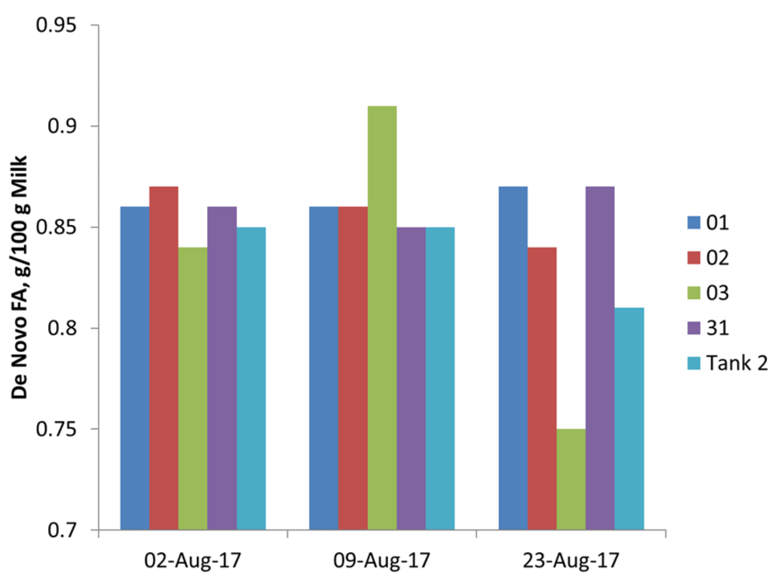
Bulk Tank/Tanker | **Group/Pen/String** | **Cow**

Bulk Tank vs. In-line Group Sampling

(More Sensitivity)



Bulk Tank De Novo FA Changed when Fat % Did Not



Milk Fatty Acid Metrics – Another Tool for Your Toolbox

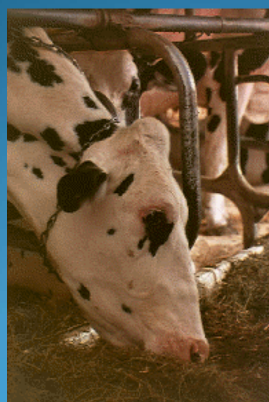
How Best to Use the Milk Fatty Acid Metrics Information

- In conjunction with
  - Diet information
  - Management information, other systems
  - On-farm assessment
  - *Don't use the FA information "in a vacuum"*

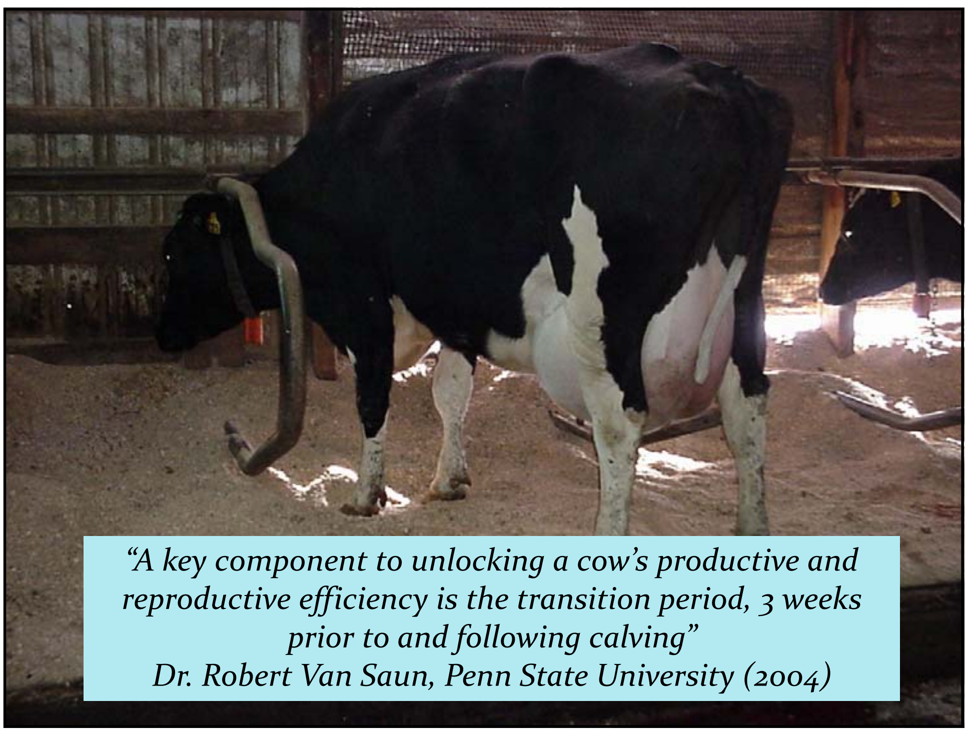
- Can give you clues as to what is happening
  - More specific than milk fat or protein %
  - Low milk fat can be caused by different factors – MIR FA information may allow you to identify what is wrong
  - May allow more rapid decision making

www.whminer.org
dann@whminer.com

Investing in Successful Transitions into Lactation



Mary Beth de Ondarza, Ph.D.
Paradox Nutrition, LLC
West Chazy, New York, U.S.A.

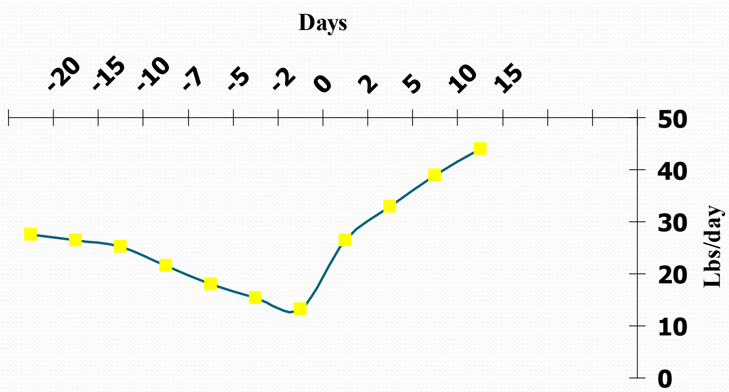


Investing in Successful Transitions

- Cow Comfort and Management
- Subclinical Hypocalcemia
- Subclinical Ketosis
- Metabolizable Protein and Amino Acids

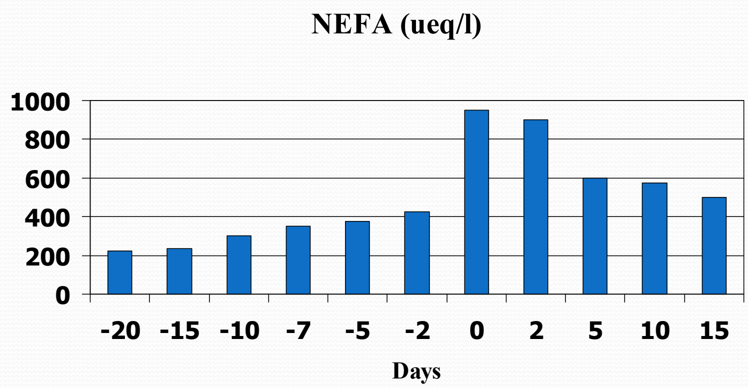
DMI Around Calving Time

- Hormones and Gut Capacity cause DMI to naturally decrease



Bertics et al., 1992

NEFA around Calving Time



Stuffed Cow Study - Wisconsin

- Last week before calving:
  - control cows - ate TMR to appetite
  - test cows - TMR refusals stuffed in
  - Test Cows “Ate” 28% more feed (same as at 21 days pre-calving)
- Test Cows Had:
  - Lower levels of fat in their livers at 1 DIM
  - Higher milkfat (4.22% vs. 3.88%) (28 DIM)
  - Higher 3.5% FCM (46 vs. 42 kg) (28 DIM)

Bertics et al., 1992

Transition Cow Comfort & Management

"Ten years ago, the focus of our fresh cow problem investigations was on nutrition and feed delivery systems. In contrast, over the past several years, the emphasis has shifted toward assessment of the transition cow environment, the sequence of pen moves just before and after calving, the time spent in each pen, and the stocking density of each pen."
(Nordlund et al. 2006)
(Univ. Wisconsin School of Veterinary Medicine)

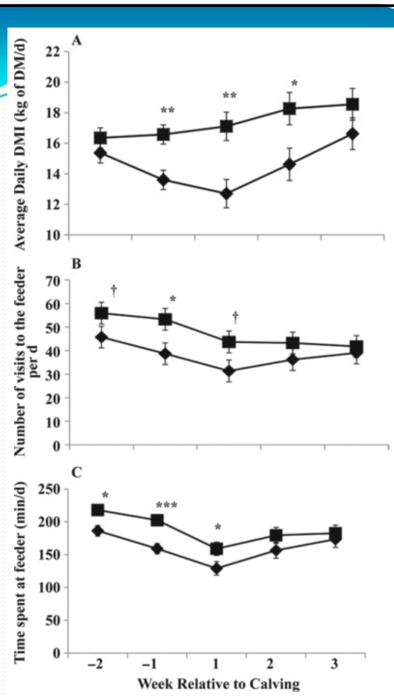
54 inch (137 cm) wide stall recommended for prefresh cows (Nordlund et al., 2006)

Purdue University Heifer Behavior Research (2003)

- Heifers That Spent More Time Lying Down and Ruminating Before Calving
- → Ate More During Week Before Calving
- →Had Higher DMI and Milk Production During First Two Weeks of Lactation

Higher DMI 1-3 days before calving → Greater DMI at 21 DIM

Grant, 2004



Feeding Behavior & Subclinical Ketosis

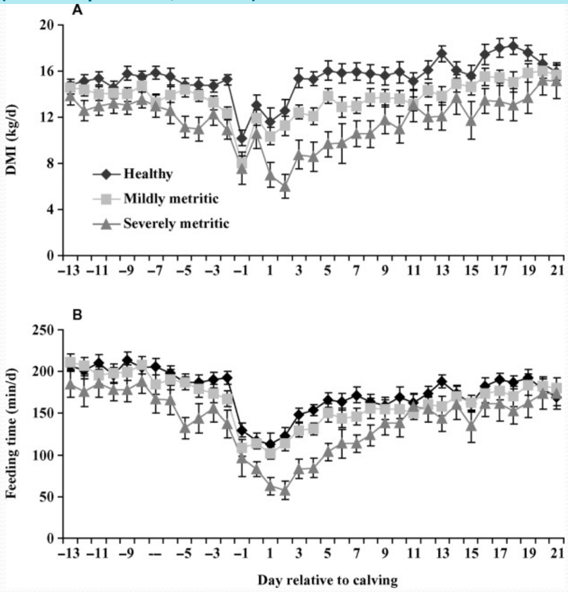
(Goldhawk et al., 2009)

101 Holsteins : -21 to 21 DIM

Ten otherwise healthy cows identified as experiencing subclinical ketosis (βHB > 1000 μmol/L at week 1) ◆ were matched with 10 healthy animals ■

During the week before calving, 1 kg less DM Intake increased the risk of subclinical ketosis by 2.2 times.

Prepartum DMI Linked to Metritis
(Huzzey et al., 2007)



101 Holstein Cows
12% severe metritis
27% mild metritis

Two weeks before seeing signs of severe metritis, cows ate less and spent less time eating. These cows also had fewer aggressive interactions at the feed bins.

For every 1 kg decrease in DMI during the week before calving, cows were 3 times more likely to have metritis.

Stress

- Can change how cows partition available nutrients
  - Reduces nutrients available for production
- Can increase fat mobilization
  - Increases potential for fatty liver
  - Suppresses immunity
- Can reduce Dry Matter Intake
- Stresses can accumulate → Metabolic Dysfunction

Causes of Stress

- Mixing first-calf heifers with older cows
- > 1 h/d in headlocks
- Short pen stays (>2 pen moves during transition)
  → Social Issues Between Cows
- Lack of Feed Availability
- Uncomfortable Stalls
- Overcrowding (>80-90%) / Competition
- Lack of Exercise
- Heat Stress

Grant, 2011

Prefresh Cow Management

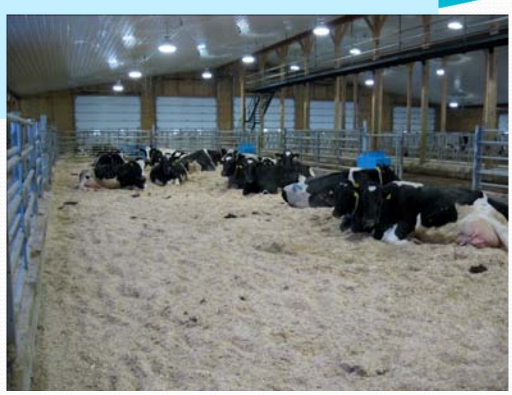
- DMI begins to decline when stocking density (relative to headlocks) exceeds 80%
- Minimum of 30 inches (76 cm) feedbunk space per cow is recommended
- 100 sq. ft per cow minimum; clean every 2-4 days
  - Grant (2017) → 140-150 sq. ft./cow
- Typically have issues due to fluctuations in numbers of cows calving on the farm
- Check prefresh cows hourly and move at the point of calving to a separate pen
- Once cow is up after calving, move her to a fresh cow pen. Cow is in separate calving pen for <2-3 hours

Nordlund et al., 2006

2008 New Miner Dry Cow Barn

- Before:
  - Older freestall barn - 46" (117 cm) stalls with mattresses
  - Far-off + Pre-fresh groups
  - After calving, moved cows on truck to milking barn
  - More issues with DA's (10%)
- Now:
  - Far-off pen (-50 to -21 DIM) = controlled energy diet
  - Move cows once/week to Pre-fresh pen
  - Pre-fresh pen (-21-0 DIM) = moderate energy, 17-18% Starch
  - Fewer metabolic problems
  - Goal = 100 lbs (45 kg) by 10 DIM

Pre-fresh Pen at Miner Institute



- 7-10 cows per pen
- 12 headlocks per pen
- 30 inches (76 cm) of feedbunk space per cow
- 150-200 sq. ft per cow
- Only move cows from bedded pack to maternity pen if they are having trouble calving and need assistance
- Transfer Alley helps move cows easily
- Headlock in Gate helps move cows easily

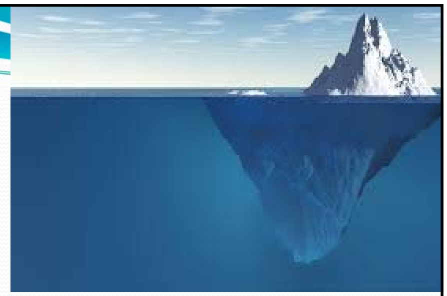
Purpose of a Prefresh Diet

- Keep cows eating & maintain rumen fill with adequate effective fiber
- Provide adequate metabolizable protein
- Provide adequate energy to reduce fat mobilization & subclinical ketosis
- Use low K forages. Reduce dietary K (<1.3%) and Na (<0.15%) and raise dietary Mg (0.4%) to improve calcium regulation
- Provide an anion source to further reduce subclinical hypocalcemia
- Provide additives such as yeast, choline, niacin, Vitamin E

Clinical Hypocalcemia
~$300/case
3-5% of cows

Subclinical Hypocalcemia
25-40% primiparous
45-80% multiparous
~$125/case

Subclinical Milk Fever



- 50% of cows have subclinical milk fever on calving day (< 8.59 mg/dL)(Martinez et al., 2012)
- For every 1 cow with milk fever, there are probably 10 with sub-clinical milk fever
- No noticeable symptoms
- **But**..... **Cows eat less**
- **And**..... Cows are more susceptible to ketosis, retained placentas, DA's, and infections
- Low Blood Ca → Reduce Immune Response

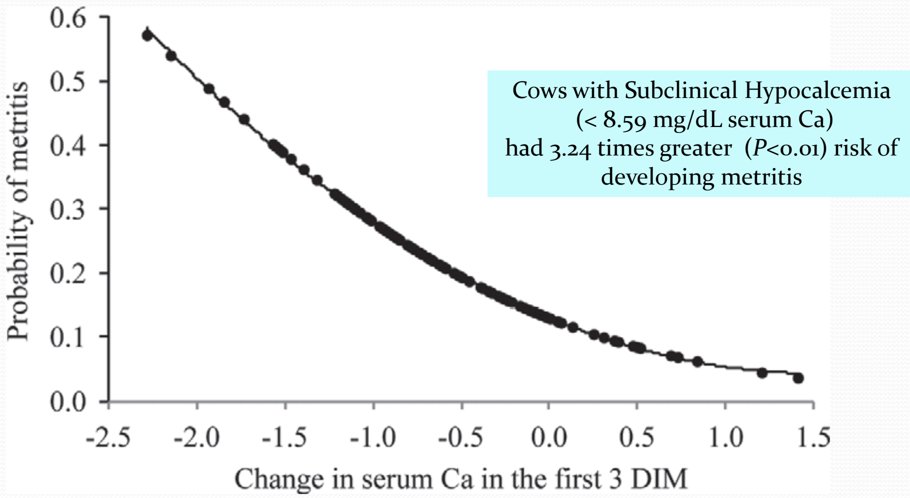
Analyzed 764 cows without clinical hypocalcemia from 6 different herds in Spain

Blood Samples collected at 24-48 h post-calving and analyzed for Ca

<u>Cows that had subclinical hypocalcemia (78%)(< 8.59 mg/dL serum Ca) were:</u>
3.7 times more likely to have a D.A.
5.5 times more likely to have ketosis
3.4 times more likely to have an R.P.
4.3 times more likely to have metritis

Normal Ca cows showed first heats sooner
But otherwise no change in reproduction

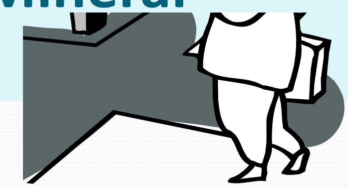
Probability of metritis relative to change in serum Ca (Martinez et al., 2012)



Strategies to Avoid Milk Fever

- Keep cows eating
- Reduce Dietary K (<1.3%) and Na (<0.15%) and Raise Dietary Mg (0.4%) to improve calcium regulation
  - High Corn Silage with Low K Hay or Straw
- Add Palatable Anionic Supplement to Induce Metabolic Acidosis for increased sensitivity to parathyroid hormone
  - Common goal = -5 to -15 mEq/100 g DM
    - Urinary pH 6.0 to 6.5 (Holsteins) & 5.8 to 6.3 (Jerseys)

Prefresh Dietary Mineral Recommends



- P – 0.30 – 0.38%
- Mg – 0.4 – 0.45%
- Na – 0.10 – 0.15%
- S – 0.35 – 0.40%
- Ca – 0.6-0.8%
- Get K as low as possible. Then, bring Cl to within 0.5% of diet K (if 1.3% K, 0.8% Cl)

Use wet chemistry to analyze forage and feed ingredient mineral content

Limit P intake to < 50 g/d to reduce hypocalcemia risk

Zeolite for Prefresh Cows (Calcium Binders; Aluminum Silicates)

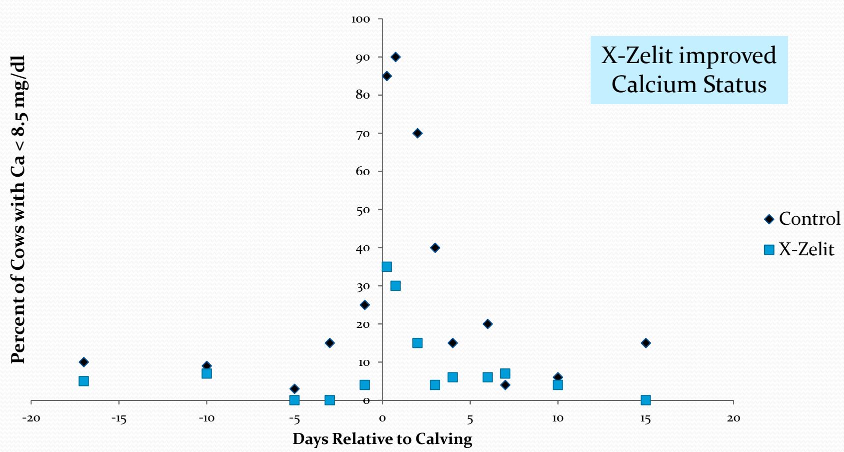
- One of oldest approaches to controlling hypocalcemia is to limit Ca intake but it is difficult to achieve 0.25% Ca in the diet
- Zeolites attract positively charged ions like Ca and Mg
- Intended to reduce Ca absorption to mobilize Ca reserves & improve Ca status after calving

- **Kerwin et al. (2017) (Cornell University)**
  - 55 multiparous Holstein cows at 21 d pre-calving
  - Control: 40% Corn Silage, 33% Wheat Straw, 27% Concentrate
  - Treatment: Control diet + 500 g/d X-Zelit (Protekta Inc.) (3.3% of DM)
  - Looked at Effect on Calcium Status

Nutrient Composition of Diets (Kerwin et al., 2017)

	Prepartum Diets		Postpartum Diet
Nutrient	Control	Treatment	Fresh
CP, %DM	14.5	14.0	17.1
Starch, %DM	17.8	17.9	23.2
Sugar, %DM	3.4	3.3	6.2
Ca, %DM	0.56	0.54	0.84
Mg, %DM	0.42	0.40	0.47
K, %DM	1.28	1.23	1.85
DCAD, mEq/100g	+15.1	+14.6	+34.7

Prevalence of Subclinical Hypocalcemia by sampling timepoint



Sign. Differences (P<0.05) Days -3 to +3

Kerwin et al., 2017

Calcium Binders - More Research Needed

- Concerns about Mg binding & blood Mg concentrations
  - Cornell Study : Serum Mg lower prepartum and immediately postpartum but no difference overall from 0 to 15 DIM
- Concerns about DMI: German Research (Grabherr et al., 2008)
  - 90 g Zeolite A/kg DM (9% of DM)
    (Triple Cornell diet concentration)
  - Reduced Prepartum DMI
    - 6.2 vs. 12 kg
  - Increased Fat Mobilization After Calving
- Concerns about price: $2.00/head/day
- Cornell study (Kerwin et al., 2017) - no reported DMI or milk yield data (coming soon)

High Forage "Goldilocks Diet"

11.5-12.25 kg DMI

- Concerns About Prolonged Overconsumption of Energy During the Dry Period
  - → Poorer Transitions; Slow Starts
  - → Lower Post-calving Dry Matter Intake
  - → Higher NEFA's and Liver Fat
- High-straw, low-energy rations (1.3 – 1.4 Mcal NE_l/kg DM) to control energy intake
- Bulky Diet which Meets Energy Needs When They Consume All that They Can Eat

12-16% Starch
40-50% Forage NDF

Janovick-Guretzky and Drackley, 2007

High Forage
"Goldilocks Diet"

25-35% of US Dry Cow Diets

Advantages

Higher DMI Fewer DA's

Less insulin resistant

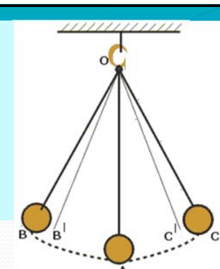
- Lower rates of lipolysis, less fatty liver, Less ketosis

Disadvantages

- Many studies do not show improvements in milk response and fat % is lower probably due to less NEFA for the mammary gland to use

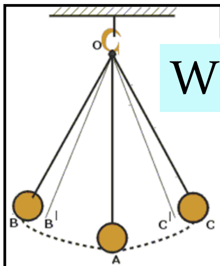
Grummer, 2017

Is Reducing NEFA's the right strategy?



- Problem: "We have selected cows that have increased reliance on mobilized body reserves" (Newbold, 2005)
- Help liver deal with mobilized fatty acids before trying to reduce fatty acid supply (Newbold, 2005)
- Balancing Act: "Provide sufficient NEFA to the mammary gland to support lactation without the cow experiencing negative effects that may result if NEFA mobilization is excessive"

Ric Grummer, 2017



What's the right prefresh diet to feed?

Can we keep the benefits
Of the Goldilocks Diet but
Reduce insulin resistance,
Improve VLDL transport, and
Provide more starch for
Microbial protein synthesis?

My Typical Prefresh Ration

Hay/Straw	2-3 kg DM
Corn Silage	6-7 kg DM
Prefresh Grain	3 kg DM
Crude Protein	15% DM
RUP	36-37% CP
NFC	32-33% DM
Starch	18-20% DM
NE_l	0.66-0.68 mcal/kg

One dry cow group or two?

- One dry cow group may be easier to manage, less stressful for the cow, and improve transition success.
- Would prefresh cows be more comfortable and less stressed if there was just one dry cow group?
- Are there very few fat cows at dry-off?
- Can most cows have a 40-50 day dry period?
- Is it difficult to make two dry cow rations?
- Do you have a separate fresh cow pen and ration?
- Is it better to separate dry cows based on parity rather than days dry?

Anionic Diets for Entire Dry Period?

- Increases dry cow diet cost.

What are the long term effects of feeding an anionic diet for the entire dry period?

-21 mEq/100 g DM = 21, 28, or 42 days (Wu et al., 2014)
- Similar Milk Production up to 42 DIM (41 kg)
- Similar Postpartum blood Ca (7.67 mg/dL)

-16 mEq/100 g DM = 21 or 42 days (Weich et al., 2013)
- Similar Milk Production up to 56 DIM (42.2 kg)
- Similar Postpartum blood Ca (6.93 mg/dL)

Oral Calcium Supplementation

Oral Calcium Administration

(Martinez et al., 2016)

- Effects of Oral Ca (Bovikalc) in 450 Holstein Cows
  - CaS1 = 86 g of Ca on day 0 and 1 postpartum
  - CaS4 = 86 g of Ca on day 0 and 1 postpartum + 43 g/d on day 2 and 4 postpartum
- Both Oral Ca strategies decreased subclinical hypocalcemia
- Oral Ca improved milk yield in multiparous cows with greater production potential but reduced milk yield in cows with average production potential
- Oral Ca improved reproduction in multiparous cows but was detrimental in primiparous

Oral Calcium Administration

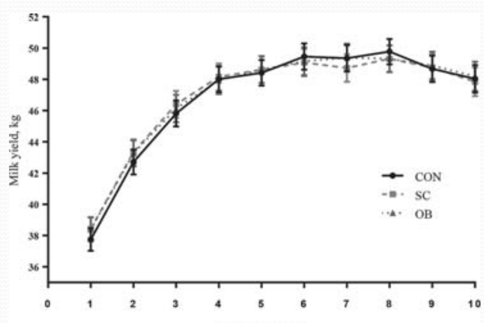
(Domino et al., 2017)

<u>Treatments</u>
Control
Subcutaneous Ca (500 mL 23% Ca gluconate at calving)
Oral Ca bolus (43 g Ca (Bovikalc) at calving and again 12 h later)

Commercial Herd in NY

Ca supplementation increased serum Ca but did not improve milk yield, health, or reproduction

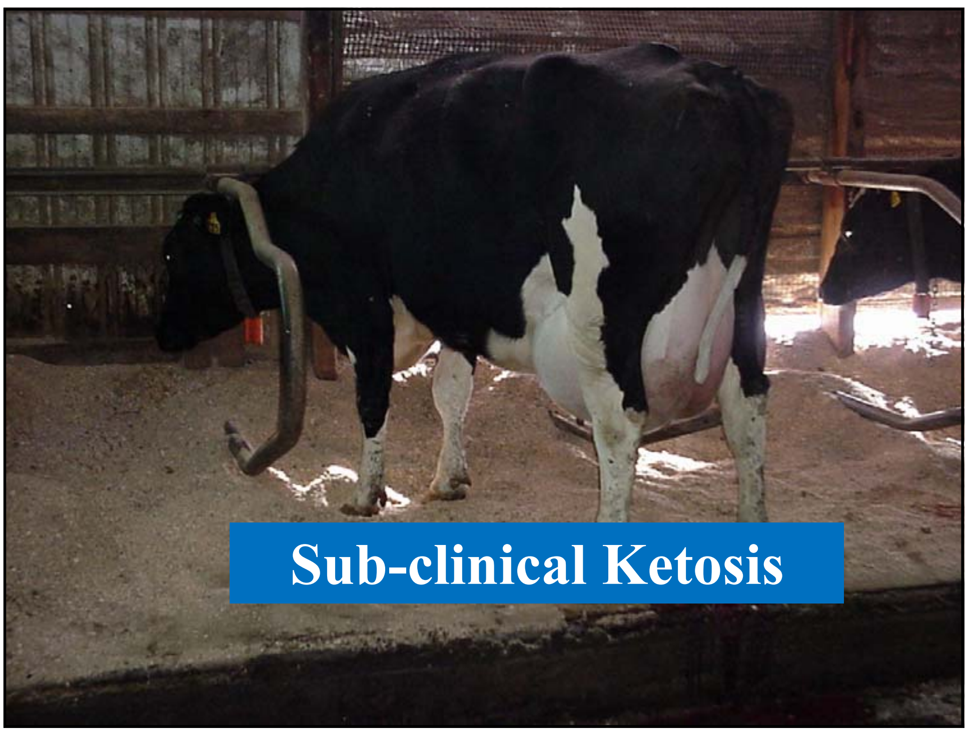
Targeted Ca supplementation may be better than whole herd supplementation



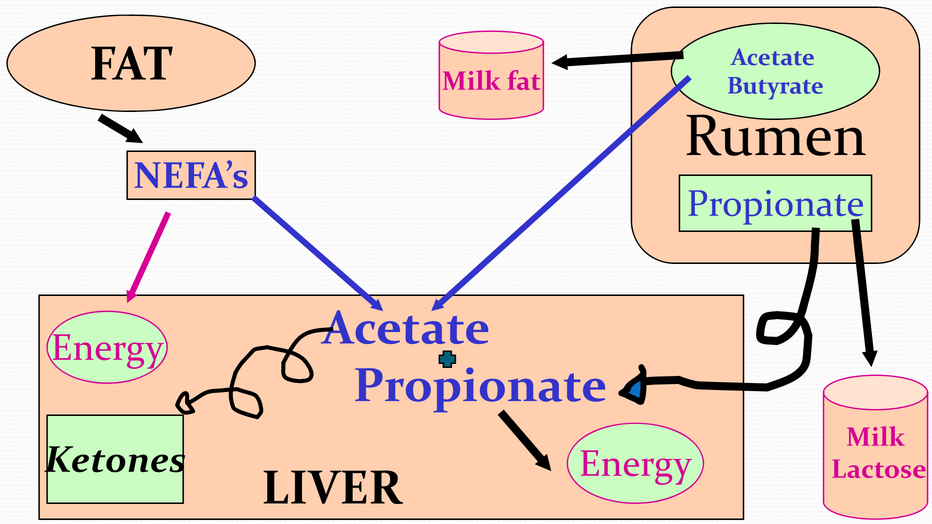
Purpose of a Fresh Cow Diet

- Provide Nutrients to Rapidly Increase Milk Yield and Dry Matter Intake
  - Added Fiber to Promote Rumen Health when Intake is Depressed and Fluctuating
- Reduce health problems (Displaced Abomasum)
- Reduce sub-clinical ketosis by promoting DMI and propionate production
- Control but not eliminate Negative Energy Balance
- Prepare Cow for Conception

When to move cows out of fresh group?
➢5 DIM, Daily Milk > 85 lbs, Full Rumen
➢21 days? No more than 30 days.
(Stacy Nichols, 2017)



Clinical + Subclinical Ketosis



Hepatic Oxidation Theory

- We need propionate to produce glucose, stimulate insulin, and reduce fat mobilization.
- But, during negative energy balance, when propionate is absorbed by the liver faster than it can be used, it stimulates the oxidation of Acetyl CoA, generating ATP, and signaling the brain to stop the cow from eating. This reduces meal size & supply of glucose precursors.
- Recommendation
  - Avoid highly fermentable diets for fresh cows
  - Use ground corn rather than high-moisture corn
  - Use nonforage fiber sources

Allen and Bradford, 2011

Effect of fresh diet starch + monensin (McCarthy et al., 2015)

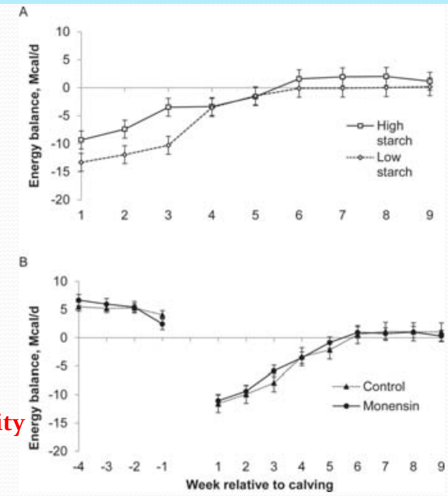
Fresh Cow Diet (0-21 DIM)
26.2% Starch vs. 21.5% Starch
0 vs. 450 mg/d monensin

High Starch → More milk, lower components, same ECM

High Starch → Higher DMI, Less BCS Loss, higher plasma glucose & insulin, decreased NEFA & BHBA

Monensin → More milk, same ECM higher DMI

Conclusion:
Diets with more propiogenic capacity do not reduce DMI



Miner Institute Study

- 72 Multiparous Holstein Cows
- 40-d Dry Period (controlled energy, high-straw)
- 91-d Lactation Period (21%, 23%, or 26% starch)

Treatment	1-21 DIM	22-91 DIM
Low/Low	21% Starch	21% Starch
Medium/High	23% Starch	26% Starch
High/High	26% Starch	26% Starch

Dann, 2012

Results of Miner Institute Study

	LL	MH	HH	SE	*P*-value
DMI, kg/d	25.2[x]	24.9[xy]	23.7[y]	0.5	0.06
3.5% FCM, kg	51.9	52.2	47.4	1.7	0.09
Fat, %	3.88[x]	3.64[y]	3.79[xy]	0.08	0.08
Fat, kg/d	1.91[x]	1.86[xy]	1.71[y]	0.06	0.09
True Protein, %	2.90	2.92	2.97	0.04	0.52
True Protein, kg/d	1.42[ab]	1.50[a]	1.34[b]	0.04	0.03
MUN, mg/dl	15.2[a]	12.7[b]	11.9[b]	0.3	<0.001

[ab] $P \leq 0.05$; [xy] $P \leq 0.10$

- Cows fed the 23% Starch diet consumed more starch than cows fed 26% starch diet because of higher DMI
- No effect of treatment on body condition score
- What we do during the first 3 weeks of lactation is critical

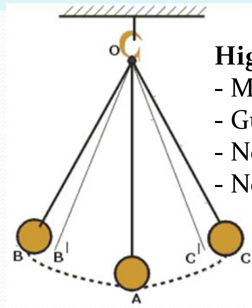
Dann, 2012

Use Highly Digestible Forages in the Fresh Cow Diet

- As feed intake increases and NEFA's are reduced during the first 21 DIM, gut fill (rumen distension) begins to limit intake and milk production.
- Inclusion of highly digestible forages, such as BMR corn silage, in the fresh cow diet can be helpful.
- A combination of highly fermentable forage with some extra chopped (2-3 inches) hay or straw can help provide needed energy and reduce gut fill while also providing effective fiber and limiting displaced abomasums in very fresh cows.

What is the best Forage NDF % and Starch Level for Fresh Cows?

Low Forage Diet
- SARA concerns?
- HOT limiting DMI?
- D.A. concerns

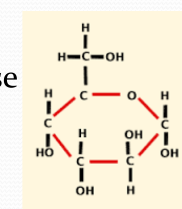


High Forage Diet
- Must have High NDFd Forage
- Gut Fill Limiting DMI?
- Not enough energy to drive milk
- Not enough propionate -> Ketosis

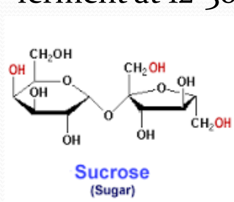
Somewhere in the Middle?
- High Forage Digestibility + Long Fiber
- Healthy Rumen + High DMI
- Some Highly Digestible Non-Forage Fiber
- Reasonable Level of Starch to Reduce Subclinical Ketosis

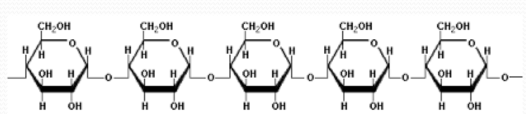
Using Sugar to Improve Transition Success

- Water-soluble carbohydrates
  - Monosaccharides = glucose, galactose, fructose
  - Disaccharides = sucrose, lactose, maltose



- Sugars ferment very quickly in the rumen
  - Rate of sugar digestion = 300%/hour (vs. starches which ferment at 12-30%/hour)





Starch

Positive Effects of Sugars

- Sugars can increase milk, milk protein & milk fat yield.
- Sugars can increase fiber digestion.
  - Sugar may stimulate rumen fungi which work to open up fiber for digestion.
- Sugars can increase dry matter intake.
- Sugars can decrease nitrogen wastage and increase rumen microbial protein.
- Sugars can increase rumen butyrate concentrations, stimulating rumen papillae and VFA absorption from the rumen.

Firkins, 2010; Oba, 2011; Sniffen & Tucker, 2011

Lactose for Transition Cows (DeFrain et al., 2006)

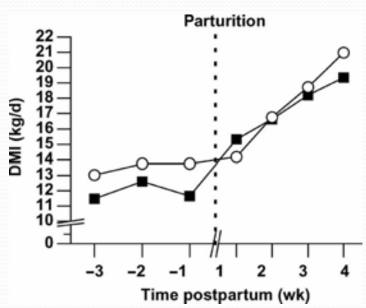
24 Multiparous Holsteins (-21 to 21 DIM

Treatment = 15.7% Lactose in Diet
Control = 25.8% Starch
Treatment = 16% Starch

Average DMI was only numerically Higher for Lactose Diet

DMI decreased from wk 2 to wk 1 prepartum for cows fed Control while DMI of cows fed Lactose did not change

Milk production in first 21 DIM was not affected by treatment (39.7 kg/d)



Feeding Lactose decreased liver lipid by 58% (P<0.01) (8.6 vs. 14.7% wet weight

Can Sugars Help Transition Cows?

- Fructose is converted more directly to glucose without stimulating liver oxidation activity

QLF Prefresh Diet Recommendations

- 7-8% sugar
- 12-14% starch
- 6-9% soluble fiber
- 32-35 lbs DM Intake

in prefresh cows

7 to 7.5% sugar for lactating cows

Dairy Herd Trial Conducted by Students at Dordt College in Iowa.

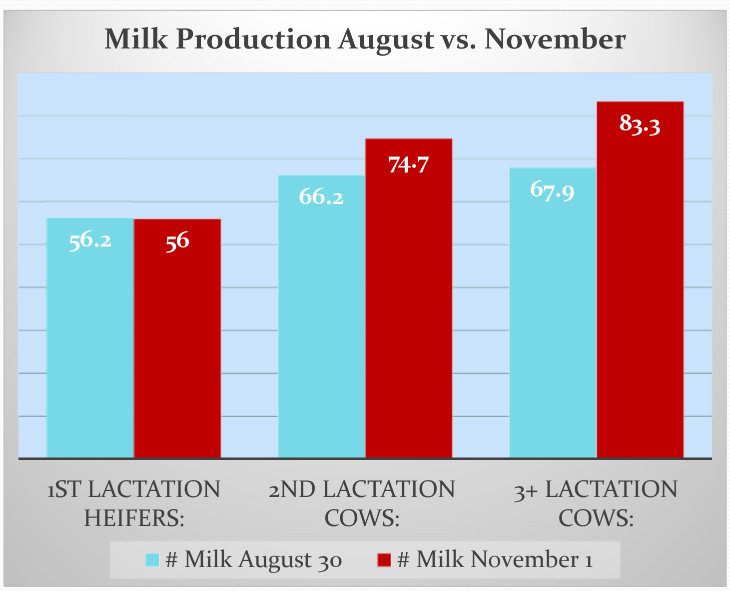
- Farm: 400 cow Commercial Holstein Herd
- QLF Dairy Transition 6 was fed at 4 pounds/cow pre-fresh and post-fresh (first 30 DIM).
- NutriTek from Diamond V was in the dry mineral.
- Diet adjusted to be iso-caloric and iso-nitrogenous to diet prior to QLF addition
- QLF liquid supplement replaced some corn and fat in the diet.

Dry Matter Intake, (lbs./day) Pre-QLF and during the QLF feeding period

	Pre-QLF Feeding	QLF Feeding Period	Difference
Pre-Fresh Mature Cows and 1st Lactation Cows	24.9	26.6	+ 1.7 lbs.
Fresh 1st Lactation Cows, DIM 1-30	34.1	38.6	+ 4.5 lbs.
Fresh Mature Cows, DIM 1-30	43.4	46.0	+ 2.6 lbs.

Pre-QLF period from Jan 1, 2016 through Sept. 15, 2016. QLF feeding period from Sept. 16, 2016 through Nov. 18, 2016, 62 days.

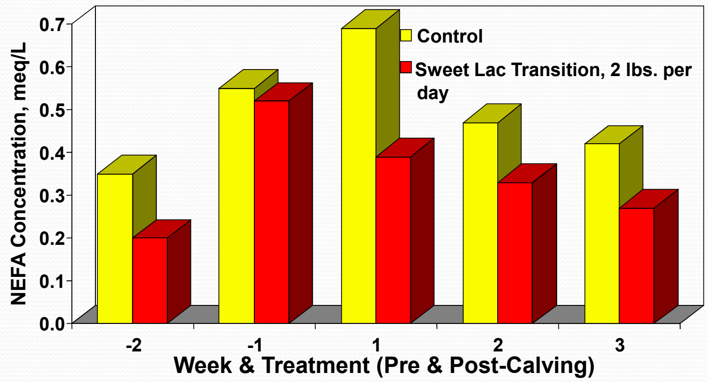
Results: Milk Production, lbs./cow



2nd lactation cows, + 8.5 pounds of milk.

3+ lactation cows, + 15.4 pounds of milk

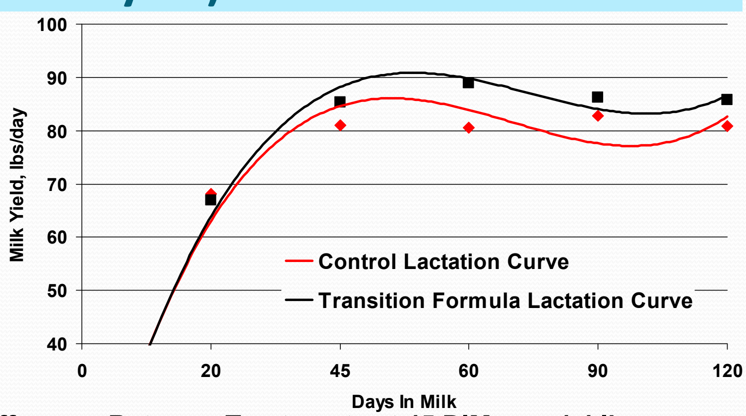
Effect of *Sweet Lac™* Transition (Sugar + Glycol) on Blood NEFA



Key Point: NEFA concentration was 30% lower in the Sweet Lac group during the 5 week sampling period

Source: Mattlink Dairy and Michigan State University

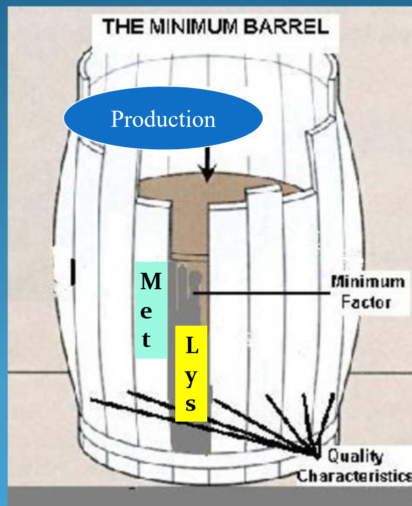
Effect of *Sweet Lac™* Transition (Sugar + Glycol) on Milk Yield



Difference Between Treatments at 45 DIM was 4.4 lbs.
Difference Between Treatments at 60 DIM was 8.5 lbs.
Difference Between Treatments at 120 DIM was 5.0 lbs.

Source: Mattlink Dairy, Dairy Comp 305

Amino Acids in Transition Diets



Transition Cow Amino Acids

- Recognize use of amino acids for glucose synthesis, liver function, and response to inflammation and oxidative stress

- Provide High Quality Metabolizable Protein
  - Adequate Prepartum MP (1100 to 1200 g/d MP)
  - Provide Rumen Available Carbohydrate and Degradable Protein for Highest Microbial Protein Synthesis
  - Provide High Quality Rumen Undegradable Amino Acids (Processed Soy, Blood Meal, RP Methionine + Lysine)

Prepartum MP Needs

- 70% of Fetal growth during last 60-70 d of pregnancy
- Insufficient dietary protein may increase use of body proteins reducing proteins available to be used in early lactation resulting in impaired health, production, and reproductive performance
- Van Saun (1993) reported lower ketosis and improved reproductive performance in mature Holsteins fed 1350 vs. 1100 g MP/d

Van Saun and Sniffen, 2016

Prepartum DMI Variability

Last 21 days before calving, mean DMI = 12.3 +/- 2.5 kg/day

- 15% of the cows ate less than 10 kg/day

Recommendations:

Formulate prefresh diet for 1300 to 1400 g MP as a safety factor to ensure that most cows consume 1080 g MP per day

French (2012) from Phillips et al., 2003

Amino Acid Profile (% of AA) After 12 Hours of *In Situ* Rumen Incubation

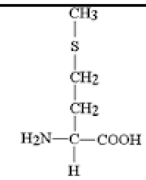
	SBM	Fishmeal	DDGS	Milk (for comparison)
Methionine	1.8	3.8	2.4	2.6
Lysine	5.4	8.5	1.2	7.6
Isoleucine	5.2	5.3	4.0	5.1
Leucine	8.6	8.9	13.8	8.9
Arginine	6.2	6.2	2.6	3.5

O'Mara et al., 1997; Degussa, 1991

Rumen-protected amino acids

- Economically supply only needed amino acids to reduce waste and cost
- Effectively achieve recommended levels of amino acids and increase Income over Feed Cost
- Use of rumen-protected amino acids saves space in the ration leaving more room for other nutrients such as fiber and starch.

Roles of Methionine



Many "Functional Effects" - independent of protein synthesis

- Involved in production of very low-density lipoprotein to reduce fat buildup in the liver and promote liver function
- Needed for making hormones and enzymes
- Can reduce oxidative stress and the negative impacts of inflammation
- Can increase carnitine which is needed by cells for energy utilization
- Can increase phagocytic activity of white blood cells to improve immunity and health

Hutjens; Osorio et al., 2014

Supplemental Met Pre + Postpartum

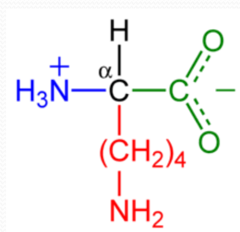
	Control	MetaSmart	Smartamine	Met P-value
Prepartum MP, g/d	1191	1248	1209	
Prepartum MP-Met, g/d	22	29	29	
Prepartum MP-Lys, g/d	79	82	80	
Post-partum MP, g/d	1563	1812	1869	
Post-partum MP-Met, g/d	28	39	40	
Post-partum Met (% of MP)	1.81	2.15	2.15	
Post-partum MP-Lys, g/d	96	110	113	
Post-partum Lys (% of MP)	6.17	6.09	6.06	
Post-partum Lys:Met	3.43:1	2.82:1	2.82:1	
Post-partum DMI, kg/d	13.3	15.2	15.6	0.06
Milk yield, kg/d	35.7	38.1	40.0	0.08
Milk fat, %	4.27	4.68	4.09	0.36
Milk protein, %	3.04	3.26	3.19	0.05
ECM, kg/d	41.0	44.8	45.0	0.03

Osorio et al., 2013

Roles of Lysine

- Essential amino acid for protein synthesis
- Lysine is important for carnitine synthesis
  - Mobilized fat is underutilized in the liver when carnitine is limiting
- Researchers stress greatest responses to RP Met occur ***when Lys is adequate***
  - ***2.8% Lys:Met***

Lysine Availability to the Cow



Blood Meal

Distiller's Grains (DDG)

ADF-CP vs. Ross In Vitro Indigestible CP

	Feed CP, %DM	ADF-CP, %CP	Indigestible CP, %CP
Regular Blood Meal	100	4.7	16
Heat damaged Blood Meal	100	1.8	93
Soybean meal solvent extracted	47.5	6.7	8
Soybean meal heat treated	45.6	7.9	11

Ross, 2013

RUP-AA Digestibility (%) estimates (cecectomized rooster assay)

	Soy-PLUS	Soybean Meal	Distillers Dried Grain	Fishmeal
Arginine	94.7	95.2	91.3	**87.3**
Histidine	90.3	**88.4**	**83.9**	**81.2**
Isoleucine	93.9	94.4	90.0	91.9
Leucine	94.9	94.2	94.4	92.3
Lysine	**87.2**	**89.9**	**72.8**	**87.6**
Methionine	95.2	95.2	93.4	90.7

Boucher, 2009

Blood Meal vs. Rumen-Protected Lysine (Nocek and Shinzato, 2012)

Early lactation cows: 4 to 7 weeks post-partum

	Control	Blood Meal	RP-Lysine
N	18	18	18
CPM MP Lysine Supply (g/d)	153.1	166.1	166.8
DMI, kg/d	20.5	20.3	20.5
Milk Yield, kg/d	42.8	42.7	44.4
3.5% FCM, kg/d	46.7	49.3	50.6
Milk Fat, %	4.06	4.43	4.32
Milk Fat, kg	1.72	1.90	1.94
Milk True Protein, %	2.65	2.62	2.66
Milk True Protein, kg	1.13	1.11	1.18

Balancing Diets for Limiting Amino Acids

- Look for ways to increase microbial protein yield such as by increasing fermentable carbohydrate and/or improving rumen health
- Evaluate ingredients for amino acid digestibility, esp lysine
- Meet ME and MP Balances
- Ensure Lys and Met > 100% of Requirements

Prefresh: 1300 g/d MP, 30-35 g mMet, 90-95 g mLys

Fresh: 12-14% MP (%DM), 2.6-2.8% Met & 7-7.2% Lys (%MP)

Aim for 3.03 g Lys/Mcal ME and 1.14 g Met/Mcal ME

French, 2016

2.8:1 Lys:Met

Investing in Successful Transitions

- Cow Comfort and Management
- Subclinical Hypocalcemia
- Subclinical Ketosis
- Metabolizable Protein and Amino Acids

Feeding and Managing for 35,000 Pounds of Production: Diet Sorting, Dry Cow Strategies and Milk Fat Synthesis

Stephen M. Emanuele, Ph.D., PAS
Senior Dairy Scientist- Technical Advisor
Quality Liquid Feed, Inc.

Where Quality Comes First

Goals for Getting to 35,000 Pounds of Milk

35% First lactation animals in herd
65% pregnant by 115 days in milk
Average 150 – 155 DIM
Peak Milk Mature Cows = 130 pounds
Peak Milk 2nd Lactation Cows = 117 pounds
Peak Milk 1st Lactation Cows = 98 pounds

32 -35 pounds DMI in pre-fresh cows
Eliminate sorting of the pre-fresh and lactating cow diets
Feed a low starch (12 – 14%), high sugar (7.5 – 8.5%), high soluble fiber (6 – 9%) pre-fresh diet.
Use technology that reduces fresh cow diseases.
Use technology that improves forage quality and increases feed intake.

Where Quality Comes First

Our Goal is to Ship 6.5 Pounds of Components per cow/day

- Example: 100 pounds of milk with a 3.6% fat test and a 3.0% protein test = 6.6 pounds of components per day/cow.
- Must drive dry matter intake in transition cows and high cows without depressing fiber digestibility.
- Traditional paradigm: Need to feed high starch diets to make milk and can't make milk on high forage diets.
- New paradigm: Feed a moderate starch diet with high sugar (7 – 8%) and high soluble fiber (6 -9%) and feed a minimum of 50% forage.
- This works because sucrose and glucose sugars increase fiber digestion compared to starch.

QLF QUALITY LIQUID FEEDS

Where Quality Comes First

Step 1: Must Eliminate Sorting of the TMR

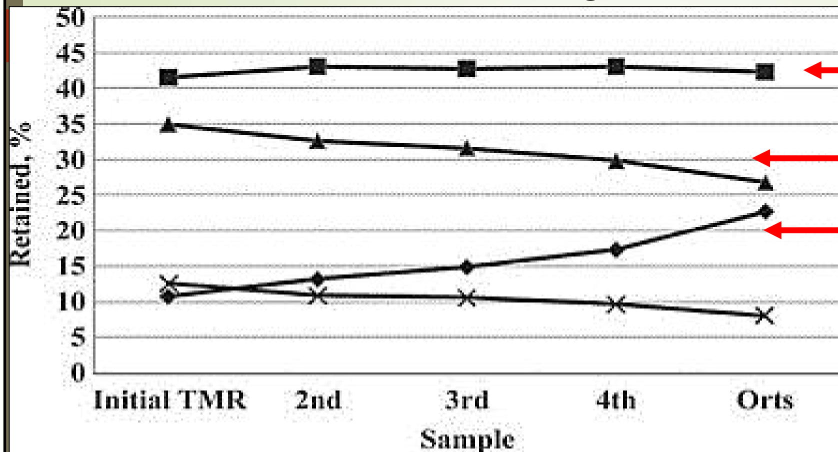
- All Cows Sort Their Ration

  - Cows sort against long particles in the diet (>19 mm).
  - Cows dig holes in the TMR to reach the short and fine particles.
  - A short or fine particle is anything smaller than 8 mm.
  - First Lactation Cows Sort More than Mature Cows.
  - Excessive sorting of the ration can increase the risk of SARA.
  - Sorting of the TMR reduces the intake of forage NDF.
- Sorting of the TMR reduces the real physically effective NDF content of the diet

QLF QUALITY LIQUID FEEDS

Where Quality Comes First

Particle Distribution Change Over Time: 50 herds in MN



2nd Pan
3rd Pan
Top Pan
Bottom Pan

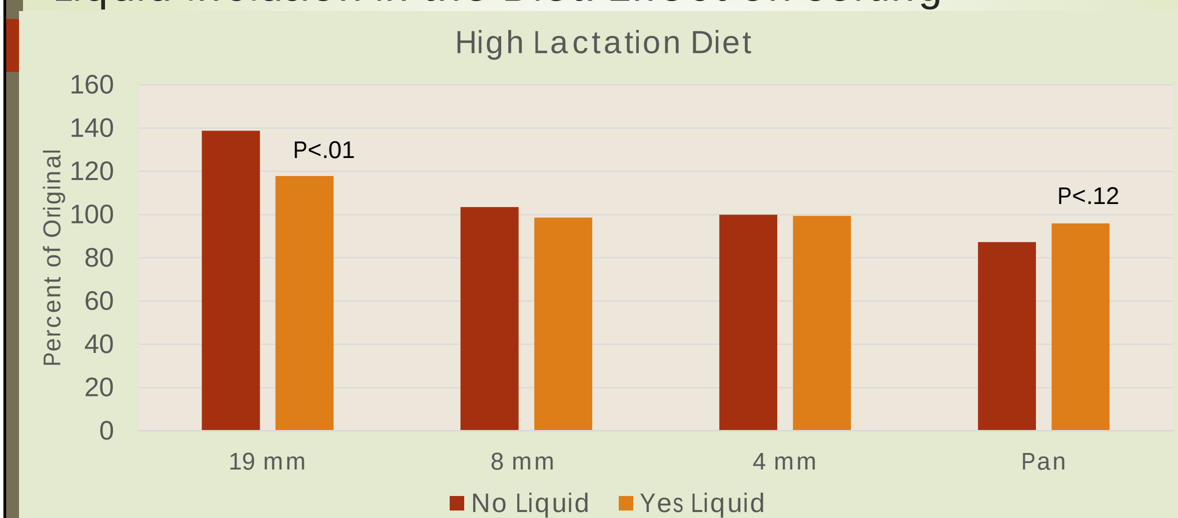
A straight line indicates that cows did not sort. A line curving up indicates that cows sorted against those particles. Cows sorted and left the long particles (>19mm) and consumed more of the short particles (3rd pan).

Top pan started at 10% and ended at 23% Cows left 50% of the long particles.

Average percentage of material retained on each sieve of the Penn State Forage and TMR Particle Size Separator over time [top (♦;>19mm), second (■;>8mm), third (>1.18mm), and bottom (×;<1.18mm) pans] for 50 freestall herds in Minnesota. Samples represent the initial TMR collected at feed delivery; the second, third, and fourth samples collected every 2 to 3h after feed delivery; and the orts.

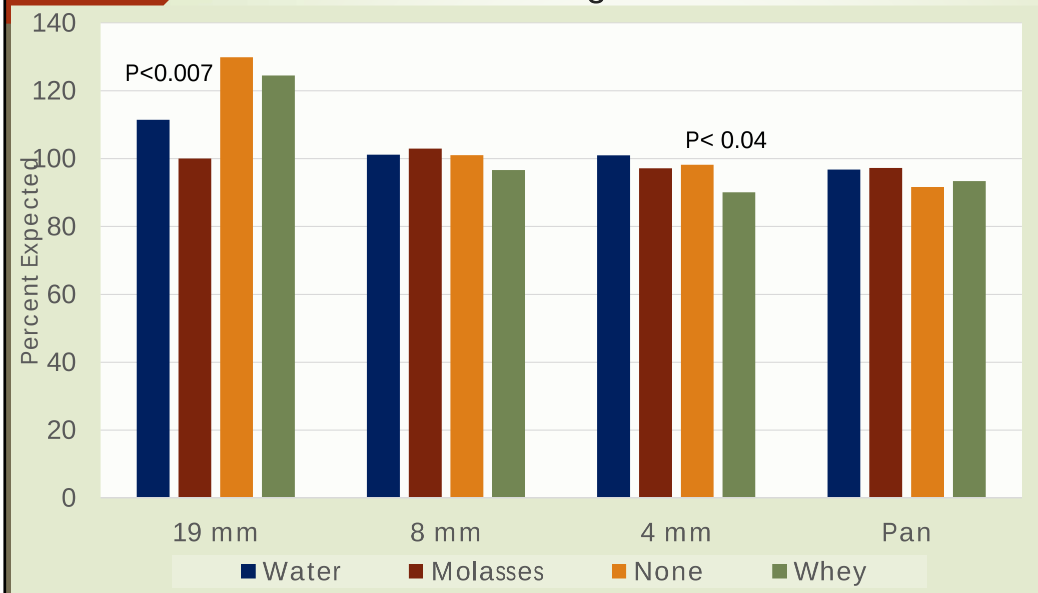
JDS 93:822-829

Liquid Inclusion in the Diet: Effect on Sorting



Value = 100 indicates no sorting. Values > 100 indicate sorting against those particles in the TMR. Inclusion of liquid in the TMR reduced the sorting of the top screen. Adding liquid reduced sorting for fine particles.

Effect of Type of Liquid on Sorting: Not All Liquids Eliminate Sorting of the TMR



Whey did not prevent the sorting of the long particles in the TMR.

Adding water was not as effective as adding molasses to reduce sorting

Step 2: Optimizing Dry Matter Intake of Transition Cows: Feeding to Enhance Fiber Digestion and Reduce Diet Sorting

- Case Studies:

  1. Paramount Dairy
  2. Dordt College
  3. Pennsylvania Dairy

QLF QUALITY LIQUID FEEDS

Where Quality Comes First

Paramount Dairy, CARO, MI

Ration

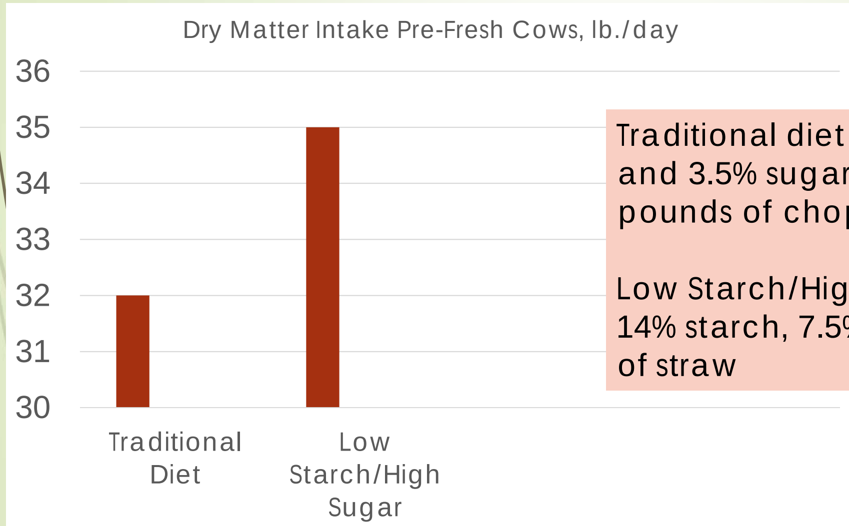
Dry and Pre-fresh cows	
Ingredient	**DM (lb./d)**
Dry cow mix	5.26
QLF-Nutritek	**3.02 (5 lbs. as fed)**
Straw	11.08
Canola	4.13
Corn Silage	9.52
Total	33.01

Started on May-5-2016

Fresh cows	
Ingredient	**DM (lb./d)**
Fresh cow mix	17.5
QLF-Nutritek	**3.02 (5 lbs. as fed)**
Straw	1.8
Haylage	8.0
Corn Silage	18
Total	48.32

Started on May-25-2016

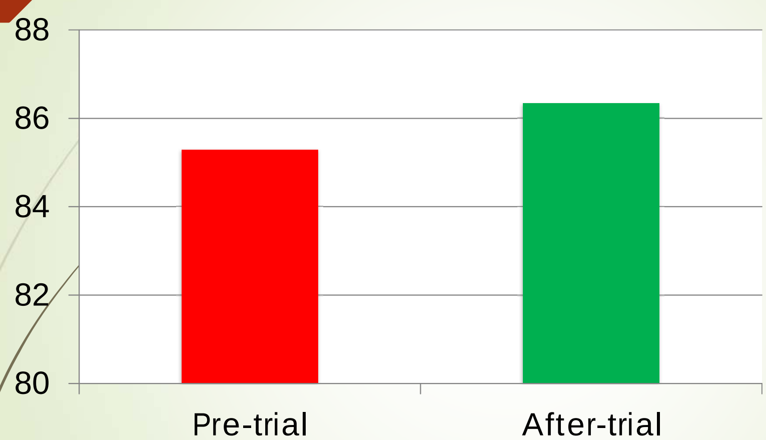
Impact of low starch, high sugar and soluble fiber diets on feed intake in close-up cows.



Traditional diet contained 16% starch and 3.5% sugar and contained 9 pounds of chopped straw.

Low Starch/High sugar diet contained 14% starch, 7.5% sugar and 11 pounds of straw

Paramount Dairy Milk yield (lb./d)

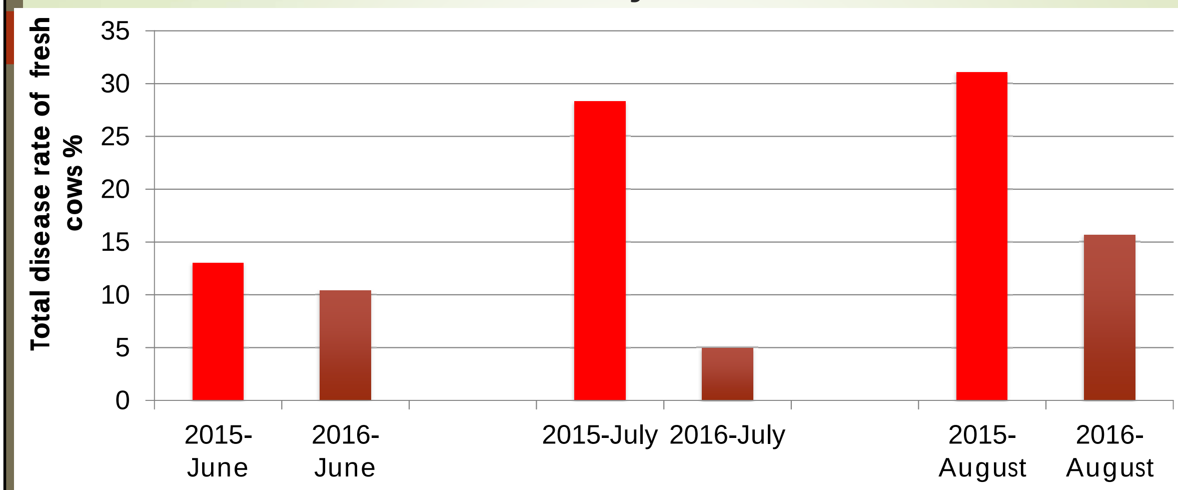


Heat Stress present in July and August 2016.

Milk increase was 1 pound but milk yield should have been lower due to heat stress.

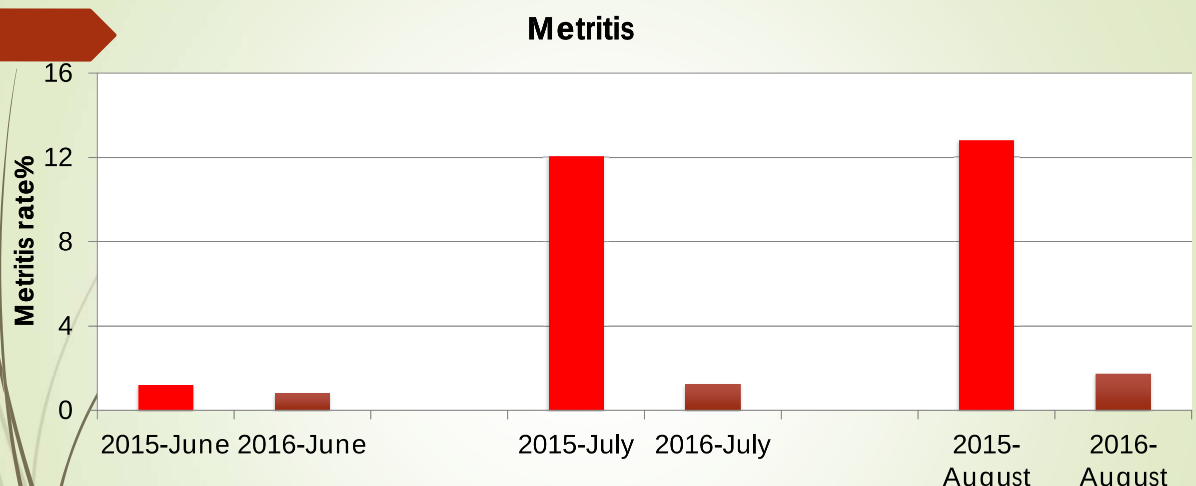
QLF+NutriTek was fed from 5/25/16 to 8/31/16. The milk yields from 3/1/16 to 5/24/16 (without QLF+NutriTek) were used as comparisons. Cows were between day 1 and 40 of lactation. SE = 0.73. P = 0.28.

Total rates of Paramount Dairy fresh cow diseases



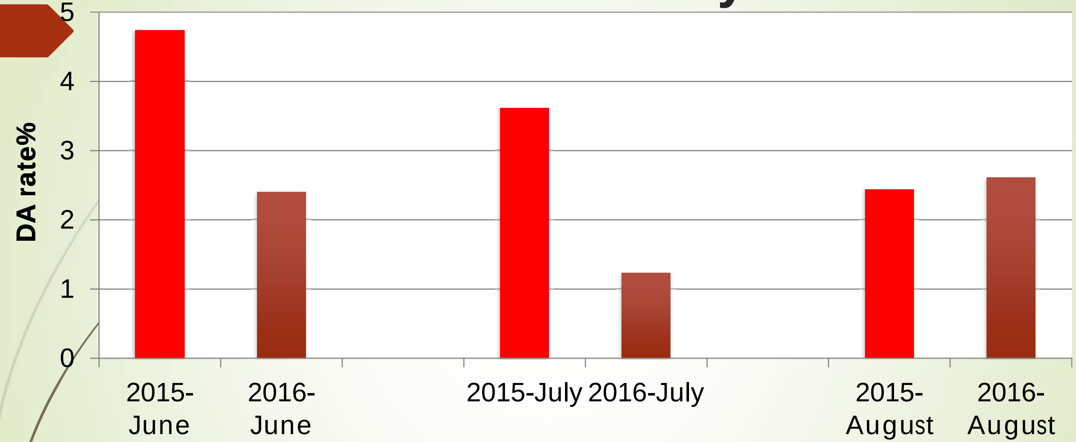
Average fresh cow disease rate for summer 2016 was 10.3%
Average fresh cow disease rate for summer 2015 was 24.1%

Metritis rates of Paramount Dairy fresh cows



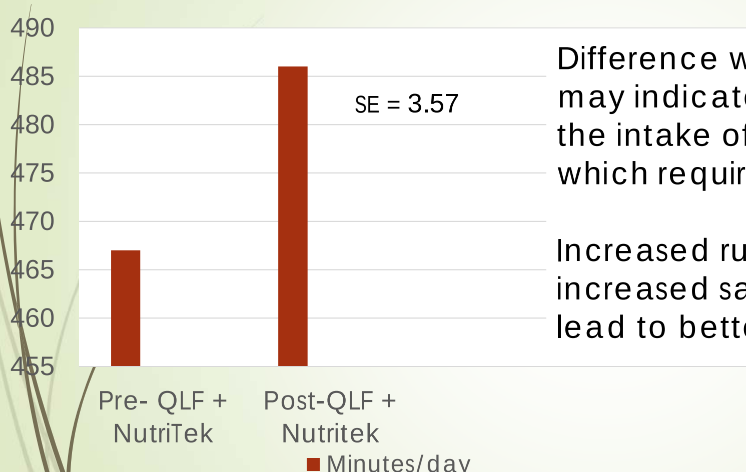
Metritis rates in summer pre-QLF + NutriTek were 8.7%
Metritis rates in summer with QLF + NutriTek were 1.3%
A reduction in Metritis rate of 85% (8.7-1.3/8.7)
Per 1000 cows that is 74 less cows with metritis. (87 – 13)

DA rates of Paramount Dairy fresh cows



DA rates in summer pre-QLF + NutriTek were 3.6%
DA rates in summer with QLF + NutriTek were 2.1%
Per 1000 cows that is 15 fewer DA'S
A reduction in DA rate of 42% (3.6 – 2.1/3.6)
15 fewer DA's is a saving of $5,100

Rumination of Cows Pre- and Post QLF + Nutritek, Minutes/day



Difference was 19 minutes per day. This may indicate that QLF+NutriTek stimulated the intake of long particles in the diet, which require increased rumination.

Increased rumination is associated with increased saliva production, which may lead to better rumen health.

Dairy Herd Trial Conducted by Students at Dordt College in Iowa.

Nicholas Leyendekker, Imanuel Feodor, Ross Schreur
Senior Students, Dordt College

QLF
QUALITY LIQUID FEEDS

Where Quality Comes First

Introduction

- Farm: Commercial Dairy, 400 cow Holstein Herd
- Issues dairy producer wanted to have fixed.

  1. Sorting of pre-fresh and post-fresh diet.
  2. Low Milk Fat Test in early lactation.
  3. Desire higher peak milk.

- QLF Dairy Transition 6 was fed at 4 pounds/cow pre-fresh and post-fresh (first 30 DIM).
- NutriTek from Diamond V was in the dry mineral.
- Diet adjusted to be iso-caloric and iso-nitrogenous to diet prior to QLF addition
- QLF liquid supplement replaced some corn and fat in the diet.

Dry Matter Intake, (lbs./day) Pre-QLF and during the QLF feeding period

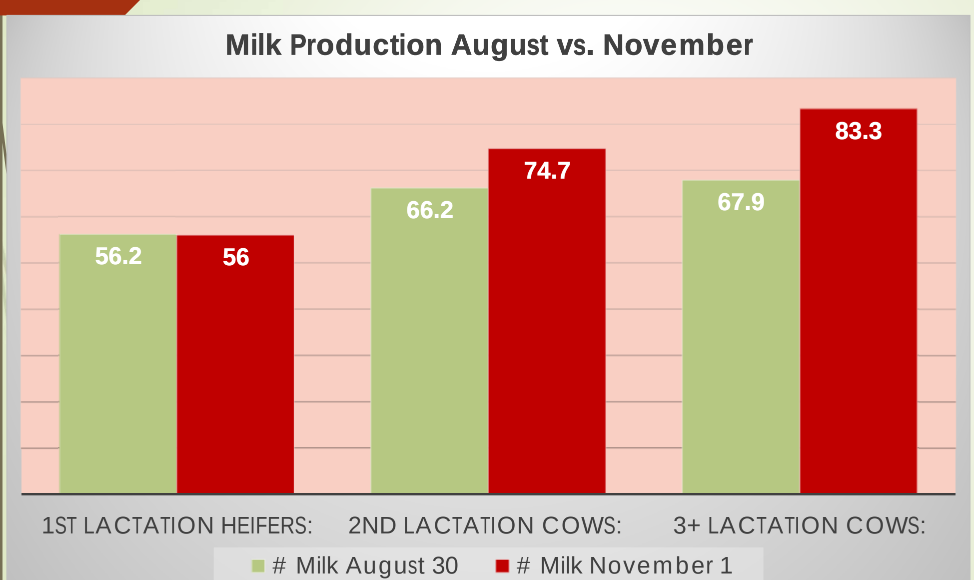
	Pre-QLF Feeding	QLF Feeding Period	Difference
Pre-Fresh Mature Cows and 1st Lactation Cows	24.9	26.6	+ 1.7 lbs.
Fresh 1st Lactation Cows, DIM 1-30	34.1	38.6	+ 4.5 lbs.
Fresh Mature Cows, DIM 1-30	43.4	46.0	+ 2.6 lbs.

Pre-QLF period from Jan 1, 2016 through Sept. 15, 2016.
QLF feeding period from Sept. 16, 2016 through Nov. 18, 2016, 62 days.

QLF QUALITY LIQUID FEEDS

Where Quality Comes First

Results: Milk Production, lbs./cow



2nd lactation cows, + 8.5 pounds of milk.

3+ lactation cows, + 15.4 pounds of milk

Milk Component Yield and ECM (lbs./day), Pre-QLF Feeding

	Pre-QLF	QLF Period	Diff.
1st lactation cows, milkfat lbs.	1.74	2.30	+0.56
1st lactation cows, milk protein lbs.	2.25	1.90	-0.35
2nd and greater lactation cows, milk fat lbs.	2.01	3.24	+1.23
2nd and greater lactation cows, milk protein lbs.	2.35	3.00	+0.65
Total pounds of fat and protein, 1st lactation cows	3.99	4.20	+0.21
Total pounds of fat and protein, 2nd and greater lactation cows.	4.36	6.24	+1.88
Energy Corrected Milk (ECM), 1st lactation cows, lbs./ day.	57.1	61.8	+4.7
Energy Corrected Milk (ECM), 2nd and greater lactation cows, lbs./ day.	64.9	89.4	+24.5

QLF QUALITY LIQUID FEEDS

Where Quality Comes First

Economic Analysis of Dordt College Trial Accounting for Increased DMI when QLF and NutriTek were Fed

	Pre-QLF	QLF Feeding Period	Diff.
Pre-Fresh Diet, $/cow/day	3.00	3.45	
Cost for 21 days Pre-Fresh, $	63.00	72.45	+9.45
Fresh Cow Diet, $/cow/day	5.21	5.69	
Cost for 60 days of lactation, $	312.60	341.40	+28.80
Difference in cost for 81 days, $/cow			+38.25
Breakeven milk (Lbs./cow/day) needed at $17/CWT			3.75
Actual Milk response, lbs.		(8.5 + 15.4)/2	11.95
ROI at $17/CWT Milk Price		(11.95 – 3.75)X 0.17	$1.39

Case Study: Pennsylvania Holstein Herd, 200 cows Rolling Herd Average: 31,025 lbs. Milk

QLF Dairy Transition 6 with and Chromium Propionate fed at 5 pounds as-fed beginning 21 days prior to calving through lactation.

Purina Animal Nutrition feeds this herd

Materials and Methods

- The demonstration herd was a 200 cow commercial herd in Pennsylvania naïve to chromium.
- Herd had been off rBST for over 2 years
- All off/all on design
- Pre-fresh cows and all lactating cows received 5 lbs. of QLF Dairy Transition 6 supplement with KemTRACE® Chromium 0.4% liquid that provided 8 mg elemental chromium/day.
- The herd was housed in a freestall barn and milked 3X
- The 2 months prior to the demonstration were used as baseline information for milk production and component analyses.
- The demonstration period ran from 12/15/16 thru 7/30/17.

Materials and Methods (cont.)

- Monthly DHIA information was collected for 9 months – 2 months prior to the demonstration (baseline period) and for 7 months during the demonstration.
- The milking herd averaged 95 – 97 lbs. on DHIA test day and herd days in milk averaged 159 – 164 during the baseline period.
- Reproductive data was collected for 22 months – 15 months prior to the demonstration and 7 months during the demonstration.
- Reproductive information was analyzed with RepMon©, a powerful reproductive analysis program developed by the University of Pennsylvania's School of Veterinary Medicine.

Results – Milk yield and composition

Table 1. Milk, milk composition, and component yields during the pre-demonstration and demonstration months.

Test Day	Oct '16 [a]	Nov '16 [a]	Dec'16 [b]	Jan '17	Feb '17	Mar '17	Apr '17	May '17	June '17
Milk (lbs.)	97.30	95.10	98.70	95.60	96.40	96.90	96.50	99.10	93.80
BF%	3.70	3.60	3.70	3.80	4.00	3.70	4.00	3.60	3.80
Protein%	3.00	3.10	3.00	3.00	3.00	3.00	3.00	3.10	3.10
BF (lbs.)	3.60	3.42	3.65	3.63	3.86	3.59	3.86	3.57	3.56
Protein (lbs.)	2.92	2.95	2.96	2.87	2.89	2.91	2.90	3.07	2.91
BF + Protein (lbs.)	6.52	6.37	6.61	6.50	6.75	6.49	6.76	6.64	6.47

[a] Pre-demonstration period
[b] Demonstration begins

Results – Milk yield and composition

Table 2. Herd performance comparison between pre-demonstration and demonstration periods

Herd Performance on Test Day	Pre-demonstration (average of 2 months)	Demonstration (average of 7 months)	Demonstration (average of 6 months – Dec thru May)
Milk (lbs.)	96.2	96.7	97.2
Butterfat %	3.65	3.80	3.80
Protein %	3.05	3.03	3.02
Butterfat (lbs.)	3.51	3.67	3.69
Protein (lbs.)	2.93	2.94	2.93
Butter + Protein (lbs.)	6.45	6.61	6.62

Feeding QLF with liquid chromium propionate appears to have resulted in .16 lb. more milk component yield.

Results – Reproductive performance

Table 3. First service conception rate in the pre-demonstration and demonstration periods.

1st Service Conception Rate	Pre-demonstration (8/1/15-7/31/16)	Demonstration (12/15/16-6/15/17)
1st lactation animals	45.5%	67.7%
≥ 2nd lactation animals	24.0%	36.6%
All animals	34.8%	52.2%

Feeding QLF with liquid chromium propionate appears to have improved the herd's 1st service conception rate.

Economic benefit to using QLF with liquid chromium

Daily butterfat yield increase per cow/day is .16 lbs.

Butterfat is worth $3.01/lb. currently.

.16 lbs. X $3.01/lb. = $.48/cow/day

Value of improved reproductive efficiency is $167.63/cow/year or $.46/cow/day. (From U. of Penn., RepMon Program).

Economic benefit from increased butterfat and reproductive improvement is $.48 + $.46 = $.94/cow/day.

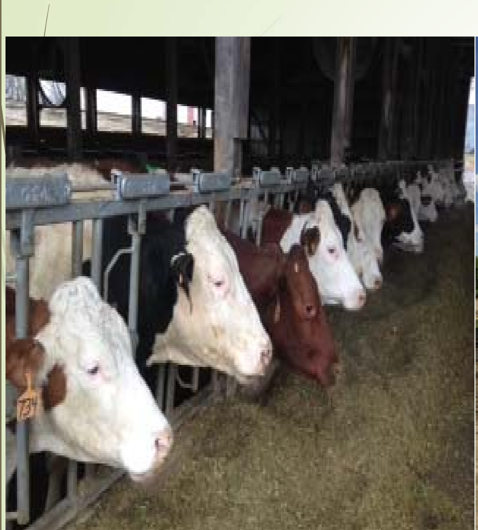
Feeding QLF with liquid chromium increased ration cost $.22/cow/day.

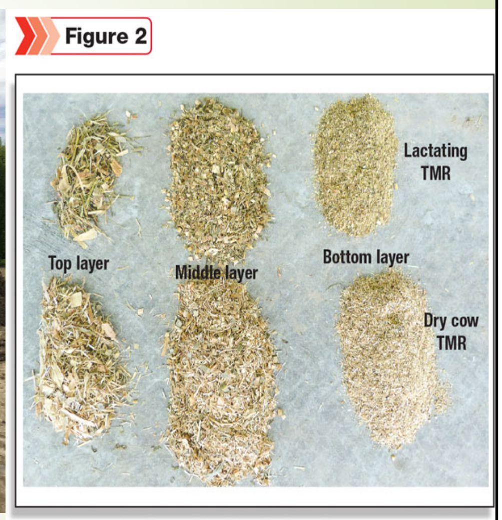
($0.17 from QLF + $0.05 from Chromium)

The producer makes on additional $.72/cow/day.

The ROI is 4.3:1

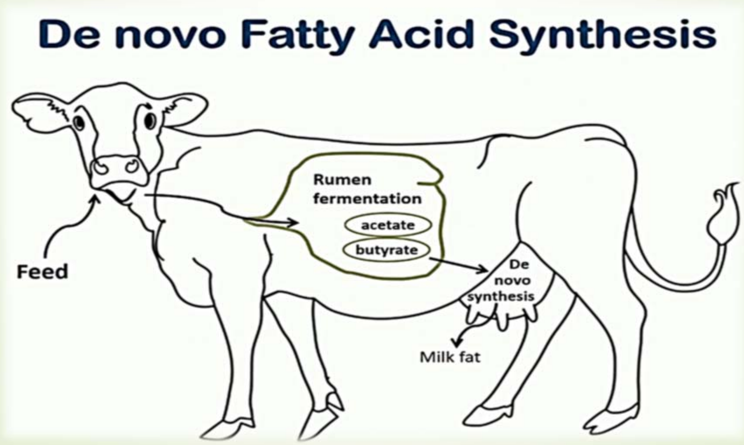
Step 3: Optimize the production of acetate, propionate and butyrate in the rumen



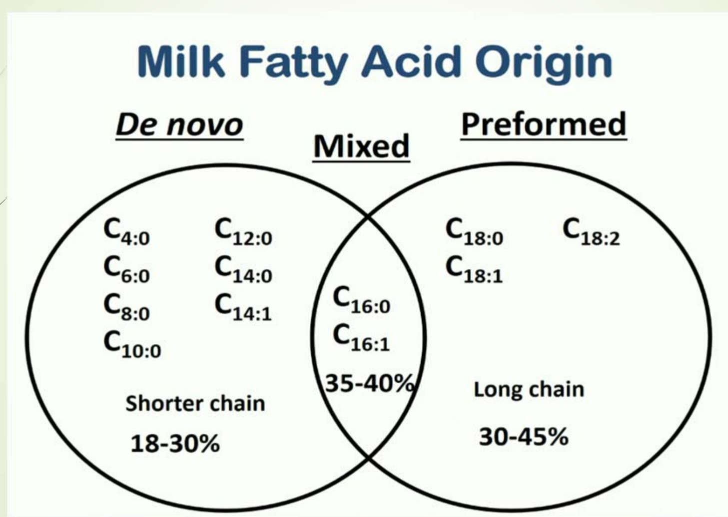


What are Short-Chain Fatty acids?

Short-Chain Fatty Acids are synthesized in the udder from acetate and butyrate. They are called De novo fatty acids because they are made by the cow. They should make up 20 – 30 % of the total milk fat



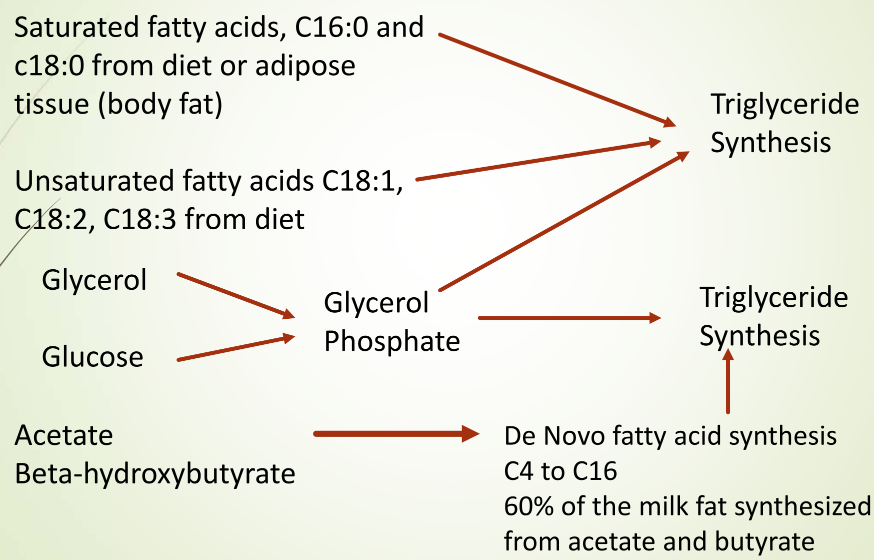
Cannot make milk fat without plenty of acetate and butyrate



What can milk fatty acid profiles tell us?

Milk fatty acid profiles tell us how well the cow is being ***fed*** *and* ***managed*** *for optimal rumen fermentation conditions.*

Milk Fat Synthesis in the Mammary Gland



Origin of C16:0 Fatty Acid in Milk

60% of C16:0 synthesized from acetate and butyrate in cows with DIM greater than 30.

40% of C16:0 comes from the diet in cows with DIM greater than 30.

Feeds containing c16:0 fatty acids: forages, corn grain, cottonseeds, soybeans, palm fat, tallow.

In fresh cows, less than 30 DIM, 25% of the C16:0 in milk comes from bodyfat mobilization, 50% from acetate and butyrate and 25% of the c16:0 in milk comes from the diet.

The Math of Milk Fat Synthesis

- Milk with 3.8% fat content contains 3.8 grams of fat per 100 grams of milk.
- De Novo fatty acid content of the milk should be 0.95 grams.
- (0.95/3.8)X 100 = 25% of the total milk fat
- De Novo + Mixed fatty acid content of the milk should be 2.3 grams.
- (2.3/3.8)X 100 = 61% of the total milk fat.
- Most efficient way to synthesize c16:0 is from butyrate.
- Feeding palm fat will raise the c16:0 content of milk and increase milk fat % but it is expensive.
- 1 pound of palm fat costs 65 cents.

Farm testing results IA and OH, Sept 2017

Farm Name	Milk Yield	Milk Fat%	Milk Protein%	MUN	DB/ FA	De Novo g/100g milk	Mixed g/100g milk	Mixed + De Novo, g/100g milk
Byker	75	3.82	3.45	12.0	0.29	0.95	1.34	2.29
RL	84	3.48	2.94	13.4	0.33	0.71	1.24	1.95
E-D	84	3.27	2.86	7.9	0.33	0.67	1.18	1.85
PF	86	3.64	3.08	15.4	0.34	0.75	1.15	1.90
Putt	95	3.96	3.08	8.38	0.33	0.85	1.25	2.1
Goal		**3.7**	**3.1**		**< 0.31**	**> 0.90**	**> 1.33**	**>2.25**

Putt Dairy feeding 1 pound of long-chain (C18) fat, which hides a rumen function issue.
E-D and RL farms have a severe rumen function issue, which is depressing milk fat%
All 4 OH dairies feeding too much polyunsaturated fat in the diet.

South Dakota Milk Fatty Acid testing results

Farm Name	Milk Yield Lbs.	Milk Fat%	Milk Protein%	DB/FA	De Novo g/100g	Mixed g/100g	Mixed + De Novo g/100g	Preformed FA, g/100g milk
R1	92	3.78	2.97	0.30	0.84	1.31	2.15	1.43
R2	84	3.79	2.99	0.30	0.93	1.30	2.23	1.34
P	92	3.52	3.16	0.32	0.78	1.18	1.96	1.36
W	84	3.78	2.97	0.29	0.90	1.46	2.36	1.35
M	78	3.85	3.05	0.31	0.86	1.29	2.15	1.52
H	88	4.03	3.10	0.30	0.92	1.39	2.31	1.49
B	75	3.82	3.45	0.29	0.95	1.34	2.30	1.30
Goal		**3.75**	**3.1**	**< 0.31**	**> 0.90**	**≥ 1.33**	**>2.3**	**≥ 1.3** **< 1.5**

To boost De Novo (Short Chain FA content of milk, increase acetate and butyrate production in the rumen. Boost fiber digestion and feed a diet that is 7 – 8 % total sugar and 6 – 8 % soluble fiber and 23 – 27% starch.

$128 shipping 1 box overnight!

Supplemental Sugar Recommendations to Optimize Dry Matter intake in Dairy Cows

- Supplement Enough! Aim for 7%- 7.5% Total Diet Sugar in lactating cow diets.
- Aim for 7.0 – 8.0 % total sugar in dry cow diets
- Focus on Higher Producing Cows
- Provide Enough Rumen Degradable Protein (10-11%)
- Provide Adequate Rumen Effective Fiber, minimum 20% peNDF
- Monitor Cow Response
  - Measure DM Intake – DM intake should increase in dry cows and fresh cows.
  - Watch MUN's – MUN's should decrease
  - Watch Manure – should see less undigested fiber in manure
  - Monitor Milk fatty acid profile, look for increase in de novo and mixed FA as grams/100 grams milk

University of New Hampshire
College of Life Sciences and Agriculture

Does Raising a Successful Calf Begin with Mom?

PETE ERICKSON, PH.D., PROFESSOR OF DAIRY MANAGEMENT AND EXTENSION SPECIALIST

Fairchild Dairy, UNH

Burley-DeMerritt Dairy, UNH

Outline

- Can how we feed the dam affect the calf?
- Management studies
  - Heat
  - Cold
- Mastitis
- Nutrition studies
  - Anionic salts
  - Niacin
- Prediction Equation
- Conclusions

Cow heat abatement and calf performance

- A large study was conducted at the University of Florida from the lab of Dr. Geoff Dahl
- Generally dry cows were split into two groups those that a were given shade only (HT) and those that were provided with shade, sprinklers and fans (CL)
- Cows were dried off 45 d before expected calving date.
- Measured calf performance

Cow data

- Heat stressed cows had a 0.3 to 0.4°C rise in rectal temperature compared to CL cows
- Respiration rate was increased 1.5 to 2.0 times in HT cows compared to CL cows
- HT cows consumed about 2.2 pounds of DM less per day than CL cows
- HT cows gained 21 and CL cows gained 57.33 pounds during the dry period ($P<0.01$)
- HT cows dry period was 4 d less than CL cows
- CL cows produced an average of 75 pounds/d while HT cows produced 61 pounds/d in the next lactation

Birth weight, colostrum IgG, 28 d serum IgG, weaning weight (Tao et al., 2012)

Variable	Heat stress	Cooling	P =
Birth weight, lb	80.5	93.7	<0.01
Colostrum IgG, g/L	86.8	77.3	0.36
28 d serum IgG, g/L	10.6 +/-1.7 g/L	15.8 +/- 1.5 g/L	0.03
Weaning weight, lb	145.3	173.1	0.04

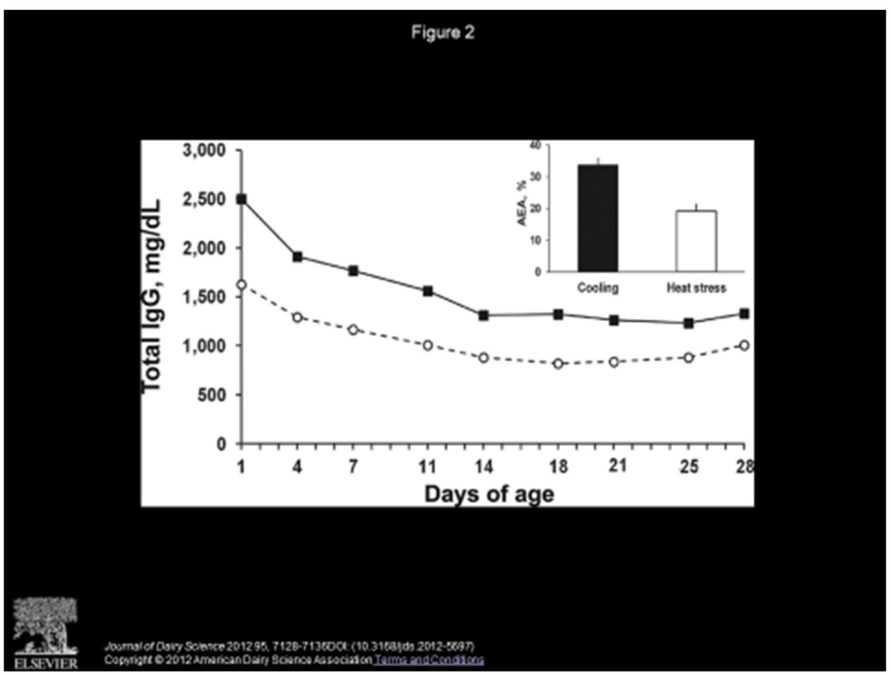
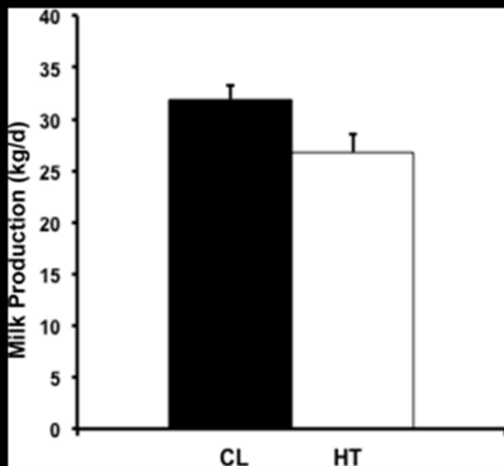
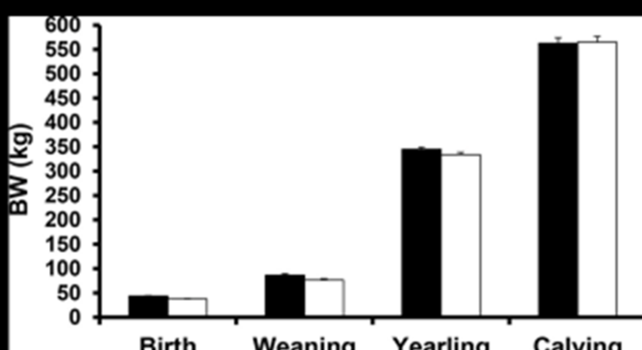


Figure 2



Journal of Dairy Science 2016 99, 3193-3198DOI: (10.3168/jds.2015-9990)

Figure 1



Journal of Dairy Science 2016 99, 3193-3198DOI: (10.3168/jds.2015-9990)

Conclusions from Florida Research

- Calves from CL cows had higher IgG over the first 28 d of life than calves from HT cows($P = 0.03$)
- Calves from CL cows were more efficient in absorbing IgG than calves from HT cows ($P < 0.01$)
- BW was greater for newborns, at weaning and yearlings ($P < 0.05$)
- Calves that were cooled in utero produced more milk ($P < 0.05$) over the initial 35 weeks after calving
- The milk production response was not associated with lower BW as they were similar

What is going on here?

- The Florida group indicate that "calves from HT dams are challenged before birth and must make physiological acommodations in response to higher heat loads, less effective placental support, and reduced maternal nutrient intake"
- The dam is acutely affected by late gestation heat stress while the calf in utero becomes programmed to be less productive for life
- From Dahl et al., (2016). J. Dairy Sci. 99: 3193-3198

Cold Stress

- Norwegian data Gulliksen et al (2008) indicated that cows calving in the winter months produced colostrum with lower IgG than any other season of the year.
- Cows calving in December, January and February produced colostrum that averaged <50 g/L

- In contrast, Conneely et al (2013) in Ireland indicated that colostrum quality was highest in autumn and lowest in early Spring
- Breed effects
- Environmental effects

High Somatic Cell Count in colostrum and its effects on calf performance

- Ferdowsi Nia et al., (2009).JPN 94:628-634
- Three groups of Holstein cows (69 total) –High 5,000,000 cells/mL (n = 21), Medium 2,138,000 cells/mL (n = 38), Low 960,000 cells/mL (n =10)
- What we know

  Prepartic mastitic glands have reduced colostrum volume and IgG mass
- Methods

  Colostrum harvested 1-2 h after calving

  Measured colostrum composition and calf growth up to 60 d

  Calves were fed starter and water ad libitum, calves received whole milk at 10% of BW for 60 d

Results- colostrum, neonate and dam

- Yield of colostrum, protein, lactose, solids and SNF were not different
- Colostrum pH (P =0.06) greater as SCC increased (6.28 - 6.40)
- Fat % dropped (P =0.04) as SCC decreased (5.9 - 4.5 %)
- IgG concentration increased as SCC increased (73 - 82 g/L)
- Dam IgG at calving increased (P <0.01) as SCC increased (17.8 g/L to 30.1)
- Calf serum IgG at 3-h after birth tended to decrease (P = 0.10) as SCC increased (16.2 – 11.4 g/L)

Calf performance

Item	Low SCC	Med SCC	Hi SCC	SEM	Lin	Quad
Birth BW	90	92.2	91.5	3.09	0.84	0.64
BW gain- 30 d	12.6	10.8	5.5	1.54	0.01	0.88
BW gain 30-60 d	52.5	46.5	47.2	3.31	0.44	0.27
BW gain birth - 60d	64.8	57.3	52.7	3.53	0.05	0.35
# d fecal	5.6	6.2	11.2	1.3	0.01	0.45

Calf performance (cont.)

- Wither heights and wither height gains were similar regardless of treatment
- Body length and body length gains were similar regardless of treatment
- Starter intake and water intake were not measured

Take Home Message

- High somatic cell colostrum can reduce performance in the first 60 d of life
- Calves gained less and were ill more often when fed high SCC colostrum
- Could pasteurization improve this?

- Prevent prepartum mastitis, calve in a clean facility
- Calves will respond favorably to lower SCC colostrum

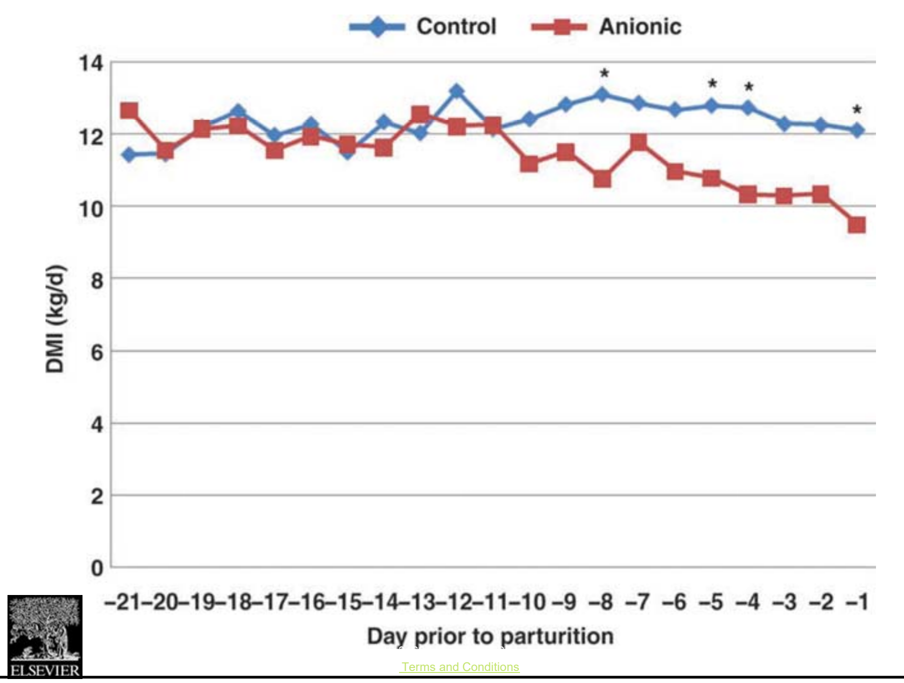
Anionic Salts in the Prepartum Period

- Feeding cows anionic salts may reduce IgG uptake from colostrum (Joyce and Sanchez, 1994) J. Dairy Sci. 77:97.
- Metabolic acidosis
- Adding sodium bicarbonate to colostrum or colostrum replacer may improve IgG uptake (Morrill et al., 2010, J. Dairy Sci. 93: 2067-2075

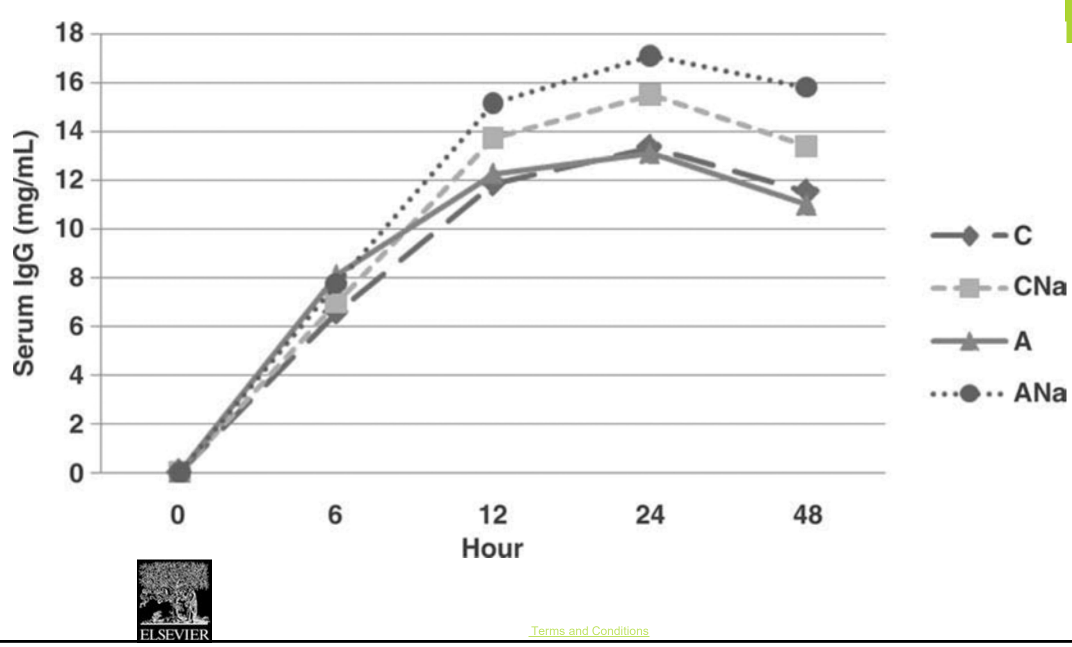
Effects of anionic salts in the prepartum cow diet and Na bicarbonate to colostrum replacer (Morrill et al. 2010)

- 40 prepartum Holstein cows
- 4 treatments cows –-100 mEq/kg, 77 mEq/kg, calves received CR with or without Na bicarbonate
- Cows were fed prefresh diets for 21 d before expected calving dates
- At birth calves were fed a lacteal based CR (132 g IgG) with or without added sodium bicarbonate to bring the pH to 7

Ingredient (% of DM)	77 mEq/kg	-100 mEq/kg
Corn silage	59.3	55.4
Grass haylage	4.0	3.7
Alfalfa hay	17.5	16.0
Straw	2.1	1.8
Calcium carbonate	0.3	0.2
Molasses	0.4	0.3
Soybean meal	2.2	1.9
Soybean hulls	6.0	5.5
Corn meal	1.3	1.2
Steam flaked corn	1.0	0.9
Ground beet pulp	4.6	3.8
Mineral–vitamin mix	1.3	1.2
SoyChlor	—	7.6
Calcium sulfate	—	0.5
Calculated nutrient content (% dietary DM)		
CP	11.1	12.0
ADF	32.1	29.7
NDF	48.1	45.5
Ca	1.18	1.18
P	0.23	0.29
Mg	0.37	0.31
K	1.38	1.33
Cl	0.54	0.90
Na	0.14	0.11
S	0.27	0.61



Control
Anionic
DMI (kg/d)
Day prior to parturition
ELSEVIER
Terms and Conditions



Serum IgG (mg/mL)
Hour
C
CNa
A
ANa
ELSEVIER
Terms and Conditions

Item	Treatment				SE	Contrast		
	C	CNa	A	ANa		SB	An	An SB
Initial BW (kg)	43.5	42.3	42.5	42.3	1.3	—	0.7	—
Passive transfer (%)	80.0	90.0	90.0	100.0	—	—	—	—
Serum IgG (g/L)								
24 h	13	15	13	17	1.7	0.01	0.5	0.44
AEA (%)	26.8	29.6	25.5	32.9	2.8	0.02	0.6	0.27
IgG AUC (g/L × h)	562	575	534	688	42	0.04	0.3	0.08

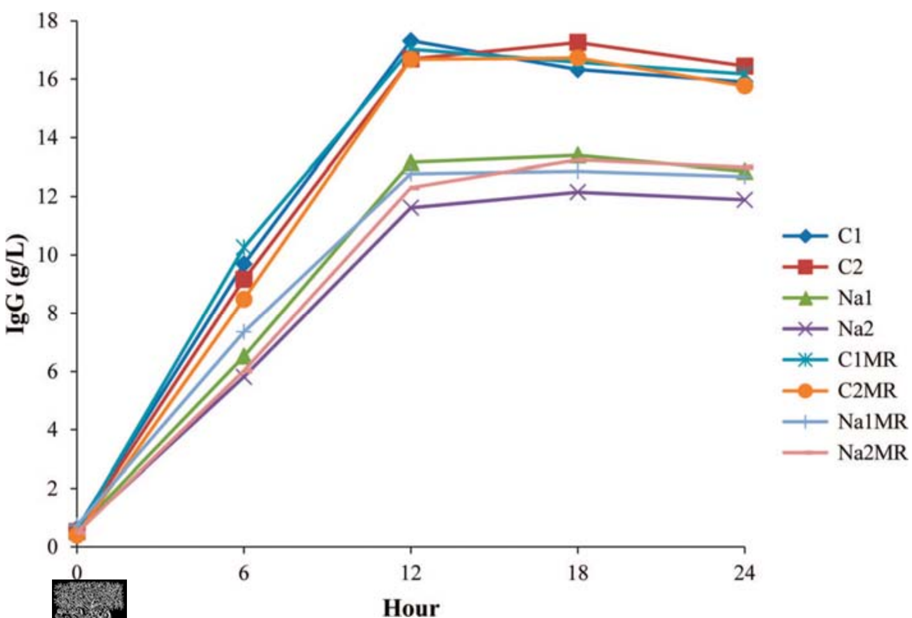
Take home messages

- Feeding anionic salts at this concentration did not impair IgG uptake in calves fed CR
- Adding sodium bicarbonate (30 g) improved IgG uptake in calves

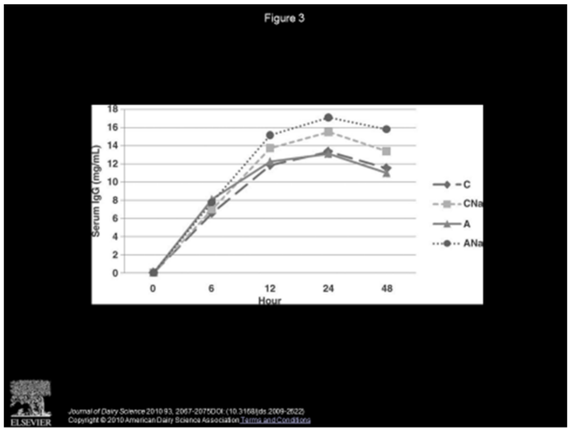
Addition of sodium bicarbonate to CR

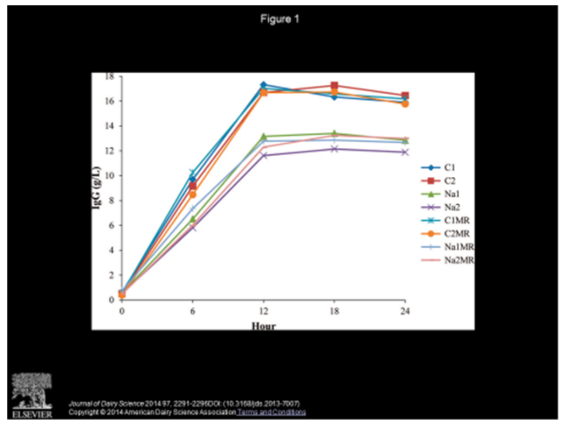
- 80 calf study
- Evaluated CR with or without NA bicarbonate, how it was fed, and if MR could be fed on the same day
- Calves fed CR with sodium bicarbonate had lower IgG uptake than calves fed CR alone!!
- Opposite Results of Morrill

Cabral et al. 2014, J. Dairy Sci. 97:2291-2296



Comparison Morrill and Cabral





Why the opposite results

- Upon further discussion with the herd owner in Cabral's study: cows were not fed an anionic salt diet.
- Many of the dams suffered from hypocalcemia.
- Could we have made the calves alkalotic? If the dams were alkalotic?

Feeding Niacin to dry cows

- Niacin supplementation increases microbial protein synthesis and increases blood flow.
- Could supplementing niacin to prepartum cows affect colostrum quality and the calf?

- Aragona et al., 2016, J. Dairy Sci.99: 3529-3538

- Twenty six Holstein cows were fed either 0 or 48g/d Niacin (not rumen protected). For 4 weeks prepartum
- Dry matter intake, colostrum yield, composition and colostrum quality were determined.
- To determine if the feeding of niacin affected calves in utero, a colostrum replacer was fed.
- Uptake of IgG was measured in the calf.

Dietary ingredient	
Corn silage	37.4
Grass haylage	30.0
RUP mix	2.1
Dry cow mix	30.4
Nutrient content	
CP	14.4 ± 1.8
ADF	27.8 +/-1.3
NDF	40.6 ± 2.7
NFC	35.6 ± 3.2
Starch	17.1 ± 2.4
Fat	2.7 ± 0.2
Lignin	3.6 ± 0.2
Ash	8.8 ± 0.5
Na	0.2 ± 0.04
Mg	0.6 ± 0.04
P	0.3 ± 0.02
S	0.4 ± 0.05
K	1.6 ± 0.1
Ca	0.7 ± 0.2
Cl	0.8 ± 0.1

Results (Prepartum cow)

Item	Treatment		SEM	P-value		
	CON	NA		Trt	Week	Trt × Week
DMI, kg/d	16.0	14.6	0.6	0.15	<0.001	—
BW, kg	812.0	809.3	4.7	0.69	<0.001	—
Urine pH	6.9	7.1		0.51	0.43	—
Glucose, mg/dL	69.5	70.6	0.99	0.40	<0.001	—
NEFA, μEq/L	305.9	378.2	72.3	<0.001	<0.001	0.003
BHB, mmol/L	0.50	0.43	0.02	0.23	<0.001	—

Colostrum characteristics

Item	Treatment[1]		SEM	P-value
	CON	NA		
Colostrum yield, L	10.6	9.5	0.6	0.19
Protein, %	14.7	17.9	1.3	0.09
Fat, %	5.5	4.7	0.8	0.45
Solids, %	23.9	22.9	1.9	0.70
IgG yield, g	749	773.8	81.6	0.80
IgG, g/L	73.8	86.8	3.1	0.01

Calf results

Item	Treatment[1]		SEM	P-value
	CON	NA		
Calf BW, kg	46.0	44.8	1.3	0.51
0-h IgG, g/L	0.4	0.7	0.3	0.49
24-h IgG, g/L	15.9	16.1	0.6	0.75
AEA, %	26.4	25.9	1.0	0.71

Take home message

- Supplemental niacin improved colostrum quality
- Did not alter in utero calf performance
- But ! Calves were not fed their dam's colostrum
- What if they were?

Feeding graded amounts of niacin to prepartum cows: Effects on colostrum and calf performance

- Thirty six Holstein cows were fed either 0,16, 32 or 48 g/d niacin for 4 weeks from predicted calving date.
- Intakes and blood parameters were measured on cows
- Calves were fed their dams colostrum and followed for 6 weeks.
- All calves were fed a 20% CP, 20% fat MR at 4 qts/d with free choice water and coarse starter

Prepartum diet and nutrient analysis

Ingredient	%DM
Corn silage	42.3
Grass silage	24.2
RUP mix (blood meal)	1.33
Dry cow mix (beet pulp, [anionic salts, minerals, molasses, soybean meal, vitamins)	29.92
Energy mix (corn meal, beet pulp)	0.3
Protein mix (SBM, distillers, canola meal)	1.3
CP	16
NDF	34.6
DCAD	-59 mMEq/kg

Cow data

Item	0 g/d	16 g/d	32 g/d	48 g/d	Linear	Quadratic
BW, lb	1756	1765	1767	1775	0.32	0.97
DMI, lb/d	35.5	35.9	34.0	32.6	0.03	0.36
BW, change	13.7	18.3	8.11	22.2	0.51	0.34
Urine, pH	6.20	5.98	6.12	6.23	0.45	0.08
BHB, mol/L	0.72	0.68	0.71	0.73	0.79	0.50
NEFA, µEq/L	230.5	217.6	248.0	240.0	0.45	0.89
IgG, g/L	24.5	23.2	25.4	24.3	0.85	0.95

Prepartum cow results

- DMI decreased as Niacin increased
- No effect on any other parameter

Colostrum quality

Item	0 g/d	16 g/d	32 g/d	48 g/d	Linear	Quadratic
Colostrum, L	11.38	10.83	12.25	8.53	0.29	0.30
IgG, g/L	57.6	72.2	67.8	83.5	0.02	0.95
IgG yield, g	548.9	768.4	807.5	577.7	0.77	0.03
Fat, %	4.51	7.30	6.90	6.10	0.28	0.05
Fat, kg	0.63	0.85	0.92	0.48	0.6	0.05
Protein, %	13.67	15.13	14.82	16.44	0.05	0.92
Protein, kg	1.49	1.77	1.76	1.22	0.35	0.04

Colostrum quality continued

Item	0 g/d	16 g/d	32 g/d	48 g/d	Linear	Quadratic
Ash, %	1.05	1.15	1.22	1.26	<0.01	0.43
Ash, kg	0.12	0.14	0.15	0.10	0.49	0.05
Total solids, %	23.1	26.4	25.8	26.7	0.05	0.29
Total solids, kg	2.61	3.09	3.18	2.06	0.37	0.05

Colostrum Quality

- Niacin fed cows produced colostrum with higher IgG, protein %, Ash % and solids %
- IgG yield, fat % and yield, and protein yield was quadratic with the greatest values in the cows fed 32 g/d,

Calf data

Item	0 g/d	16 g/d	32 g/d	48 g/d	Linear	Quadratic
BW, lb	99.9	99.7	99.7	91.7	0.26	0.44
24 h IgG, g/L	28.5	32.2	29.9	31.0	0.68	0.48
AEA, %	51.7	52.3	50.8	43.8	0.24	0.48
MRI, g/d	449	449	449	449		
Starter, lb/d	1.59	1.43	1.49	1.14	0.07	0.53
ADG, lb/d	1.06	1.00	1.17	0.81	0.12	0.07
ADG/DMI	0.32	0.33	0.46	0.33	0.36	0.07
Final Wt, lb	146.4	141.6	152.4	129.4	0.23	0.23

Calf results

- No difference in initial BW, IgG uptake, or AEA
- Starter intake tended to be less in calves born of cows fed niacin
- But, ADG had quadratic tendencies with the greatest gains over 6 weeks being calves born of cows fed 32 g/d niacin
- Calves from niacin fed cows consumed less starter, but gained more up to 32 g/d.
- Improved feed efficiency in calves of dams fed niacin up to 32g/d
- Could this be due to a component of the colostrum causing a more developed small intestine (more efficient absorption)?

Can we predict colostrum quality before a cow calves?

- 9 New Hampshire dairy farms were used.
  - Holstein cows
  - One lactation
  - DHI
- 111 samples were taken
- Colostrum IgG was measured using RID

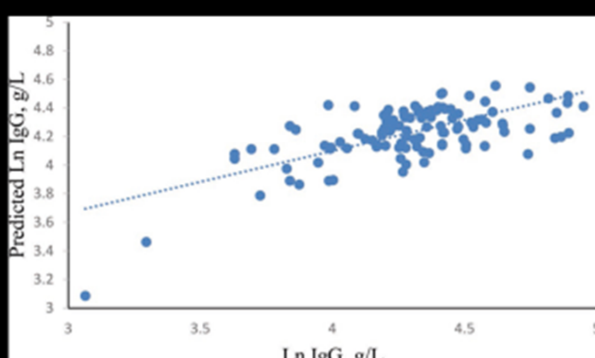
- Cabral et al., 2016 J.Dairy Sci. 99:4048-4055

Item	Mean	SD	Minimum	Maximum
Colostrum characteristics				
Time, h	4.75	3.8	1.0	14.5
COL, kg	7.87	7.2	0.5	39.7
IgG, g/L	77.4	23.4	21.4	141.4
DHI information				
DIM	323	44	245	442
PROD, kg	11,729	2,430	6,530	18,132
FY, kg	436	102	191	807
FP, %	3.74	0.4	2.3	4.8
PY, kg	358	75	180	574
PP, %	3.03	0.19	2.6	3.6
SCS	2.08	1.29	0.2	6.2
DD, d	61.2	16.4	39	147
OD, d	124	80.1	26	338
DO, d	104	51	37	257
PAR	2.16	1.3	1	7
Predicted transmitting abilities				
PTAD	202.7	133.9	−90.0	551
PTAM, kg	99.2	117.3	−240	428
PTAF, kg	3.2	4.0	−7.20	13.78
PTAP, kg	2.7	3.1	−4.32	11.93
Environmental temperature				
D<, d	5.70	7.44	0	20
D, d	11.68	6.48	0	21
D>, d	3.44	5.05	0	20
Sex	1.45	0.50	1	2
PASWK	1.19	2.55	0	9

Model development

- A model was developed using the variance inflation factor in SAS and the best fit was determined
- Correlations were determined using the CORR term in SAS
- Transforming data to Ln improved the model

Figure 1



Journal of Dairy Science 2016 99, 4048-4055DOI: (10.3168/jds.2015-9868)

- Ln IgG = 4.03864 + 2.28887 × Ln FY − 2.15129 × Ln FP − 2.25429 × Ln PY + 2.10609 × Ln PP + 0.14457 × Ln PAR – 0.00025683 × PTAM + 0.01553 × D> – 0.05018 × PASWK; R^2 = 0.56.
- Previous fat yield, previous protein %, parity, days over the TNZ (68 F) were positively related to colostrum quality, while previous fat %, previous protein yield, predicted transmitting ability for milk and weeks on pasture during the dry period were negatively related to colostrum quality

Validation

- 27 colostrum samples from 9 different NH farms were taken
- IgG was measured and the respective cow data from each farm was run through the model

Data for model variation

Item	Mean	SD	Minimum	Maximum
IgG, g/L	88.3	19.7	27.7	116.3
FY, kg	459	129	207	727
FP, %	3.86	0.45	3.20	5.0
PY, kg	362	88	203	553
PP, %	3.11	0.24	2.80	3.60
PAR	2.44	1.42	1	7
PTAM	59.1	174	−366	438
D>	3.70	2.51	0	9
PASWK	1.17	3.03	0	9

Actual vs. Predicted value for colostrum quality

Item	Actual IgG, g/L	Predicted IgG, g/L
Mean	88.3	76.2
SD	19.7	13.0
Minimum	27.7	43.1
Maximum	116.3	99.0

Conclusions for Equation

- We were able to accurately predict colostrum quality
- More data in other parts of the US or the NE needs to be added (PA?)
- Goal is to have a program that producers can download on their computer or phone to predict colostrum quality

Overall conclusions

- Provide heat abatement during the warm weather dry periods- definite pay off in healthier calves and more milk when they become cows
- Prepartum mastitis can cause problems with calf performance keep calving areas dry and clean, dry treat cows.
- Niacin may improve colostrum quality and improve some growth factors which may improve intestinal development- preliminary data on calf work
- Previous Dam performance, and environment can affect colostrum quality

Acknowledgements

- Former Graduate Students who worked in this area:

Dr. Kimberley Morrill

Dr. Rosemarie Cabral

Dr. Colleen Chapman

- Current Graduate Students who work in this area

Kayla Aragona

- NH AES
- Walker Milk Fund
- NC 2042

Questions

2016 Pennsylvania Department of Agriculture Livestock Evaluation Center Dairy Beef Wrap-Up

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Penn State

PROJECT SUMMARY

In 2016, the PA Beef Producers Working Group, a collaboration of the PA Beef Council, Penn State Extension, Center for Beef Excellence, and the Pennsylvania Cattlemen's Association, with support from the Pennsylvania Department of Agriculture (PDA), completed a demonstration of calf-fed Holsteins reared for beef. The PA Beef Producers Working Group partnered with PDA and JBS to provide the Holstein calf-fed demonstration and offered tours of the demo in conjunction with Ag Progress Days.

SOURCING

All Holsteins (44 head) were sourced from a single location, Cold Springs Farms, LLC, and placed on feed at the PDA Livestock Evaluation Center (LEC) on April 21. Calves weighed 546 ± 85 lbs upon arrival and were 9 months old. Prior to feedlot entry, steers were already started on grain and consuming approximately 10 lbs of grain per head per day. Holsteins had also been previously implanted with Ralgro (36 mg zeranol; Merck Animal Health, Parsippany, NJ) in February of 2016. Calves were transitioned on to a 62 Mcal ration (containing corn, silage, distillers dried grains, and minerals) over the course of 10 days. Cattle consuming the 62 Mcal ration ended up consuming approximately 20 lbs of corn per head and 4 lbs of distillers grains per head each day. Calves were weighed at arrival and data on growth performance were collected over the course of the demonstration.

GROWTH PERFORMANCE

Cattle consumed 28 lbs of DM, ~ 36 lbs as delivered, on average for the 209 days they were at the LEC. As a group, the calves gained 3.96 lbs per day (without shrink) for the entire duration of the demonstration. There was some variation in gain with the calf gaining the least amount throughout the demo at 3.46 lbs on average and the one gaining the most at 4.51 lbs per day on average. These tremendous gains led to a feed conversion ratio of 7:1. Feed conversion is an important economic indicator in the feedlot and this means that for every 7 lbs of feed these calves ate, on a DM basis, they gained 1 lb of gain. This was equivalent to approximately 9 lbs of feed delivered for every pound of gain. More often the expectation would be that Holsteins have closer to a 7.5 to 8 lbs feed intake (DM basis) for every lb of gain. Why did the steers at the LEC perform so well?

DISCUSSION OF SUCCESS

A large part of the success of this demonstration has to be attributed to the health of the calves. These Holstein calves were well started and came in with no health issues. The group as a whole dealt with very few challenges throughout the course of the demonstration. Management also played a role in the performance of these calves. The staff at the LEC ensured that these calves always had fresh feed in front of them. Every day. For 209 days. They never ran out of feed. In addition to feed management, these calves were implanted. They were implanted initially with Ralgro (described above) and then implanted again, 28 days after feedlot arrival, with Encore (44 mg of estradiol, Elanco Animal Health, Greenfield, IN). This is a mild, long duration implant that is labeled for up to 400 days; however, we chose to reimplant these calves again with a terminal implant 105 days later (133 days after feedlot entry) and used Component TE-S (24 mg estradiol, 120 mg trenbalone acetate; Elanco Animal Health). These implants helped sustain average daily gains in these Holsteins throughout the 209 days.

There is some concern in the industry over the use of implants and their effects on meat quality. However, as a group, out of 44 Holsteins, 38 of them qualified USDA Choice when they were slaughtered at just 15 months of age. The cattle weighed 1,343 ± 130 lbs when they were weighed off at the LEC and their carcasses ranged from 677 to 861 lbs. On average the group dressed at 58.9%, with 33 carcasses obtaining USDA Yield Grade 1 or 2. Rib eye areas averaged 12.2 inches for the 44 head, and there were no Yield Grade 4 carcasses.

ECONOMICS

The economics on these cattle are variable depending on the scenario you choose to look at. In the LEC production system, feed cost $140/ton delivered. Additional costs of implants, bedding, yardage etc. led to a cost of $2.96/hd per day. Because cattle were bought by JBS when the market was on an upswing at $1.50/lb and sold on a down swing at $0.97/lb the 44 head on this demonstration did lose approximately $188 per head. However, had these calves been forward contracted in April at $1.11, they would have broken even. Subsequently, calves at 550 lbs were only valued at $0.85 at the end of this trial, so buying and selling these calves in the same market (buying at $0.85 and selling at $0.97) would have netted a profit of $176 per head.

The point being, cattle economics vary daily and the market shifts can be unpredictable. Being in the cattle business, whether its a calf-fed Holstein or native beef business, is not a one-season option. It is a revolving cycle that one must ride, both the highs and the lows. These calves outperformed our expectations, but they could not outperform the markets. However, forward contracting would have absorbed some of the risk of the high priced calves and would have helped improve profitability by reducing the end losses.

ACKNOWLEDGEMENTS

This project was a collaboration between Penn State Extension, PA Beef Council, Center for Beef Excellence, and the Pennsylvania Cattlemen's Association. Support provided by the PA Department of Agriculture.

PennState Extension

Feedlot Nutrition for Holsteins

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Why Dairy Beef?

Supply and demand: Dairy steers contribute 15 to 20 percent of the fed beef market in the U.S.

Wardynski, 2015; Progressive Dairymen

PennState Extension

Traditionally....

Veal consumption lbs per capita, 1910-2006

SOURCE: Adapted from "U.S. per Capita Food Consumption: Meat (individual)," in *Data Sets: Food Availability—Custom Queries*, U.S. Department of Agriculture, Economic Research Service, February 15, 2007, http://www.ers.usda.gov/Data/FoodConsumption/FoodAvaiQurriable.aspx (accessed January 26, 2009)

The good

- Easy temperament
- Uniformity of genetics
  - Predictable growth
- Marbling potential
- Fewer respiratory issues once in lot

- Byproduct?
  - Low price

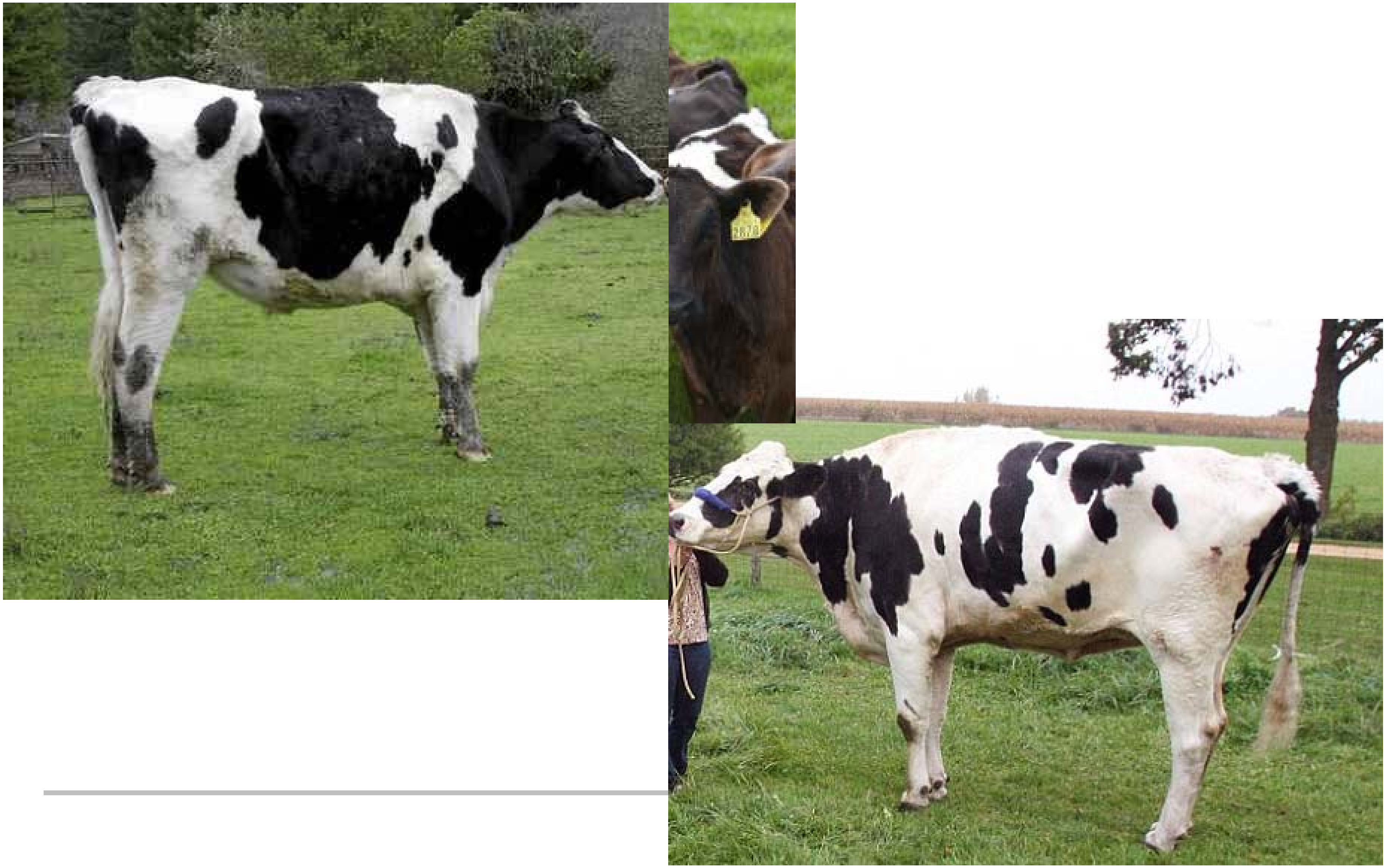
The bad

- Easy temperament
- More DOF (300 to 400+)
  - 9 to 20% greater energy requirement than beef
- Increased feed intake/water intake
  - Increased manure output
  - Wet pens
- Pattern eaters, greater risks
  - Liver abscess
  - Acidosis?

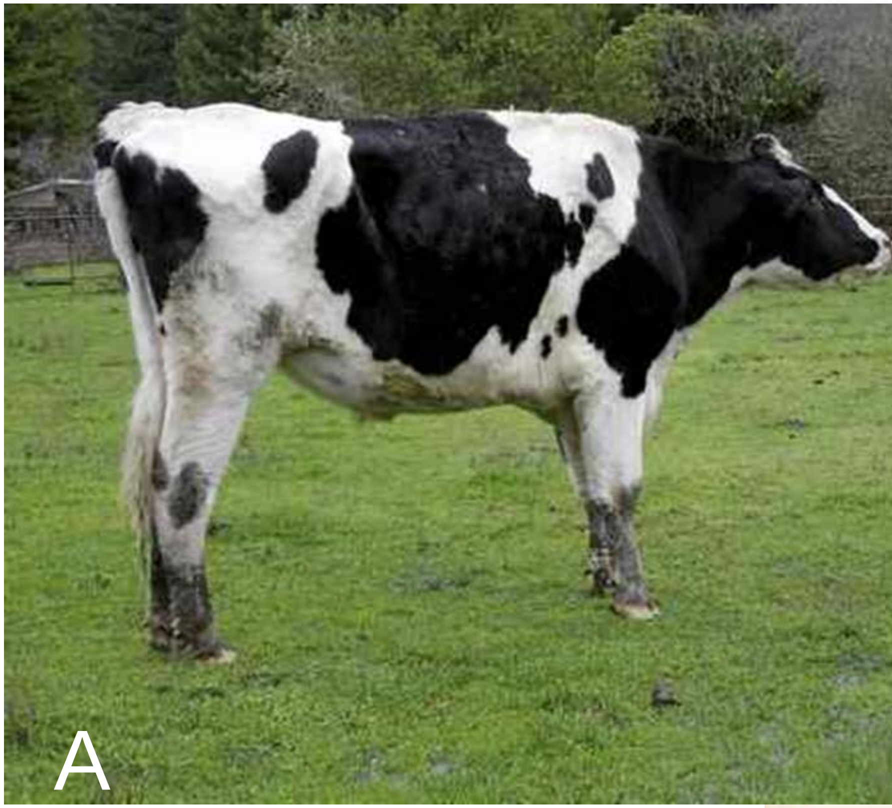
The ugly

- Price swings….
- Historic feeding regimes

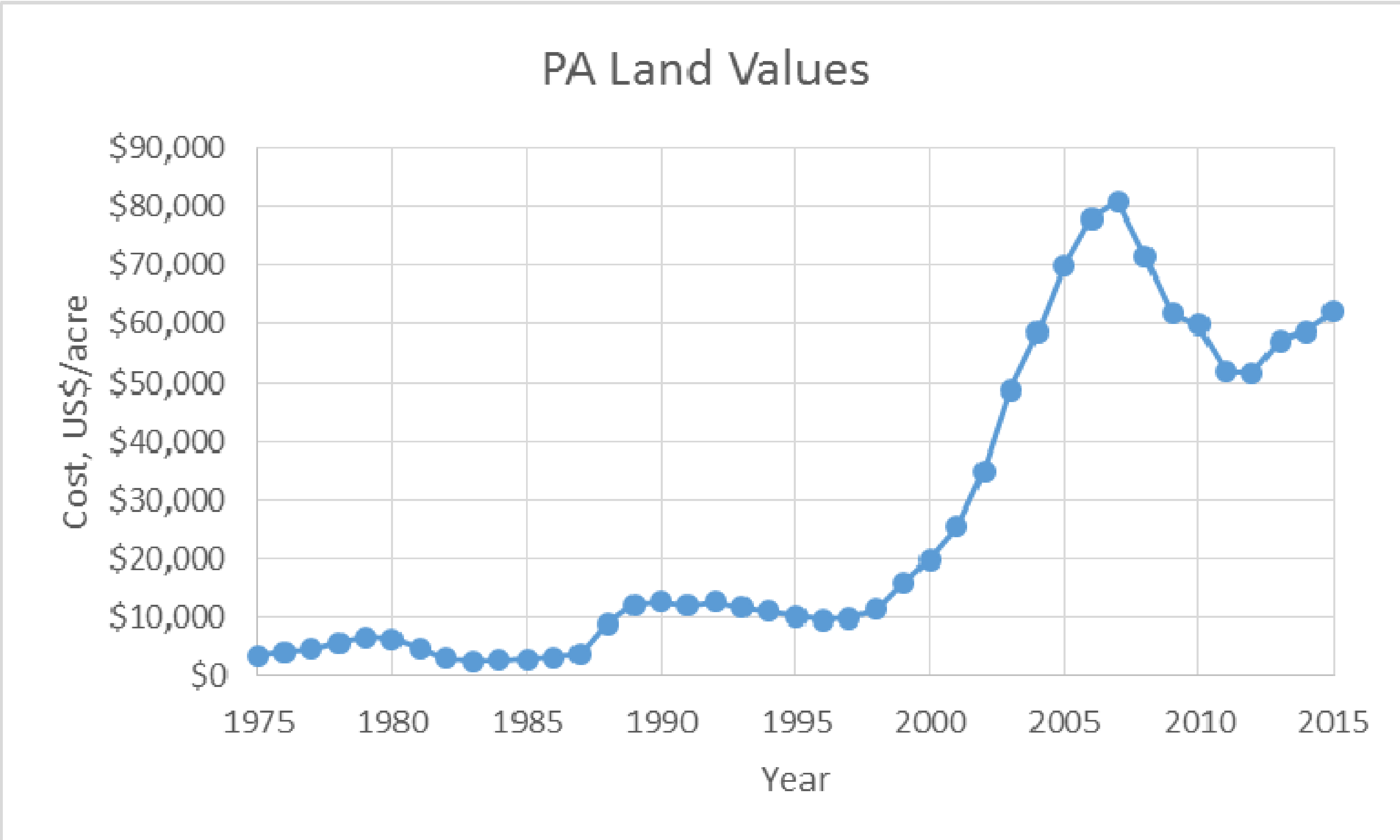
Past....



How can we get from A to B?



PA Land values



http://www.ers.usda.gov/data-products/major-land-uses.aspx#25970

2000 Beef NRC, Net Energy for Gain

Processing Method	NEg, Mcal/lb
Whole	0.68
HMC	0.76
Dry rolled	0.68
Cracked	0.70
Steam flaked	0.73
Corn silage	0.53
Orchardgrass hay, 2nd cut	0.40

Diet scenarios

	Nutrients in 15% DDGS Diet			
Feed	%	Protein	Fat	NE_g, Mcal/lb
DDGS	15	4.5	2.8	0.10
Corn	70	6.3	1.7	0.49
Hay	10	1.0	0.3	0.04
0% CP supplement	5	-	-	-
Total		11.8	4.6	0.63

Cheaper option (-$6/ton)– BUT +30 DOF

	Nutrients in 15% DDGS Diet			
Feed	%	Protein	Fat	NE_g, Mcal/lb
DDGS	15	4.5	1.7	0.10
Corn	50	4.5	1.3	0.34
Hay	30	3.0	0.9	0.12
0% CP suppl.	5	-	-	-
Total		12.0	3.9	0.56

Cheaper by $33/ton– have to handle silage

	Nutrients in 25% DDGS Diet			
Feed	% DM	Protein	Fat	NE_g, Mcal/lb
DDGS	15	6.5	2.8	0.14
Corn	60	4.5	1.3	0.38
Silage	20	1.6	0.7	0.10
0% CP supplement	5	-	-	-
Total		12.5	5.0	0.62

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Project YR 1– Background on calves

- Single sourced calves from one dairy
  - All born August 2015
- Grown by Cold Spring Farms, LLC
  - Manchester, PA
  - Dan and Steve Gross
- Implanted with Ralgro in Feb 2016
- Received at LEC April 21, 2016
  - Incoming weight 544 ± 90 lbs

Project YR 1- Management

- At receiving:
  - Held on hay over the weekend
  - Gave vaccines and weighed
- Fed for ad libitum intake
  - Intake ~28 lbs DM (~35 lbs as-fed) per head each day
  - 62 Mcal diet (Average grain intake, 25 lbs as-fed/hd/day)
  - Corn, DDGS, silage, urea, and mineral
- Weighed every 28 d

Project YR 1- Management

- Implanted with Encore 28 d after feedlot entry
- Reimplanted with Component TE-S on d 133
- Slaughtered after 209 d on feed
  - Age = 15 months

Project YR 1- Performance Summary

Initial BW, lbs	545 ±90
Final BW, lbs	1343 ±150
ADG, lbs	3.96 ±0.5
DMI, lbs	27.66
as % BW	2.93
F:G	6.99

Project YR 1- Carcass Characteristics

	Average	Low	High
HCW	779	677	861
Dressing, %	60.4	53.7	63.9
Marbling	446	325	689
BF	0.26	0.08	0.48
Ribeye Area	12.3	9.7	16.0
YG	2	1	3
Choice, %	88.1		

Project YR 1- Bottom line economics

	True test	If contracted	Nov 2016 prices
Pay weight IN, lbs	24,660	24,660	24,660
Price in	$ 1.50	$ 1.50	$ 0.85
Pay weight OUT, lbs	57,664	57,664	57,664
Price out	$ 0.97	$ 1.11	$ 0.97
Feedlot costs	$ 27,241.87	$ 27,241.87	$ 27,241.87
Total Costs	$ 64,231.87	$ 64,231.87	$ 48,202.87
Total return	$ 55,934.08	$ 64,237.70	$ 55,934.08
Net Return	$ (8,297.79)	$ 5.83	$ 7,731.21
Net Return per hd	$ (188.59)	$ 0.13	$ 175.71

Use of implants?

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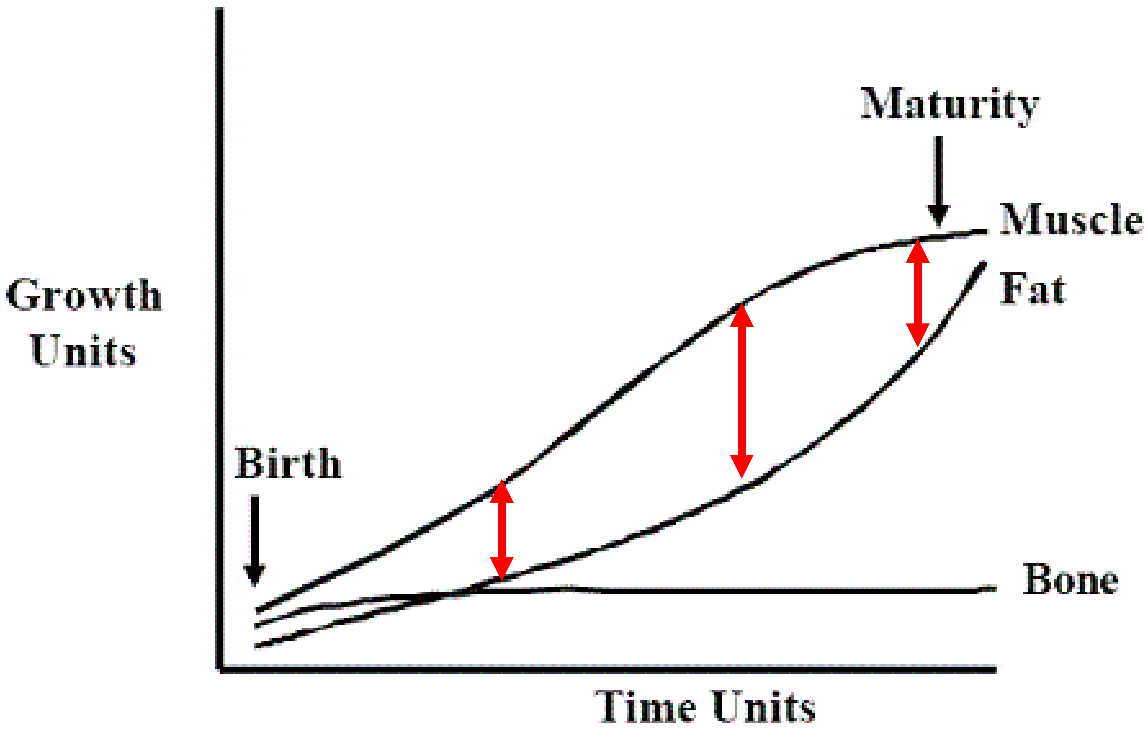
Cattle Growth Curves



Hormones

Three categories in vertebrate animals:

1. Peptide hormones (e.g., thyroid releasing hormone (TRH), vasopressin, **rbST**)

2. Monoamines (e.g., thyroxine, epinepherine)

3. Lipid and phospholipid-derived hormones (e.g., steroid hormones, including testosterone, estrogen, and cortisol)

Hormones

- Approximately 24 FDA approved hormones, based on estrogen, androgens, or progestins
- Most are implantable hormones, used in beef cattle

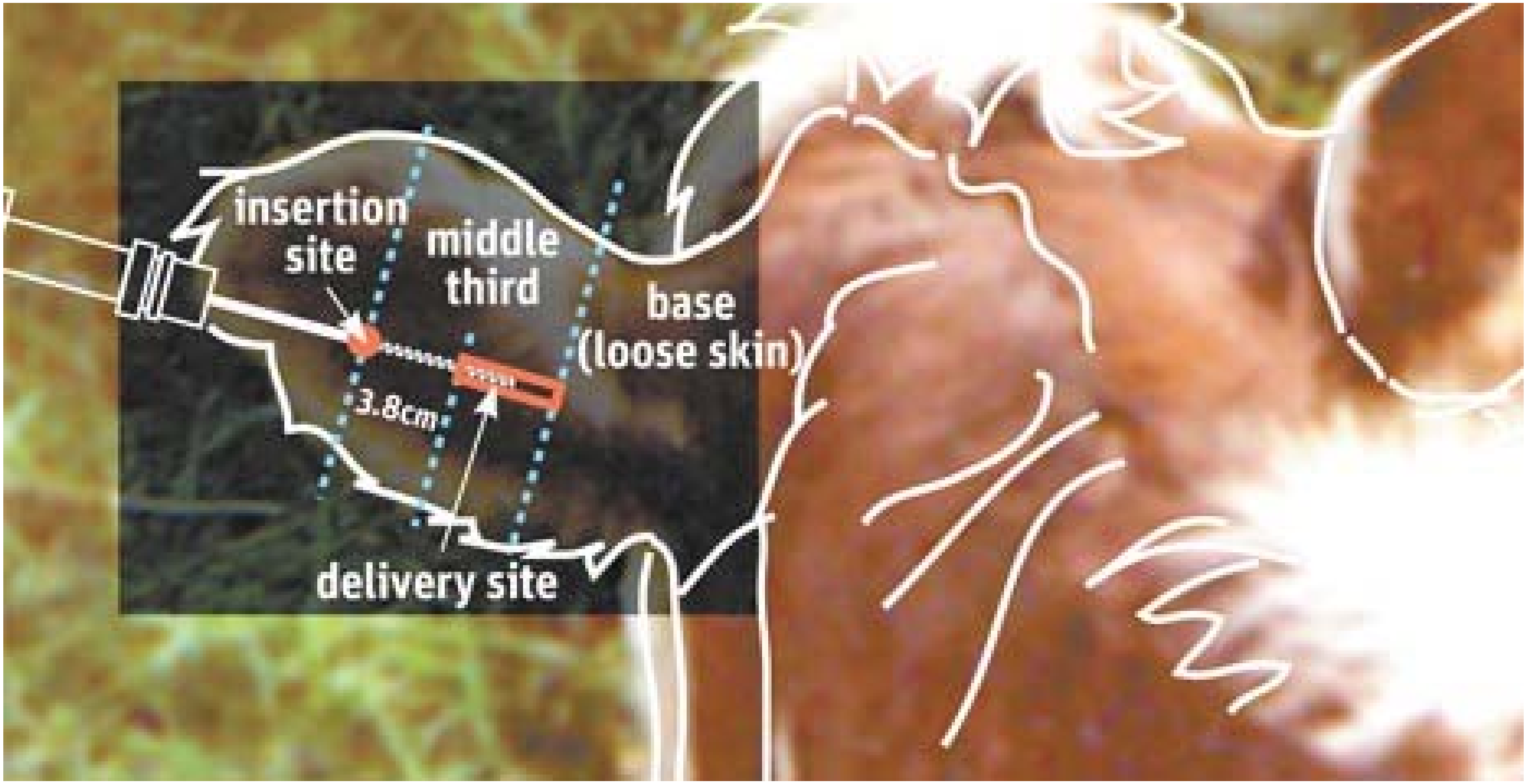
- **Melengesterol acetate (MGA)**
  - Synthetic progestin
  - Prevents estrus behavior
  - Improves gain and feed efficiency ~5%
  - No withdrawal period

Implants are crucial in Holsteins!

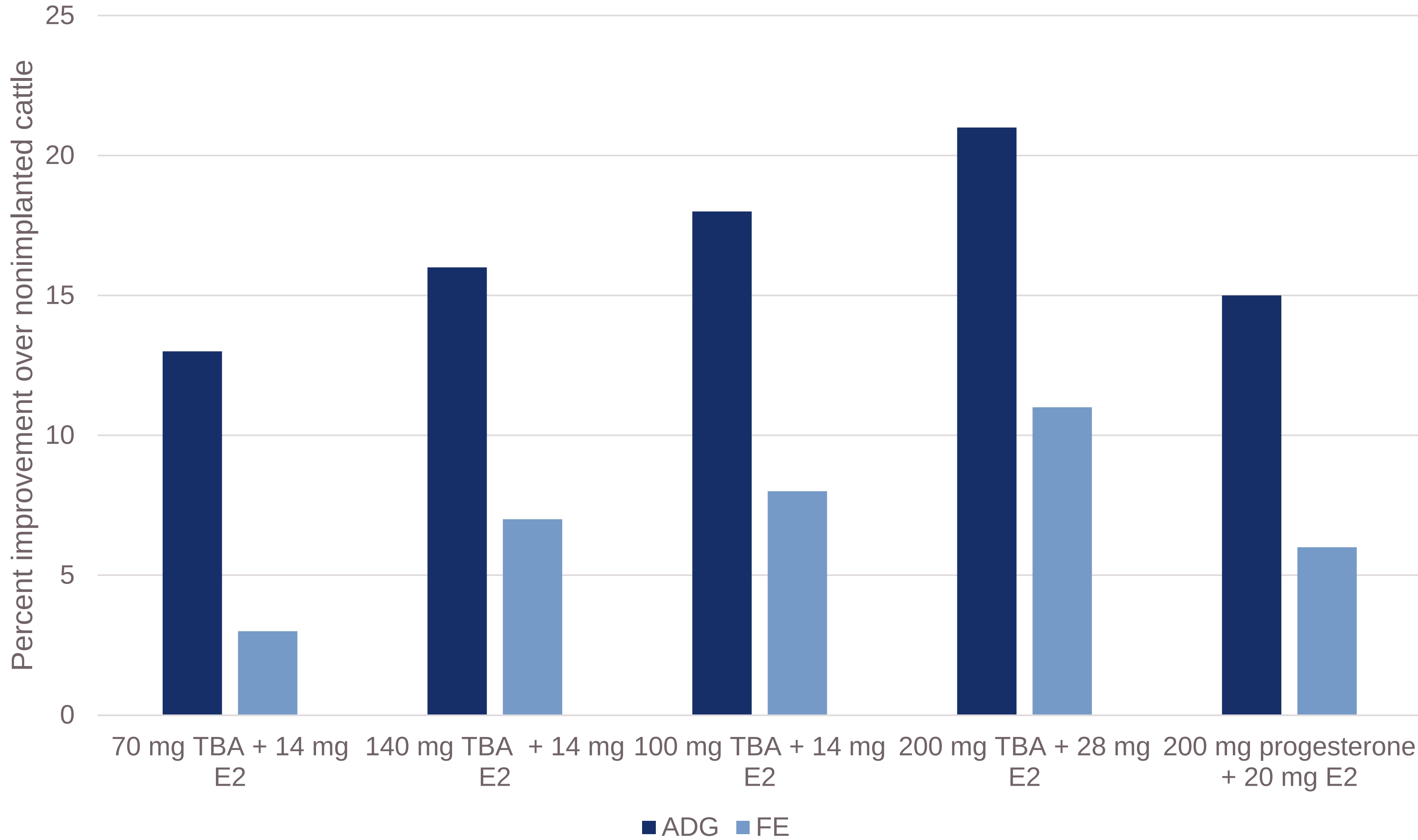
Implant Technique

Implants are crucial in Holsteins!

Implant Technique



Examples of implant vs none



Implant response

- Increase gains by 10-20%
- Improve feed efficiency by 3-10%
- Increase final weight at equal days on feed
- Increased lean and decreased fat at same body weight

- Improve profit $50-100/head

Estrogenic activity per serving

Food	ng/serving
Beef, implanted 3 oz.	
Beef, non-implanted, 3 oz.	1.3
Potatoes	
Peas	
Ice cream	
Cabbage	
Wheat germ	
Soybean oil	

[1]Preston, R.L. 1997. Rationale for the safety of implants. pp. 199-203. Oklahoma Agricultural Experiment Station P-957.

[2]Thompson et al. 2006. Phytoestrogen content of foods. Nutr & Cancer. 54:184

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Daily estrogen production in humans

Class	Nanograms per day
Female, before puberty	54,000
Non-pregnant women	480,000
Pregnant women	20,000,000
Male, before puberty	**41,000**
Adult male	**136,000**

Another Perspective

http://feedstuffsfoodlink.com/story-facts-growth-hormones-75-71791

Project YR 2– Background on calves

- Single sourced calves from one dairy
  - All born June -August 2016

- Grown by Cold Spring Farms, LLC
  - Manchester, PA
  - Dan and Steve Gross

- Received at LEC April 6, 2016
  - Incoming weight 700 ± 75 lbs

Project YR 2- Management

- Split into 2 groups of 20
- Group A
  - Implanted with Component E at feedlot entry
  - Reimplanted with Component TE-S on d 116

- Slaughtered after 178 d on feed
  - Age = 14 to16 months

Project YR 2- Performance Summary

	Implant	No Implant
n, animals[1]	20	19
Initial BW, kg	697 ± 63	698 ± 77
Final BW, kg	1371 ± 150	1282 ± 79
First Implant, d 0 to 116		
ADG, KG	3.94 ± 0.78	3.66 ± 0.48
Second Implant, d 117 to 178		
ADG, KG	3.51 ± 0.99	2.55± 0.64

Project YR 2- Carcass Characteristics

	Implant	No Implant
n, animals[1]	20	19
HCW	784	726
Dressing percentage, %	59.6	59.0
USDA YG	2.3	2.6
USDA Quality Grade, #		
Prime	1	1
Choice	10	14
Select	7	4
Standard	2	0

Project YR 2- Bottom line economics

	Implanted	Not Implanted
Pay weight IN, lbs	14,420.60	14,459.40
Price in	0.85	0.85
Pay weight OUT, lbs	27,426	24,354
Price out	$ 1.04	$ 1.04
Feedlot costs	$ 9,882.68	$ 9,875.68
Total Costs	$ 22,140.19	$ 22,166.17
Total return	$ 25,118.00	$ 23,862.00
Net Return	$ 2,977.82	$ 1,695.84
Net Return per hd	$ 148.89	$ 89.25

Visual appraisal of finish

Not your average beef steer!

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Calf 453

Not much brisket “fill”

May be modest on some

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Should have a strong blocky shape

May be narrower through the backend

Calf 453

Take this calf…

Here.

Keys to success

- Formulate a ration to optimize muscling and growth
- Use technologies to improve the "genetics"
- DO NOT FORGET THE ANIMAL
  - Intakes
  - Visual assessments

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It only takes 2 minutes.

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Is Value-added Dairy the Answer?

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What is value-added dairy?

Setting a product apart from the competition so that consumers are willing to pay more or allowing that product to reach a new market

New products

Alternate production systems

New marketing practices

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Examples

Products	Production system	Marketing
Cheese	Grass-fed	Buy Local
Butter	Organic	PA Preferred
Flavored milks	Goat or sheep	Farmers Markets
Yogurt	A2	On-farm Markets
Ice Cream	Breed-specific	Community Supported Agriculture (CSA)
Kefir		Restaurants
Cottage Cheese		
Raw milk		

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Value-added Dairy Products

- May use raw or pasteurized milk
- Product composition requirements or standards of identity
- May require extended storage before can be marketed
  - Space needs
  - Lag in starting sales
- Source for ingredients
- Packaging

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Why Consider a Value-Added Enterprise?

- Improve profitability
- Support another generation/family
- Passion/interest in the product(s)
- Loss of current market

- Sustainability of the dairy business!

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Motivation for starting dairy processing

 # 1

Maintain small family operation

 # 2

Improve financial sustainability of dairy business

 # 3

Passion for dairy product produced

 # 4

Provide business opportunity for current & future generations

Source: Cornelisse, S., 2017 PA Artisan and Farmstead Dairy Processing Needs Assessment, unpublished.

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Growth of value-added dairy
(PA as a snapshot)

- 68 permitted raw milk producers
  - 34 permitted raw milk bottlers
- 132 cheese plants**
  - 79 in 2016 (USDA)
- Artisan cheese producer numbers
  - 56 permits for raw milk cheese manufacture in 2017**
- Increased number of farms selling milk from goats & sheep***

*Source: Jeffery Roberts
**Source: PDA
***USDA Ag Census 2012

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What are some drawbacks?

- Requires investment in infrastructure & equipment
- Adds work & responsibilities
- Regulated with numerous agency involvement
- Exposure to additional risk & liability
- May require you to make product/product line changes to satisfy customers

Source: Reed, B., L.J. Butler, and E. Rilla. Farmstead and Artisan Cheeses: A Guide to Building a Business.

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Important Start-Up Questions

- Do I want to do this?
- Are family members interested or in agreement?
- Is this right for the farm?
- Do you have, or have access to, the skills and knowledge necessary?
  - Production, management, marketing, HR, public relations/communication, etc.

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Important Start-Up Questions

- What resources will you need?
- Do you have access to the resources required and people with the skills or knowledge you need?
- What is the profit potential?
- Are the financial resources available for start-up or transition?

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Important Start-Up Questions

- For each product, what will you need?
  - Facilities
    - Manufacture, Storage, Retail?
  - Production Equipment & Supplies
  - Marketing supplies
  - Additional employees?
- Additional requirements/needs
  - Insurance, legal, inventory control, regulatory

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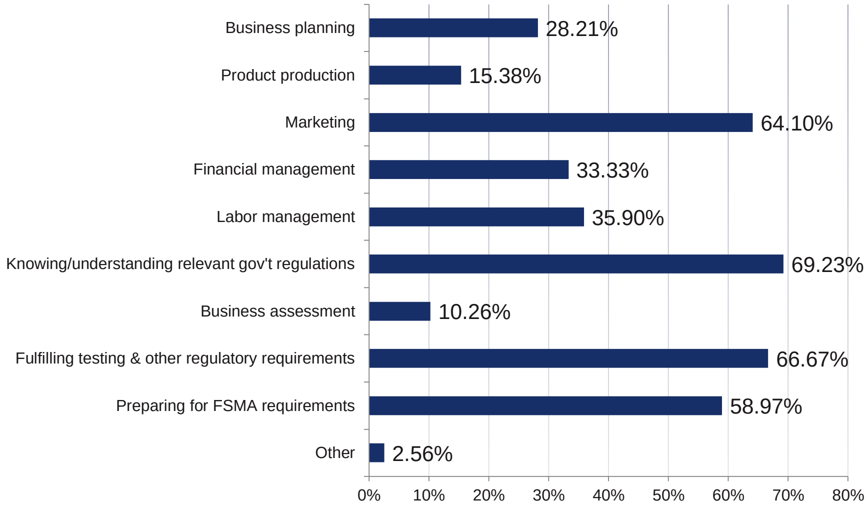
Most challenging aspects of operating artisan/farmstead dairy business



Source: Cornelisse, S., 2017 PA Artisan and Farmstead Dairy Processing Needs Assessment, unpublished.

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Marketing Considerations

- Are consumers interested?
  - If so, who are they?
    - End users or intermediate buyers
- Perform market research
  - Demographic, geographic, psychographic, behavioral
- Consumer price sensitivity
- Can you coordinate supply & demand?
  - Calculate market demand

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Weekly product yield estimates

	Percent dedicated to whole milk cheese production			
	10	25	50	100
Herd size	*pounds*			
10	36	89	179	358
15	54	134	268	537
25	89	224	447	894
50	179	447	894	1,788
100	358	894	1,788	3,577

46,488 lbs annually

Milk production estimates are average approximations of weekly cow production volumes and are not associated with any particular breed. Recognizing that milk production is a function of several factors, these estimates are used only to illustrate how quickly supplies can accumulate. Note also that milk-cheese conversion rates are highly variable depending on the type of cheese produced. Those used here are representative of hard cheese (e.g., cheddar) production.

Sources: Mark Stephenson, Cornell University; Tatiana Stanton, Cornell University; Carol Delaney, University of Vermont; Stephanie Clark, Washington State University

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Market - Mintel Cheese report (2016)

- 93% of Americans eat natural cheese
- Sales grew 19% between 2011 & 2016
- 85% of cheese eaters agree that cheese is a healthy snack – good source of protein
  - 63% look at protein content when purchasing "healthy" foods
- Product claims on the rise
- 6% purchasing cheese from online supermarket (Peapod, Amazon Fresh)
- 70% want to sample before buying

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Cheese Trends*^

- Specialty cheese sales grew 16.1% from 2011 to 2013
  - Down from a 28% growth between 2003-2005
- Specialty cheese is increasing as a percentage of overall cheese sales
  - 20.5% in 2011 to 22.4% in 2013

*Mintel, SFA State of the Industry Report – The Market – May 2014
^Mintel, Cheese – US – October 2013

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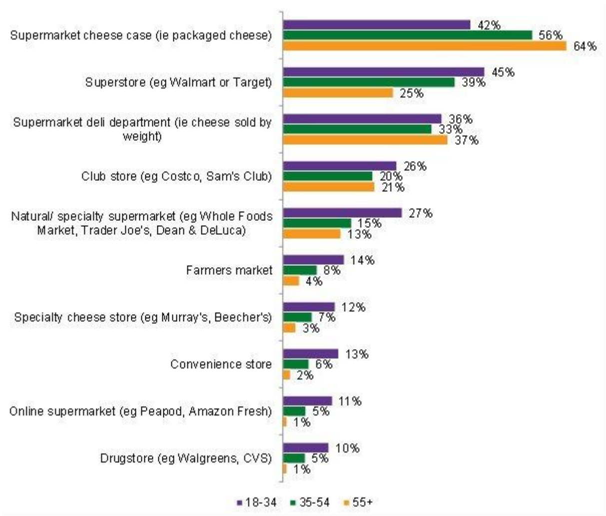
Purchase Locations, by age



Younger consumers have a higher rate of purchasing from non-traditional locations

Source: Mintel – US – Cheese 2016

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Marketing Strategy

Your Marketing Mix:

- Product
- Placement
- Price
- Promotion

Pricing

- Know ***YOUR*** costs of production
  - Marketing costs
    - Certifications needed?
  - Distribution costs
- What to charge?
  - Competitive analysis
  - Pricing objective(s) & method(s)
  - Point-of-sale feedback
  - Consumer demand

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Direct Market Outlets

- Farmer's markets
- Pick-your-own
- Farm/Roadside market or stand
- CSA (community supported agriculture)
- Internet
- Mail Order
- Food Service/Catering

Wholesale Outlets

- Cooperatives
- Marketing/trading clubs
- Restaurants
- Stores (specialty or general grocery)
- Auctions
- Institutional food service
- Farm-to-school programs

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Marketing Considerations

- How and where will product(s) be marketed?

Distribution Options	Market Channel Options
Self-distribution	Food service
Packers, brokers	Retail stores
Co-operative	Specialty stores
Non-profit	Non-profit
	Direct to consumer

- What are the pros & cons of each to ***YOU***?

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Market Channel Pros & Cons

Wholesale

- Lower price/lb
- Less seasonal
- High delivery efficiency
- Low level of interaction w/ end users
- Higher volume sales, enabling higher usage of milk

Retail

- Higher price/lb
- More seasonal
- Low delivery efficiency
- High level of interaction w/ end users
- Gateway to potential wholesale customers

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Placing Your Product Well

Place your product with **care**:

- ***Careful selection*** – make it easy to find your product
- ***Careful treatment*** – make sure the atmosphere around your product matches the "image."
- ***Careful image*** – make sure the customer gets a correct perception of your product/service
- ***Careful consistency*** – make sure the physical and mental placement carries the image you want to convey – all of the time!

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PLYMOUTH
NEIGHBORLY
PLYMOUTH ARTISAN CHEESE
SAGE & HERBS
GARLIC PEPPERCORN
SMOKED
HUNTER
PLYMOUTH
HOT PEPPER


CHEESE BOARD

Photos: East Hill Creamery Facebook page 9/1/17

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Vs.

What messages are you conveying with product images?

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Take Home Tips for Marketing

- Offer quality and consistency
- Invest time to know
  - customers -- target market
- Track sales and income figures
- Regularly consider the need to reinvent your business/product
- Always promote your business/product
- **Never** price below your cost of production

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On the production side:

- Right herd for intended product(s)
  - Quality, quantity, genetics
- Change in production needed
  - Diet, grazing requirements, exercise, housing, herd health program
- Farm management to support enterprise
- Appearance of the farm
- Location, location, location of the farm

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On the production side:

- Milk quality for processing
  - SCC
  - Bacteria counts
    - SPC, PIC, LPC, Coliform
  - Components
- Storage
- SOPs for milking, herd health, sanitation
- Market for surplus milk
- Source for additional milk

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On the production side:

- Managing labor for farm and processing
  - Family involvement or hired labor
  - Need expertise in farming and processing
  - Segregation of duties
  - Production schedule
  - Control of traffic
  - Transportation and retail of product
- Support network
- Time for transitions

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ASK…

Why do you farm?

Are you a “cow” person?

Are you passionate about creating a product?

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Processing Facility Considerations

- Need separation from farm operations
- Products will dictate equipment needs
- Plan review with regulators before construction
- Consider cleaning and sanitation
- Don’t overlook storage space needs
- Water quantity and quality
- Waste and waste water disposal

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Regulatory Considerations

- Plan ahead and have conversations early
- Building permits if new facility
- License from PA Dept. of Ag
- Register with FDA
- FSMA Requirements
  - Good Manufacturing Practices (GMPs)
  - Food Safety Plan
- Find a lab for testing
- Third party audits

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Survey of Grass-based VT Dairies

- Data from 71 grass-based dairies in VT
- Average sales from value-added $7554
  - $772/cow profit for value-added group
  - $290/cow for interested group
  - $412/cow for not interested group
- Farmers needed technical info on
  - How to make value-added products
  - How to market value-added products
  - How to finance a value-added operation

Source: Wang et al. (2016) at www.joe.org

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If a producer expresses interest…

- Encourage them to gather information
- Form a team or an off-shoot of their profit team to explore value-added
  - In PA, apply for team funding from Center for Dairy Excellence
  - Include processing specialists/resources
- Encourage them to consider all aspects
  - Time, $$$, labor, desire to make products, skills needed, markets, …

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If a producer expresses interest…

- Market & financial feasibility studies
  - Run financial projections with sensitivity analyses
  - Investment analysis
  - A cash flow analysis
- Write a business plan
  - Organization
  - Financial
  - Marketing
  - Human Resources
- Talk with insurance companies

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Where to look for resources

- Talk to other on-farm processors
- Short courses and workshops
  - Exploring Value-Added Dairy on Jan. 23
  - Cheese Making, Cultured Products, Pasteurizer Operators, Ice Cream, Food Sanitation and Safety
  - Preventive Controls for Human Foods -Dairy Foods
- Regulatory agencies

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Where to look for resources

- Industry groups or associations
- Extension services
- Food science programs

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Thank You!

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Understanding Dairy Nutrition Terminology

Mat Haan, Penn State Dairy Educator, Berks County
Lucas Mitchell, Penn State Department of Animal Science

Dairy Cattle Nutrition Workshop
November 15, 2017

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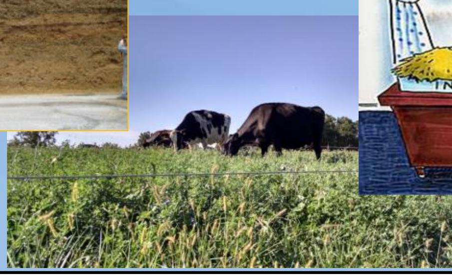
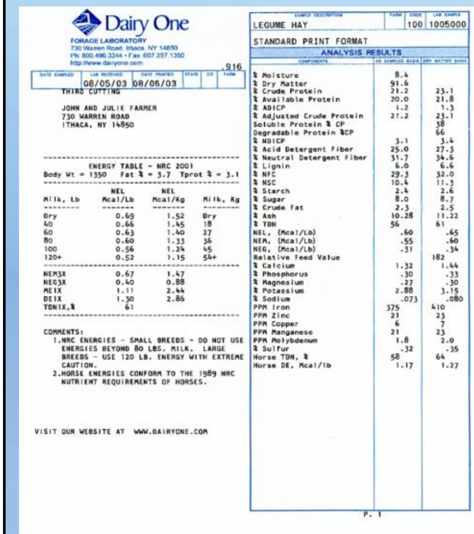
- Interpreting a Forage Analysis
- Tools for Evaluating Forages and Feeding Systems
- Hands-on sample analysis



Forage Analyses



Dairy One
FORAGE LABORATORY
730 Warren Road, Ithaca, NY 14850
Ph: 800.496.3344 • Fax: 607.257.1350
http://www.dairyone.com

.916

DATE SAMPLED	LAB RECEIVED	DATE PRINTED	STATE	CO	FARM
	08/05/03	08/06/03			

THIRD CUTTING

JOHN AND JULIE FARMER
730 WARREN ROAD
ITHACA, NY 14850

ENERGY TABLE - NRC 2001
Body Wt = 1350 Fat % = 3.7 Tprot % = 3.1

Milk, Lb	NEL Mcal/Lb	NEL Mcal/Kg	Milk, Kg
Dry	0.69	1.52	Dry
40	0.66	1.45	18
60	0.63	1.40	27
80	0.60	1.33	36
100	0.56	1.24	45
120+	0.52	1.15	54+
NEM3X	0.67	1.47	
NEG3X	0.40	0.88	
ME1X	1.11	2.44	
DE1X	1.30	2.86	
TDN1X,%	61		

COMMENTS:
1.NRC ENERGIES - SMALL BREEDS - DO NOT USE ENERGIES BEYOND 80 LBS. MILK. LARGE BREEDS - USE 120 LB. ENERGY WITH EXTREME CAUTION.
2.HORSE ENERGIES CONFORM TO THE 1989 NRC NUTRIENT REQUIREMENTS OF HORSES.

VISIT OUR WEBSITE AT WWW.DAIRYONE.COM

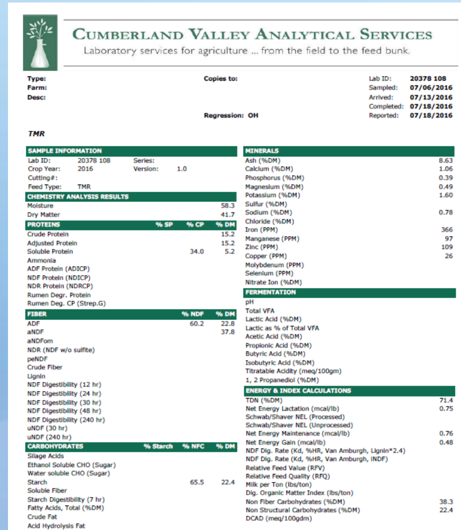
SAMPLE DESCRIPTION	FARM	CODE	LAB SAMPLE
LEGUME HAY		100	1005000

STANDARD PRINT FORMAT

ANALYSIS RESULTS

COMPONENTS	AS SAMPLED BASIS	DRY MATTER BASIS
% Moisture	8.4	
% Dry Matter	91.6	
% Crude Protein	21.2	23.1
% Available Protein	20.0	21.8
% ADICP	1.2	1.3
% Adjusted Crude Protein	21.2	23.1
Soluble Protein % CP		38
Degradable Protein %CP		66
% NDICP	3.1	3.4
% Acid Detergent Fiber	25.0	27.3
% Neutral Detergent Fiber	31.7	34.6
% Lignin	6.0	6.6
% NFC	29.3	32.0
% NSC	10.4	11.3
% Starch	2.4	2.6
% Sugar	8.0	8.7
% Crude Fat	2.3	2.5
% Ash	10.28	11.22
% TDN	56	61
NEL, (Mcal/Lb)	.60	.65
NEM, (Mcal/Lb)	.55	.60
NEG, (Mcal/Lb)	.31	.34
Relative Feed Value		182
% Calcium	1.32	1.44
% Phosphorus	.30	.33
% Magnesium	.27	.30
% Potassium	2.88	3.15
% Sodium	.073	.080
PPM Iron	375	410
PPM Zinc	21	23
PPM Copper	6	7
PPM Manganese	21	23
PPM Molybdenum	1.8	2.0
% Sulfur	.32	.35
Horse TDN, %	58	64
Horse DE, Mcal/lb	1.17	1.27

P. 1



Cumberland Valley Analytical Services
Laboratory services for agriculture ... from the field to the feed bunk.

Type:
Farm:
Desc:

Copies to:

Regression: OH

Lab ID: 20378 108
Sampled: 07/06/2016
Arrived: 07/13/2016
Completed: 07/18/2016
Reported: 07/18/2016

TMR

SAMPLE INFORMATION			
Lab ID:	20378 108	Series:	
Crop Year:	2016	Version:	1.0
Cutting#:			
Feed Type:	TMR		

CHEMISTRY ANALYSIS RESULTS			
Moisture			58.3
Dry Matter			41.7
PROTEINS	**% SP**	**% CP**	**% DM**
Crude Protein			15.2
Adjusted Protein			15.2
Soluble Protein		34.0	5.2
Ammonia			
ADF Protein (ADICP)			
NDF Protein (NDICP)			
NDR Protein (NDRCP)			
Rumen Degr. Protein			
Rumen Deg. CP (Strep.G)			
FIBER		**% NDF**	**% DM**
ADF		60.2	22.8
aNDF			37.8
aNDFom			
NDR (NDF w/o sulfite)			
peNDF			
Crude Fiber			
Lignin			
NDF Digestibility (12 hr)			
NDF Digestibility (24 hr)			
NDF Digestibility (30 hr)			
NDF Digestibility (48 hr)			
NDF Digestibility (240 hr)			
uNDF (30 hr)			
uNDF (240 hr)			
CARBOHYDRATES	**% Starch**	**% NFC**	**% DM**
Silage Acids			
Ethanol Soluble CHO (Sugar)			
Water soluble CHO (Sugar)			
Starch		65.5	22.4
Soluble Fiber			
Starch Digestibility (7 hr)			
Fatty Acids, Total (%DM)			
Crude Fat			
Acid Hydrolysis Fat			

MINERALS	
Ash (%DM)	8.63
Calcium (%DM)	1.06
Phosphorus (%DM)	0.39
Magnesium (%DM)	0.49
Potassium (%DM)	1.60
Sulfur (%DM)	
Sodium (%DM)	0.78
Chloride (%DM)	
Iron (PPM)	366
Manganese (PPM)	97
Zinc (PPM)	109
Copper (PPM)	26
Molybdenum (PPM)	
Selenium (PPM)	
Nitrate Ion (%DM)	
FERMENTATION	
pH	
Total VFA	
Lactic Acid (%DM)	
Lactic as % of Total VFA	
Acetic Acid (%DM)	
Propionic Acid (%DM)	
Butyric Acid (%DM)	
Isobutyric Acid (%DM)	
Titratable Acidity (meq/100gm)	
1, 2 Propanediol (%DM)	
ENERGY & INDEX CALCULATIONS	
TDN (%DM)	71.4
Net Energy Lactation (mcal/lb)	0.75
Schwab/Shaver NEL (Processed)	
Schwab/Shaver NEL (Unprocessed)	
Net Energy Maintenance (mcal/lb)	0.76
Net Energy Gain (mcal/lb)	0.48
NDF Dig. Rate (Kd, %HR, Van Amburgh, Lignin*2.4)	
NDF Dig. Rate (Kd, %HR, Van Amburgh, iNDF)	
Relative Feed Value (RFV)	
Relative Feed Quality (RFQ)	
Milk per Ton (lbs/ton)	
Dig. Organic Matter Index (lbs/ton)	
Non Fiber Carbohydrates (%DM)	38.3
Non Structural Carbohydrates (%DM)	22.4
DCAD (meq/100gdm)	

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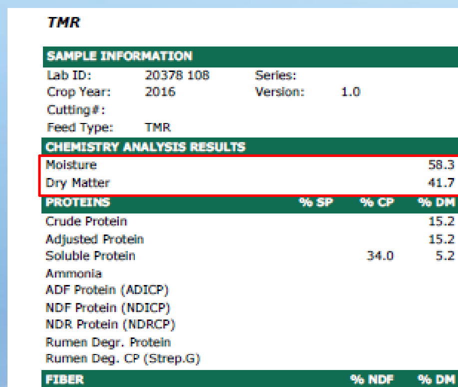
Forage Analyses: Dry Matter

- When all the water is removed from the forage what remains is the “dry matter”
- DM concentration can change frequently in fermented feeds
  - monitored frequently and adjust ration



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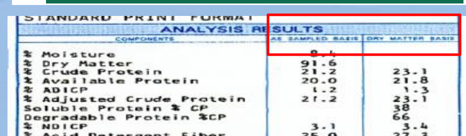
Rumen Degr. Protein			
Rumen Deg. CP (Strep.G)			
FIBER		**% NDF**	**% DM**



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% Acid Detergent Fiber	25.0	27.3

Forage Analyses: Dry Matter

Table 1. Typical dry matter values of forages

Forage	DM, %	Moisture, %
High moisture corn		
Shelled corn	68-74	26-32
Shelled corn, sealed silo	74-78	22-26
Ground ear corn	62-64	36-38
Ground ear corn, sealed silo	64-70	30-36
Corn silage		
Bunker silo	30-35	65-70
Bag silo	30-40	60-70
Upright silo	30-40	60-70
Upright, sealed silo	35-45	55-65
Hay crop silage		
Bunker silo	30-35	65-70
Bag silo	35-45	55-65
Upright silo	30-45	55-70
Upright sealed silo	40-50	50-60
Balage	40-60	40-50
Hay		
Small rectangular bales	80-82	18-20
Large round bales	82-85	15-18
Large square bales	85-88	12-15

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Forage Analyses: Protein

- **Crude Protein**
  - Most common measurement of protein
  - CP = Nitrogen Content X 6.25
  - Tells you nothing about rumen degradability of protein or amino acid concentration

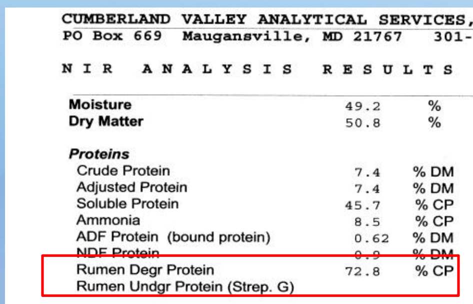
TMR

SAMPLE INFORMATION

Lab ID:	20378 108	Series:	
Crop Year:	2016	Version:	1.0
Cutting#:			
Feed Type:	TMR		

CHEMISTRY ANALYSIS RESULTS			
Moisture			58.3
Dry Matter			41.7
PROTEINS	**% SP**	**% CP**	**% DM**
Crude Protein			15.2
Adjusted Protein			15.2
Soluble Protein		34.0	5.2
Ammonia			
ADF Protein (ADICP)			
NDF Protein (NDICP)			
NDR Protein (NDRCP)			
Rumen Degr. Protein			
Rumen Deg. CP (Strep.G)			
FIBER		**% NDF**	**% DM**
ADF		60.2	22.8
aNDF			37.8
aNDFom			
NDR (NDF w/o sulfite)			
peNDF			
Crude Fiber			
Lignin			

Forage Analyses: Protein



CUMBERLAND VALLEY ANALYTICAL SERVICES,
PO Box 669 Maugansville, MD 21767 301-

N I R A N A L Y S I S R E S U L T S

Moisture	49.2	%
Dry Matter	50.8	%
Proteins		
Crude Protein	7.4	% DM
Adjusted Protein	7.4	% DM
Soluble Protein	45.7	% CP
Ammonia	8.5	% CP
ADF Protein (bound protein)	0.62	% DM
NDF Protein	0.9	% DM
Rumen Degr Protein	72.8	% CP
Rumen Undgr Protein (Strep. G)		

- **Rumen Degradable Protein**
  - Degraded in the rumen
  - Available on some forage tests
- **Rumen Undegradable Protein**
  - Bypasses rumen and digested in small intestine
  - Value not available, but could be calculated

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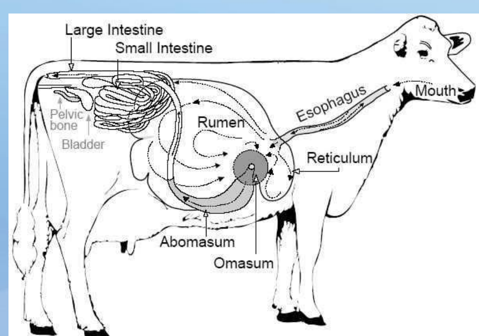
Forage Analyses: Protein

- **Metabolizable protein**
  - Protein (amino acids) actually absorbed from gut and available for use by the cow
  - Combination of RUP and microbial protein
  - Not shown on most forage analyses, but calculated in ration balancing programs



Carbohydrates

Structural
- Hemicellulose
- Cellulose
- Lignin

Nonstructural
- Starch
- Sugar

Structural Carbohydrates

- NDF
  - Hemi-cellulose
  - Cellulose
  - Lignin
- ADF
  - Cellulose
  - Lignin

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Forage Analyses: Carbohydrates

Crude Protein		15.2
Adjusted Protein		15.2
Soluble Protein	34.0	5.2
Ammonia		
ADF Protein (ADICP)		
NDF Protein (NDICP)		
NDR Protein (NDRCP)		
Rumen Degr. Protein		
Rumen Deg. CP (Strep.G)		
FIBER	**% NDF**	**% DM**
ADF	60.2	22.8
aNDF		37.8
aNDFom		
NDR (NDF w/o sulfite)		
peNDF		
Crude Fiber		
Lignin		
NDF Digestibility (12 hr)		
NDF Digestibility (24 hr)		
NDF Digestibility (30 hr)		
NDF Digestibility (48 hr)		
NDF Digestibility (240 hr)		
uNDF (30 hr)		
uNDF (240 hr)		

- **Neutral Detergent Fiber**
  - Can be well digested in rumen depending on other dietary factors
  - Increases with plant maturity
  - High NDF in forages
    - Increases rumen fill
    - Decreases passage rate
    - **Decreases dry matter intake**

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Forage Analyses: Carbohydrates

Rumen Degr. Protein		74.7	17.2
Rumen Deg. CP (Strep.G)			
FIBER		**% NDF**	**% DM**
ADF		81.1	30.4
aNDF			37.5
aNDFom			33.3
NDR (NDF w/o sulfite)			
peNDF			
Crude Fiber			
Lignin		18.70	7.01
NDF Digestibility (12 hr)			
NDF Digestibility (24 hr)			
NDF Digestibility (30 hr)		45.3	17.0
NDF Digestibility (48 hr)			
NDF Digestibility (240 hr)			
Indigestible NDF		51.5	19.3
CARBOHYDRATES	**% Starch**	**% NFC**	**% DM**
Silage Acids		16.5	5.0
Ethanol Soluble CHO (Sugar)		17.7	5.3

- **NDF Digestibility**
  - *In Vitro* digestible fraction of NDF expressed as percentage of the NDF content of a feed sample.
  - Various time-points
    - 30-h is typical
    - 24-h may be more representative of high producing cows
  - Used to evaluate available energy of a feed

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Forage Analyses: Carbohydrates

Rumen Degr. Protein	74.7	17.2
Rumen Deg. CP (Strep.G)		

FIBER	% NDF	% DM
ADF	81.1	30.4
aNDF		37.5
aNDFom		33.3
NDR (NDF w/o sulfite)		
peNDF		
Crude Fiber		
Lignin	18.70	7.01
NDF Digestibility (12 hr)		
NDF Digestibility (24 hr)		
NDF Digestibility (30 hr)	45.3	17.0
NDF Digestibility (48 hr)		
NDF Digestibility (240 hr)		
Indigestible NDF	51.5	19.3

CARBOHYDRATES	% Starch	% NFC	% DM
Silage Acids		16.5	5.0
Ethanol Soluble CHO (Sugar)		17.7	5.3

- **Acid Detergent Fiber**
  - Moderately digested in the rumen
  - **Relates to the extent of digestion of the forage**
  - Higher the value the less of the forage is digested

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Forage Analyses: Carbohydrates

Rumen Degr. Protein	74.7	17.2
Rumen Deg. CP (Strep.G)		

FIBER	% NDF	% DM
ADF	81.1	30.4
aNDF		37.5
aNDFom		33.3
NDR (NDF w/o sulfite)		
peNDF		
Crude Fiber		
Lignin	18.70	7.01
NDF Digestibility (12 hr)		
NDF Digestibility (24 hr)		
NDF Digestibility (30 hr)	45.3	17.0
NDF Digestibility (48 hr)		
NDF Digestibility (240 hr)		
Indigestible NDF	51.5	19.3

CARBOHYDRATES	% Starch	% NFC	% DM
Silage Acids		16.5	5.0
Ethanol Soluble CHO (Sugar)		17.7	5.3

- **Lignin**
  - Completely indigestible to rumen microbes and cow
  - High values will decrease NDF digestibility
  - BMR Corn Silage Contains less lignin than traditional corn silage allowing bacteria to digest more of the plant cell wall

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Forage Analyses: Carbohydrates

Titratable Acidity (meq/100gm)	3.52
Soil Contamination Probability	Probable moderate contamination
Nitrate Probability	
NIR Statistical Confidence	Excellent prediction potential
Vomitoxin Probability	
Corn Silage Processing Score	
ENERGY & INDEX CALCULATIONS	
TDN (%DM)	62.3
Net Energy Lactation (mcal/lb)	0.64
Net Energy Maintenance (mcal/lb)	0.63
Net Energy Gain (mcal/lb)	0.37
NDF Dig. Rate (Kd, %HR, Van Amburgh)	5.13
Starch Dig. Rate (Kd, %HR, Mertens)	
Relative Feed Value (RFV)	162
Relative Feed Quality (RFQ)	162
Milk per Ton (lbs/ton)	
Dig. Organic Matter Index (lbs/ton)	693
Non Fiber Carbohydrates (%DM)	30.0
Non Structural Carbohydrates (%DM)	7.8
DCAD (meq/100gdm)	
Summative Index %	101.3

- **Nonstructural Carbohydrates (NSC)**
  - Determined using an enzymatic method
  - Contains starch, sucrose, and fructans
  - Can be lost during respiration when forages are not immediately stored properly
  - Rapidly digested in the rumen
- **Non-Fiber Carbohydrates (NFC)**
  - NFC = 100% - (%NDF + %CP + %Fat + %Ash)
  - Contains pectin and organic acids

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Forage Analyses: Carbohydrates

NDF Digestibility (30 hr)		61.5	20.5
NDF Digestibility (48 hr)			
NDF Digestibility (240 hr)		73.6	24.6
Indigestible NDF		26.4	8.8
CARBOHYDRATES	**% Starch**	**% NFC**	**% DM**
Silage Acids		17.7	9.4
Ethanol Soluble CHO (Sugar)		1.7	0.9
Water Soluble CHO (Sugar)			
Starch		74.1	39.4
Soluble Fiber		12.2	6.52
Starch Digestibility (7 hr, 4 mm)	79		
Fatty Acids, Total			2.91

- **Starch**
  - 2 – 5% in legumes
  - 1 – 3% in grasses
  - 25 – 40% in corn silage
- **Starch Digestibility**
  - 7 hours, pass a 4 mm screen
  - >70% is optimal
  - <50% is poor

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Forage Analyses: Minerals

MINERALS	
Ash (%DM)	8.63
Calcium (%DM)	1.06
Phosphorus (%DM)	0.39
Magnesium (%DM)	0.49
Potassium (%DM)	1.60
Sulfur (%DM)	
Sodium (%DM)	0.78
Chloride (%DM)	
Iron (PPM)	366
Manganese (PPM)	97
Zinc (PPM)	109
Copper (PPM)	26
Molybdenum (PPM)	
Selenium (PPM)	
Nitrate Ion (%DM)	

- **Ash**
  - measure of all the minerals in the forage
  - High content may indicate soil contamination
  - Typical values:
    - Corn silage = 5%
    - TMR = 9%
    - Legume/grass hay = 9%

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Forage Analyses: Minerals

- Macro Minerals
  - Calcium, Phosphorus, Magnesium, Potassium
  - Forages are good sources of these minerals
  - Concentration of minerals in forages depends on concentration in soil
  - Supply of macro minerals by forages may be enough to avoid supplemental feeding
  - Minerals will interact with each other

MINERALS	
Ash (%DM)	8.63
Calcium (%DM)	1.06
Phosphorus (%DM)	0.39
Magnesium (%DM)	0.49
Potassium (%DM)	1.60
Sulfur (%DM)	
Sodium (%DM)	0.78
Chloride (%DM)	
Iron (PPM)	366
Manganese (PPM)	97
Zinc (PPM)	109
Copper (PPM)	26
Molybdenum (PPM)	
Selenium (PPM)	
Nitrate Ion (%DM)	

Mineral	TMR	Corn silage	Legume hay	Grass hay
Calcium	0.6 to 0.7%	0.28%	1.52%	0.58%
Phosphorus	0.37%	0.26%	0.26%	0.23%
Magnesium	0.2%	0.17%	0.30%	0.20%
Potassium	1.0 to 1.1%	1.2%	2.53%	2.01%

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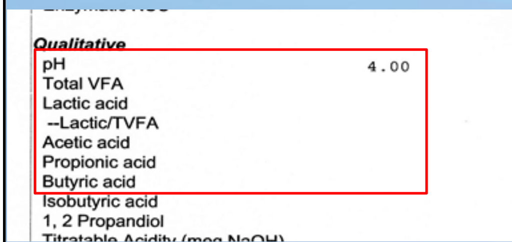
Forage Analyses: pH & VFAs


Qualitative
pH 4.00
Total VFA
Lactic acid
--Lactic/TVFA
Acetic acid
Propionic acid
Butyric acid
Isobutyric acid
1, 2 Propandiol

- Indication of fermentation quality
- pH of Corn Silage in range of 3.8 to 4.2
- VFAs
  - Lactic Acid –
    - Dominant VFA from good fermentation
    - Should comprise greater then 70% of VFA
  - Acetic acid

Typical Fermentation Profiles of Corn Silage and Haylage

	Corn Silage, 30 – 40% DM	High Moisture Corn, 70 – 75% DM	Legume Silage, 30 – 40% DM	Legume Silage, 45 – 55% DM	Grass Silage, 30 – 35% DM
Lactic Acid, %DM	4 - 7	0.5 – 2.0	7 - 8	2 – 4	6 - 10
Acetic Acid, %DM	1 – 3	< 0.5	2 - 3	0.5 – 2.0	1 - 3
Propionic Acid, %DM	< 0.1	< 0.1	< 0.5	< 0.1	< 0.1
Butyric Acid, %DM	0	0	< 0.5	0	0.5 – 1.0
Ethanol, %DM	1 - 3	0.2 – 2.0	0.2 – 1.0	0.5	0.5 – 1.0
Ammonia-N, %CP	5 - 7	< 10	10 - 15	<12	8 - 12

Kung and Shaver, 2001. Interpretation and Use of Silage Fermentation Analysis Reports.

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Forage Analyses: Energy Predictions

ENERGY & INDEX CALCULATIONS	
TDN (%DM)	71.4
Net Energy Lactation (mcal/lb)	0.75
Schwab/Shaver NEL (Processed)	
Schwab/Shaver NEL (Unprocessed)	
Net Energy Maintenance (mcal/lb)	0.76
Net Energy Gain (mcal/lb)	0.48
NDF Dig. Rate (Kd, %HR, Van Amburgh, Lignin*2.4)	
NDF Dig. Rate (Kd, %HR, Van Amburgh, iNDF)	
Relative Feed Value (RFV)	
Relative Feed Quality (RFQ)	
Milk per Ton (lbs/ton)	
Dig. Organic Matter Index (lbs/ton)	
Non Fiber Carbohydrates (%DM)	38.3
Non Structural Carbohydrates (%DM)	22.4
DCAD (meq/100gdm)	

- **Net Energy Lactation**
  - Empirical equation, varies by feedstuff and location
  - NEL (Mcal/lb) = 0.794 – 0.00344 x ADF
- **Total Digestable Nutrients**
  - Summative equation
  - $TDN = CP \times e^{-0.012 \times ADIN} + 0.98 \times (100 - NDF_{CP} - EE - CP - Ash) + 0.94 \times (EE \times 2.7) + 0.75 \times (NDF_{CP} - L) \times [1 - (L/NDF_{cp} 0.667)] - 7$
- **Relative Feed Value**
  - An index used to compare the quality of forages relative to the feed value of full bloom alfalfa.
  - Determined by its content of ADF and NDF.

TOOLS FOR EVALUATING FORAGES AND FEEDING SYSTEMS

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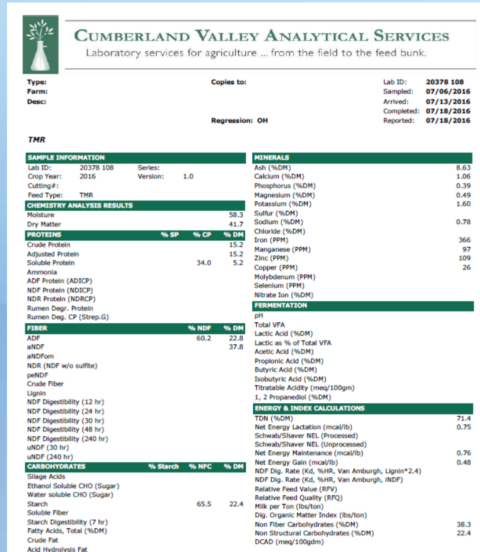
Forage Analyses



CUMBERLAND VALLEY ANALYTICAL SERVICES
Laboratory services for agriculture ... from the field to the feed bunk.

Type:
Farm:
Desc:

Copies to:

Regression: OH

Lab ID:	**20378 108**
Sampled:	**07/06/2016**
Arrived:	**07/13/2016**
Completed:	**07/18/2016**
Reported:	**07/18/2016**

TMR

SAMPLE INFORMATION			
Lab ID:	20378 108	Series:	
Crop Year:	2016	Version:	1.0
Cutting#:			
Feed Type:	TMR		

CHEMISTRY ANALYSIS RESULTS	
Moisture	58.3
Dry Matter	41.7

PROTEINS	% SP	% CP	% DM
Crude Protein			15.2
Adjusted Protein			15.2
Soluble Protein		34.0	5.2
Ammonia			
ADF Protein (ADICP)			
NDF Protein (NDICP)			
NDR Protein (NDRCP)			
Rumen Degr. Protein			
Rumen Deg. CP (Strep.G)			

FIBER	% NDF	% DM
ADF	60.2	22.8
aNDF		37.8
aNDFom		
NDR (NDF w/o sulfite)		
peNDF		
Crude Fiber		
Lignin		
NDF Digestibility (12 hr)		
NDF Digestibility (24 hr)		
NDF Digestibility (30 hr)		
NDF Digestibility (48 hr)		
NDF Digestibility (240 hr)		
uNDF (30 hr)		
uNDF (240 hr)		

CARBOHYDRATES	% Starch	% NFC	% DM
Silage Acids			
Ethanol Soluble CHO (Sugar)			
Water soluble CHO (Sugar)			
Starch		65.5	22.4
Soluble Fiber			
Starch Digestibility (7 hr)			
Fatty Acids, Total (%DM)			
Crude Fat			
Acid Hydrolysis Fat			

MINERALS	
Ash (%DM)	8.63
Calcium (%DM)	1.06
Phosphorus (%DM)	0.39
Magnesium (%DM)	0.49
Potassium (%DM)	1.60
Sulfur (%DM)	
Sodium (%DM)	0.78
Chloride (%DM)	
Iron (PPM)	366
Manganese (PPM)	97
Zinc (PPM)	109
Copper (PPM)	26
Molybdenum (PPM)	
Selenium (PPM)	
Nitrate Ion (%DM)	

FERMENTATION	
pH	
Total VFA	
Lactic Acid (%DM)	
Lactic as % of Total VFA	
Acetic Acid (%DM)	
Propionic Acid (%DM)	
Butyric Acid (%DM)	
Isobutyric Acid (%DM)	
Titratable Acidity (meq/100gm)	
1, 2 Propanediol (%DM)	

ENERGY & INDEX CALCULATIONS	
TDN (%DM)	71.4
Net Energy Lactation (mcal/lb)	0.75
Schwab/Shaver NEL (Processed)	
Schwab/Shaver NEL (Unprocessed)	
Net Energy Maintenance (mcal/lb)	0.76
Net Energy Gain (mcal/lb)	0.48
NDF Dig. Rate (Kd, %HR, Van Amburgh, Lignin*2.4)	
NDF Dig. Rate (Kd, %HR, Van Amburgh, iNDF)	
Relative Feed Value (RFV)	
Relative Feed Quality (RFQ)	
Milk per Ton (lbs/ton)	
Dig. Organic Matter Index (lbs/ton)	
Non Fiber Carbohydrates (%DM)	38.3
Non Structural Carbohydrates (%DM)	22.4
DCAD (meq/100gdm)	

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Sample Collection

- Collect a representative sample
  - Hay
    - 20 to 25 cores per lot of hay
  - Silage
    - Avoid spoiled material
    - 10 to 12 locations
  - TMR
    - Sample within 20 minutes of feeding
    - Fill 5 gallon bucket with grab samples from entire length of feed area
    - Sub-sample from bucket
  - Pasture
    - 25 to 30 locations
    - Grab sample of what cows are eating

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Representative Sample

Picture - https://www.ag.ndsu.edu

Picture - http://pasturedairy.kbs.msu.edu

Picture - https://hayandforage.com

Picture - http://www.agronomy.k-state.edu/

20 tons of hay harvested. ⇨ 2 pounds sent to forage lab. ⇨ 0.5 grams used for analysis.

40,000 lbs

18,143,694 g

907 g

VFA Identification

- Indication of how well silage, haylage, baleage fermented
- Main VFAs
  - Lactic acid
  - Acetic acid
  - Butyric acid
  - Propionic acid
  - Iso-butyric acid

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pH

- Corn silage 3.8 and 4.2
- Haylage 5.5 to 6.0

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Dry Matter Determination

- Changes in DM should be monitored frequently and ration adjusted
- Methods
  - Koster Dryer
  - Microwave Oven
  - NRI

On-farm NIR Analyzers

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Penn State Particle Separator

- A tool to quantitatively determine the particle size of forages and TMR.

http://extension.psu.edu/animals/dairy/health/nutrition/forages/forage-quality-physical/separator

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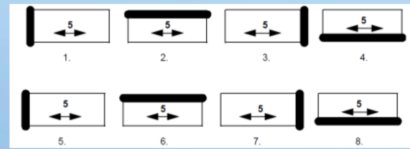
Using the Penn State Particle Separator

- Stack particle separator boxes
- Place sample in upper sieve
- On a flat surface shake sieves in one direction 5 times, rotate sieve ¼ turn, shake five times, rotate sieve ¼ turn,…..
  - Total of 8 sets



- 1 shake per second
- stroke length of 7 inches
- Weigh content of each sieve and bottom pan
- Calculate particle size

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Penn State Particle Separator

Particle size recommendations for lactating cows.

Screen	Pore Size (inches)	Particle Size (inches)	Corn Silage (%)	Haylage (%)	TMR (%)
Upper Sieve	0.75	> 0.75	3 to 8	10 to 20	2 to 8
Middle Sieve	0.31	0.31 to 0.75	45 - 65	45 to 75	30 to 50
Lower Sieve	0.16	0.16 to 0.31	20 to 30	30 to 40	10 to 20
Bottom Pan	-	< 0.16	< 10	< 10	30 to 40

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Grain Particle Size

- Fine ground corn will have greater digestibility than more coarsely ground corn.

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Time laps Cameras

- Monitor what is happening in barn when you are not around
  - Feed push up
  - Feed bunk use
  - Feed availability

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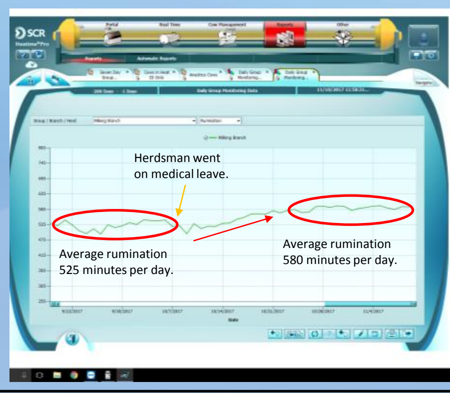
Rumination Monitors

- Monitor changes in animal behavior related to:
  - Feed changes
  - Heat stress
  - Management changes
  - Herd / cow health



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On-line Feed Library

- Dairy One Feed Component Library
  - Crop Year
  - State (PA, NY, MI, CA)
  - Crop
- www.dairyone.com

THANK YOU!

ANTIBIOTIC ALTERNATIVES FOR YOUNGSTOCK

Jud Heinrichs
Dairy Science
Penn State

Penn State **Extension**

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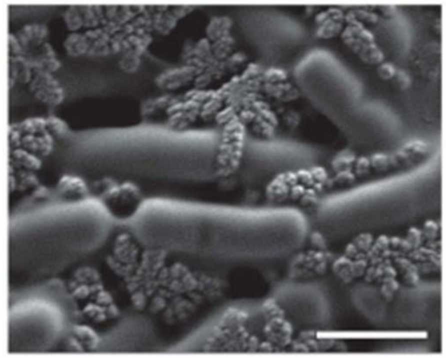
Topics for today

- Overview of the issue
- Product types
- Some data
- How to pick a product
- How management helps

Overview

- The emergence and spread of antibiotic resistance has created a growing global threat.
- The use of antibiotics in any setting drives resistance expansion everywhere.
  - Also increases risks of environmental contamination and food residues.



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ON NOVEMBER 7, 2017

WHO: Stop giving antibiotics to healthy animals

World Health Organization releases guidelines on the use of antibiotics in food-producing animals

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What is the FDA doing?

- Phasing out the use of medically important antimicrobials in food animals for production purposes (enhancing growth or feed efficiency)
- To bring the therapeutic uses of such drugs (to treat, control, or prevent specific diseases) under the oversight of licensed veterinarians
- Effective date 1/1/2007- New FDA Veterinary Feed Directive.

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Antibiotic alternatives in milk fed calves

- Major place where antibiotics were used in the past for dairy youngstock
  - Some used in respiratory issues in weaned calves/older heifers
  - Mastitis in cows- another issue

Background

- Antibiotics first studied in 1950's and used widely after that point
- 1991 NAHMS study-

Calf and Heifer Management in the US-

53% of farms and 71% of calves were fed medicated milk replacers (3 wk-weaning).

- Was concern in the USDA at that point in time.
- 1/1/2006 –feeding antibiotics banned in the EU

NAHMS Dairy Studies

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Alternative products

- Play a critical role in the reduction of antibiotics
- Vaccines- very promising
- Pre- and pro-biotics
  - Oligoosaccharides
- Some organic acids
- Herb and plant extracts

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Antibiotic Alternatives: Timing and Mode of Action

Timing of Administration	Mechanism of Action
Can be applied continuously	
Phytochemicals	Target bacteria
Organic acids	Target bacteria
Probiotics	Improve gut health
Prebiotics	Improve gut health
Narrow window – around initial infection	
Hydrolases/Bacteriophages	Target bacteria
Antimicrobial peptides	Target bacteria
Narrow window – before infection	
Immune modulators	Stimulate/Enhance immune response
Applied before infection	
Vaccines	Prime immune response

Talkington et al., 2017

Definitions- probiotics

- Probiotics are live cultures of microorganisms (e.g., yeast, fungi, and bacteria) that are added to the diet to improve the balance of microbial communities in the gastrointestinal tract.
- Definition of probiotic- 'is opposite of antibiotic'.
- Live microbial feed supplements that beneficially affect the host animal by improving its microbial balance.

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Definitions- probiotics

– Probiotics had a beginning in the 1970's recommended in young ruminants to prevent diarrhea from enterotoxigenic bacteria and enhance the rate of rumen bacteria/protozoal establishment.

– An FAO report as well as several meta-analyses, and systematic reviews have concluded that probiotics are effective at enhancing productivity and preventing or treating disease in beef as well as dairy cattle and calves.

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Examples of bacteria used in direct-fed microbial products for calves.

- Lactobacillus acidophilus
- L. lactis
- L. plantarum
- L. casei
- Bacillus subtilis
- B. lichenformis
- Enterococcus faecium
- Bifidobacterium bifidum
- B. longum
- B. thermophilum

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Definitions- prebiotics

- Prebiotics are organic compounds such as certain sugars that, when added to the diet, are indigestible by animals but are broken down by certain beneficial microorganisms in the gut, which selectively stimulates these and other microorganisms' growth.
- However, the various ways in which these products work and the diverse biological impacts they can exert—for instance, on the immune systems of animals that ingest them—are not completely understood

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Pre-biotics- common in foods

Food	Amount of food to achieve 6 g serving of prebiotics
Raw Chicory Root	9.3 g (0.33 oz)
Raw Jerusalem Artichoke	19 g (0.67 oz)
Raw Dandelion Greens	24.7 g (0.87 oz)
Raw Garlic	34.3 g (1.21 oz)
Raw Leek	51.3 g (1.81 oz)
Raw Onion	69.8 g (2.46 oz)
Cooked Onion	120 g (4.2 oz)
Raw Asparagus	120 g (4.2 oz)
Raw Wheat Bran	120 g (4.2 oz)
Whole Wheat Flour, Cooked	125 g (4.4 oz)
Raw Banana	600 g (1.3 lb)

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- Both prebiotics and probiotics help beneficial microorganisms to outcompete harmful bacteria
- may also have other effects such as modulating the immune system.

- In general, the efficacy of prebiotics seems to be determined by a variety of factors, including the type of prebiotic, animal age and species, animal health status, the housing type, and management practices, all of which have to be considered in the decision whether to use these alternatives.

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Definitions- phytochemicals

- Phytochemicals are non-nutritive plant chemicals that have protective or disease preventive properties.
- They are non-essential nutrients, meaning that they are not required by the human body for sustaining life. It is well-known that plant produce these chemicals to protect themselves but recent research demonstrate that they can also protect humans against diseases.
- There are more than thousand known phytochemicals.

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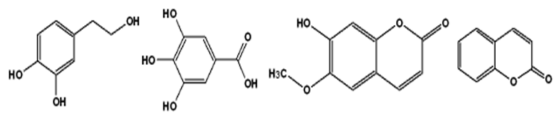
How do phytochemicals work?



Essential oils- includes a wide variety of plant extracts- often an alcohol, ester or aldehyde derivatives of phenylpropanoids or terpinoids.

Most EO are biologically active molecules that have antimicrobial activities.

Enzymes- perhaps in the future

- Mechanism behind the effectiveness of infeed enzymes as growth promoters is not fully understood
  - may include changes to the gut microbiota
  - prevention of damage caused by undigested plant parts rubbing against the inner lining of the intestine
  - breakdown of larger molecules into compounds with prebiotic activity
- impacts on the composition of the intestinal content and its digestibility
  - In-feed enzymes are also promising interventions for preventing certain diseases such as necrotic enteritis in chickens

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- Antimicrobial peptides are another potentially promising alternative for growth promotion that may aid in disease prevention and possibly treatment.
- Antimicrobial peptides are short molecules with antibacterial properties that are toxic to certain bacteria.
  - Some work in chickens and pigs
  - Combining with probiotics

Benefical bacteria-

- Ferment carbohydrates and produce short-chain fatty acids. SCFA reduce intestinal pH and inhibit the growth of some pathogens.
- Promote the growth of intestinal cells and may affect cell differentiation, thereby improving digestion and absorption.
- Provide a barrier effect against pathogens by competitive exclusion, meaning commensal species compete for the same sources of nutrients as potential pathogens.
- Effectively restrict the growth of potential pathogens.
- Interact with the animal’s immune system. Bacteria in the intestine promote the development of the immune system (both structure and function) in young animals.
- Also signal the immune system to produce immunoglobulins and other components to maintain the competence of the immune system.

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Immune modulators

- Chicken IgY derived from egg yolk
- Immunoglobulin Y is an alternative to antibiotics in the treatment of various infections with antibiotic-resistant pathogens [e.g., *Escherichia coli*,*Salmonella*, *Staphylococcus*, *Coronavirus*, and *Rotavirus]*

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Antibiotic Alternatives: Timing and Mode of Action

Timing of Administration	Mechanism of Action
Can be applied continuously	
Phytochemicals	Target bacteria
Organic acids	Target bacteria
Probiotics	Improve gut health
Prebiotics	Improve gut health
Narrow window – around initial infection	
Hydrolases/Bacteriophages	Target bacteria
Antimicrobial peptides	Target bacteria
Narrow window – before infection	
Immune modulators	Stimulate/Enhance immune response
Applied before infection	
Vaccines	Prime immune response

Talkington et al., 2017

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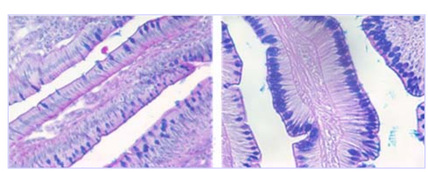
How do these work?

- Try to use examples of various types of outcomes
- Before 2000, very few reports.
- Last 2-4 years, huge numbers of papers published. Europe banned antibiotics in 2006.
- Most are positive!



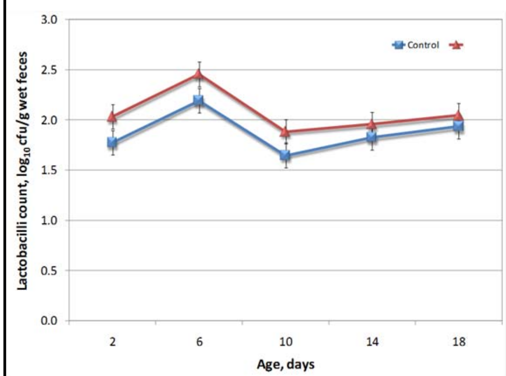
What do these products do?

- Change gut microflora- temporarily
- Less stress
- Improve feed efficiency
- Improve immune status
- Improve ADG

Changing fecal bacterial populations

- Good bacteria
  - Lactobacillus
  - Bifidobacterium
- Bad bacteria
  - Clostrudium
  - Oscillospira
  - E coli

Changes in fecal bacterial populations



Prophylactic use of a standardized botanical extract for the prevention of naturally occurring diarrhea in newborn Holstein calves Teixeira et al., 2017

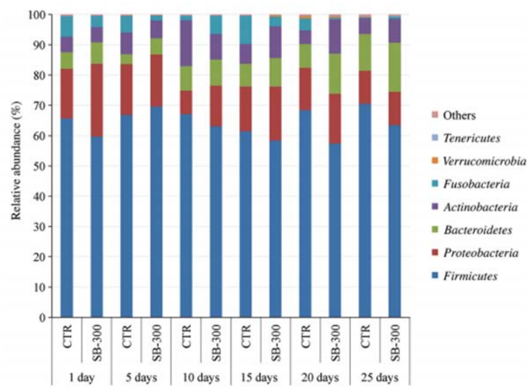
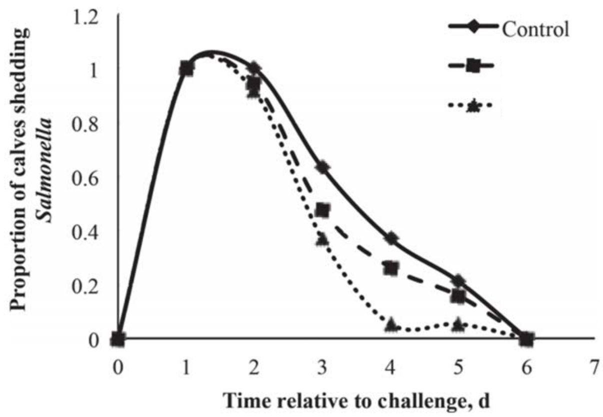


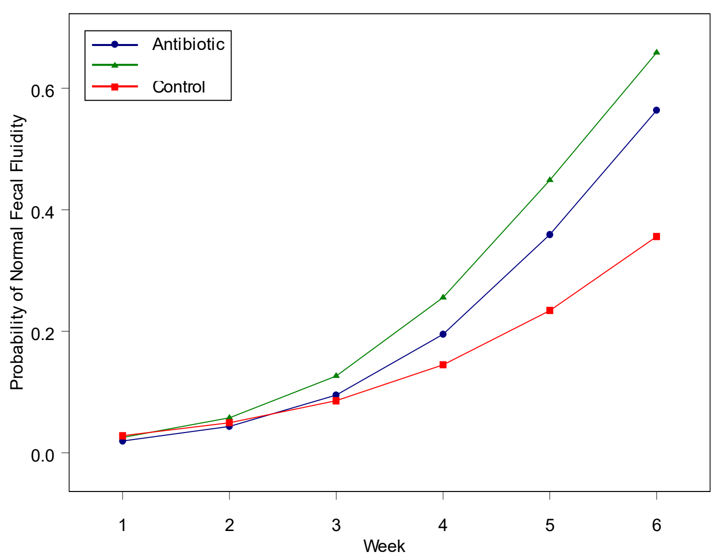
Figure 4. Descriptive distribution of the mean relative abundance (%) of the most prevalent bacterial phyla identified in fecal samples of control calves (CTR, n = 19) and calves receiving standardized botanical extract (SB-300, n = 18). Control calves were administered 10 mL of sterile water (added to milk), twice daily, for the first 15 d of life; calves in the SB-300 group were fed 500 mg of a standardized botanical extract (SB-300, Jaguar Animal Health, San Francisco, CA) diluted in 10 mL of sterile water. Fecal samples were collected once daily at 1, 5, 10, 15, 20, and 25 d of life. Color version available online.

Journal of Dairy Science Vol. 100 No. 4, 2017



Effects of ! on proportion of calves shedding *Salmonella* in feces JDS 2017

Figure 1. Probability of normal fecal fluidity scores by week of age for calves fed one of three milk replacer diets



- The present study demonstrated that directly feeding *B. subtilis natto* to calves during the preweaning period increased growth performance by improving ADG
- aerage daily gain and feed efficiency
- JDS 2010

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Prophylactic use of a standardized botanical extract for the prevention of naturally occurring diarrhea in newborn Holstein calves Teixeira et al., 2017

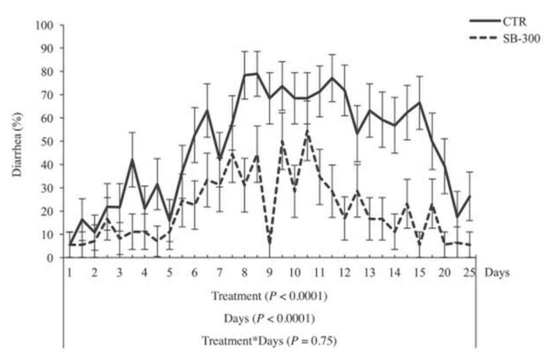
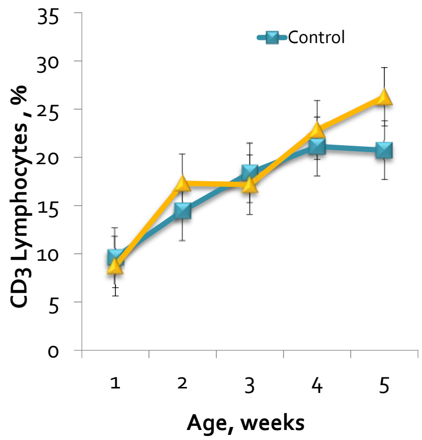
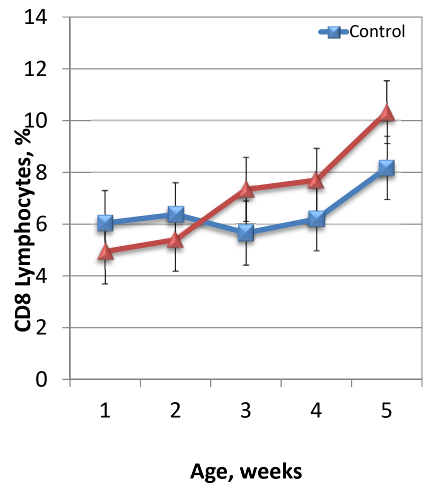


Figure 2. Diarrhea was recorded every day for all the calves in the study; an event of diarrhea was confirmed when a calf fecal sample presented at least one of the twice-daily measurements of fecal DM ≤10.0%. Treatments were administered twice daily with whole milk for the first 15 d of life. The effect of treatment, days, and the interaction between treatment and days are also displayed. Control calves (n = 19) were administered 10 mL of sterile water (added to milk), twice daily, for the first 15 d of life; calves in the SB-300 group (n = 18) were fed 500 mg of a standardized botanical extract (SB-300, Jaguar Animal Health, San Francisco, CA) diluted in 10 mL of sterile water. The y-axis represents the model-adjusted proportion of calves with diarrhea and x-axis represents days into the study. Values are least square means ± standard errors.

Journal of Dairy Science Vol. 100 No. 4, 2017

Effects on immunity





Prebiotics

- ADG were significantly greater when fed a diet of milk replacers with a specific type of prebiotic (galactosyl-lactose) than when fed a diet of milk replacer without prebiotic.
- Even though relatively few studies have evaluated the efficacy of prebiotics for disease prevention in young calves, statistically significant improvements in gut health have been reported.
- However, young calves differ from older cattle because the rumen. Prebiotics are quickly digested in the fully formed rumen, and thus are rendered ineffective

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Prebiotics

A comparison of 7 commercial galacto-oligosaccharides found a difference between preparations in number and types of detected structures, degree of polymerization, and distribution of glycosidic linkages (van Leeuwen et al., 2014, 2016).

Given the importance of complexity and diversity for the effectiveness of OS as a prebiotic, it is important to remember that different supplements may elicit different responses.

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Increasing intake of essential fatty acids from milk replacer benefits performance, immune responses, and health of preweaned Holstein calves
Garcia et al., JDS 2015

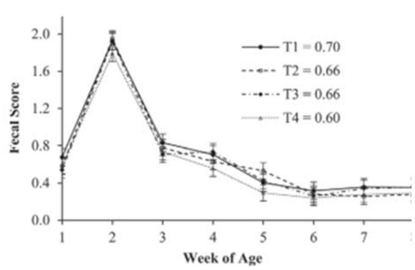

Figure 2. Average weekly fecal scores of preweaned Holstein calve fed linoleic and α-linolenic acids at 0.119 and 0 (T1), 0.187 and 0.01 (T2), 0.321 and 0.036 (T3), or 0.593 and 0.076 (T4) g/kg of $BW^{0.75}$ in milk replacer. Possible scores were 0 for firm feces, no diarrhea; 1 fo soft feces, no diarrhea; 2 for mild diarrhea; and 3 for watery, sever diarrhea. Linear effect of treatment ($P = 0.07$) and effect of age (< 0.01).

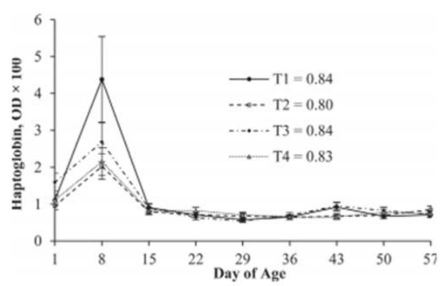

Figure 3. Concentrations of haptoglobin in plasma of preweaned Holstein calves fed linoleic and α-linolenic acids at 0.119 and 0 (T1), 0.187 and 0.017 (T2), 0.321 and 0.036 (T3), or 0.593 and 0.076 (T4) g/kg of $BW^{0.75}$ in milk replacer. Effect of treatment by age interaction ($P = 0.02$); slice effect at d 8 and 43 ($P < 0.05$).

Prebiotics

The relative abundance of OS, particularly those structures with prebiotic potential, were greater in beef-source milk compared with dairy-source milk, which suggests that dairy calves are likely deprived of diet-source OS.

Sischo et al., 2016

Changes in the intestinal bacterial community, short-chain fatty acid profile, and intestinal development of preweaned Holstein calves. 1. Effects of prebiotic supplementation depend on site and age

- Adding galacto-oligisaccharides resulted in more lactic acid bacteria in the colon
- Greater small and intestinal epithelial tissues
- Had increased fecal scores and less growth (and intake).

Castro, J. J. et al., 2016 JDS

Plant extracts- crypto

- Effect of pomegranate-residue supplement on Cryptosporidium parvum oocyst shedding in neonatal calves.
- Suggest – may be potentially positive effects.
- JDS 2014

Penn State **Extension**

J Vet Med A Physiol Pathol Clin Med. 2006 Apr;53(3):154-6.

Full Text Online Library

Effect of dried oregano leaves versus neomycin in treating newborn calves with colibacillosis.

Bampidis VA[1], Christodoulou V, Florou-Paneri P, Christaki E.

Author information

Abstract

Treatment with neomycin (as a positive control) and dried oregano leaves on mortality, number of days scouring and severity of scours due to Escherichia coli were examined in 30 Holstein calves. Calves were assigned to one of the treatments following clinical signs of diarrhoea (i.e. faecal score >2), and treated either with an oral solution of neomycin sulphate, to provide 10 mg neomycin sulphate per kg calf body weight per 24 h, or dried oregano leaves, to provide 10 mg oregano essential oil per kg calf body weight per 24 h. The number of scouring days, severity of scouring and mortality rates were similar between the treatments. This study indicates that dried oregano leaves administered as an oral solution to calves with diarrhoea may be as effective in the treatment of colibacillosis as neomycin.

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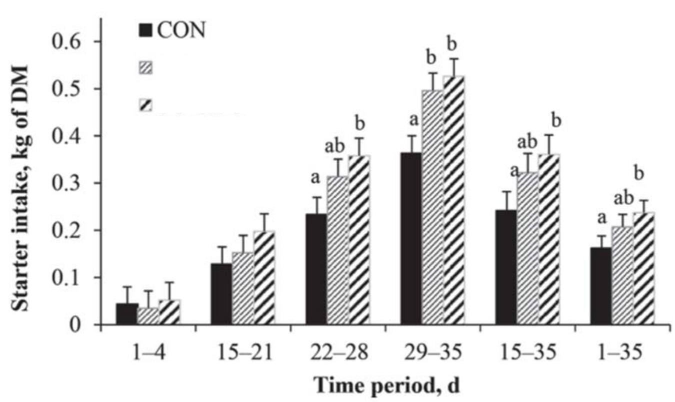
Scientific Evidence of Efficacy in Milk-fed Calves

Product	Growth Promotion	Disease Prevention	Disease Treatment	Evidence of No Efficacy
Probiotics	Strong	Strong		
Prebiotics	Some	Some		
Organic acids				
In-feed enzymes				
Antimicrobial peptides	Some	Some		
Phytochemicals (e.g. essential oils)	Some	Some	Some	
Cu, Zn, other heavy metals				Potential toxicity
Immune modulators		Strong		
Vaccines		Strong		
Bacteriophages, endolysins, lysozyme, other hydrolases		Some		

Talkington et al., 2017

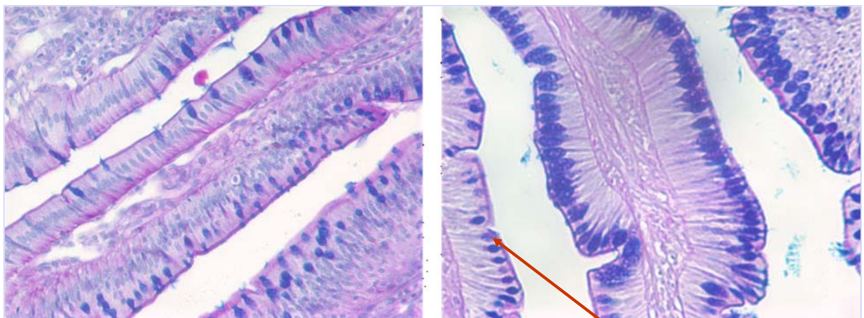


Effects of ... in calf starter intake JDS 2017

Positively Alters Gut Morphology

<u>400Xmagnification</u>

Control



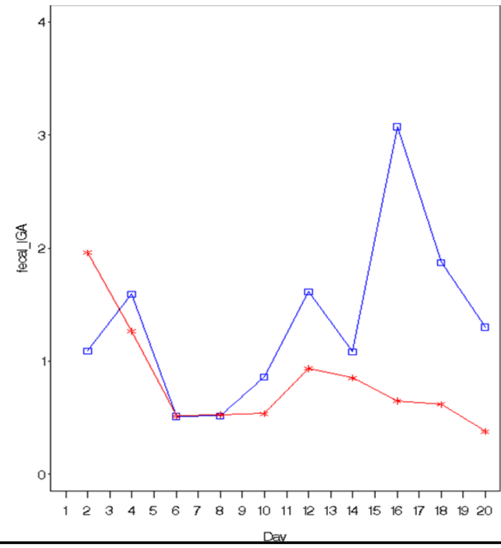
Goblet Cells

Growth, ruminal measurements, and health characteristics of Holstein bull calves fed an Aspergillus oryzae fermentation extract

- Milk replacer, starter, total dry matter intake, gross and histological rumen measurements, rumen pH, fecal and respiratory scores, growth, and total medical costs were not affected by treatment.

Yohe et al., JDS 2015

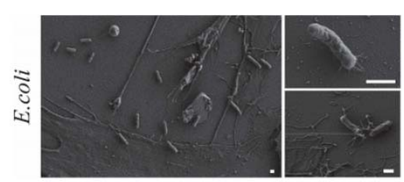
Fecal IgA – xxx Calf Study



Heinrichs et al., 2012

Probiotiics?

- The Effect of Ruminal Fluid Preparations on the Growth and Health of Newborn, Milk-Fed Dairy Calves
- T. V. Muscato,* L. O. Tedeschi,* and J. B. Russell
- JDS 2002
- Calves given rumen fluid had less scours and improved growth



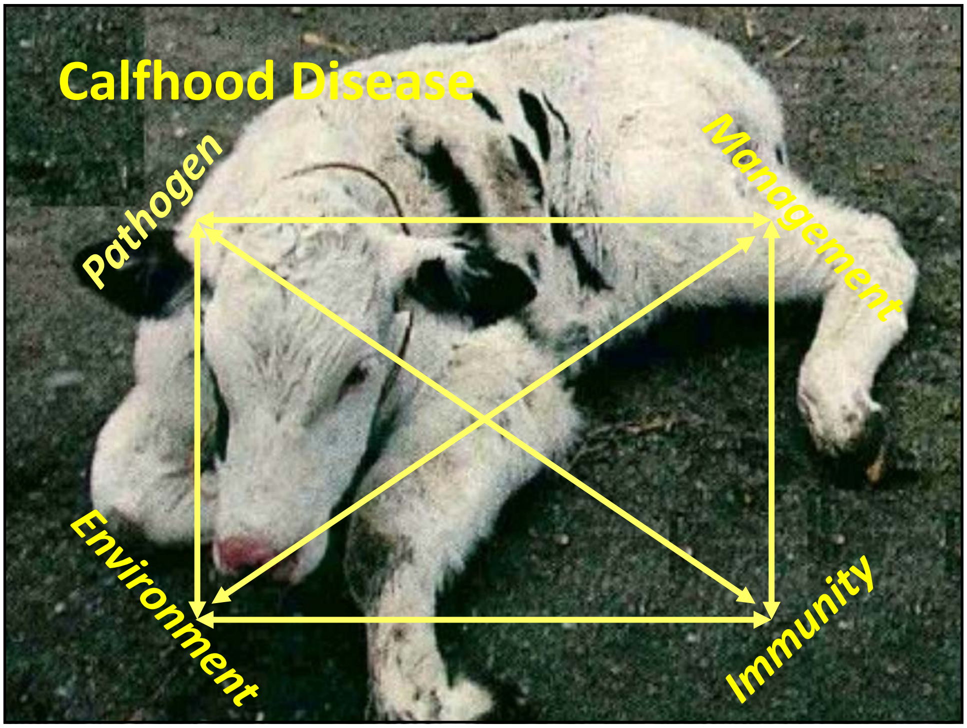
What to look for in an antibiotic aternative

- Reasonably good data.
- From a variety of farms/climates/situations- hope to be similar to where you are?

- **Sound explanation of mode of action**
- Seem to work on good situations best?

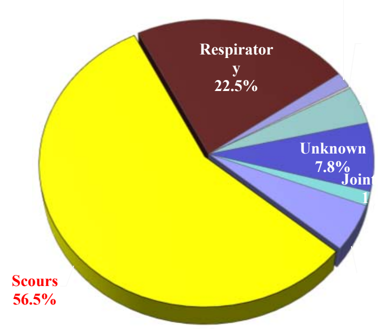
What to look for in an antibiotic aternative

- Dry matter intake- individual animals
- Feed efficiency (better than growth)
- Growth (not just from more DMI)
- Health (can be some issues)
- Immunity- Ig levels over time, cellular aspects, blood
- Stress hormones –haptaglobin
- Gut/fecal bacteria – species and levels
- Good explanation of mode of action

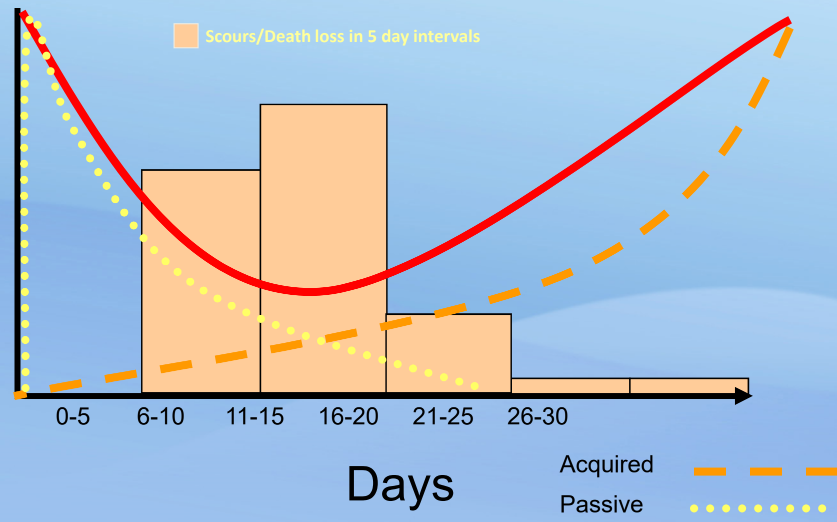


Dairy calf mortality

- NAHMS 2007
- 75% of calf losses in first year occur in 1st month of life.



Calf Immunity



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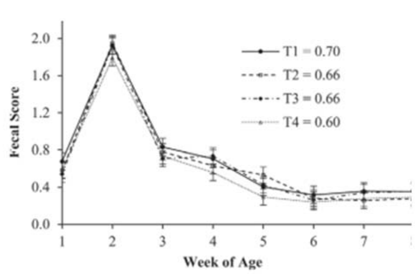
Garcia et al., JDS 2015



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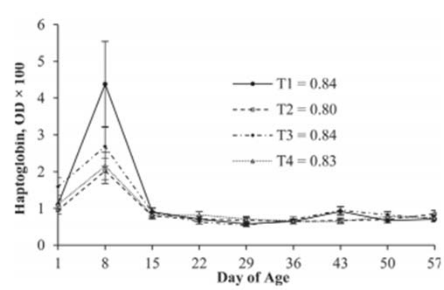

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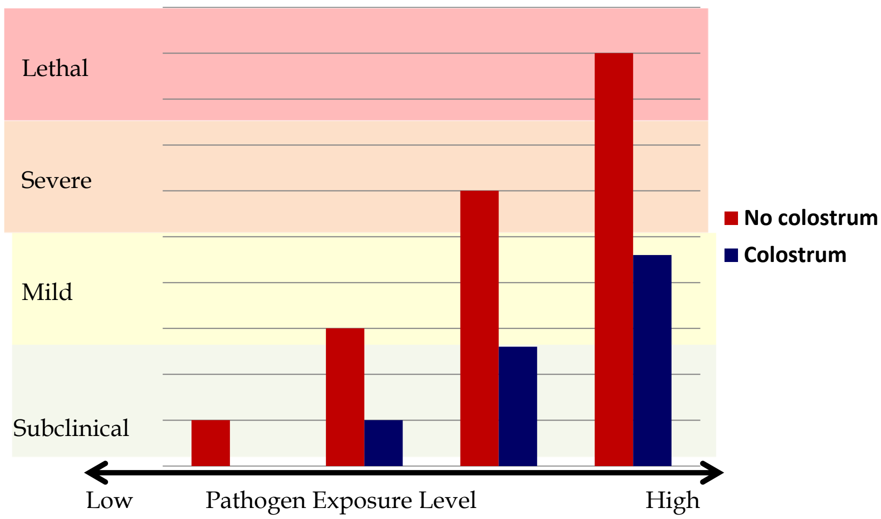
Antibodies from colostrum become a calf's first defense

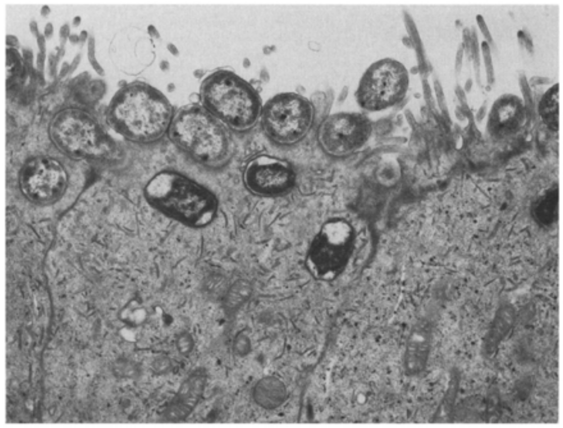


Key Factors in Colostrum Management

- Feed colostrum as soon as possible after birth.
- Feed good quality colostrum >50 g/L.
- Feed large volume of colostrum.

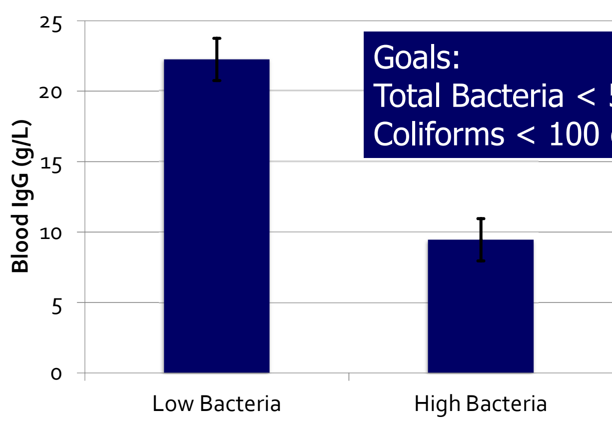
- To manage- you must have measurements

Calves can absorb bacteria too!



Factors affecting Ig concentration in colostrum

- Colostrum bacteria concentration



Goals:
Total Bacteria < 50,000 cfu/mL
Coliforms < 100 cfu/mL

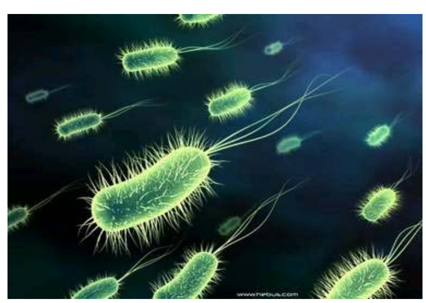
Blood IgG levels depends on:

- **Timing of colostrum feeding**
- **Quantity of colostrum fed**
- **Quality of colostrum**
  - **Ig and bacteria**

If you test and the colostrum is low

- 1st choice - frozen colostrum from your freezer
- 2nd choice – colostrum substitute
- If a herd health issue and/or general low absorption of Ig issue- pasteurize your colostrum

When you check calves and their blood protein levels are too low; fix the problem.



Measuring Passive Transferr

- Serum IgG concentration.
  - Use of radial immunodiffusion.
  - > 10 g/L at 24 - 48 h of age.
- Serum total protein.
  - Use of a refractometer.
  - > 5.5 g/L at 24 - 48 h of age.

Nutrition to improve immunity

- We can use feed additives for baby calves to improve health
  - In milk or milk replacers
  - In calf starters



Methane emissions from dairy operations

Alex N. Hristov
Department of Animal Science
The Pennsylvania State University

PENN STATE's DAIRY CATTLE NUTRITION WORKSHOP, Nov. 15-16, 2017

PennState
College of Agricultural Sciences

Talk outline

- Methane inventory uncertainties on global, national, and local scales
- Emission sources, intensity, units
- Techniques for measuring livestock methane emissions
- Mitigation strategies
- Take-home message

Anthropogenic Methane Emissions in the United States

Improving Measurement, Monitoring, Reporting, and Development of Inventories

Methane is the second most prevalent greenhouse gas emitted in the United States. Although it is shorter-lived in the atmosphere than carbon dioxide, methane is more efficient at absorbing heat. More accurate inventories of human-emitted methane in the United States and a framework for long term monitoring and reporting would help improve the scientific bases of strategies for reducing emissions.

At the request of NASA, NOAA, EPA, and DOE, this study will examine approaches to measuring, monitoring, reporting, and developing inventories of anthropogenic emissions of methane to the atmosphere. The geographic scope of this study is limited to the United States. This study will assess published inventories of U.S. methane emissions, characterize their uncertainty, and identify opportunities for improving these estimates.

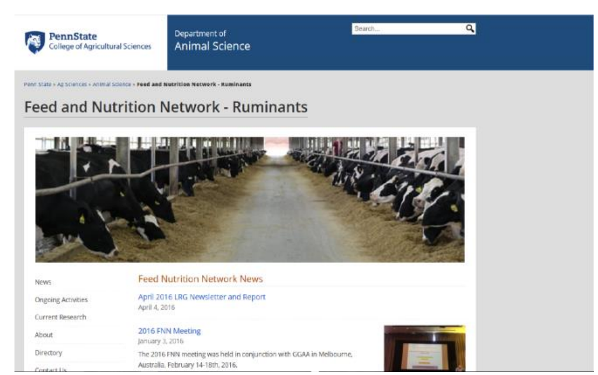
The Feed and Nutrition Network

Global Research Alliance on Agricultural GHG

Livestock Research Group

International collaboration in database development: THE GLOBAL NETWORK PROJECT

Research Networks, including FNN

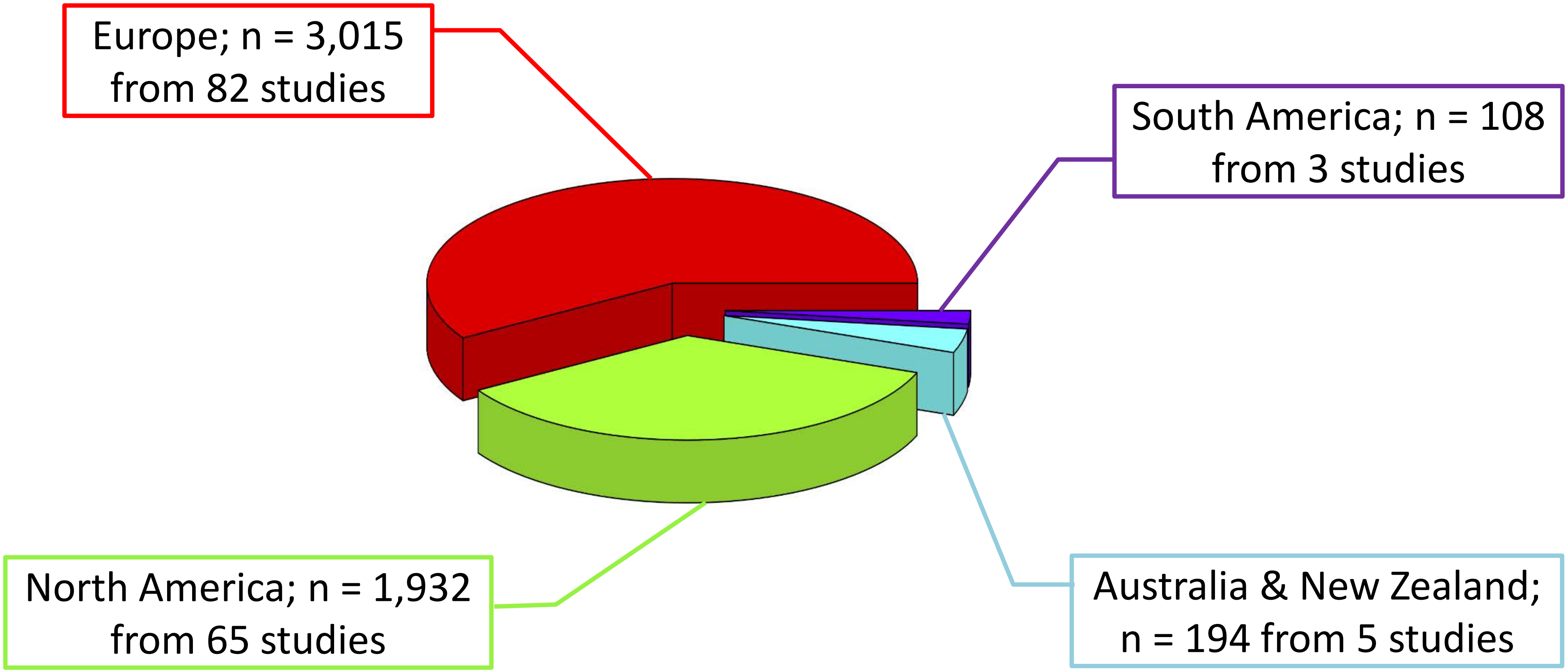


ENTERIC METHANE EMISSIONS: PREDICTION AND MITIGATION, THE GLOBAL NETWORK PROJECT

A. N. Hristov, E. Kebreab, M. Niu, J. Oh, C. Arndt, A. Bannink, A. R. Bayat, A. F. Brito, D. Casper, L. A. Crompton, J. Dijkstra, P. C. Garnsworthy, N. Haque, A. L. F. Hellwing, P. Huhtanen, M. Kreuzer, B. Kuhla, P. Lund, J. Madsen, S. C. McClelland, P. Moate, C. Muñoz, N. Peiren, J. M. Powell, C. K. Reynolds, A. Schwarm, K. J. Shingfield, T. M. Storlien, M. R. Weisbjerg

PennState
College of Agricultural Sciences

Dairy database (n = 5,249)



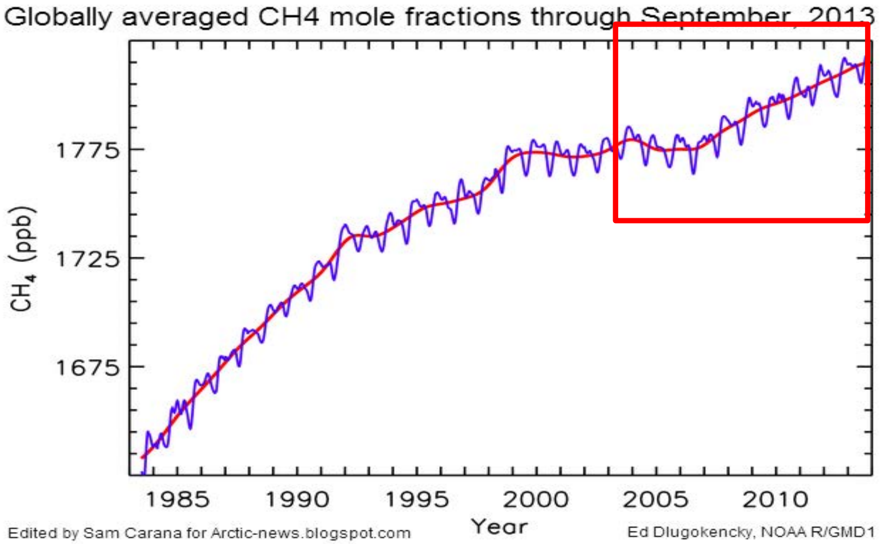
Enteric methane prediction models

Model Development			Model Performance
Level	Model	Predictor	RMSPE, %
1	GEI Level	GEI	15.8
2	DMI Level	DMI	15.6
3	**DMI & NDF Level**	**DMI, NDF**	**14.5**
4	DMI & EE Level	DMI, EE	15.8
5	Dietary Level	DMI, EE, NDF	14.8
6	Dietary Composition Level	EE, NDF	24.1
7	MY Level	MY	20.1
8	ECM Level	ECM	18.7
9	Performance	ECM, MP	17.7
10	**Animal Level**	**DMI, EE, NDF, MF, BW**	**14.5**
11	Animal without DMI Level	EE, NDF, MP, ECM, BW	16.3
-	IPCC, 2006	GEI	16.1
-	IPCC, 1997	GEI	16.6

Niu et al., submitted

Top-down vs. bottom-up methane inventories and uncertainties

Global methane inventories



1. **Is this growth real?**
   a) $CH_4 + \cdot OH \rightarrow \cdot CH_3 + H_2O$

Q1: Our approach indicates that significant OH-related uncertainties in the CH_4 budget remain, and we find that <u>it is not possible to implicate</u>, with a high degree of confidence, rapid global CH_4 emissions changes as the primary driver of recent trends when our inferred OH trends and these uncertainties are considered.

Rigby et al., 2017 (PNAS)

2. If the growth is real, what is causing it?

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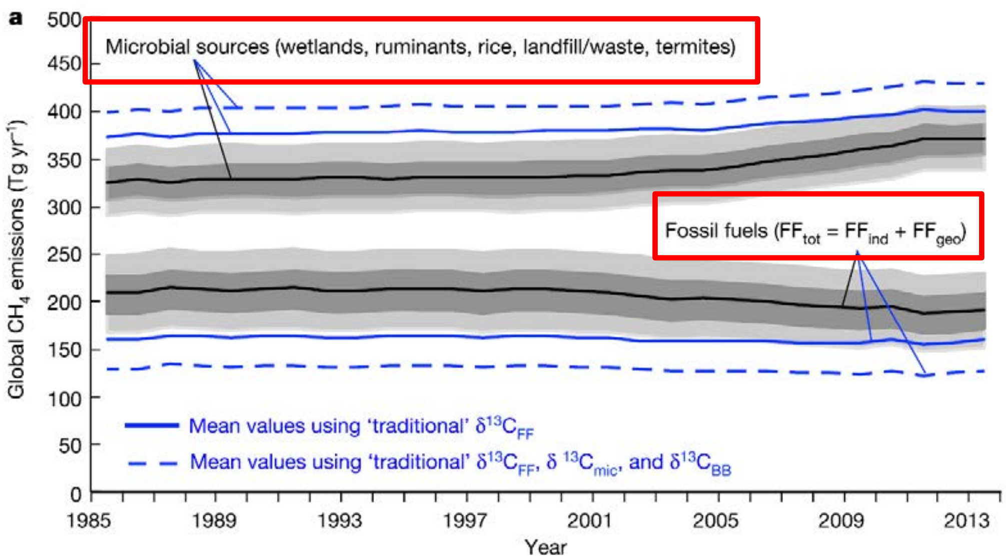
Global methane inventories

Schwietzke et al., 2016 (Nature)



Schwietzke et al., 2016 (Nature)

......the recent temporal increases in microbial emissions have been substantially larger (than from fossil fuel)

Schaefer et al., 2016 (Science)

.....Post-2006 source increases are predominantly biogenic, outside the Arctic, and arguably more consistent with agriculture than wetlands

How reliable are the isotope data?

Turner et al., 2017 (PNAS)

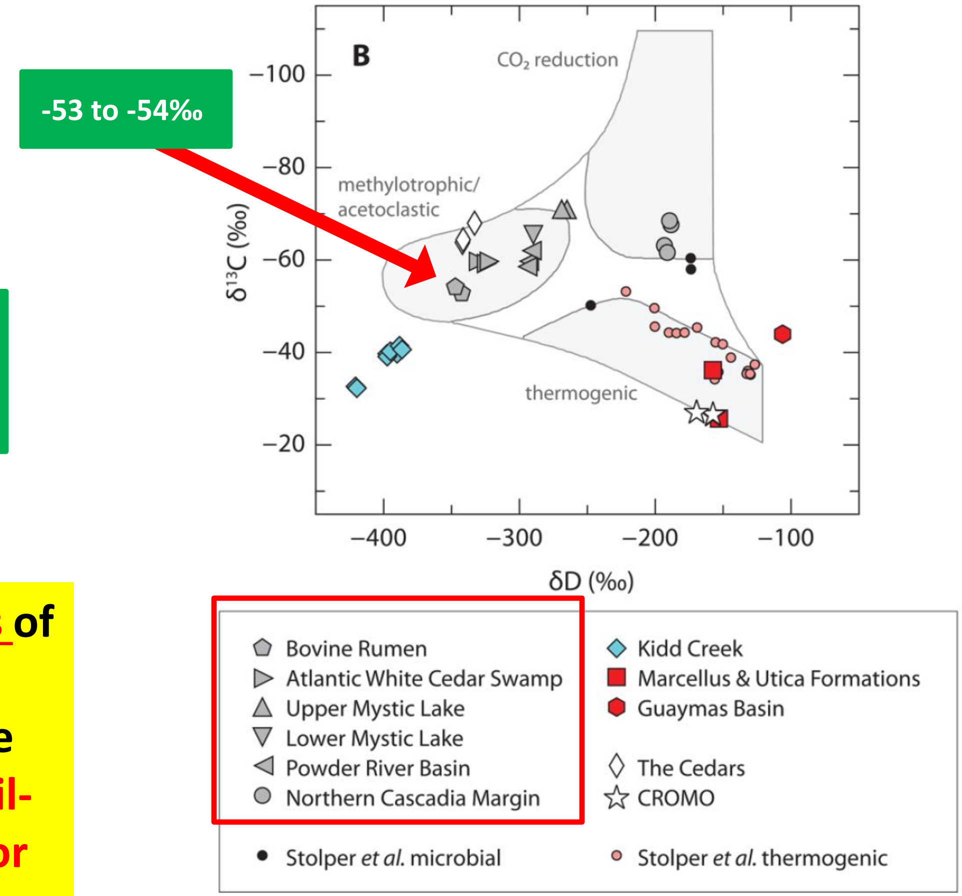
$\delta^{13}CH_4$; fossil-fuel

-15‰ to -76‰

-31‰ to -93‰

$\delta^{13}CH_4$; biogenic

….a <u>large overlap in isotopic signatures</u> of fossil fuel and non-fossil methane……..analysis presented here demonstrates that an increase in fossil-fuel methane sources could be a major contributor to the renewed growth in atmospheric methane since 2007



Wang et al., 2016 (Science)

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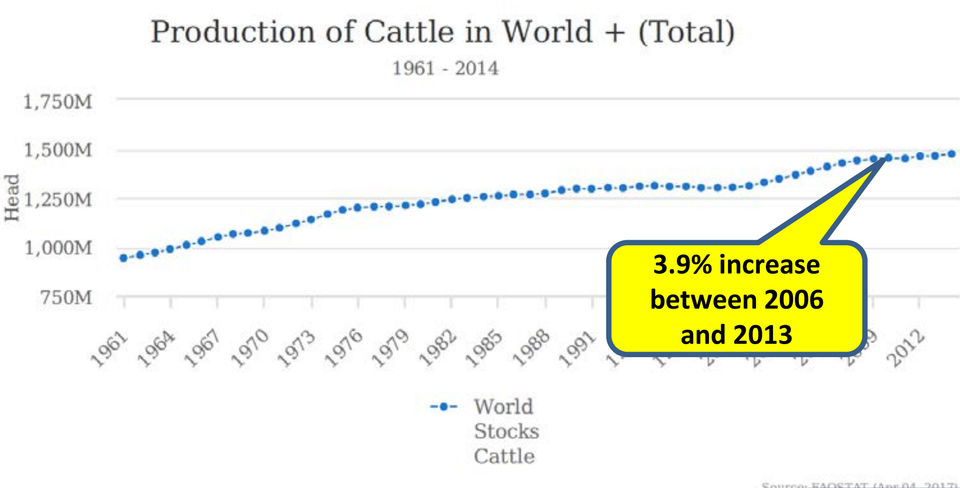
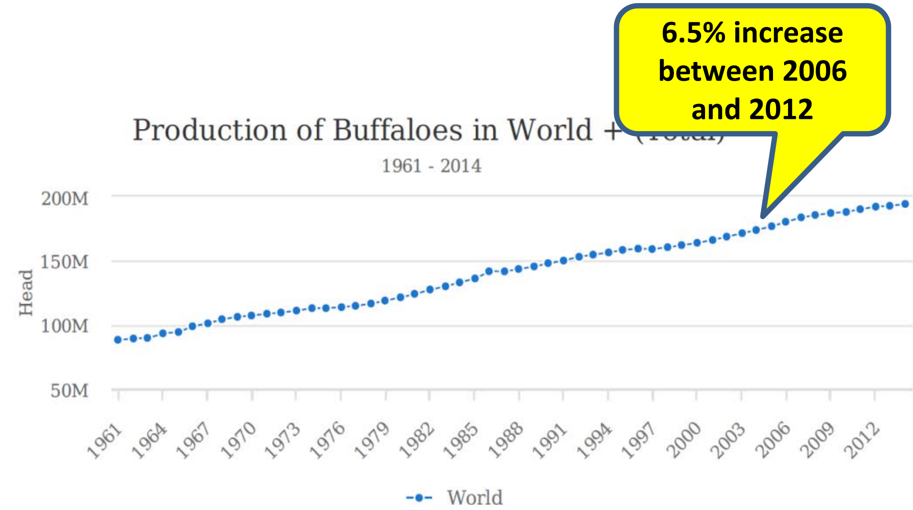
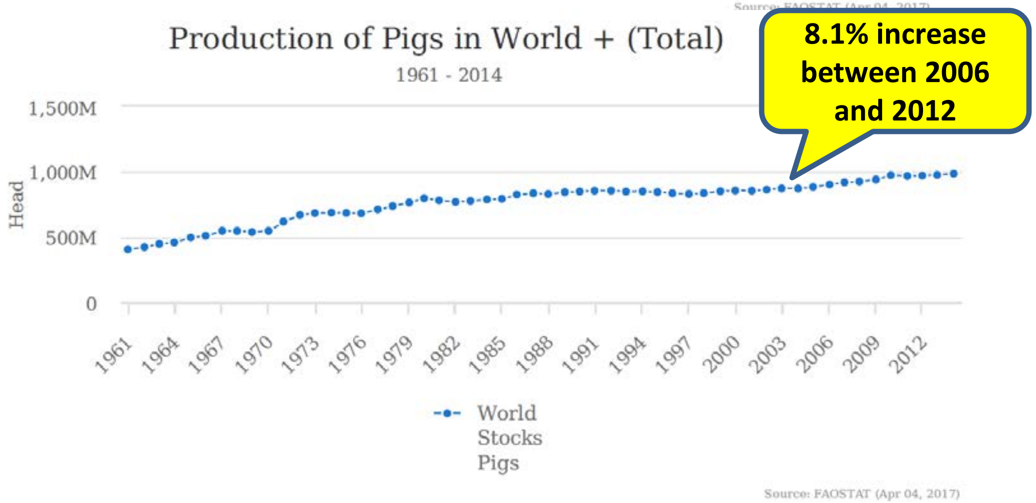
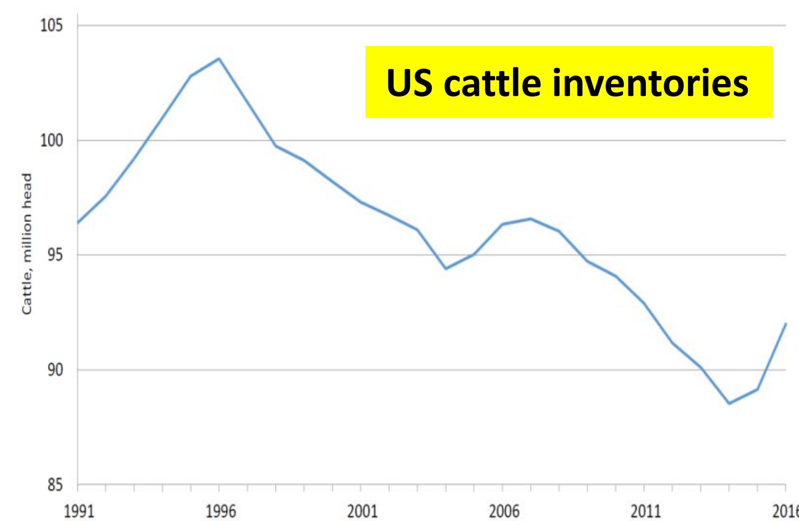
We have to also consider the global livestock population trends









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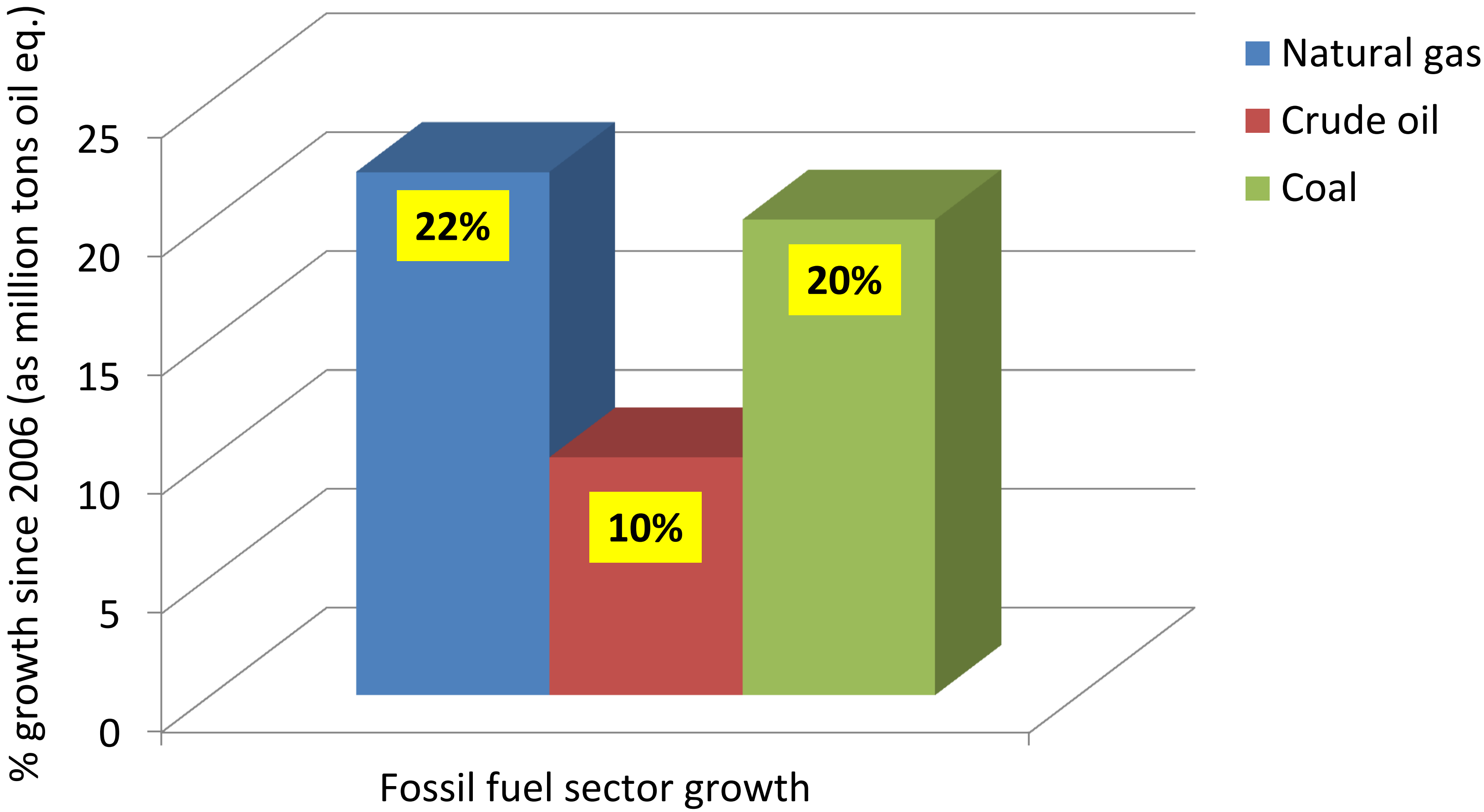
BP Statistical Review of World Energy, June 2016

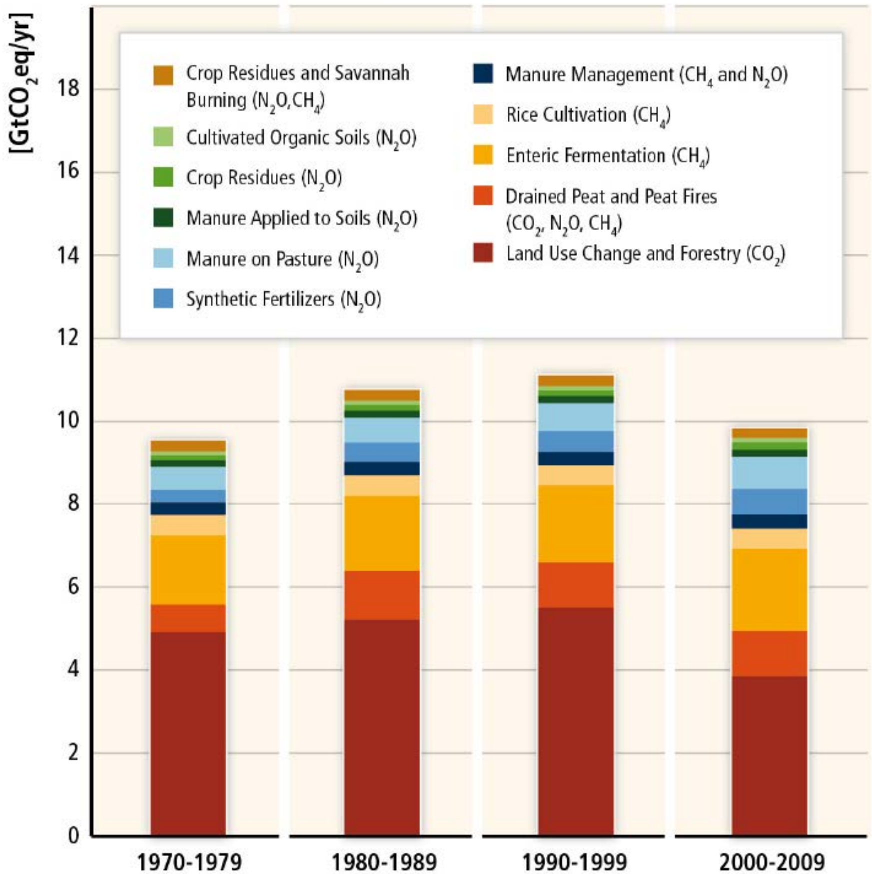
Trends in global fossil fuel production, 2006 - 2015

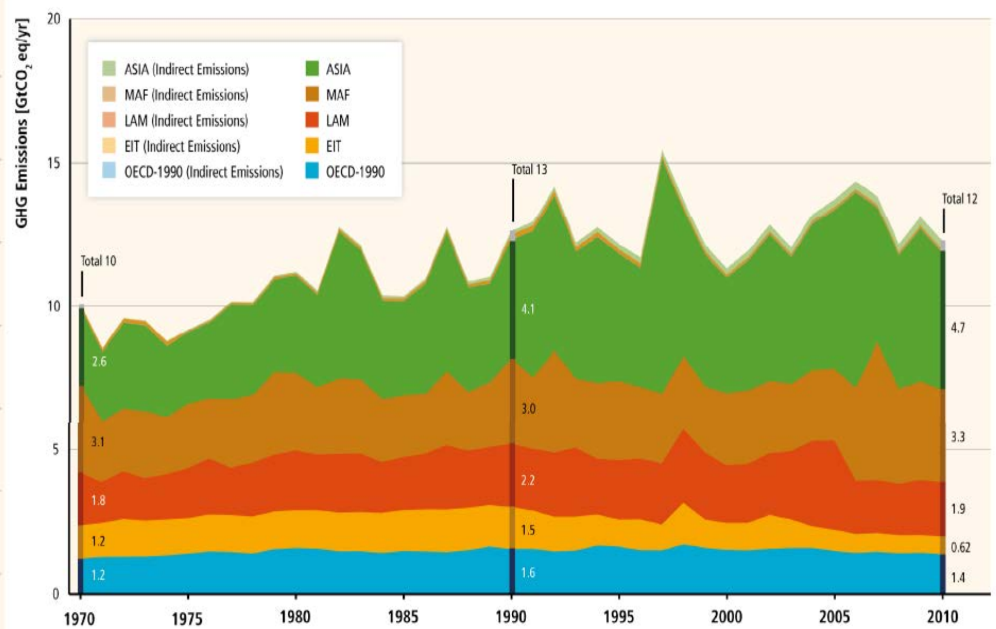


Bottom-up global and national methane inventories

IPCC 2014 Report: AFOLU = about 25% of man-made GHG

Annual total non-CO_2 GHG emissions from agriculture in 2010 are estimated to be 5.2–5.8 $GtCO_2$ eq/yr and comprised **about 10–12% of global anthropogenic emissions**





LAM = Latin America and Caribbean
MAF = Middle East and Africa
OECD = Organization for Economic Cooperation and Development
EIT = Economies in Transition

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USEPA 2017 inventory

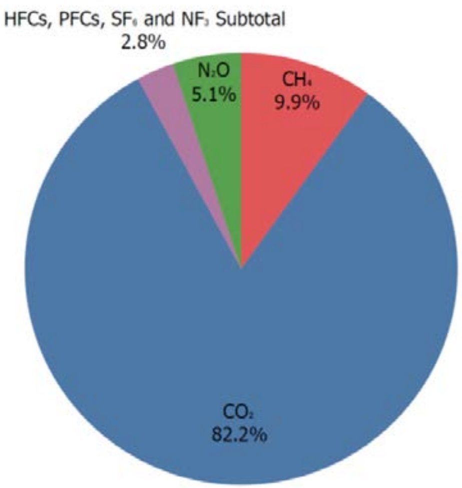
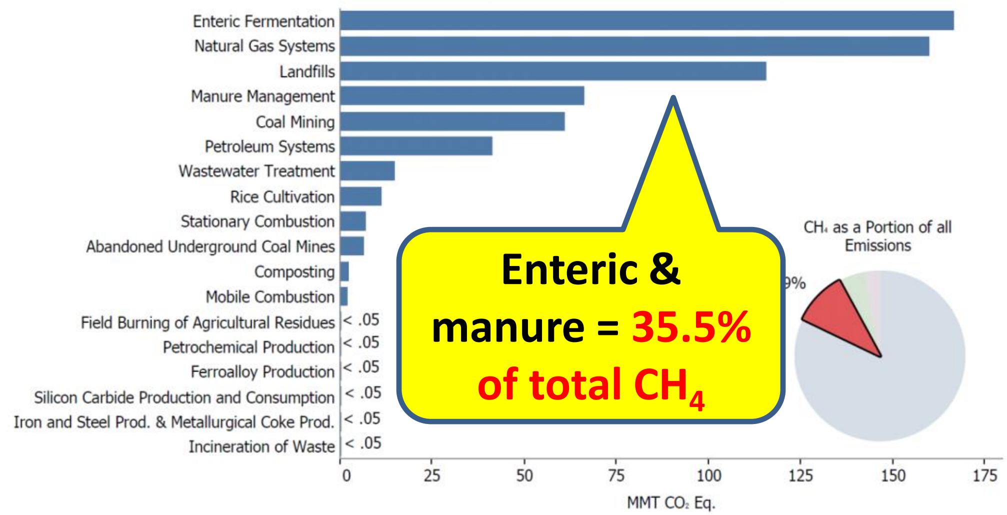


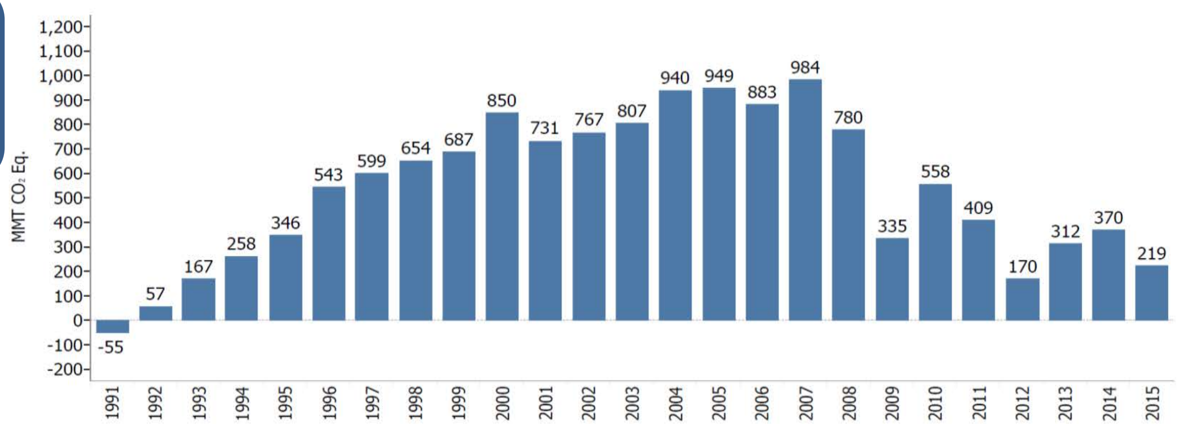
Figure ES-8: 2015 Sources of CH_4 Emissions (MMT CO_2 Eq.)



Enteric & manure = 35.5% of total CH_4

Enteric & manure = 3.8% of total CO_2eq

Figure ES-3: Cumulative Change in Annual Gross U.S. Greenhouse Gas Emissions Relative to 1990 (1990=0, MMT CO_2 Eq.)



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Wecht et al., 2014

US methane accounting controversy

40 to 90% higher than USEPA's estimates

Table 1. U.S. Fluxes of Methane in 2004 [Tg a^{-1}]

Source Type	*EPA* [2013][a]	EDGAR v4.2[b]	*Miller et al.* [2	ork[d]
Total			47.2 ± 1.9	37.0 ± 1.4
Anthropogenic	28.3 (24.6, 32.3)	25.8	44.5 ± 1.9	30.1 ± 1.3
Livestock	8.8 (7.7, 10.4)	8.5	16.9 ± 6.7	12.2 ± 1.3
Natural Gas and Oil	9.0 (7.2, 13.4)	6.3		7.2 ± 0.6
Landfills	5.4 (2.5, 7.9)	5.3		5.8 ± 0.3
Coal Mining	2.7 (2.3, 3.2)	3.9		2.4 ± 0.3

PNAS

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LETTER

Livestock methane emissions in the United States

The recent study by Miller et al. (1) provides a comprehensive, quantitative analysis of anthropogenic methane sources in the United States using atmospheric methane observations, spatial datasets, and a high-resolution atmospheric transport model. The authors conclude that "...emissions due to rumi- beef and dairy cattle requirements and ranged from 3.8 (calves < 500 lbs live weight), to 9–10 (cattle on feed or other steers and heifers > 500 lbs), 11 (beef cows), and 22 kg/d (dairy cows). Methane production rates were estimated at 8–13 (cattle on feed) or 20 g/kg (all other cate- be unsubstantiated by the above "bottom-up" approach. There is a need for a detailed inventory of manure systems for all farm animal species and categories, which will help to more accurately estimate greenhouse gas (and ammonia) emissions from animal manure in the United States.

Environmental Science & Technology

Article

pubs.acs.org/est

Discrepancies and Uncertainties in Bottom-up Gridded Inventories of Livestock Methane Emissions for the Contiguous United States

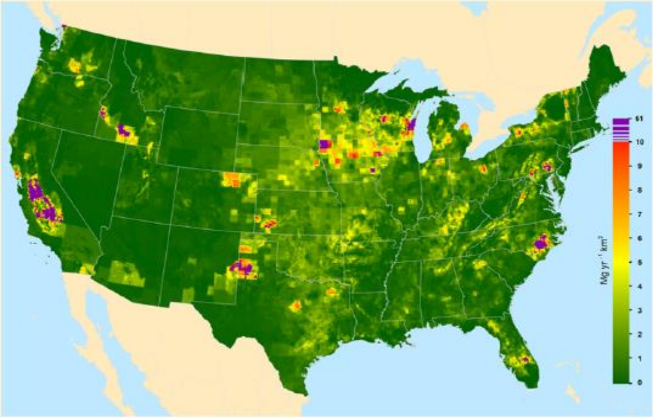
Alexander N. Hristov,*,† Michael Harper,† Robert Meinen,† Rick Day,‡ Juliana Lopes,† Troy Ott,† Aranya Venkatesh,§ and Cynthia A. Randles§

†Department of Animal Science, and ‡Department of Ecosystem Science and Management, The Pennsylvania State University, University Park, Pennsylvania 16802, United States

§ExxonMobil Research and Engineering Company, Annandale, New Jersey 08801, United States

Supporting Information

ABSTRACT: In this analysis we used a spatially explicit, simplified bottom-up approach, based on animal inventories, feed dry matter intake, and feed intake-based emission factors to estimate county-level enteric methane emissions for cattle and manure methane emissions for cattle, swine, and poultry for the contiguous United States. Overall, this analysis yielded total livestock methane emissions (8916 Gg/yr; lower and upper 95% confidence bounds of ±19.3%) for 2012 (last census of agriculture) that are comparable to the current USEPA estimates for 2012 and to estimates from the global gridded Emission Database for Global Atmospheric Research (EDGAR) inventory. However, the spatial distribution of emissions developed in this analysis differed significantly from that of EDGAR and a recent gridded inventory based on USEPA. Combined enteric and manure methane emissions from livestock in Texas and California (highest contributors to the national total) in this study were 36% lesser and 100% greater, respectively, than estimates by EDGAR. The spatial distribution of emissions in gridded inventories (e.g., EDGAR) likely strongly impacts the conclusions of top-down approaches that use them, especially in the source attribution of resulting (posterior) emissions, and hence conclusions from such studies should be interpreted with caution.



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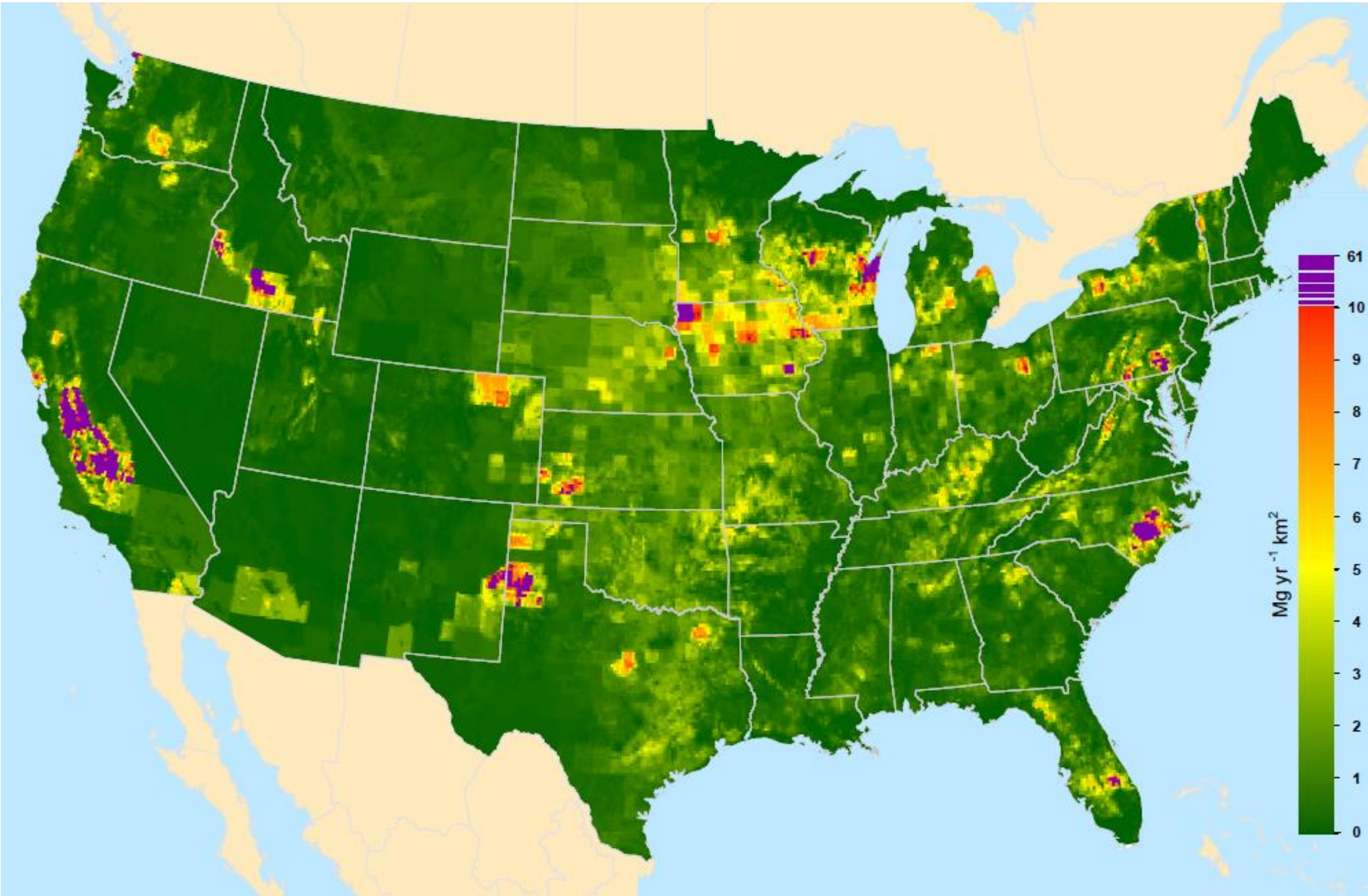
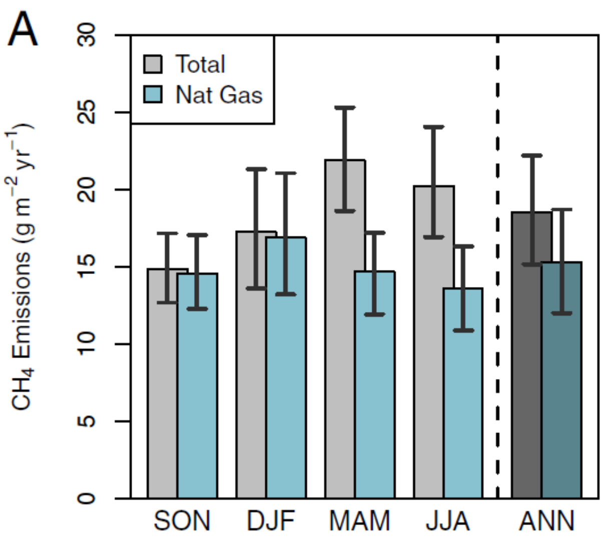
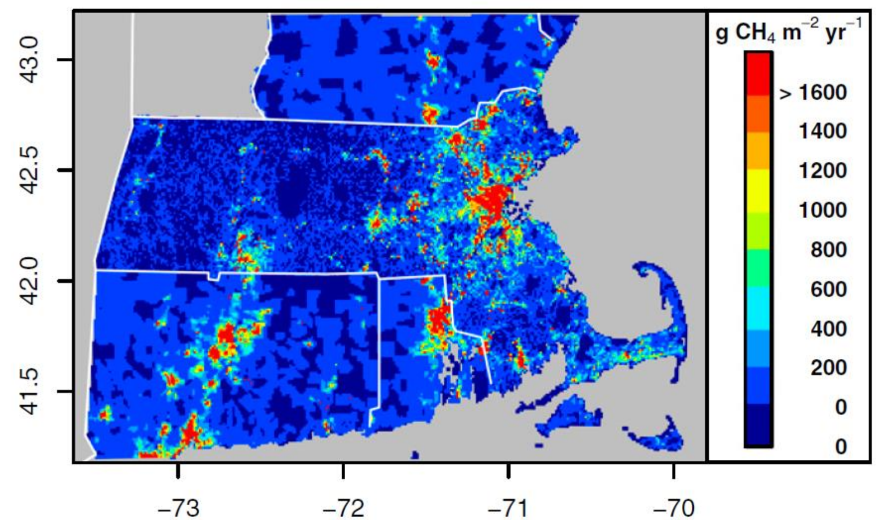
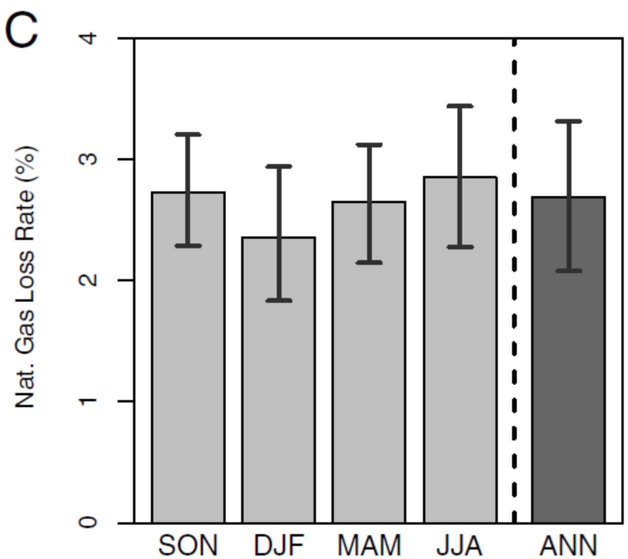


McKain et al., 2016 (PNAS)

City methane emissions







About 6 scf methane/person/d

28-55 kg methane/person/yr

(IPCC 2006 emissions for NA dairy cows: enteric = 128 & manure = 78 kg/hd/yr)

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Livestock methane emissions

Greenhouse gases from agriculture

- Carbon dioxide – livestock contribution is unknown
- Methane – over a 100 year period, has 25 times the global warming potential of CO_2
  - Enteric fermentation and manure management
- Nitrous oxide - over a 100 year period, has 298 times the GWP of CO_2
  - Soil and manure management

USEPA, 2017

Global Warming Potential

- Greenhouse gases, for example, CO_2, methane (CH_4) and nitrous oxide (N_2O), are chemically stable and persist in the atmosphere over timescales of a decade to centuries or longer, so that their emission has a long-term influence on climate.
- Carbon dioxide does not have a specific lifetime because it is continuously cycled between the atmosphere, oceans and land biosphere and its net removal from the atmosphere involves a range of processes with different time scales.

Gas	GWP
CO_2	1
CH_4[a]	25
N_2O	298
HFC-23	14,800
HFC-32	675
HFC-125	3,500
HFC-134a	1,430
HFC-143a	4,470
HFC-152a	124
HFC-227ea	3,220
HFC-236fa	9,810
HFC-4310mee	1,640
CF_4	7,390
C_2F_6	12,200
C_4F_{10}	8,860
C_6F_{14}	9,300
SF_6	22,800
NF_3	17,200

Source: IPCC (2007)

USEPA, 2017

Global Warming Potential

United Nations
Framework Convention on
Climate Change

Species	Chemical formula	Lifetime (years)	Global Warming Potential (Time Horizon)		
			20 years	100 years	500 years
CO_2	CO_2	variable §	1	1	1
Methane *	CH_4	12±3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170

OXFORD MARTIN SCHOOL

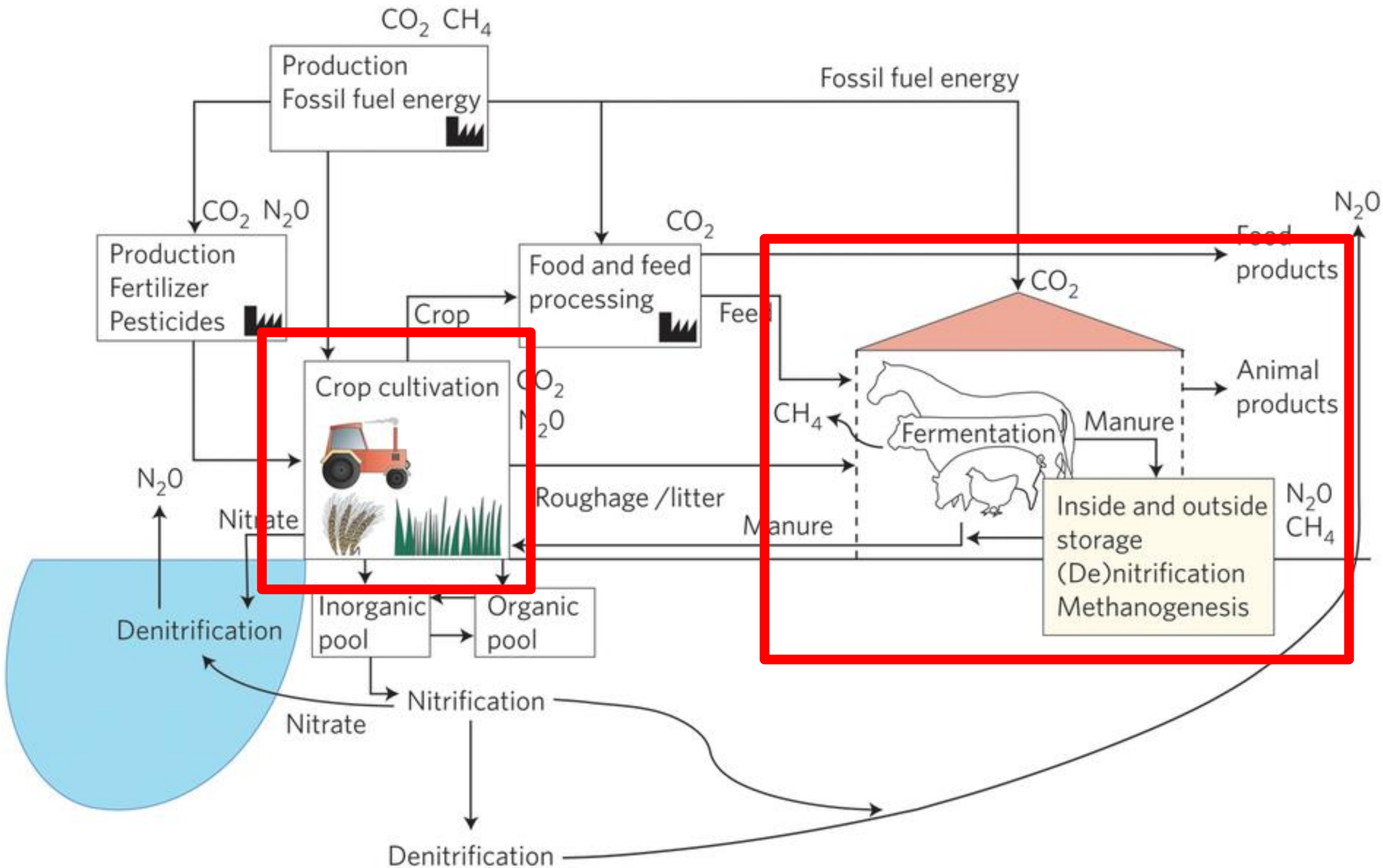
UNIVERSITY OF OXFORD

Table Two: 'Greenhouse gas exchange rates', or what a tonne of each gas is worth in terms of tonnes of CO_2 under various climate metrics, for the three most important greenhouse gases and two illustrative HFCs.[37]

Gas	Global Warming Potential		Global Temperature Change Potential		
	GWP_{20}	GWP_{100}	GTP_{20}	GTP_{40}	GTP_{100}
Carbon dioxide	1	1	1	1	1
Nitrous oxide	264	265	277	285	234
Methane	84	28	67	26	4
HFC-134a	3710	1300	3050	1173	201
HFC-152a	506	138	174	36	19
Black carbon[38]	3200	910	925	n.a.	130

Petherick, 2012 (Nature Climate Change)

GHG emissions from animal ag



Source: Thoma et. al, Greenhouse Gas Emissions of Fluid Milk in the U.S., University of Arkansas, 2010. Carbon footprint = 17.6 lbs CO2e per gallon of milk consumed. Natural variability and uncertainty in data ranges from 15.3 to 20.7 lbs. CO2e. Based on 2007-2008 data.

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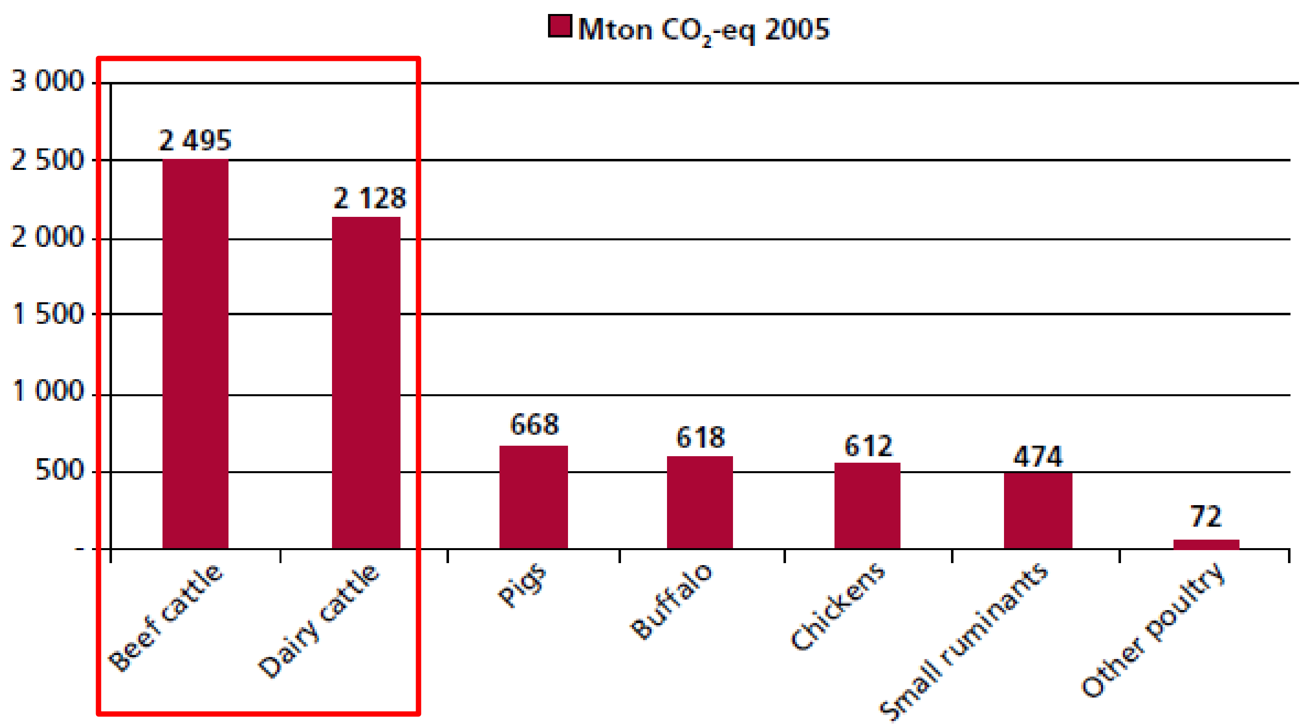
Gerber et al., 2012

Species contributions to GHG emissions

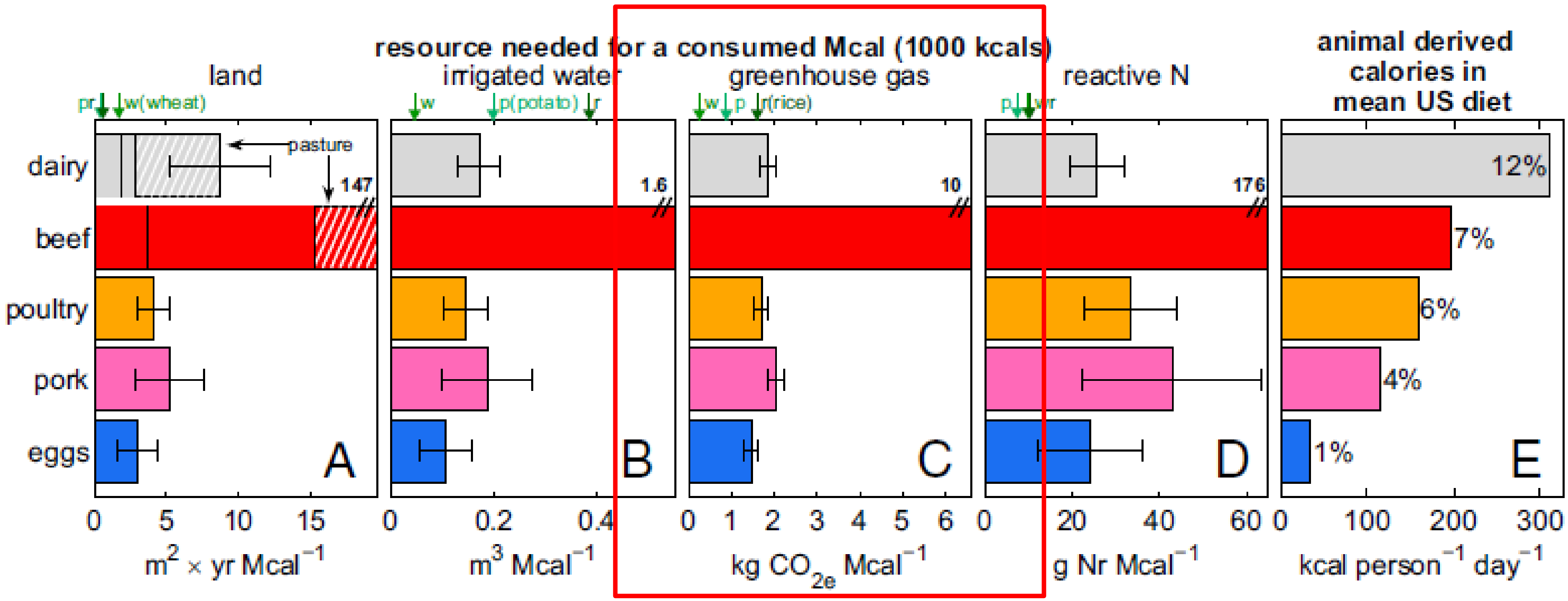
FIGURE 2
Total emissions from the global livestock sector, by main animal species and commodities



Source: Gerber *et al.*, 2012.

Eshel et al., 2014, PNAS

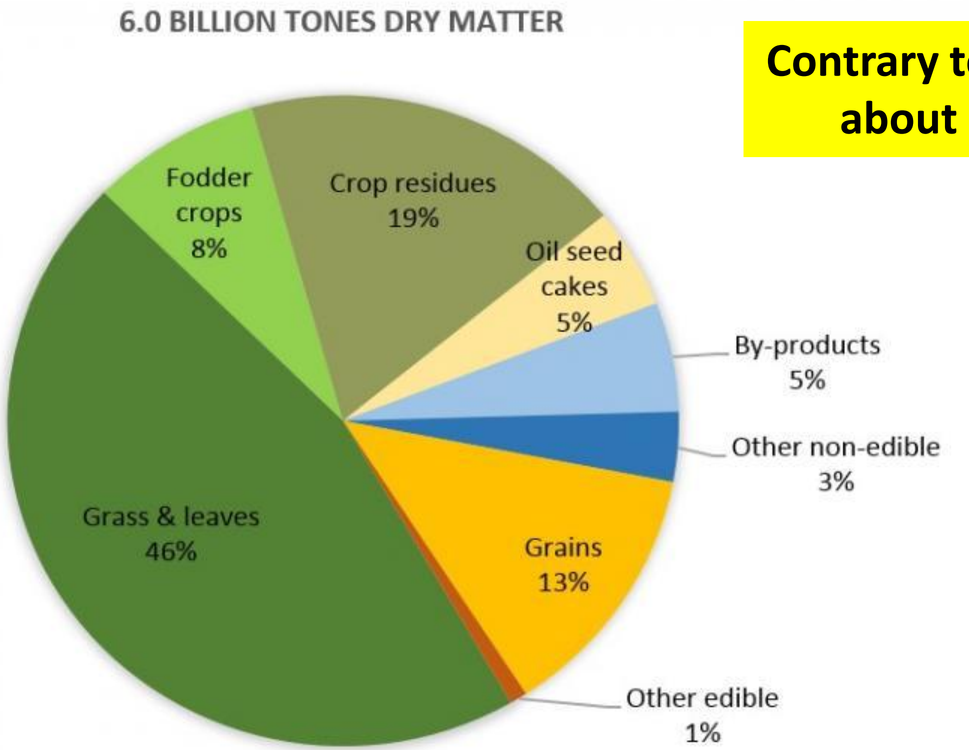
Environmental footprint of animal production



Mottet et al. (FAO), 2017

Livestock: On our plates or eating at our table?

Contrary to previous estimates: about 3 kg grain/kg beef

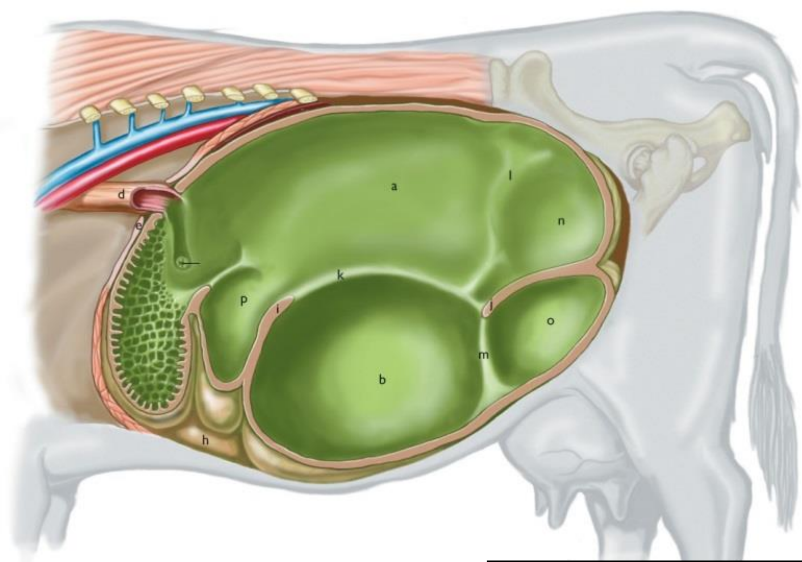


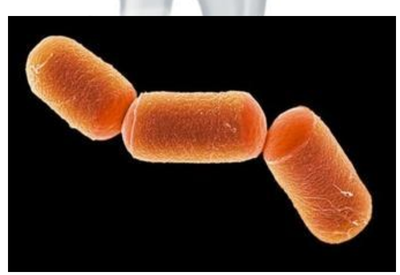
Fodder crops: grain and legume silage, fodder beets
Crop residues: straws and stover, sugar cane tops, banana stems
By-products: brans, corn gluten meal and feed, molasses, beetroot pulp and spent breweries, distilleries, biofuel grains
Other non-edible: second grade cereals, swill, fish meal, synthetic amino acids, lime
Other edible: cassava pellets, beans and soy beans, rapeseed and soy oil


Pre-settlement GHG emissions from wild ruminants in the continental U.S. were estimated at about 86% of the current emissions from livestock
(Hristov, 2012; J. Anim. Sci.)

Sources of methane in a ruminant production system

In dairy systems: probably close to half/half





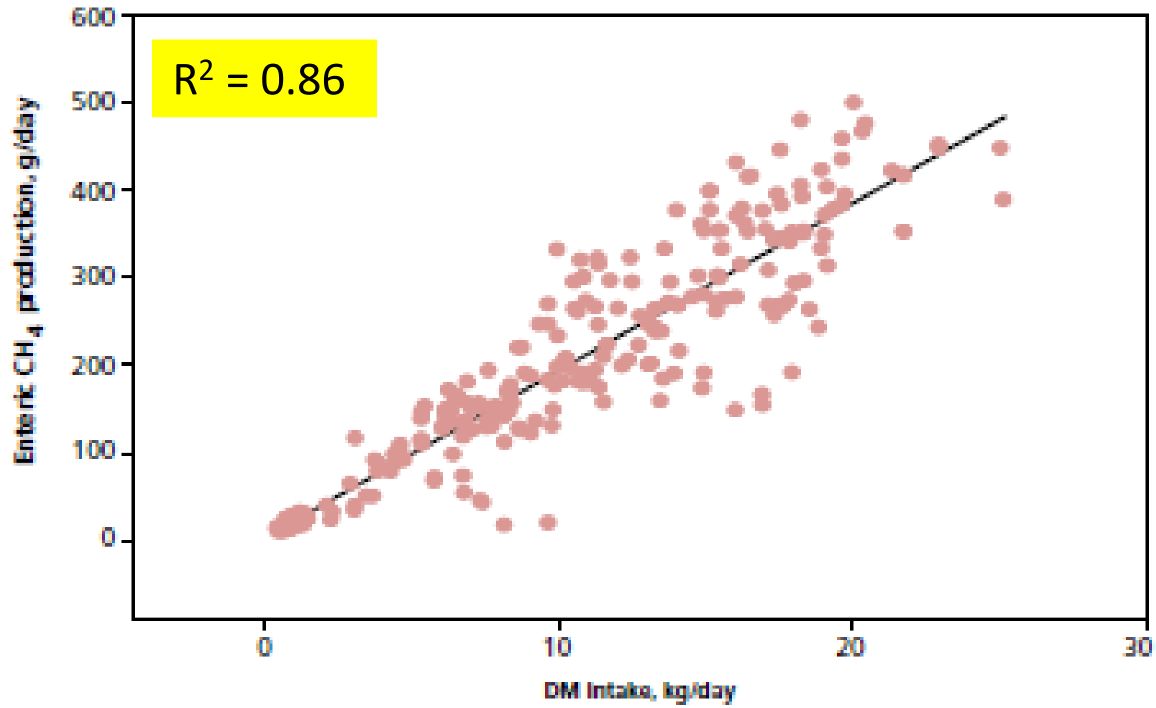
Methanobrevibacter

Hristov et al., 2013

Factors affecting enteric methane emission

Other factors:
Animal genetics
Diet composition
- fiber/starch
- fat

FIGURE 4
Relationship between dietary DM intake and enteric CH_4 production



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Factors affecting manure methane emission

- Emissions are primarily from storage
  - Manure solids content
  - Anaerobiosis
  - Carbon availability
  - Temperature
  - Storage time
  - Wind

- Very little emission when applied on soil

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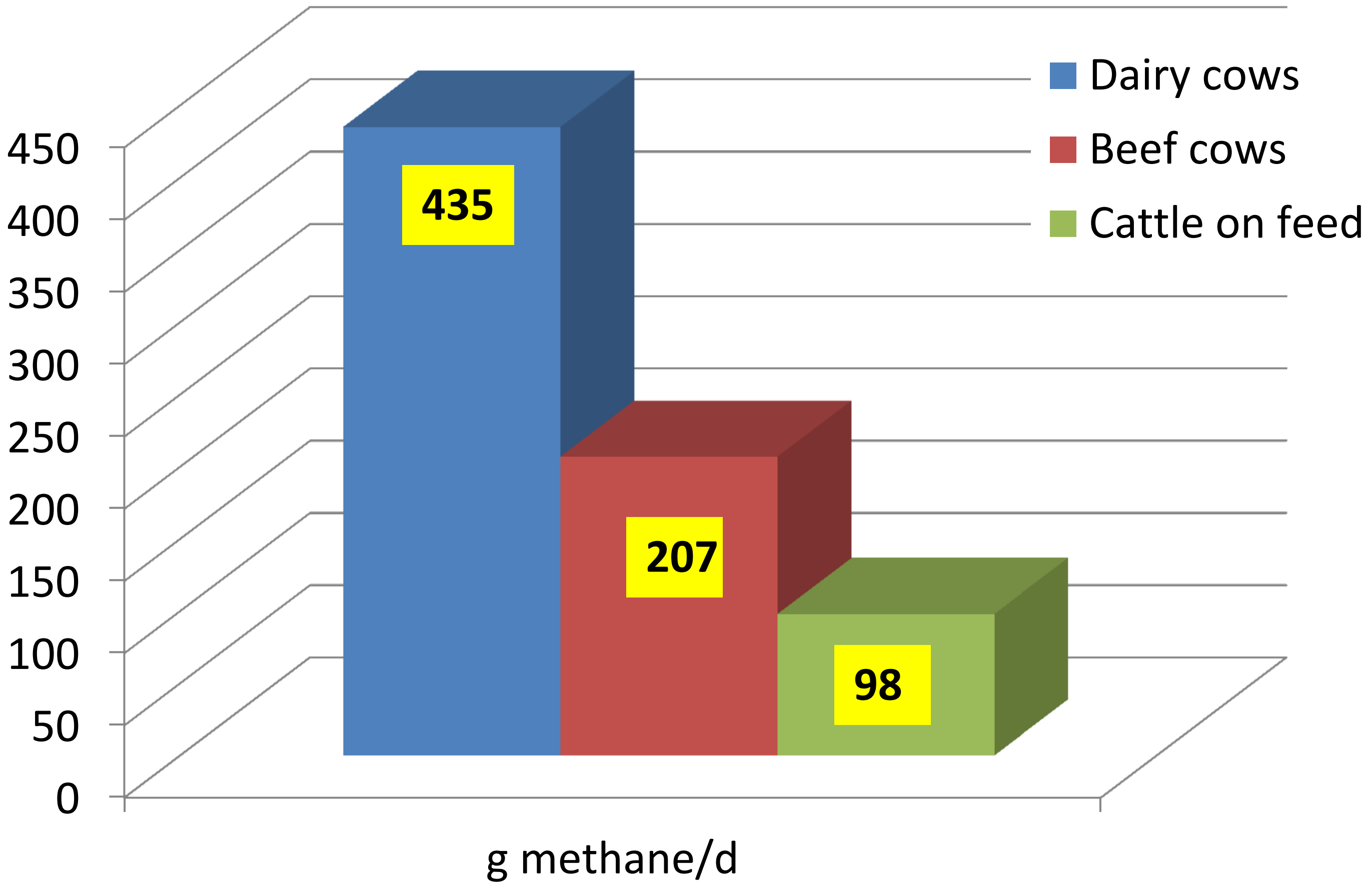
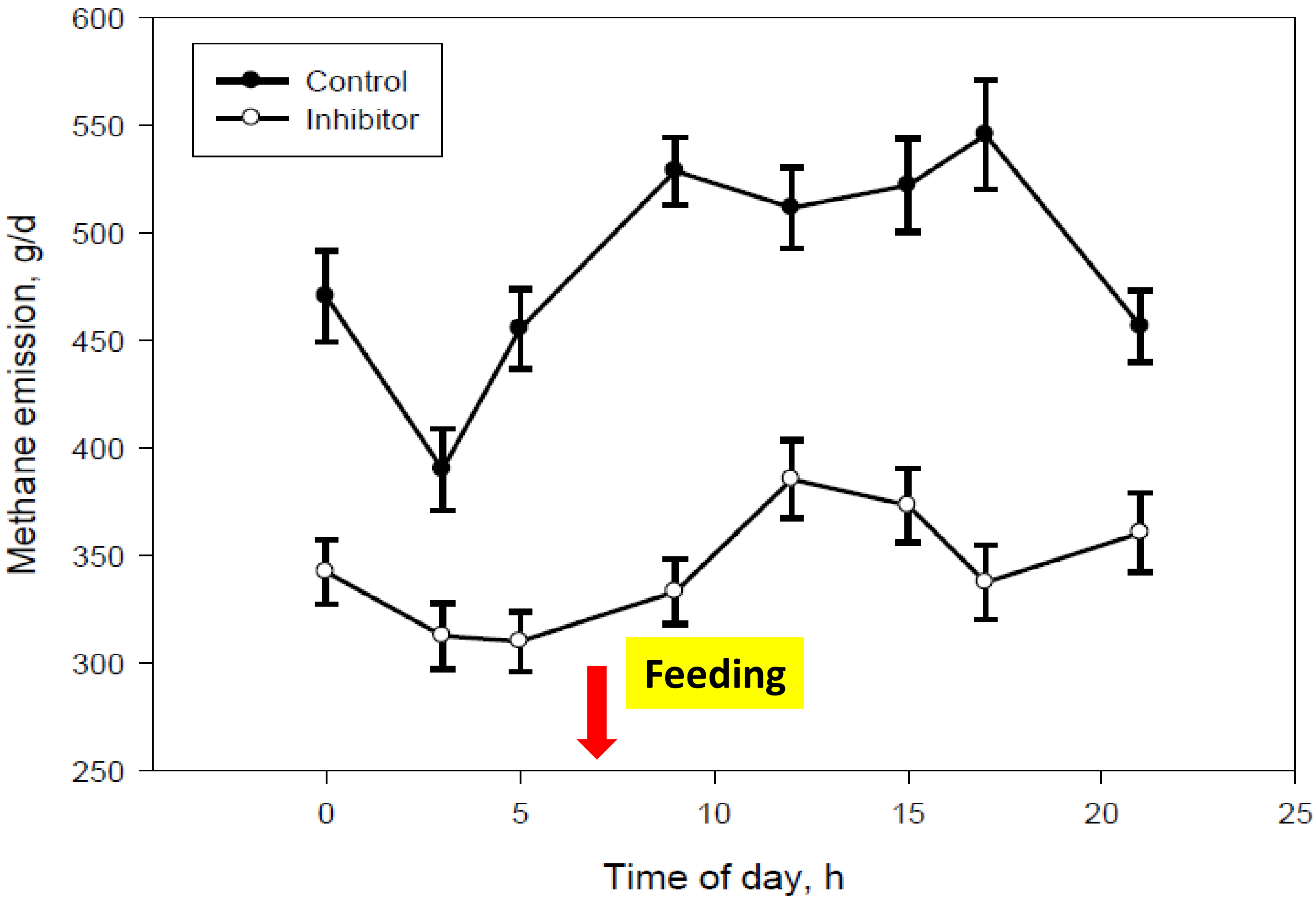
Enteric methane emission rates by cattle categories



Hristov, 2015

Hristov et al. (2015)

Diurnal pattern of methane emissions in dairy cows



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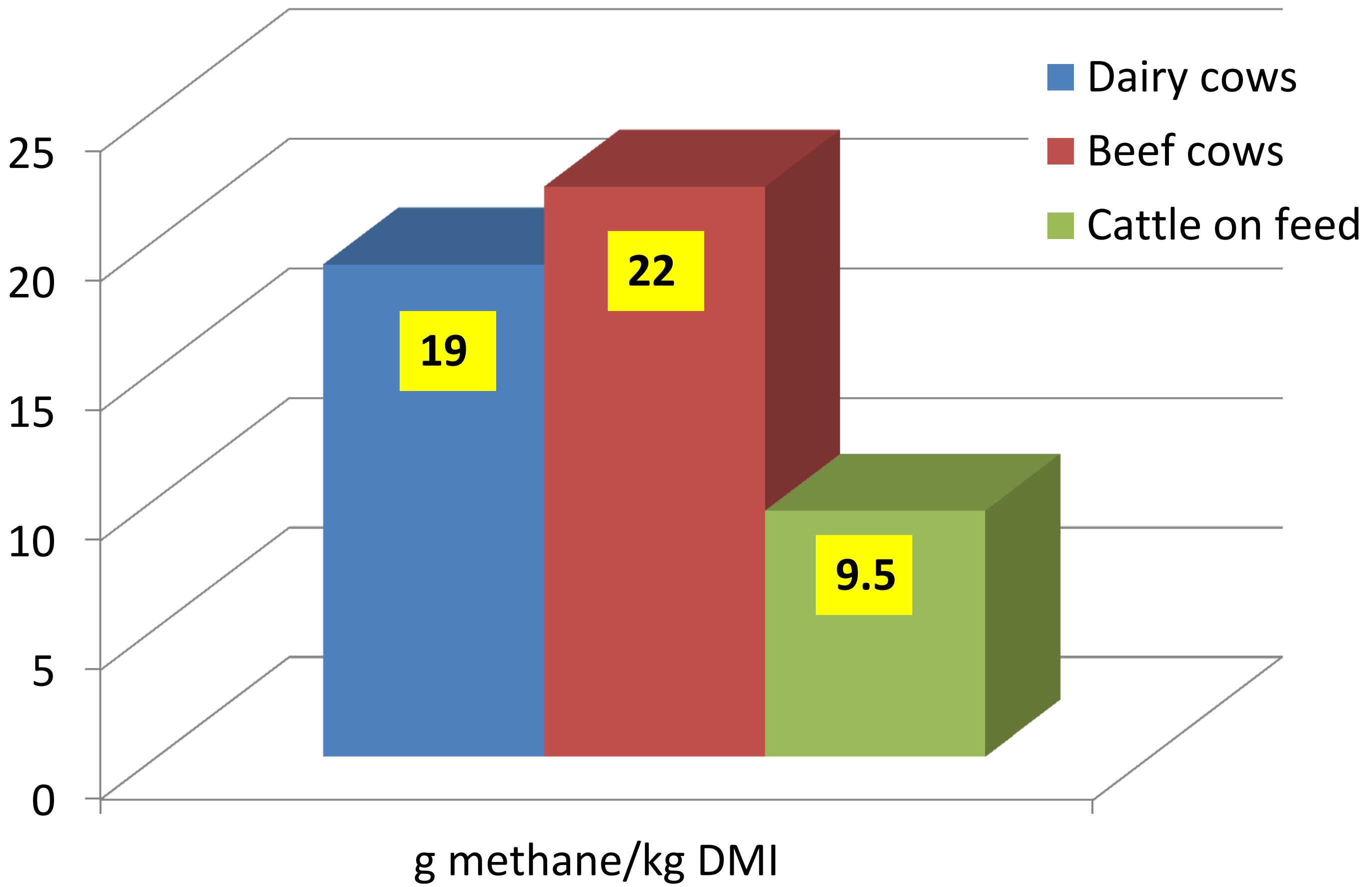
Hristov, 2015

Enteric methane **yield** by cattle category



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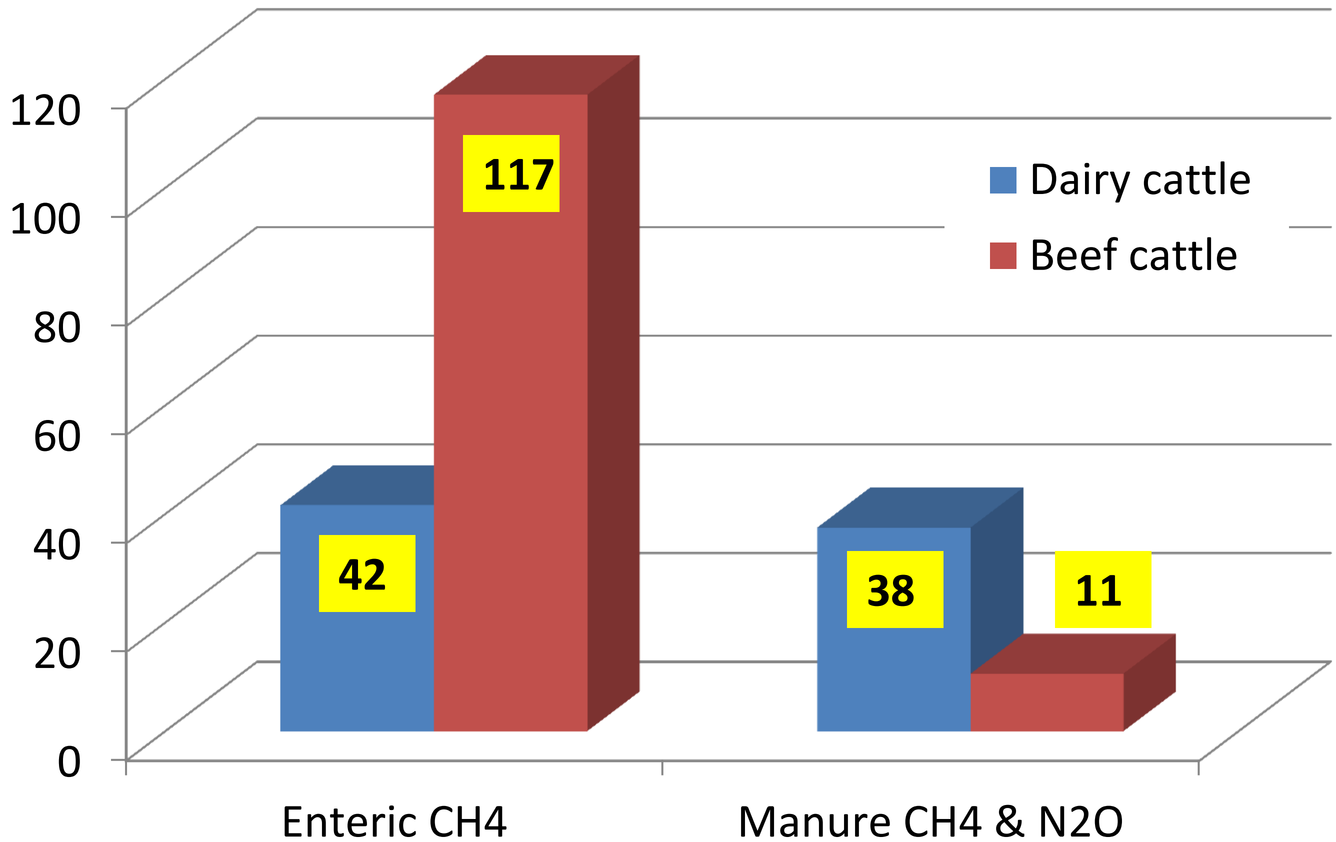
USEPA, 2015

Total GHG emissions from dairy and beef cattle in the US (MMT CO_2 eq)



Chamber Techniques


8:500

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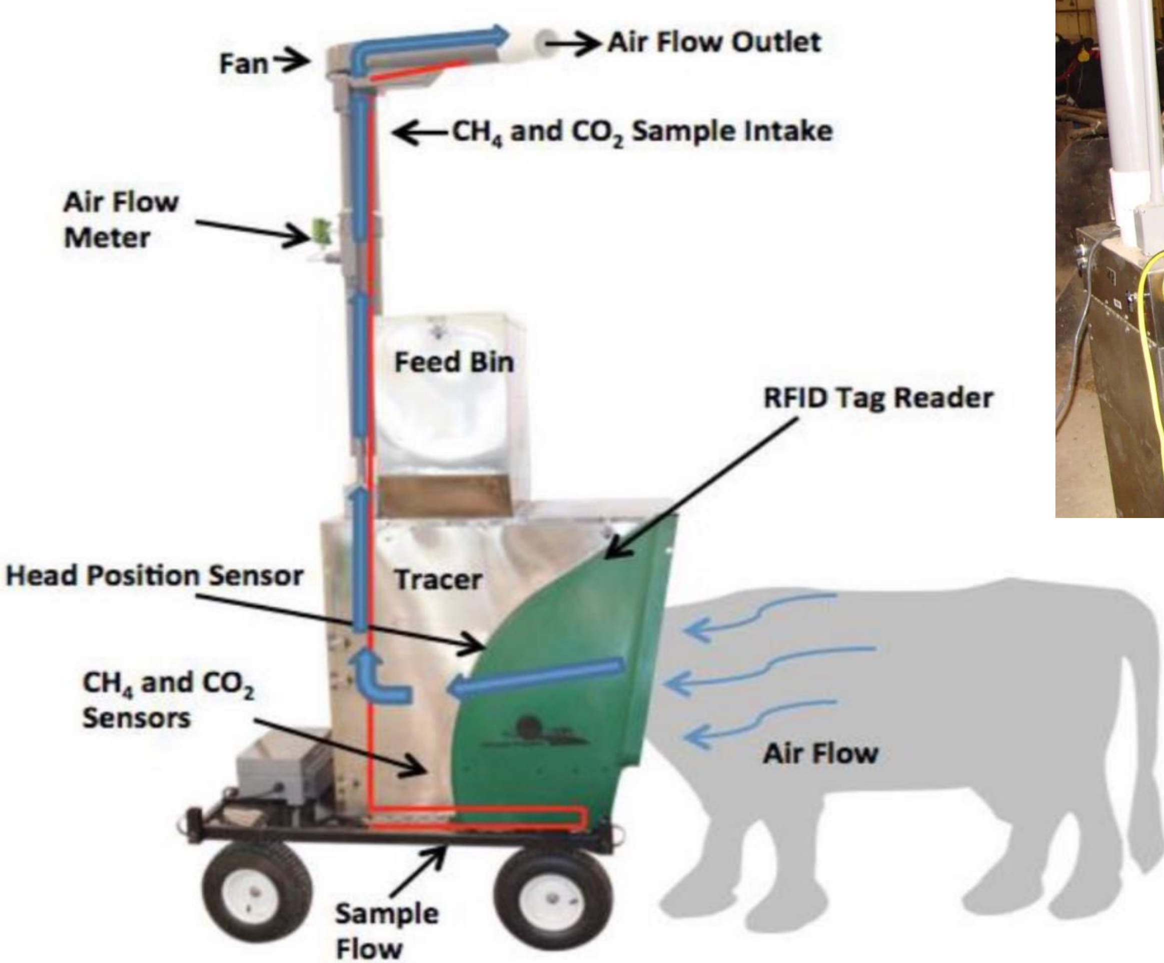
Armsby’s calorimeter

The GreenFeed system

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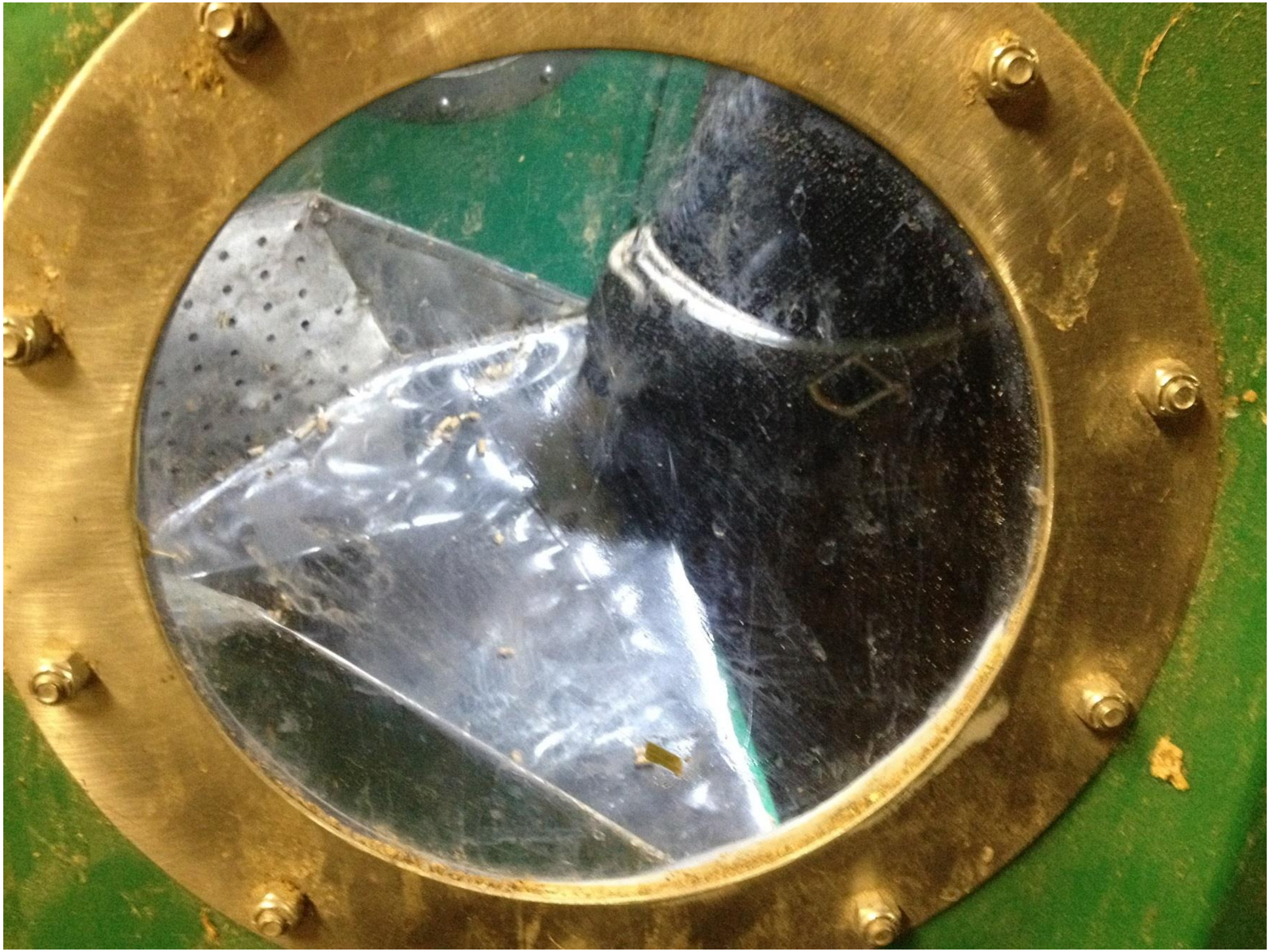

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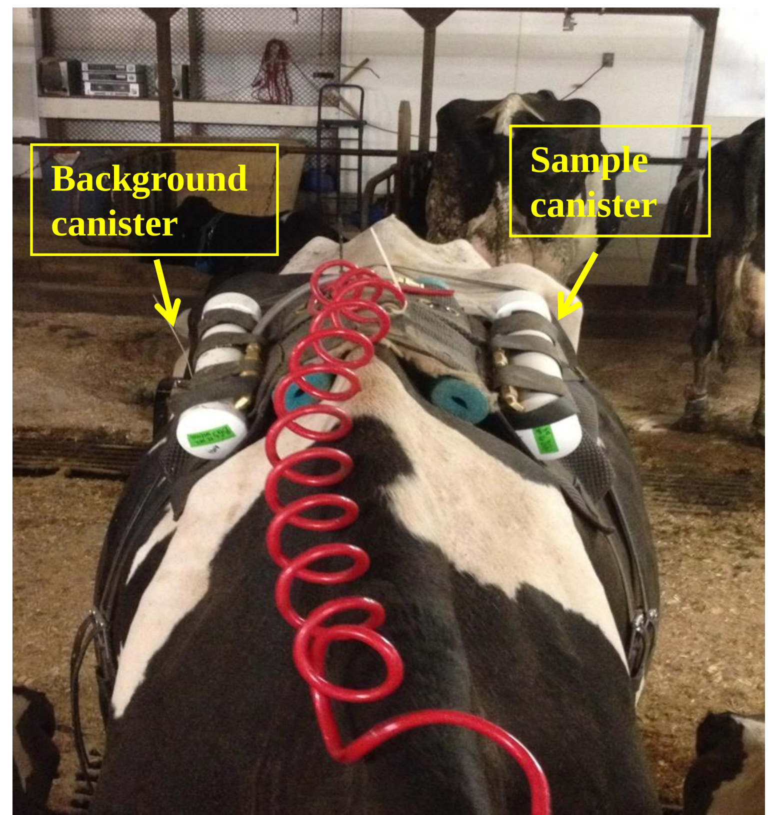
The SF_6 technique



Manure emissions measurement techniques: flux chambers

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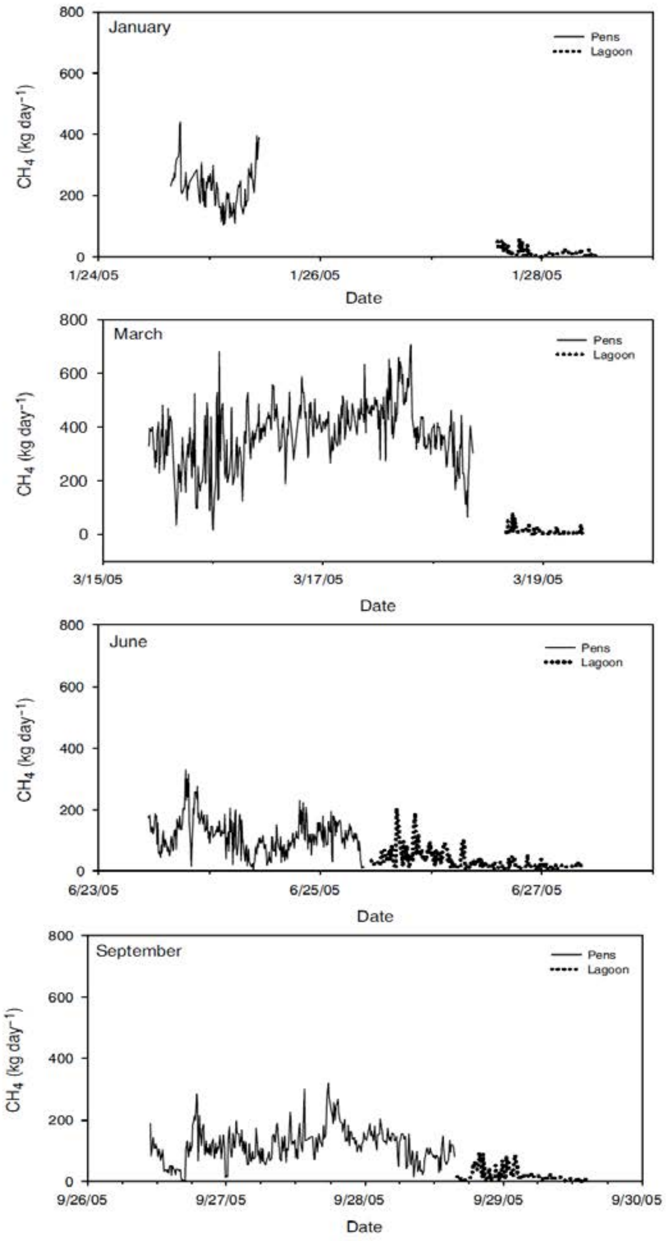
Bjorneberg et al., 2009



Open-path FTIR spectrometry

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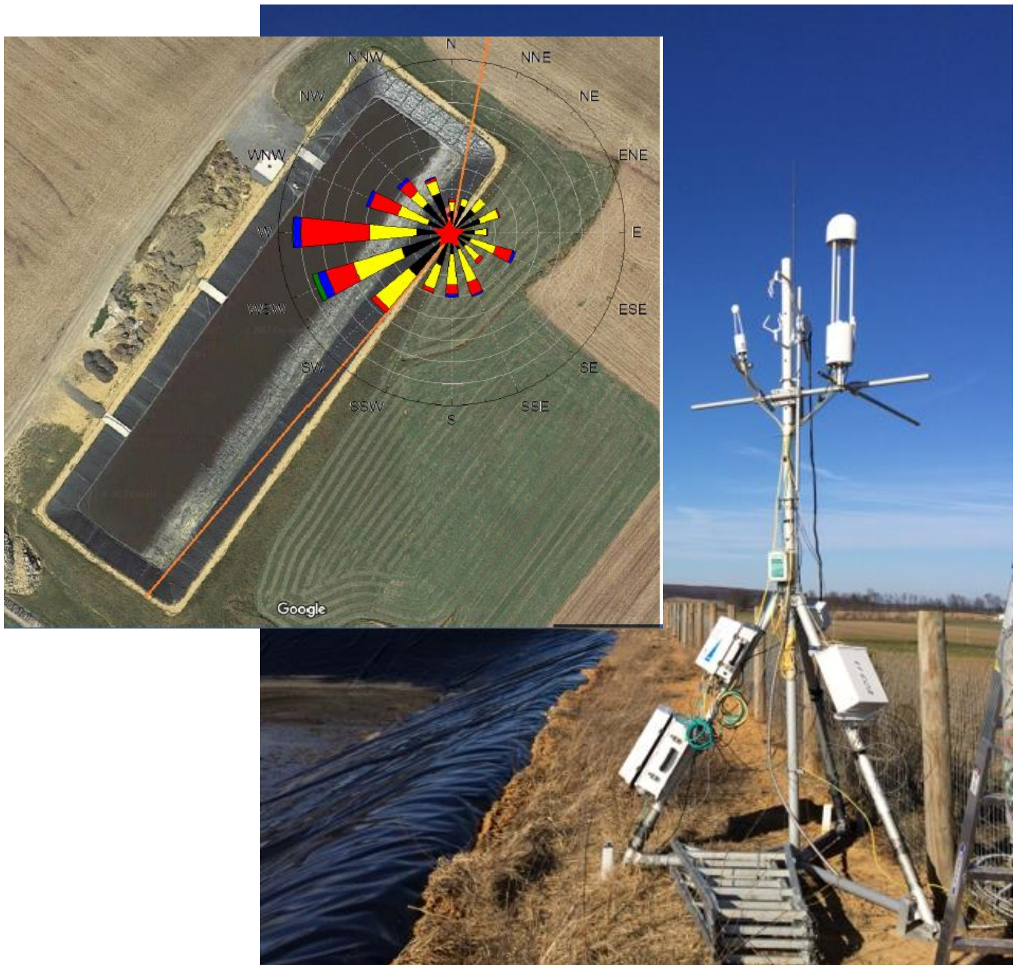
Manure emissions measurement techniques: eddy covariance



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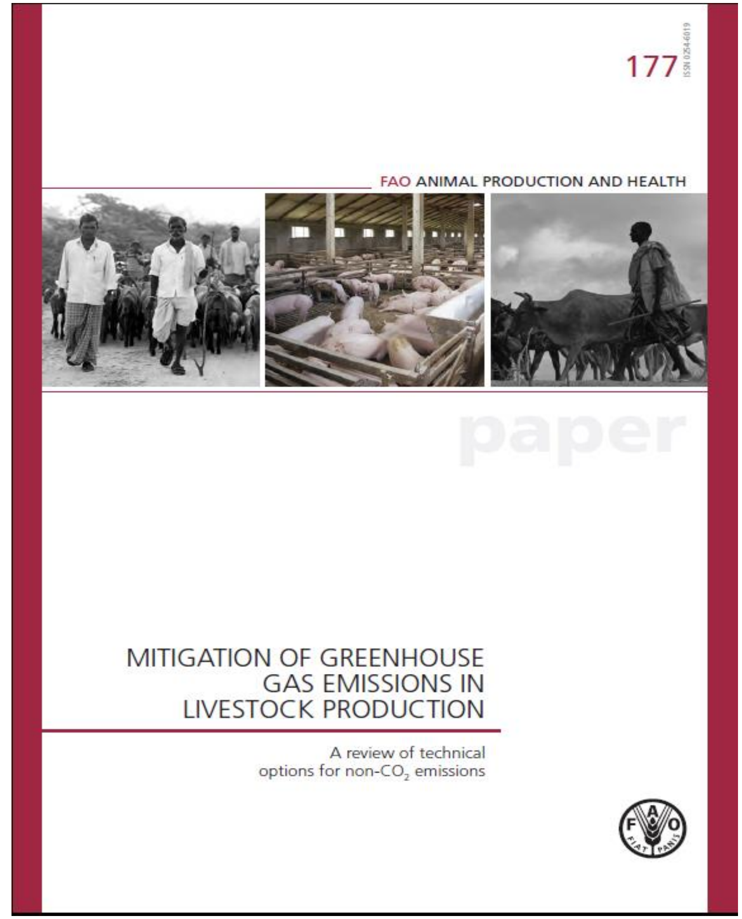
GHG Mitigation Options for the Livestock Industries

FAO, 2013



SPECIAL TOPICS — Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane mitigation options

A. N. Hristov, J. Oh, J. L. Firkins, J. Dijkstra, E. Kebreab, G. Waghorn, H. P. S. Makkar, A. T. Adesogan, W. Yang, C. Lee, P. J. Gerber, B. Henderson and J. M. Tricarico

J ANIM SCI 2013, 91:5045-5069.
doi: 10.2527/jas.2013-6583 originally published online September 17, 2013

SPECIAL TOPICS — Mitigation of methane and nitrous oxide emissions from animal operations: II. A review of manure management mitigation options

F. Montes, R. Meinen, C. Dell, A. Rotz, A. N. Hristov, J. Oh, G. Waghorn, P. J. Gerber, B. Henderson, H. P. S. Makkar and J. Dijkstra

J ANIM SCI 2013, 91:5070-5094.
doi: 10.2527/jas.2013-6584 originally published online September 17, 2013

SPECIAL TOPICS—Mitigation of methane and nitrous oxide emissions from animal operations: III. A review of animal management mitigation options[1]

A. N. Hristov,*[2] T. Ott,* J. Tricarico,† A. Rotz,‡
G. Waghorn,§ A. Adesogan,# J. Dijkstra,‖ F. Montes,¶ J. Oh,* E. Kebreab,**

Animal (2013), 7:s2, pp 220–234 © Food and Agriculture Organization of the United Nations 2013
doi:10.1017/S1751731113000876

animal

Technical options for the mitigation of direct methane and nitrous oxide emissions from livestock: a review

P. J. Gerber[1†], A. N. Hristov[2], B. Henderson[1], H. Makkar[1], J. Oh[2], C. Lee[2], R. Meinen[2], F. Montes[3], T. Ott[2], J. Firkins[4], A. Rotz[5], C. Dell[5], A. T. Adesogan[6], W. Z. Yang[7], J. M. Tricarico[8], E. Kebreab[9], G. Waghorn[10], J. Dijkstra[11] and S. Oosting[11]

nature climate change

REVIEW ARTICLE

PUBLISHED ONLINE: 21 MARCH 2016 | DOI: 10.1038/NCLIMATE2925

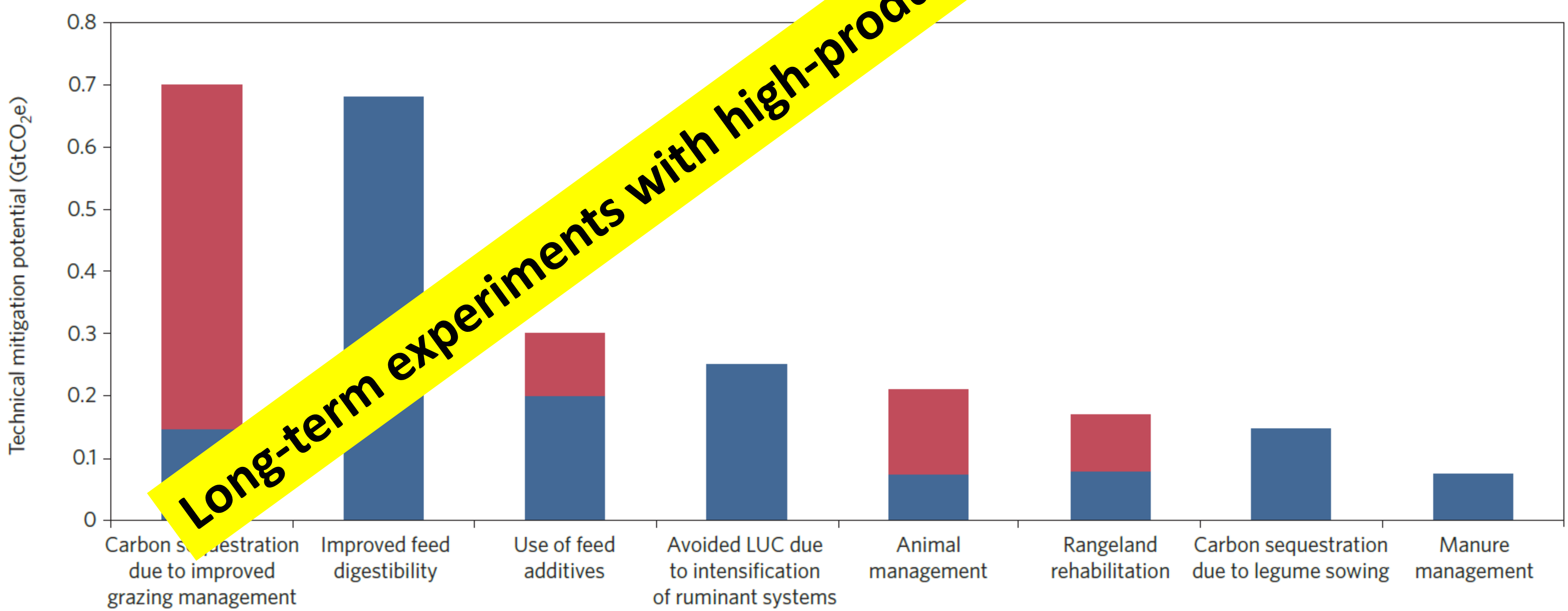
Greenhouse gas mitigation potentials in th… livestock sector

Mario Herrero[1*], Benjamin Henderson[1], Petr Havlík[2], Philip K. Thornton[1,3] … T. Conant[4], Pete Smith[5], Stefan Wirsenius[1,6], Alexander N. Hristov[7], Pierre Gerbe… …aret Gill[5], Klaus Butterbach-Bahl[10,11], Hugo Valin[2], Tara Garnett[12] and Elke St…

NATURE CLIMATE CHANGE DOI: 10.1038/NCLIMATE2925

REVIEW ARTICLE

Long-term experiments with high-producing animals are lacking



Mitigation practices

- Improving forage quality ✓
- Feeding concentrates ✓
- Lipids ✓
- Plant-derived bioactive compounds
- Protozoa
- Nitrates ✓
- Ionophores ✓
- Probiotics
- Seaweeds (*Asparagopsis taxiformis*)
- Methane inhibitors ✓
- Manipulation of the rumen microbiome
- Precision feeding ✓
- Animal genetics, selecting for low-methane emission ✓
- Improving animal health ✓
- **IMPROVING ANIMAL FEED EFFICIENCY AND PRODUCTIVITY** ✓

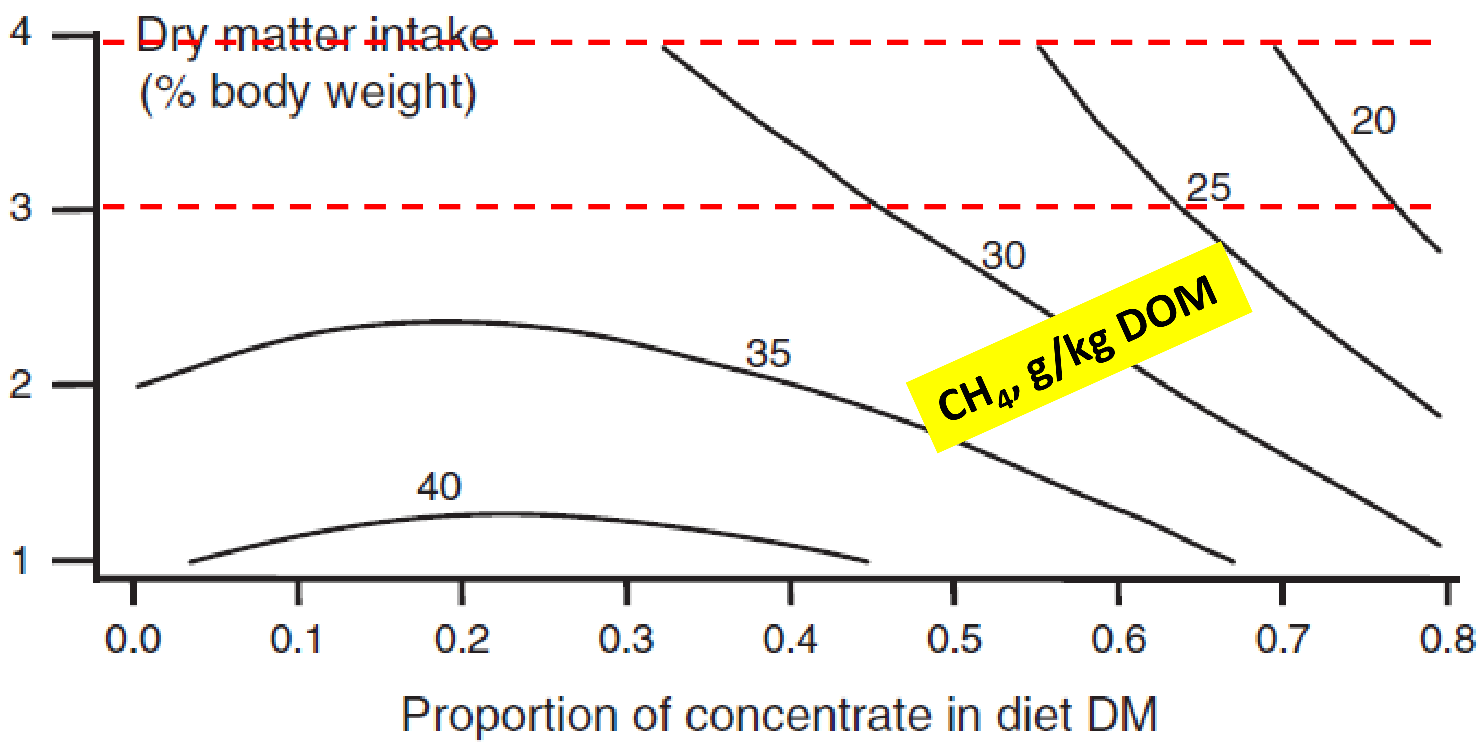
Hristov et al., 2013

Forage quality

- Increased forage digestibility is expected to increase animal production and decrease eneteric CH_4 production per unit of product (Ei)
- It appears, C4 grasses produce more CH_4 than C3 grasses and introduction of legumes in warm climate may offer a potential mitigation opportunity, although low persistence and a need for long establishment periods are important agronomic constraints
- Enteric CH_4 emission may be reduced when corn silage replaces grass silage
- Legume silages may also have an advantage over grass silage due to their lower fiber content and the additional benefit of replacing inorganic N fertilizer
- With all silages effective preservation will improve silage quality and reduce GHG emission intensity
- Forage with higher sugar content (high-sugar grasses or harvested in the afternoon) may reduce urinary N losses and consequently, N_2O emission from manure applied to soil, but more research is needed.
- The best mitigation option in this category is to increase forage digestibility in order to enhance digestible energy intake and animal productivity, thus reducing overall GHG emissions per unit of animal product

Sauvant and Nozière, 2016

Feed intake and concentrate inclusion effects on methane emission



Hristov et al., 2013

Dietary lipids

- Lipids have a proven enteric CH_4-mitigating effect:
  - However, may depress DMI
  - Which may actually increase feed efficiency (??)
- May decrease milk production and milk fat test
  - Potentially enhanced by combination with other rumen modifiers – monensin
  - A meta-analysis of 31 studies (with 105 treatments) in which lipid supplementation was the main effect:
  - DMI was reduced in 49% of the studies (by 5.6%)
  - 29 studies with dairy cows – milk production was reduced in 15% of the studies (by 9%)
  - **CH_4 production reduced in 81% of the studies (by 20%)**

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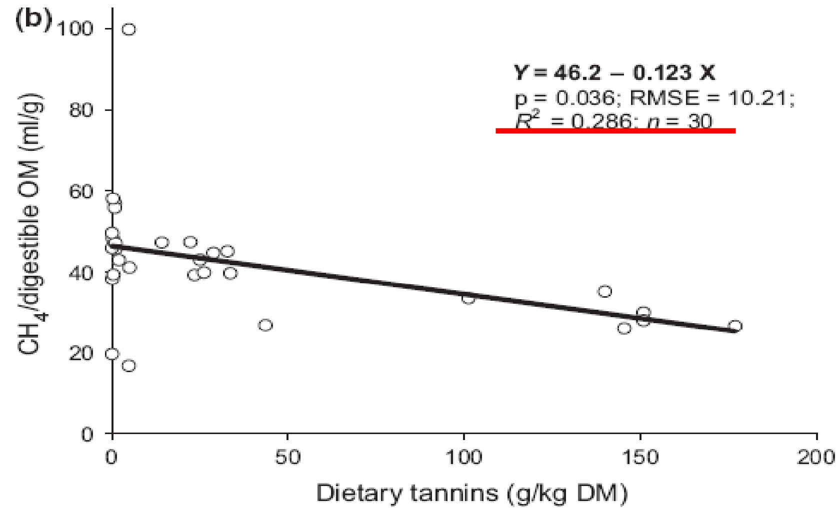
Jayanegara et al., 2011

PBAC – tannins & saponins



- Tannins – meta-analysis of in vivo experiments (up to 40 exp.)
  - **Negative slopes for OMD, CPD, NDFD, total VFA, propionate, butyrate, ammonia, bacteria, protozoa**
  - Reduced enteric CH_4 emission
- Other issues: LONG-TERM effects??
  - Very variable results - type, concentration and astringency of the tannins
  - **Yields of temperate and tropical tanniferous legumes is usually less than that of corresponding grasses**
  - Anti-nutritional when dietary CP concentrations are limiting production
- Positive effects reported for **tea saponins….need confirmation…..**

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Essential oils

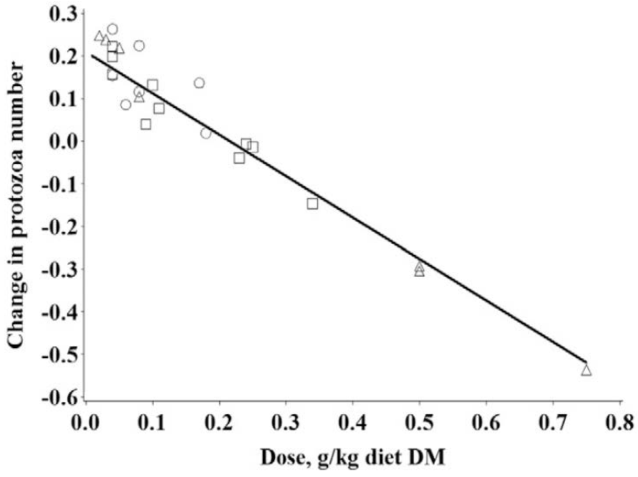

Figure 1. Effect of supplementation dose of essential oils and their bioactive compounds (EOBC; g/kg diet DM) on changes in protozoa numbers ($\times 10^5$/mL) relative to control (no EOBC supplementation) in ruminants (○, beef cattle; □, dairy cattle; Δ, small ruminants). Equation is: Protozoa counts = 0.210 (±0.0418; $P < 0.001$) – EOBC dose × 0.973 (±0.1613; $P < 0.001$), n = 24, root mean square error = 0.1513.

Khiaosa-ard and Q. Zebeli, 2014

- Proven antimicrobial effects
  – in vitro, in vivo in monogastrics
- Large doses required in vivo
  – Higher doses are likely to affect negatively DMI and animal production
- So far, no consistent positive effects in vivo
- Adaptability, long-term effect??

Hristov et al., 2013

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Mitigation through rumen protozoa

Guyader et al., 2014

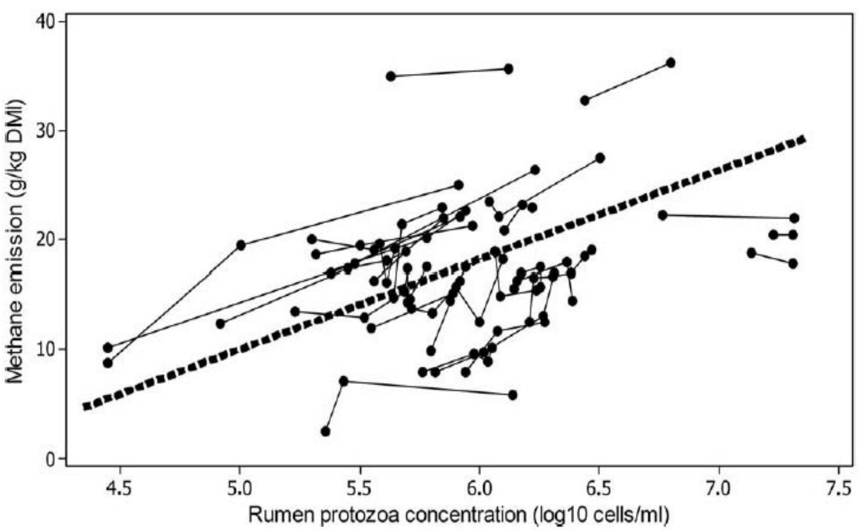
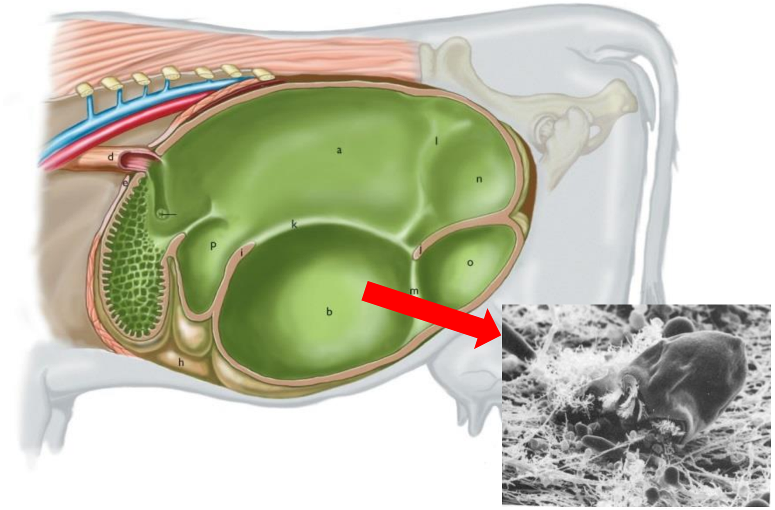
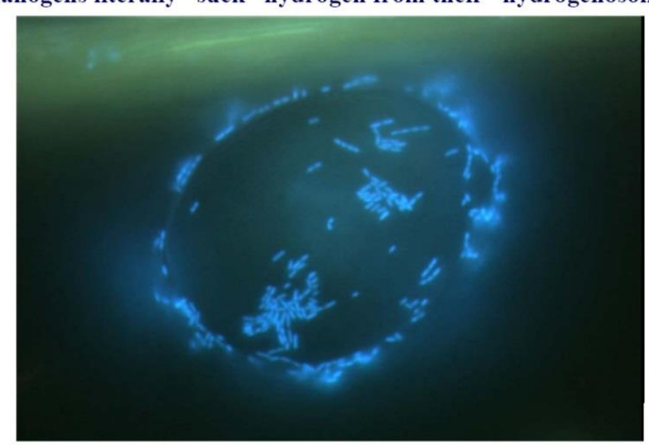


Figure 1 Relationship between methane emission and rumen protozoa concentration (raw data). The black dashed line represents the average within-experiment relationship (equation (2)).



Rumen protozoa are often colonized by methanogens, and the methanogens literally "suck" hydrogen from their "hydrogenosomes."



© Rumen Microbiology and Its Role In Ruminant Nutrition. 2002.

(Courtesy S.H. Zinder)

4

Hristov et al., 2013

Nitrates – an example of a promising rumen modifier with uncertain side effects..

- Alternative electron sink…..does reduce enteric CH_4 emission
- Persistency of the effect (??)
- Toxicity of intermediate products – nitrite
  - The rumen ecosystem can adapt – however, the adaptation can be lost quickly
- Do we need more N in the diet? May be applicable to diets that need NPN
  - If used in licking blocks – access has to be limited
- Nitrate in the basal diet? NH_3 losses and manure NH_3/N_2O; N_2O production in the rumen

About 16% reduction in a meta-analysis by Lee et al. (2015)

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Petersen et al., 2015

Nitrate may increase N_2O emission and urinary nitrate excretion

The mitigation effect of nitrates decreased by 12 to 18% due to N_2O emissions

Table 5. Emissions of CH_4 and N_2O were calculated for the 24-h period … ds 4 and 5, N_2O emissions after upscaling based on dry matter (DM) intake (see text). The percentage greenhouse gas … one and to $CH_4 + N_2O$ were calculated. Cows on the individual treatments are identified in Table 2.

Diet	CH_4 emission	GHG mitiga…	…	GHG mitigation, $CH_4 + N_2O$
g NO_3^- kg^{-1} DM	g CO_2 eq kg^{-1} DM	%	…q kg^{-1} DM	%
		Period 4		
0	974.3a (31.0)		0.4d (0.2)	
5	697.8b (15.7)	−28.4 (0.7)	3.7cd (0.1)	−28.0 (0.7)
14	733.6bc (39.4)	−24.5 (6.4)	14.1b (2.8)	−23.1 (6.2)
21	519.7d (34.3)	−46.5 (5.2)	67.2a (4.5)	−39.6 (5.0)
		Period 5		
0	816.5a (60.0)		0.5c (0.2)	
5	689.8a (46.7)	−15.5 (0.5)	4.0c (1.3)	−15.0 (0.7)
14	791.8a (40.9)	−2.1 (12.2)	13.5b (2.4)	−0.5 (12.6)
21	658.5a (14.4)	−18.8 (7.7)	15.3a (0.9)	−16.9 (8.0)

Hristov et al., 2013

Other mitigation options

- **Ionophores**:
  - Ionophores, through their effect on feed efficiency, would likely have a moderate CH_4 mitigating effect in ruminants fed high-grain or grain-forage diets. In ruminants fed pasture this effect is less consistent.
- **Probiotics**:
  - There is not sufficient evidence for direct enteric CH_4 mitigating effect of yeast and other microbials with probiotic mode of action. Yeast products, however, appear to stabilize pH and promote rumen function, especially in dairy cattle, resulting in small but relatively consistent responses in animal production and feed efficiency, which might moderately decrease CH_4 emission per unit of product.
- **Manipulation of rumen archaea and bacteria**:
  - None of the existing technologies are ready for practical application, but vaccines could be applied to all ruminants, including those with little human contact, such as sheep and beef animals on pasture. **To be effective, the vaccines have to cover the entire methanogen community**. The extent of reductions in methanogenesis may only be 5-10 %, and **persistence of the effect is unknown.**

Seaweeds

- In 2015 a Canadian study reported up to 18% methane reduction by stormtoss seaweeds in vitro
- An Australian study found 99% methane reduction with 2% (feed DM) *Asparagopsis taxiformis* in vitro

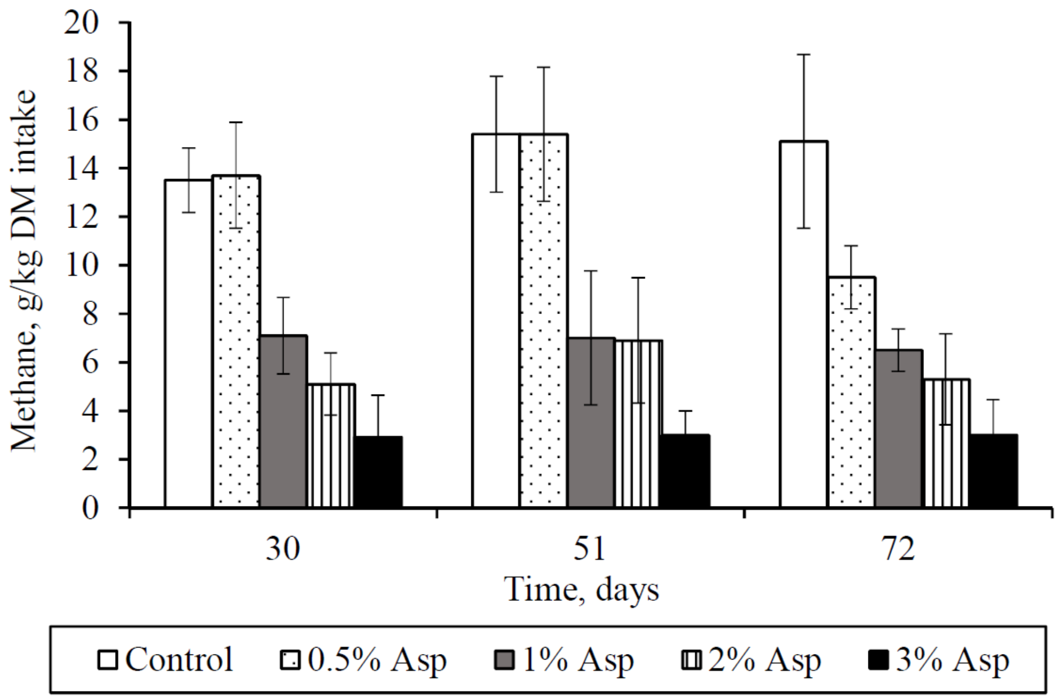
Asparagopsis taxiformis

Li et al., 2016

Asparagopsis taxiformis

- The bioactives from *Asparagopsis* have been identified as bromoform and dibromochloromethane
- Mechanism similar to that of bromochloromethane (BCM)
  - reacts with reduced vitamin B_{12} inhibiting cobamide-dependent methyl groups leading to methanogensis, thus inhibiting methane production

- A study with sheep (restricted feeding @ 1.5% of BW)
- Sharp reduction in methane emission
- Effects on DMI, fiber digestibility, and animal productivity are unclear at this point



Hristov et al., 2013

Mitigation through animal management

- Increasing animal productivity can be a very successful strategy for mitigating GHG emissions from the livestock sector in both developed and developing countries, with a greater mitigating potential in developing countries.
- Achieving the genetic potential of the animal for production through proper nutrition, and use of local breeds or crossbreeds are recommended approaches for improving animal productivity and reducing GHG emissions per unit of product.
- The potential of using RFI as a selection tool for low CH_4-emitters is an interesting mitigation option, but currently there is little evidence that low-RFI animals have a lower CH_4 yield per unit of feed intake or product. Therefore, the immediate gain in GHG reductions through RFI is considered uncertain.
- Selection for feed efficiency, however, will yield animals with lower GHG emission intensity. Breed difference in feed efficiency should also be considered as a mitigation option.

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Intensification of the US dairy industry

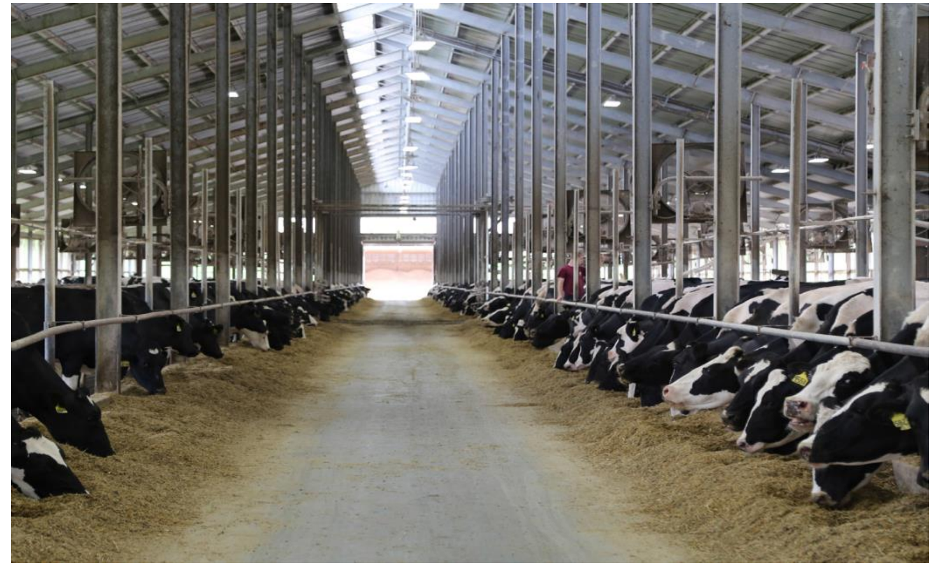


Figure 1: Milk production per cow in the US

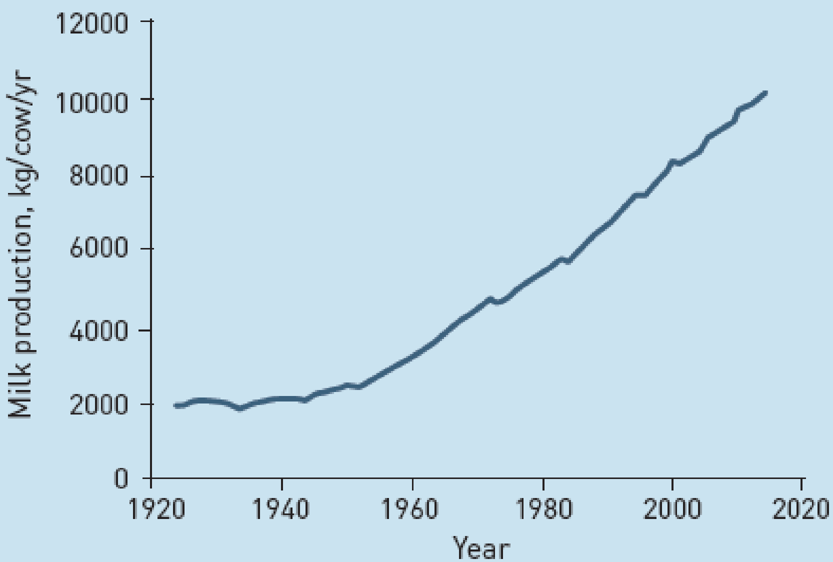
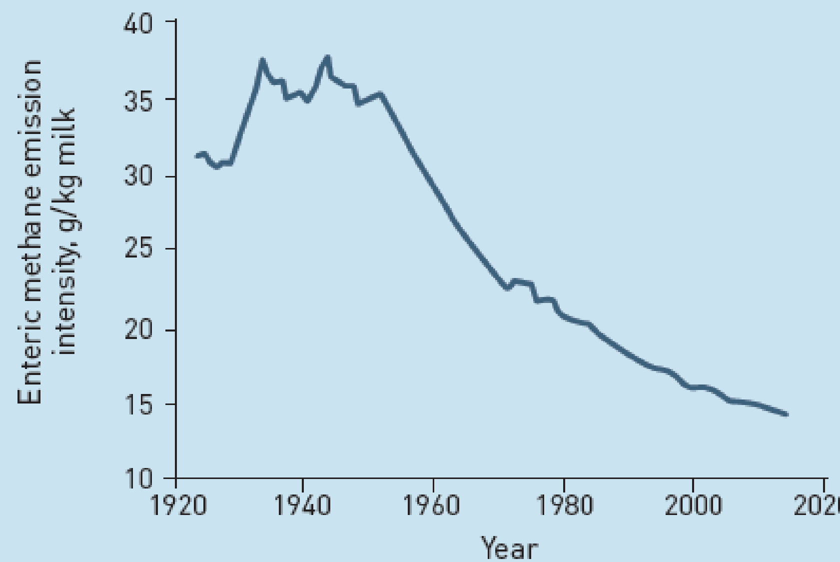


Figure 2: Intensity of enteric methane emissions from dairy cows in the US



Hristov, 2015

Precision feeding

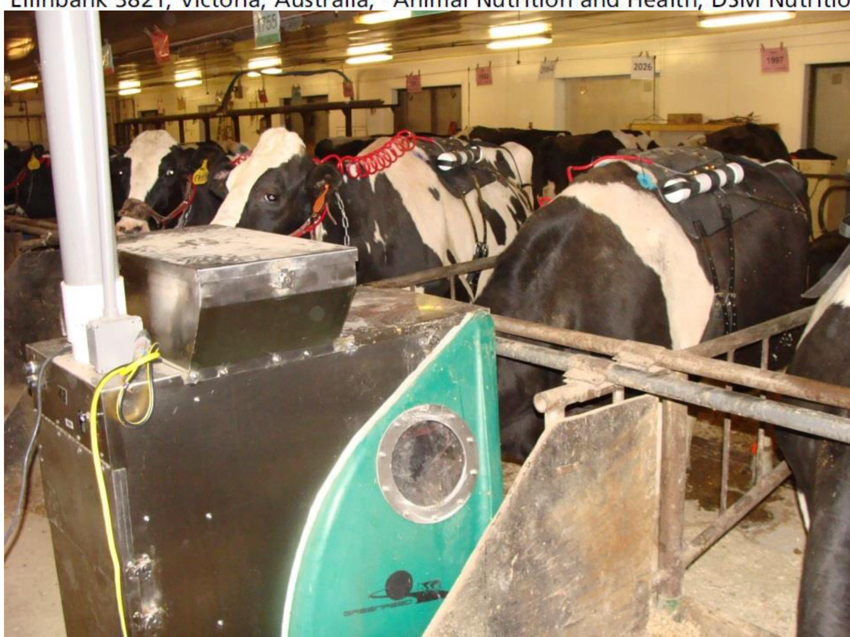
- The original term "**precision agriculture**" was coined in relation to plant nutrition, namely "a series of technologies that allow the application of water, nutrients and pesticides only to the places and at the times they are required, thereby optimizing the use of inputs" (Day et al., 2008; Godfray et al., 2011)
- **In animal nutrition**, precision feeding may have different dimensions, but from a practical standpoint and farm sustainability perspective it refers to **matching animal requirements with dietary nutrient supply**

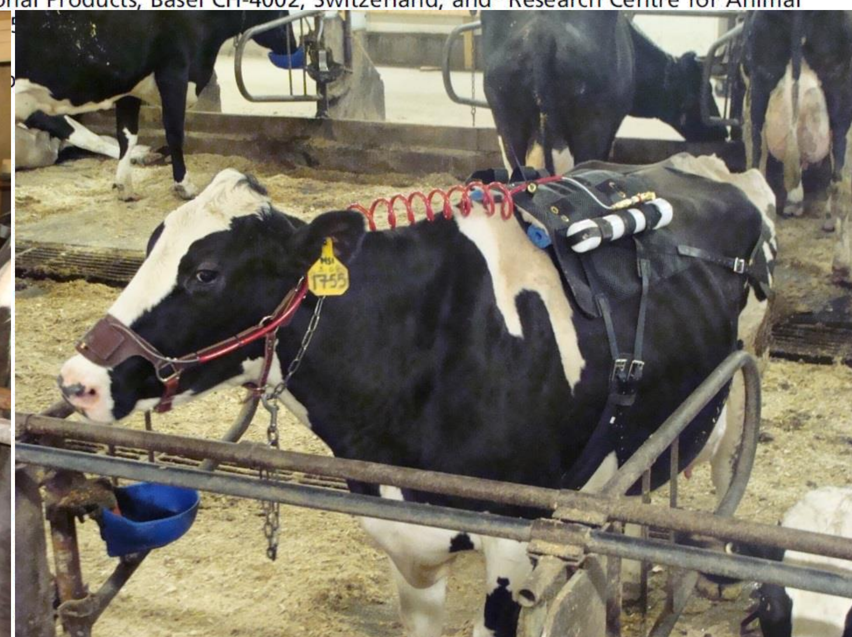
AGRICULTURAL SCIENCES

An inhibitor persistently decreased enteric methane emission from dairy cows with no negative effect on milk production

Alexander N. Hristov[a,1], Joonpyo Oh[a], Fabio Giallongo[a], Tyler W. Frederick[a], Michael T. Harper[a], Holley L. Weeks[a], Antonio F. Branco[b], Peter J. Moate[c], Matthew H. Deighton[c], S. Richard O. Williams[c], Maik Kindermann[d], and Stephane Duval[e]

[a]Department of Animal Science, The Pennsylvania State University, University Park, PA 16802; [b]Departamento de Zootecnia, Universidade Estadual de Maringá, PR 87020-900, Brazil; [c]Agriculture Research Division, Department of Economic Development Jobs Transport and Resources, Ellinbank Centre, Ellinbank 3821, Victoria, Australia; [d]Animal Nutrition and Health, DSM Nutritional Products, Basel CH-4002, Switzerland; and [e]Research Centre for Animal





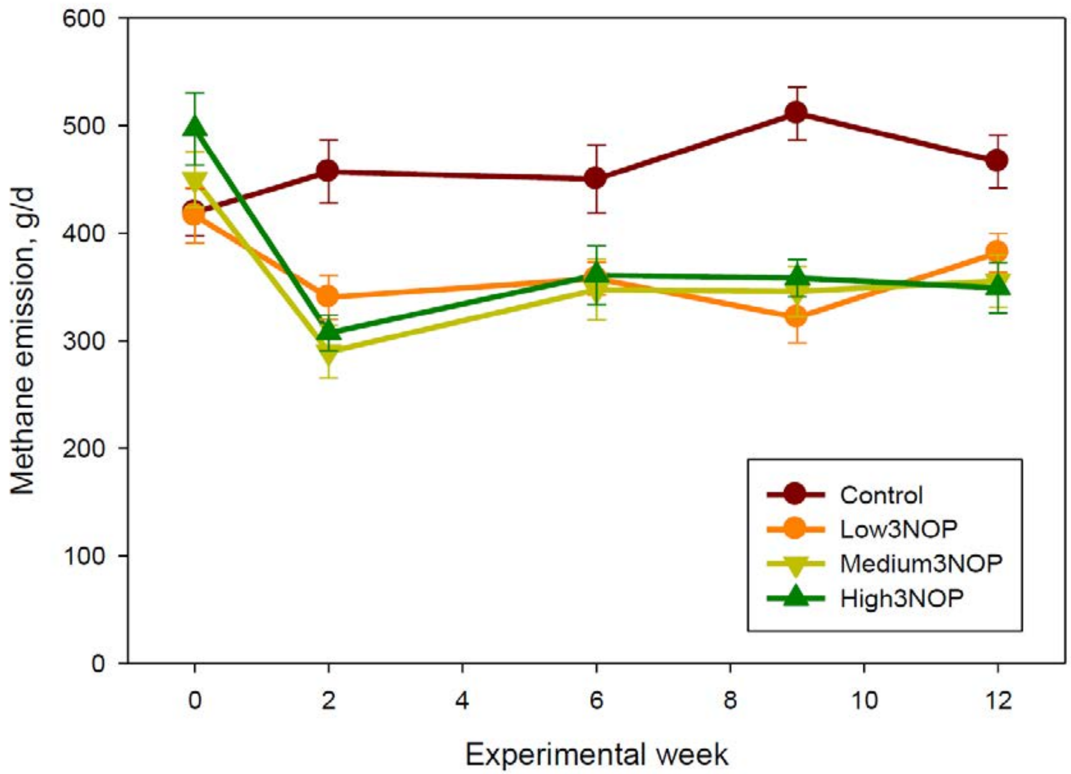
80 mg/kg feed dry matter, decreased methane emissions from high-producing dairy cows by 30% and increased body weight gain without negatively affecting feed intake or milk production and composition. The inhibitory effect persisted over 12 wk of treatment, thus offering an effective methane mitigation practice for the livestock industries.

an effect in sheep (12). The nutrient requirements of high-producing dairy cows are much greater than those of nonlactating or low-producing cows (13) and hence any reduction in feed intake caused by a methane mitigation compound or practice would likely

Hristov et al., 2015

Effect of 3NOP on methane emission

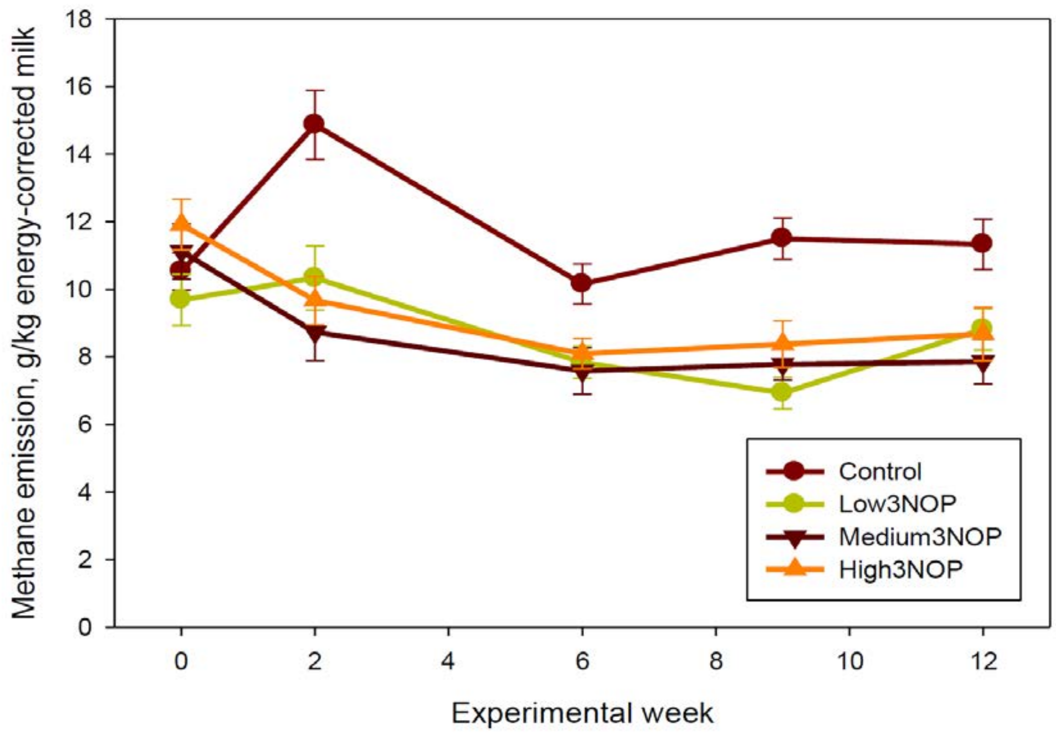
29% lower; Means: 481, 363, 333, and 329 g/cow/d; SEM = 15.9; $P_L < 0.001$



Hristov et al., 2015

Effect on methane emission intensity

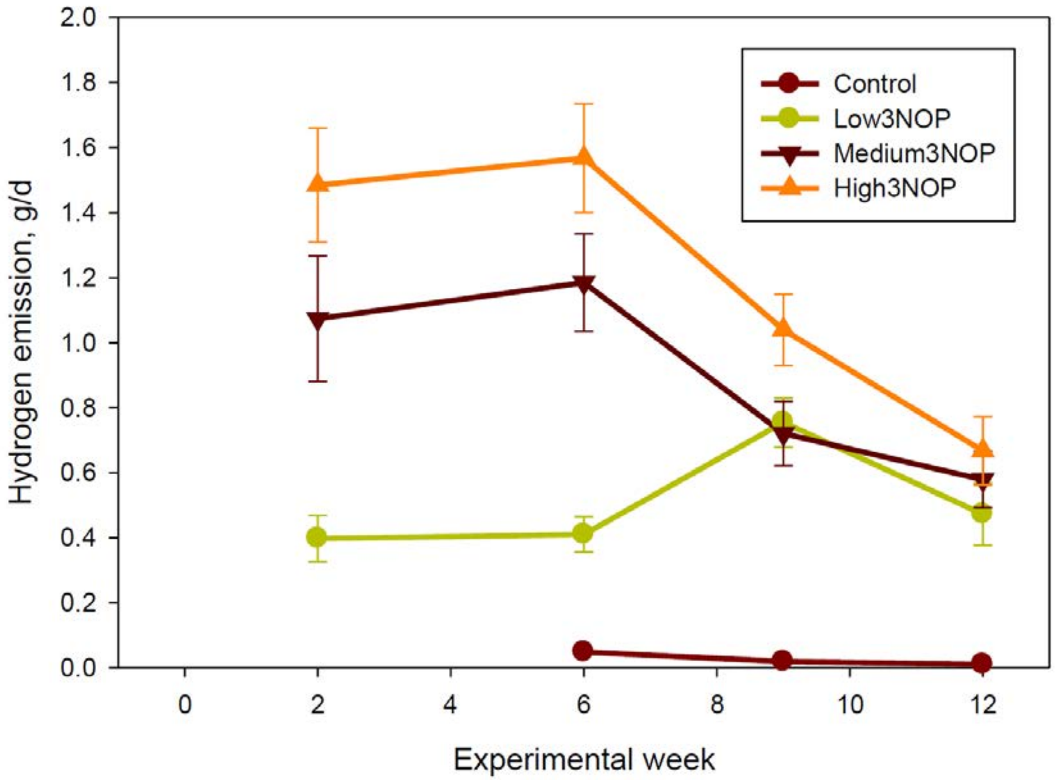
31% lower; Means: 12.0, 8.7, 7.9, and 8.3 g/kg ECM; SEM = 0.48; $P_L < 0.001$



Hristov et al., 2015

Effect on hydrogen emission

Means: 0.02, 0.48, 0.96, and 1.27 g/cow/d; SEM = 0.116; $P_L < 0.001$



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Hristov et al., 2015

Production data

Table 1. Effect of 3-nitrooxypropanol on feed dry matter intake, lactation performance, and body weight change of Holstein dairy cows

	Treatment[1]					P-value[2,3]		
Item	Control	Low3NOP	Medium3NOP	High3NOP	SEM[4]	C vs. Trt.	L	Q
Dry matter intake, kg/d	28.0	28.0	27.7	27.5	0.45	0.58	0.38	0.69
Milk yield, kg/d	46.1	46.4	45.9	43.6	1.21	0.59	0.21	0.19
ECM yield,[5] kg/d	44.9	45.2	46.2	43.9	1.59	0.91	0.84	0.44
Feed efficiency,[6] kg/kg	1.64	1.65	1.67	1.62	0.033	0.94	0.80	0.41
Milk fat, %	4.08	3.98	4.02	4.25	0.123	0.98	0.43	0.15
Milk fat yield, kg/d	1.85	1.81	1.87	1.85	0.086	0.98	0.90	0.85
Milk protein, %	3.06	3.14	3.12	3.13	0.033	0.07	0.14	0.31
Milk protein yield, kg/d	1.37	1.46	1.45	1.33	0.042	0.42	0.75	0.02
Milk lactose, %	4.78	4.79	4.81	4.77	0.026	0.69	0.95	0.32
Milk lactose yield, kg/d	2.16	2.22	2.25	2.04	0.069	0.90	0.43	0.05
Body weight, kg	664	672	672	664	5.0	0.38	0.83	0.13
Body weight change,[7] g/d	210	353	451	330	71.2	0.05	0.09	0.16

[1]Control = 0 mg/kg of 3NOP, Low3NOP = 40 mg/kg of 3NOP, Medium3NOP = 60 mg/kg 3NOP, and High3NOP = 80 mg/kg 3NOP (dietary dry matter basis). Data, except body weight change, are presented as covariate-adjusted means.
[2]Contrasts: C vs. Trt., Control vs. all 3NOP treatments; L, linear effect of treatment; Q, quadratic effect of treatment.
[3]Treatment × experimental week interactions for dry matter intake, milk yield, feed efficiency, and body weight: $P = 0.05$, 0.97, < 0.001, and 0.93, respectively; milk composition and ECM yield data $P \geq 0.17$.

Lopes et al., 2016

Rumen fermentation data

Molar proportions (*P* < 0.05):
Acetate: 65.7 vs. 61.7%
Propionate: 19.3 vs. 20.3%
Butyrate: 11.2 vs. 13.1%

Item	Control[1]	3NOP	SEM[2]	*P*-value
pH	6.35	6.41	0.082	0.67
Total VFA, m*M*	90.01	85.76	2.958	0.42
Acetate (A)	59.11	52.94	2.195	0.08
Propionate (P)	17.41	17.41	1.304	0.99
Butyrate	10.06	11.29	0.433	0.08
Isobutyrate	0.51	0.49	0.049	0.51
Valerate,	1.91	1.96	0.073	0.67
Isovalerate	1.01	1.76	0.147	0.001
A:P ratio	3.51	3.12	0.277	0.001
Ammonia, m*M*	2.93	1.94	0.404	0.02

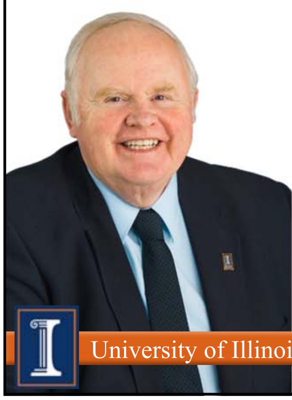
[1]Means are LS means; [2]Standard Error of the Mean.

Take-home message

- Discrepancies in top-down vs. bottom-up methane emission inventories
- There are several established methods for measuring enteric and manure methane emissions
- We have a pretty good idea of enteric emissions from livestock, but we may be underestimating manure emissions
- There are a variety of mitigation techniques available to the livestock industries
- Mitigation techniques targeting enteric CH_4 emissions may be difficult to implement and yield a limited effect
  - Assessment techniques can affect experimental outcomes
  - The ultimate verification for a rumen modifier is a long-term, continuous design experiment
- Improving forage digestibility and feed efficiency and use of effective feed additives are among the most realistic and applicable short-term mitigation practices for intensive dairy production systems
- Manipulating the host and microbial genetics may be promising mitigation options in the future
- Approval **and use** of 3NOP could lead to a substantial reduction of greenhouse gas emissions from the ruminant livestock sector
- Finally, a variety of possible interactions (whole-farm scale) must be considered when evaluating mitigation practices


QUESTIONS?
IACUC #44118
2134
Control
1940
Control
2082
1831
1845
2026
1997
1940
GREENFEED

Feeding Considerations Impacting Lameness and Hoof Health



Penn State Workshop
November 15, 2017

Mike Hutjens, Professor of Animal Sciences Emeritus

University of Illinois at Urbana-Champaign

Today's Workshop

- An overview of feeding relationships to lameness and hoof health

- Results of a new Wisconsin field study on digital dermatitis (DD)

University of Illinois at Urbana-Champaign

Fact 1: Prevalence of Lameness

Selected rates reported research:

Farm average = 21 to 55%

Range for individual farms ~3 to 80%

Fact 2:
Farmer Perception of Lameness

2.5 to 4 times

Lower lameness prevalence

than estimated by researchers

University of Illinois at Urbana-Champaign

Fact 3:

An Important Animal Welfare Issue

Consequences of Lameness

- Animal welfare
- Locomotion and posture
- Foot shape
- Culling rate
- Reduced milk production
- Decreased reproductive performance

Effect of Lameness on Cull Rates

Culling rates for lame and non-lame cows before the start of breeding events at 95 days

5.4% for non-lame cows vs. 30.8% for lame cows (approximately 6 times the control group)

Melendez *et al.*, 2003, Theriogenology 59:927-937

Effects of Lameness on Reproductive Performance

Cows developing lameness within 30 days post-calving were **2.6 times** as likely to develop cystic ovarian disease before breeding compared with normal cows.

University of Illinois at Urbana-Champaign

Melendez *et al.* 2002, Theriogenology 59:927-937.

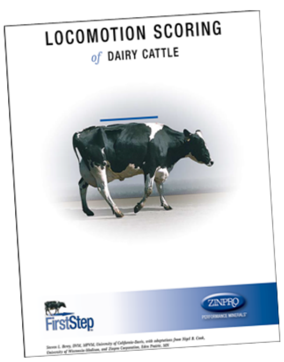
Evaluating Lameness at the Farm Level

University of Illinois at Urbana-Champaign

Locomotion Scoring

Score	Description	Back	Assessment
1	Normal	Flat	Cow stands and walks with a level back. Gait is normal.
2	Mildly lame	Flat or Arched	Cow stands with level back, but back is arched when walking. Gait is normal.
3	Moderately Lame	Arched	Cow stands and walks with an arched back. Gait is short-strided.
4	Lame	Arched	Arched back is always evident, and gait is one deliberate step at a time. Cow favors one or more legs/feet.
5	Severely Lame	3-legged	Cow is unable or very reluctant to bear weight on one or more limbs/feet.

Adapted from Sprecher et.al. (Theriogenology 47:1179-1187;1997)



Locomotion Scoring

Courtesy of

ZINPRO PERFORMANCE MINERALS™

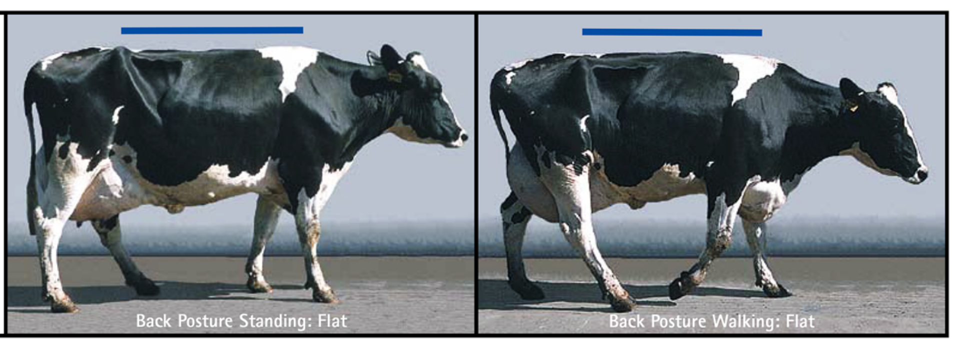
Locomotion Score 1

Clinical Description:

Normal

Description:

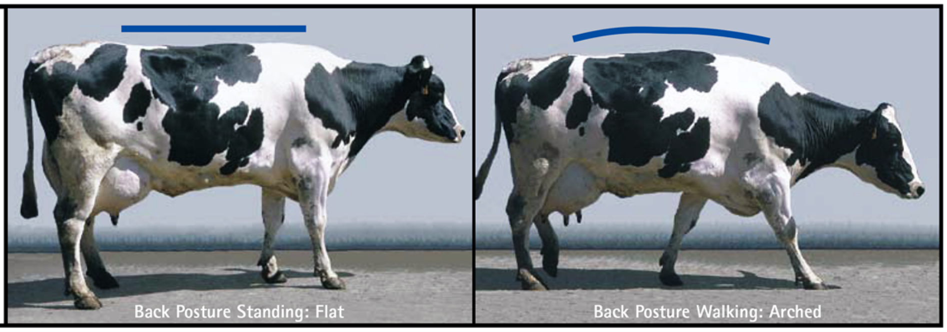
Stands and walks normally with a level back. Makes long confident strides.



Locomotion Score 2

Clinical Description:
Mildly Lame

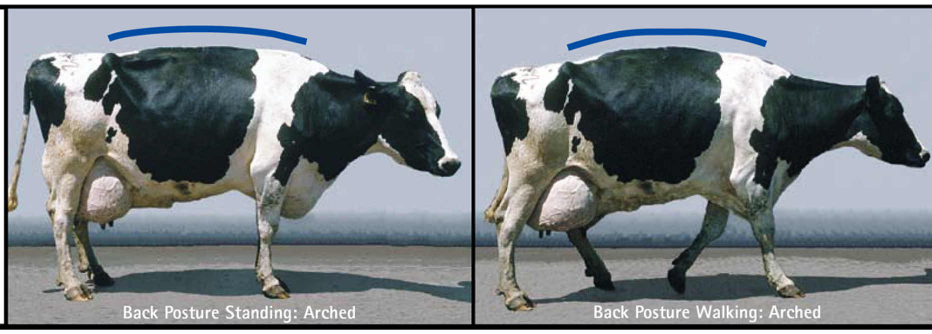
Description:
Stands with flat back, but arches when walks. Gait is slightly abnormal.



Locomotion Score 3

Clinical Description:
Moderately Lame

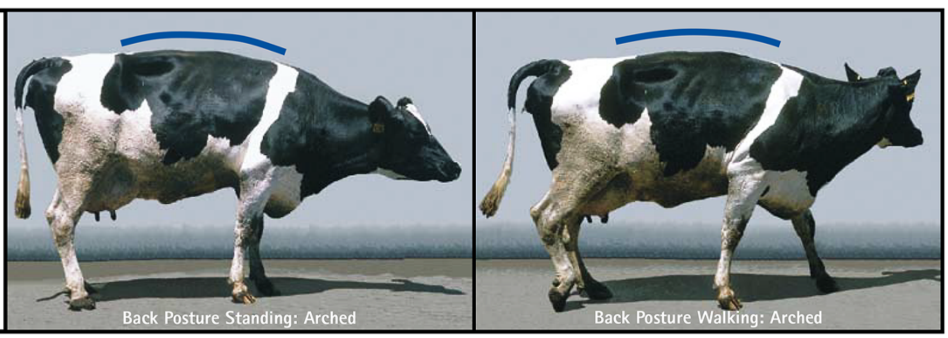
Description:
Stands and walks with an arched back and short strides with one or more legs. Slight sinking of dew-claws in limb opposite to the affected limb may be evident.



Locomotion Score 4

Clinical Description:
Lame

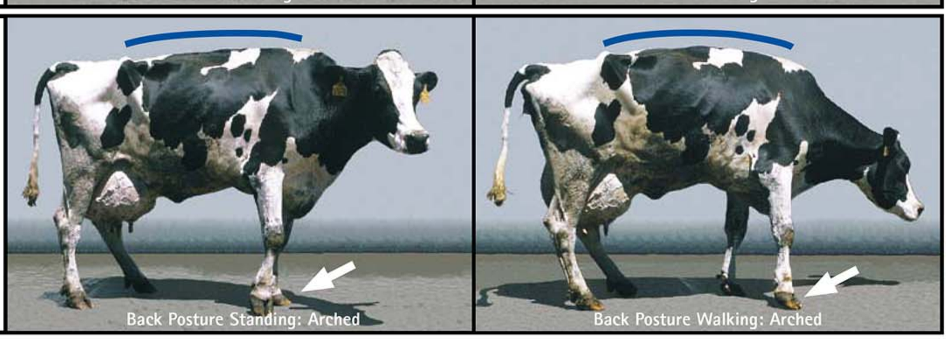
Description:
Arched back standing and walking. Favoring one or more limbs but can still bear some weight on them. Sinking of the dew-claws is evident in the limb opposite to the affected limb.



Locomotion Score 5

Clinical Description:
Severely Lame

Description:
Pronounced arching of back. Reluctant to move, with almost complete weight transfer off the affected limb.



* Adapted from Sprecher, D.J.; Hostetler, D.E.; Kaneene, J.B. 1997. Theriogenology 47:1178-1187 and contribution from Cook, N.B., University of Wisconsin.

Cost of Lameness

	Amount Lost	Value
Death	2% - replacement cost $2200	$44
Culling	12% replacement/cull $2200 - $600	$192
Milk Loss	940 lb milk at $0.09/lb	$170
Reproduction	20 extra days at $3.00/day	$60
Treatment	.05 hr. labor + trimmer fee + supplies	$32
	Total	**$498**

Adapted from CL Guard, 2008 Bovine Lameness Seminar & 2006 AABP Proceedings 2006.

Impact of Lameness Scores (California)

Score	Percent	Milk Drop	DMI drop
Score 1	75	none	none
Score 2	15	none	1 %
Score 3	9	5 %	3 %
Score 4	< 0.5	17 %	7 %
Score 5	< 0.5	36 %	16 %

Significance of Locomotion Scores

Cows with a locomotion score 3

2.8 times more likely to have increased days to 1st service

15.6 times more likely to have increased days open

9.0 times more likely to have more services per conception

8.4 times more likely to be culled than herd mates

Sprecher, *et al.*, Theriogenology, 1997, 47:1179-1187.

Understanding Laminitis

Laminitis

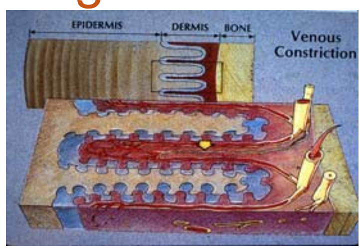
- Inflammation of the vascular hoof tissues
  - laminae = vascular hoof tissues
  - itis = inflammation
- Sensitive laminae
  - associated with the bone
- Insensitive laminae
  - associated with the hoof wall

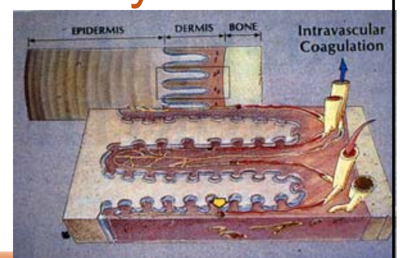
Laminitis Relationships

- Sensitive laminae die without oxygen from reduced of blood flow
- Corium becomes inflamed
- Inflammation and edema increase pressure inside hoof wall causing pain
- Painful animals walk less
  - Natural pumping action reduced
  - Blood flow stagnates inside hooves
  - Further damage to sensitive laminae occurs

Pathogenesis of Laminitis

- Vascular damage during laminitis caused by:
  - Venous constriction
  - Intravascular coagulation
- Vascular events thought to mediated by:
  - Endotoxins
  - Histamine
  - Lactate

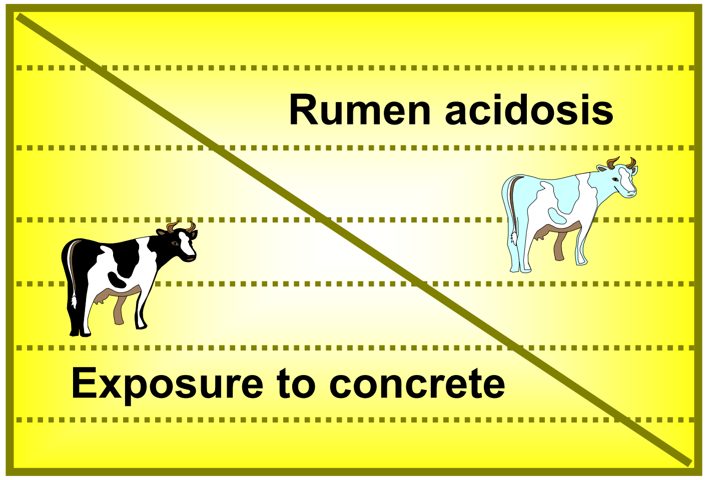




Factors That Might Weaken the Suspensory Apparatus

1. Enzymes (metalloproteinases) breakdown or weaken the collagen fibers in the corium
2. Weakness may be brought about by hormonal changes at or around calving (such as relaxin)
3. Factors causing structural alteration of the collagen fiber bundles

Degree of Interaction



Feeding Factors

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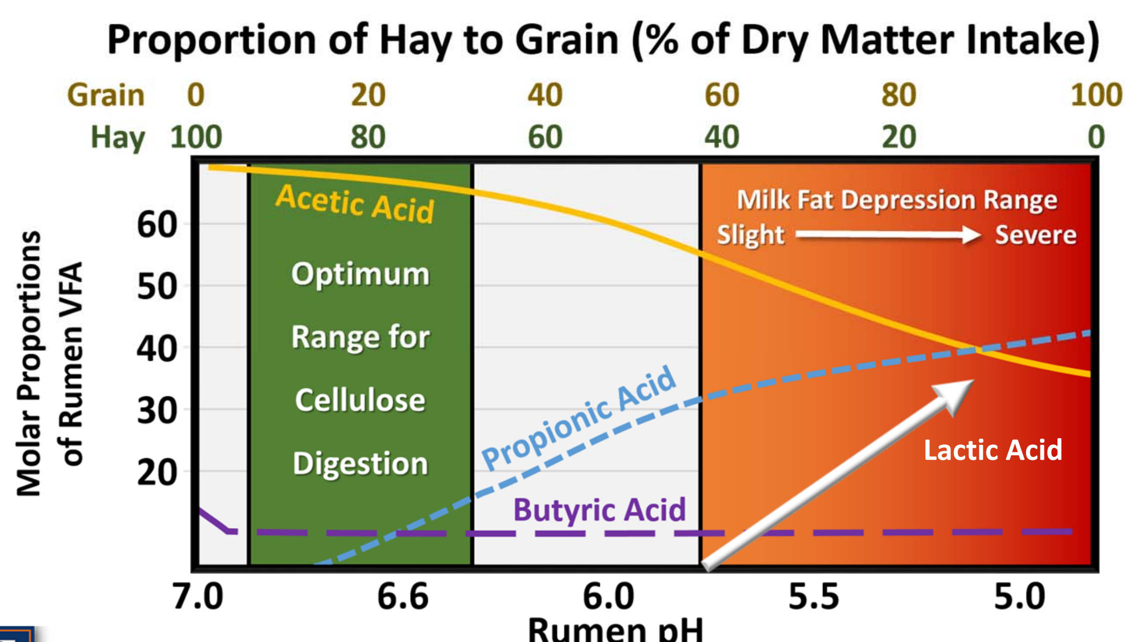
Excess Rapidly Fermentable Carbohydrates

- VFA exceeds rumen wall absorption
- Reduces rumen pH - below 5.5
- Lactic acid bacteria proliferate
- Vasoactive substances released in blood
- Damage to vessels in sensitive laminae



Signs of Acidosis

- Free choice bicarb consumption
  (< 45 g or 0.1 per cow per day)
- Erratic shifts in dry matter intake
  (> 2 lb or 1 kg per cow per day)
- Laminitis (> 10% lameness score 3)
- Loose fecal droppings (manure score < 2.5)
- Consumption of bedding and dirt

Transition Phase Risks for Laminitis

- Rumen microbial populations
  - pH affects types of microbes
    - ✓ starch digesters vs fiber digesters
  - May take 10-14 days to stabilize
- Rumen papillae
  - Surface area for VFA absorption
  - Require 6-8 weeks to develop
  - Every acidotic episode sets them back

Starch and Sugar Considerations

- Starch levels (22 to 30%)
- Rumen starch availability (55 to 85%)
- Starch sources (wheat>barley>corn)
- Sugar levels (5 to 7%)

Fiber Carbohydrate Guidelines

Total aNDFom 28 to 33%

uNDF-30 (forages) 12 to 14%

Effective NDF 19 to 22%

ADF 19 to 21%

Lignin 3 to 4%

Physically effective fiber

- Minimum of 450 minutes of cud chewing using rumen monitoring devices (550 to 600 minutes)
- 5lb (2kg) of feed particles over ¾ inch (18 mm)
- > 50% of total dry matter in top two boxes of the Penn State Box (> 8% top; >40% 2nd box)

Penn State Separator / IL) (3rd boxes)

	Top	Middle	Bottom
	---------------% (as fed)---------------		
TMR	2-8	> 40	<50
Haylage	> 20	> 60	< 25
Corn silage	5-15	> 50	<35

(3/4 TLC Process)

Penn State Separator Guidelines
(IL—3rd box @ 1.1 mm)

	Top	2nd	3rd	Bottom
	---------------	% (as fed)		---------------
TMR	2- 8	> 40	< 30	< 20
Haylage	> 20	> 40	< 20	< 5
Corn silage (3/4 TLC-Process)	5-15	> 50	< 30	< 5

Penn State Separator / PA
(3rd box at 4.0 mm)

	Top	2nd	3rd	Bottom
	----------------	% (as fed)	----------------	
TMR	2-8	30-50	30-50	< 20
Haylage	10-20	40-75	20-30	< 5
Corn silage	3-8	10-20	30-40	< 5

Reducing Feed Sorting

- Reduce forage particle size < 2 inches
- Increase forage quality
- Reduce the amount of hay
- Add 5 to 7 pounds of water and evaluate
- Considering adding liquid molasses, corn distillers solubles, or other wet ingredient
- Feed more frequently each day

Protein Quality and Quantity

- Higher levels of RDP (< 11% RDP) or total quantity of protein (<16.5%%) may produce rumen fermentation that impacts hoof hardness
- Sulfur containing amino acids can impact hoof health (0.25 to 0.28% of DM)

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PUFA (polyunsaturated fatty acids)

- Reduce fiber digestion in the rumen and shift rumen microbial population
- Shift rumen VFA pattern (less acetate)
- < 500 grams of total ration PUFA/cow/day
- < 225 grams of vegetable oil in the free form and/or under 50 grams of fish oil

Copper Aspects

- Synthesis and maintain elastic tissue (tendons)
- Produce thiol oxidase increasing hoof hardness via disulfate keratin bonds
- Immunity role as superoxide dismutase
- 10 to 15 ppm (1/4 from organic sources)

Zinc Considerations

- Component of 300 enzyme systems
- Improve wound healing, keratin synthesis, and epithelium maintenance
- Improve hoof hardness and hoof health
- 40 to 60 ppm
  (1/4 to 1/3 from organic sources)

Organic Zinc and Hoof Health

Hoof health (3,000 cows study)

- 34% reduction white line ($P<0.001$)
- 11% reduction sole ulcers ($P<0.05$)
- 33% reduction in digital dermatitis ($P<0.01$)

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Additional Mineral Considerations

- Manganese: Bone density and joint structure with oxidative damage control (40 to 60 ppm)
- Sulfur: amino acids synthesis and vitamins (biotin and thiamine) (0.25 to 0.28%)
- Calcium and phosphorous: Bone formation and skeletal soundness

Biotin

Improve hooves by reducing heel warts, claw lesions, white line separations, sand cracks, and sole ulcers; increase milk yield

- **Level:** 10 to 20 mg/cow/day for 6 mo to 1 year
- **Cost:** 4 to 10 cents/cow/day
- **Benefit to Cost Ratio:** 4:1

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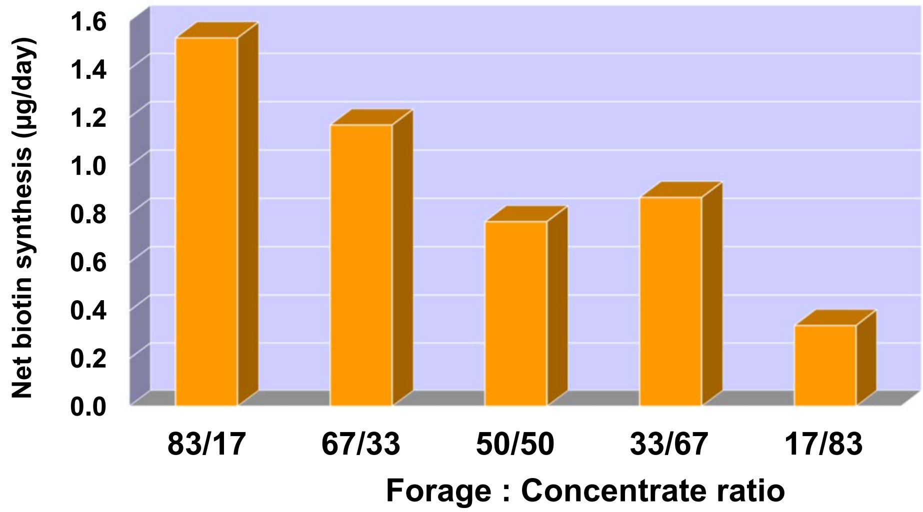
Synthesis of Biotin - an *in vitro* study



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Da Costa Gomez et al., 1998

Influence of biotin on foot lesions

Clinical summary

Lesion	Reference	Biotin dose	Response
Sole ulcer	Hagemeister, (1996)	10 mg	Significant reduction in sole ulcers and heel erosion
Sole ulcer	Lischer et al, (1996) Koller et al, (1998)	20 mg	New horn formed more rapidly Structure of new horn was improved
Digital dermatitis	Distl & Schmid, (1994)	20mg	20-37% lower incidence of "heel warts" in an 11 month study
Vertical fissures	Campbell et al, (1996)	10mg (Beef cows)	Incidence of sandcracks: Control 29.4% Treatment 14.3%

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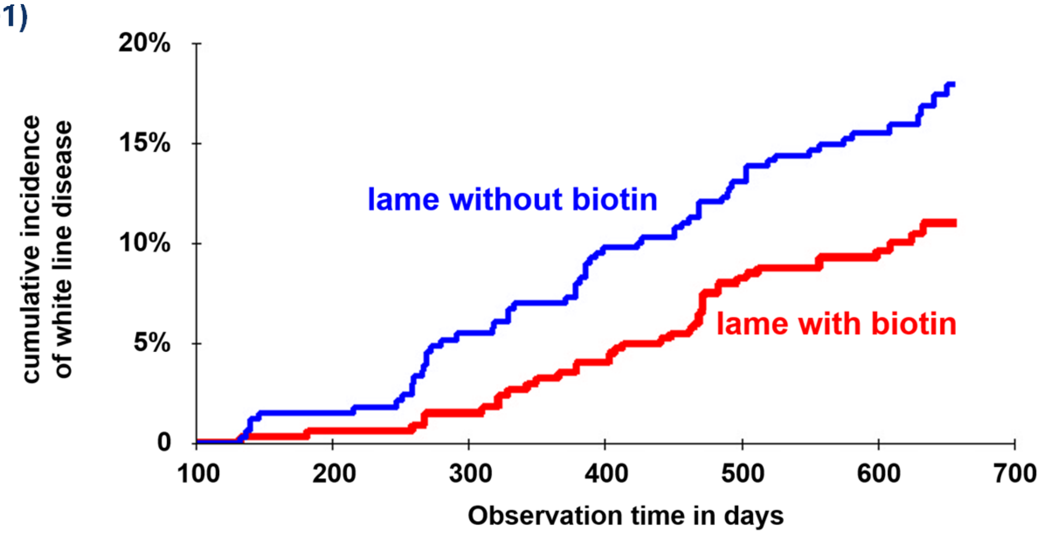
Influence of biotin on foot lesions

Clinical summary

Lesion / Study	Reference	Biotin dose	Response
White line Disease	Midla et al, (1998)	20 mg	Significant improvement in prevalence of white line lesions at 100 days of lactation
	Hedges et al, (2001)	20 mg	Biotin halved the risk of clinical lameness caused by white line lesions. Biotin supplemented animals required fewer repeat treatments (17.5% v. 30%)
Pasture fed Cattle	Fitzgerald et al, (2000)	20 mg	Supplemented herds had a significant reduction in lesions causing lameness

The influence of 20 mg/day biotin supplementation on the incidence of clinical lameness caused by white line disease in dairy cattle (Hedges et al 2001)



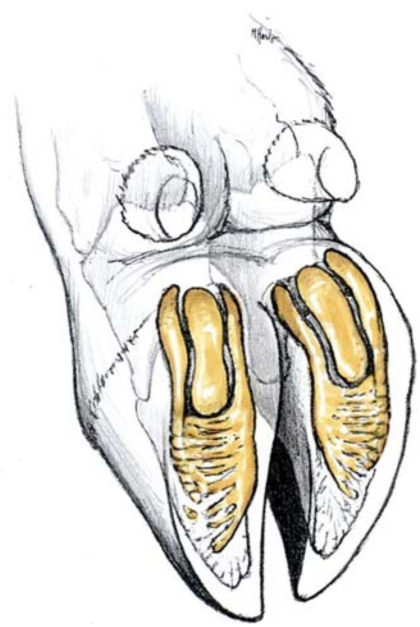
Feed Additives

- Rumen buffers (0.75% ration dry matter)
- Monensin (300 to 450 mg)
- Yeast products (levels as recommended)
- Organic zinc (1/3 of total zinc added)
- Biotin (15 to 20 mg/day)

Digital Cushion in Cows

- Cushions contain a higher amount of fat in mature cows compared to heifers
- Fat content is softer - contains a larger amount of MUFA (mono-unsaturated fat)

Ch. J. Lischer and P. Ossent, 12th International Lameness Symposium, Orlando, FL, 2002.



Impact of Changing Body Condition Score

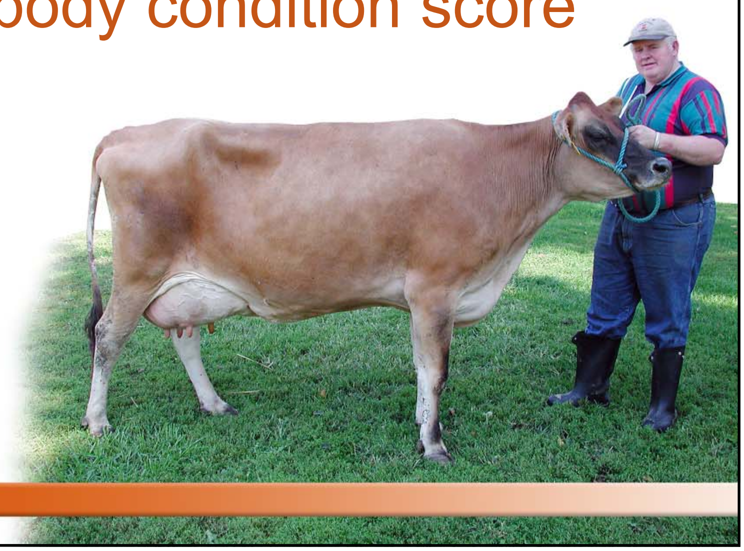
- Digital cushion thickness (DCT) provides cushion to the hoof structure.
- Cows with the highest DCT had 15% lower lameness scores compared to lowest DCT scored cows.
- DCT continues to drop after calving with the lowest level at 120 days after calving
- Target: Avoid dropping more than 0.5 BCS after calving (reflects dry matter intake and environment)

What's New In Lameness Nutrition?

Impact of body condition score

Added iodine in non-lactating cows

53
I
Iodine
126.90447



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Feeding Organic Iodine (EDDI)

- Ethylene diamine dihydroiodide
- Adding 3.8 ppm to the total ration DM (NOT ALLOWED FOR LACTATING COWS BY FDA)
- Feed this level for 60 to 90 days before lesions appear
- Response is earlier in younger animals
- Maximum level for lactating cows is 49.9 mg of EDDI / animal / day

WI Steer Digital Dermatitis (DD) Study

- 120 Holstein steers from 300 to 595 lbs
- Added 3.8 ppm iodine as EDDI
- Results:

Item	Control	Iodine	
DD lesion (cm)	1.71	1.10	(P <0 .08)
M2* lesions (%)	55	30	< 0.11)

* M2 lesion: acute, active, and ulcer > 2.0 cm

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WU Heifer Study Digital Dermatitis (DD)

- 153 heifers were followed for 16 weeks
- All heifers were fed iodine for a minimum of 49 days
- 6.1% of control heifers had DD
  while iodine fed group had 2.5% DD (P < 0.05%)
- Risk was 1.59 greater for control heifer to have DD
- Fewer repeat cases of DD with iodine

Minimizing Lameness On The Farm

- **Nutrition**
- **Cow comfort**
- **Footbath management**
- **Corrective hoof trimming**

Future

- Early detection - technology will help
- Cow comfort / hoof care programs--continue to improve cow's environment & management
- Nutrition--rumen health, BCS, PUFA, minerals, vitamins, and additives
- Genetics/Genomics/Gene technology--better feet and legs with hoof quality

Recommended Reference

- http://www.zinpro.com/lameness/dairy
- Overlay of hoof structure
- Dairy and beef applications
- Excellent photos of hoof disorders
- Available as:
  - Book
  - Apple and Android Application

In Summary

- Lameness is a highly visible and important animal welfare issue
- Failure to deal with it in timely fashion is partly a consequence of
  - A lack of awareness or a failure to detect
  - Inadequate facilities for examination & treatment

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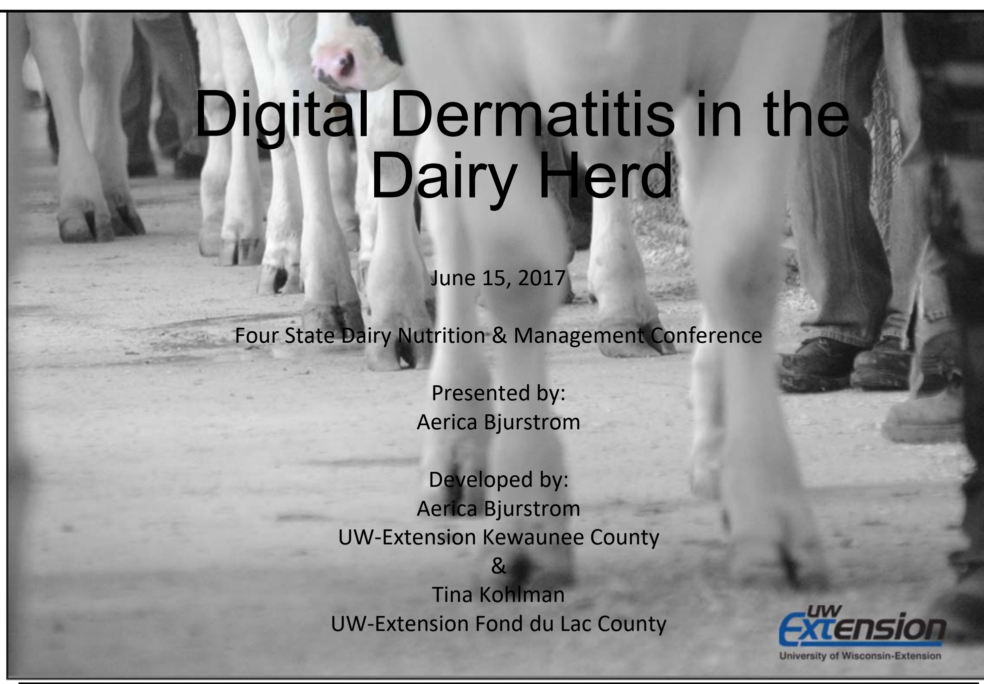

Digital Dermatitis in the Dairy Herd

June 15, 2017

Four State Dairy Nutrition & Management Conference

Presented by:
Aerica Bjurstrom

Developed by:
Aerica Bjurstrom
UW-Extension Kewaunee County
&
Tina Kohlman
UW-Extension Fond du Lac County

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What is digital dermatitis?

- Digital dermatitis (DD) (also known as hairy heel warts) effects heifers and cows
- Once a cow has it, she can never be cured, only managed

Photo credit: Cornell University Extension

- First reported: Italy, 1974
- First appeared in the US in the early 1980s
- Rapidly spread in the mid 1990s
- Reported on 70% of *all* US dairies
- 95% of all dairies (500 cows or more)

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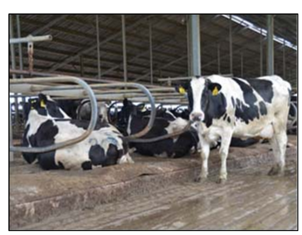
Risk Factors

- Wet conditions
- Poor foot hygiene
- Presence of infected animals in the herd
- Poor footbath management
- High milk producing cows
- Early lactation
- Low parity
- Low heel height



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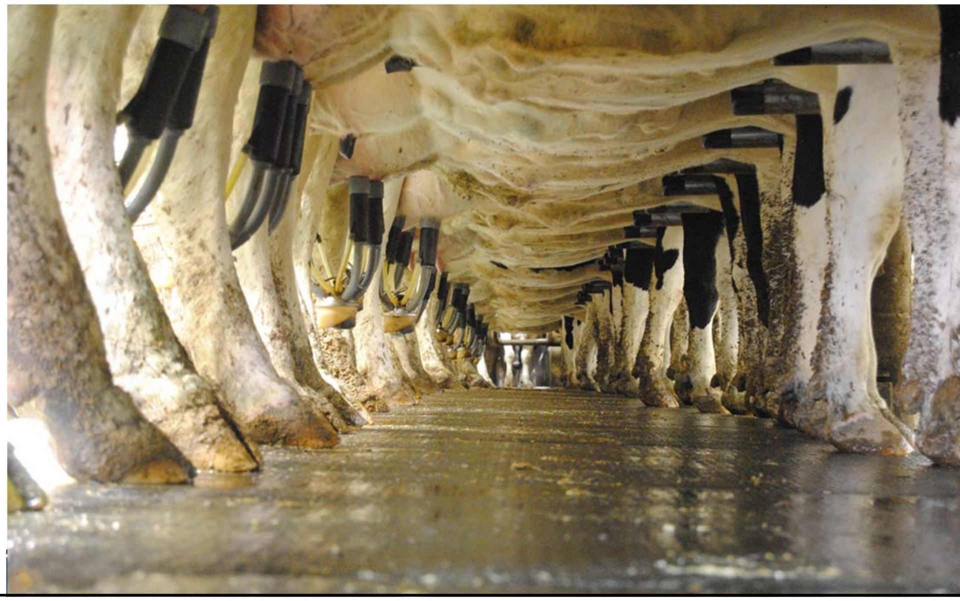
Field Study



Objectives

- Determine the prevalence of three primary stages of Digital Dermatitis (DD) on dairy operations.
  - M0 (no signs of lesion)
  - M2 (acute, active lesion)
  - M4 (chronic, nonactive lesion)
- Determine hoof health management practices regarding managing DD on eastern WI dairy operations.

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Project Design

- Select group of cows on eastern WI dairy operations
- Small
  - –150 cows or less in tie-stall/stanchion barn
- Medium
  - –Up to 700 cows in free-stall
- Large
  - –more than 700 cows

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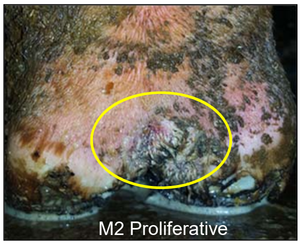
What we were looking for…



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Herds Scored

- 11,817 observations
- 45 herds
  - 15 small
  - 19 medium
  - 11 large
- Smallest herd 22 cows
- Largest herd 6,700 cows
- Average size 607 cows

- Small
  - 22-115 cows
  - Average 63 cows
  - 100% scored
- Medium
  - 70-590 cows
  - Average 257 cows
  - Average 84% scored
- Large
  - 850-6,200 cows
  - Average 1,955 cows
  - Average 43% scored

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Prevalence of Digital Dermatitis in Select Group of Cows on Surveyed Eastern WI Farms

Lesion	Number of Cows	% Cows Scored	Avg per Farm (%)	Min (%)	Max (%)
				Range	
M0	9,591	81.1	76.0	49	100
M2	212	1.8	3.5	0	27
M4	2,014	17.1	20.1	0	50
Total	11,817				

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Prevalence of Digital Dermatitis in Select Group of Cows on Surveyed Eastern WI Farms

Herd Size	Low (≤5)	Moderately Low (5-10%)	Moderately High (10-25%)	High (≥25%)
Small	13.3	13.3	26.7	46.7
Medium	10.5	0.0	26.3	63.2
Large	36.4	9.0	27.3	27.3
Total	17.8	6.7	26.7	48.9

Goal is to have a low (≤5%) prevalence of DD within a group of cows

Nearly 18% of surveyed operations (n=8) had ≤ 95% healthy feet within select group of cows

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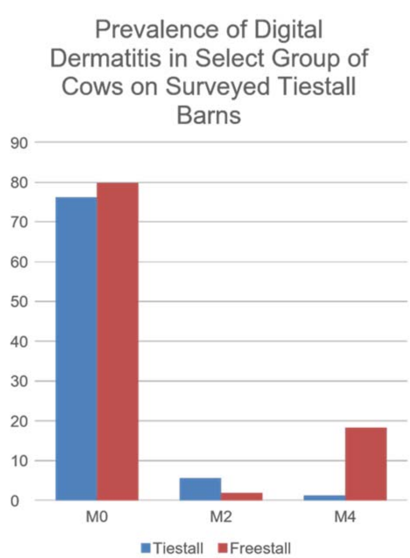
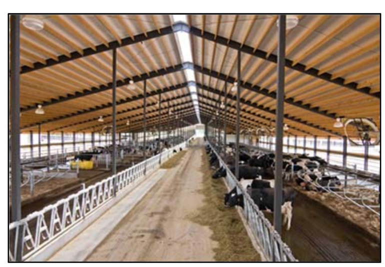



Tiestall (n=15), 917 cows


Freestall (n=30) 10,900 cows

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Prevalence of Digital Dermatitis in Selected Group of Cows on Surveyed Eastern WI Farms

Footbath Frequency

Footbath Frequency	Operations	M0 (%)	M2 (%)	M4 (%)
No footbath	11	71.5	6.9	21.5
1 to 3 times per week	16	74.1	3.1	22.8
4 to 7 times per week	13	79.6	1.7	18.4

Footbath length recommendations: 10-12 feet
Average length from participating farms on field survey: 6' 9"

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Prevalence of Digital Dermatitis in Selected Group of Cows on Surveyed Eastern WI Farms

Hoof Trimming Frequency

	Operations	M0 (%)	M2 (%)	M4 (%)
(Bi)Weekly	11	82.9	1.1	16.0
(Bi)Monthly	16	70.1	5.3	24.6
Quarterly	8	72.9	3.0	24.0
(Bi)Annually	7	76.1	7.0	18.4

Image Source: Birkelman's Welding

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Prevalence of Digital Dermatitis in Selected Group of Cows on Surveyed Eastern WI Farms

Treatment Type

Treatment	Operations	M0 (%)	M2 (%)	M4 (%)
Spray	7	74.4	5.4	20.1[b]
Treatment with footwrap	32	78.5[a]	3.1	18.4[b,c]
Treatment without wrap	6	65.0[a]	4.0	29[c]

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Take Back to the Barn

- Prevalence of DD in tiestall and freestall operations was similar
- Concentration of footbath solution, trimming frequency, and treatment type had an impact on stage and chronicity of DD lesion

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Prevalence of Digital Dermatitis in Eastern Wisconsin Dairy Herds

http://fyi.uwex.edu/dairy/

Developed and presented by:
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Questions?

Management Opportunities to Resolve Before Starting an Amino Acid Program

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Milk protein prices continue to vary in 2017 with butter/milk fat commanding higher prices. In the future, consumers will come back to focus on milk protein, its quality, and source of animal protein. The following take home messages will be supported in the presentation.

- Evaluating current true milk protein content (opportunities to improve or find weak links—Table 1)
- Driving dry matter intake (increases microbial amino acid yield)
- Use of rumen modeling programs (estimate amino acid status)
- Selecting feed ingredients (improve RUP and amino acid profiles)
- Impact of milk urea nitrogen (effectiveness of capturing dietary nitrogen and efficiency)
- Genetic consideration (breeding for pounds of components)
- Factors lowering milk protein (environmental aspects and feed components)

Table 1. Milk fat percent and true protein percent profiles for Holstein and Jersey herds at various stages of lactation (days in milk) and various levels of milk yield in 2016. (Source: North Carolina DHI Processing Center)

Holstein									
Milk yield, lbs.	**Lactation No.**	**Fat % by days in milk**				**True Protein % by days in milk**			
		1 - 40	**41 - 100**	**101 - 199**	**200 - 305**	**1 - 40**	**41 - 100**	**101 - 199**	**200 - 305**
30,000	1	3.9	3.5	3.6	3.8	2.9	2.8	3.0	3.2
30,000	2	3.8	3.4	3.5	3.8	2.9	2.8	3.0	3.2
30,000	3+	4.0	3.4	3.5	3.7	2.9	2.8	3.0	3.2
26,000	1	3.8	3.5	3.6	3.9	2.8	2.8	3.1	3.2
26,000	2	3.7	3.4	3.6	3.8	2.8	2.8	3.0	3.2
26,000	3+	3.9	3.4	3.6	3.8	2.8	2.7	3.0	3.2
23,000	1	3.4	3.3	3.6	3.8	2.5	2.6	3.0	3.1
23,000	2	3.3	3.3	3.6	3.8	2.5	2.6	3.0	3.2
23,000	3+	3.7	3.4	3.6	3.8	2.7	2.7	3.0	3.2
19,000	1	2.9	3.0	3.5	3.7	2.2	2.4	2.8	3.0
19,000	2	2.9	3.1	3.5	3.7	2.3	2.5	2.9	3.1
19,000	3+	3.5	3.4	3.6	3.8	2.6	2.6	2.9	3.1

Number of Holstein herds used: 30,000 lb—292 herds, 27,000 lb—1022 herds; 23,000 lb—1998 herds, and 19,000 lb—1014 herds.

Jersey									
Milk yield, lbs.	**Lactation No.**	**Fat % by days in milk**				**True Protein % by days in milk**			
		1 - 40	**41 - 100**	**101 - 199**	**200 - 305**	**1 - 40**	**41 - 100**	**101 - 199**	**200 - 305**
21,000	1	4.0	4.2	4.6	5.0	3.1	3.2	3.5	3.7
21,000	2	4.2	4.3	4.6	5.0	3.5	3.3	3.5	3.8
21,000	3+	4.3	4.4	4.6	4.9	3.4	3.3	3.5	3.8
19,000	1	4.1	4.3	4.8	5.2	3.1	3.2	3.6	3.8
19,000	2	4.0	4.3	4.8	5.1	3.1	3.2	3.6	3.9
19,000	3+	4.4	4.3	4.8	5.0	3.3	3.2	3.6	3.8
17,000	1	3.6	4.0	4.6	4.9	2.8	3.0	3.5	3.7
17,000	2	3.6	4.1	4.6	4.9	2.8	3.1	3.5	3.7
17,000	3+	4.3	4.4	4.8	5.0	3.3	3.3	3.6	3.8
15,000	1	3.1	3.7	4.3	4.8	2.4	2.8	3.3	3.6
15,000	2	3.3	3.7	4.3	4.6	2.6	2.8	3.3	3.5
15,000	3+	3.8	4.1	4.6	4.9	3.0	3.1	3.5	3.8

Number of Jersey herds used: 21,000 lb—17 herds, 19,000 lb—59 herds, 17,000 lb—92 herds, and 15,000 lb—121 herds.

Management Opportunities To Resolve Before Starting An Amino Acid Program

Mike Hutjens
Extension Dairy Specialist
University of Illinois Extension

Interest in Milk Protein

- Most dairy farmers are paid for pounds of milk solids, not volume or percentage.
- Over 40 percent of milk is consumed as cheese in the U.S.
- Fairlife milk: 50 percent higher in protein with reduced lactose, .
- Greek yogurt is increasing in popularity

Milk Marketing in 2017

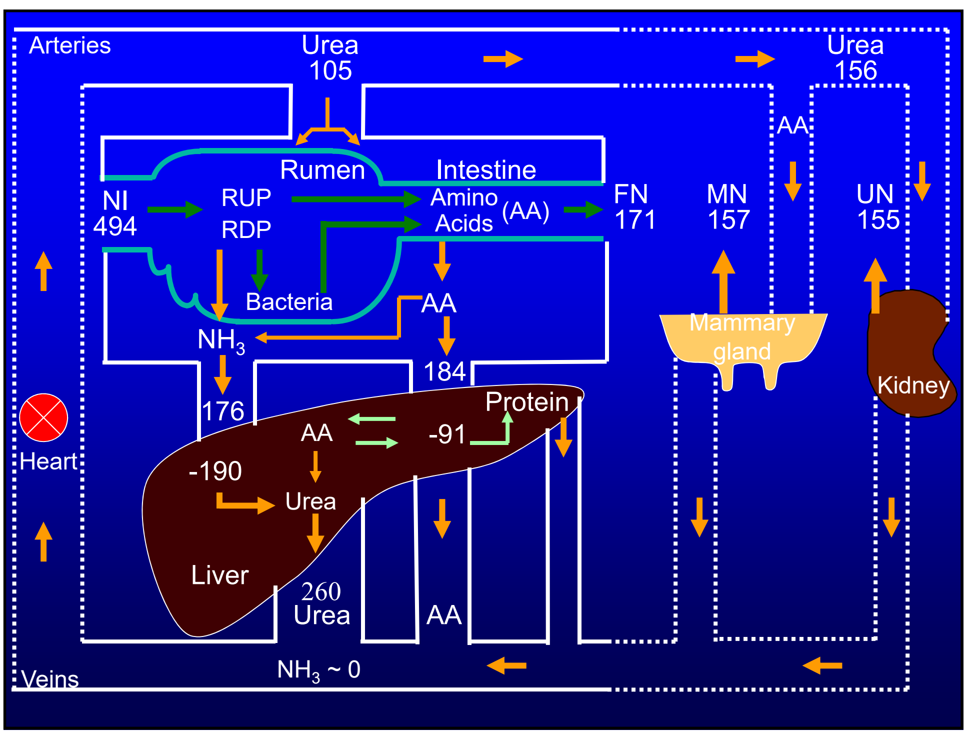
- Milk fat is $2.96 a pound (July, 2017)
- Milk true protein is 1.22 a pound (July, 2017)
- Butter is determining 40 percent of the current milk price at the farm gate
- The world is "short" of milk fat with the U.S. the lower priced butter in exporting countries
- What is the future pricing of milk protein?
  - Consumer response
  - Signals to dairy managers

2016-2017 Component Prices

Component	-------------------Month	--------------------		
	July 16	Dec 16	Apr 17	July 16
	---------------- ($/lb)	----------------------		
Milk protein (true)	1.91	2.60	1.70	1.23
Milk fat	1.99	2.33	2.34	2.94
Other solids	0.08	0.21	0.34	0.26
Class III	$15.24	$17.40	$15.22	$15.45

Amino Acids Are Required by Cows

1. Enhance feed intake & use of energy
2. Supply **nitrogen** to microbes
   - Ammonia
   - Amino acids
   - Peptides
3. Supply **amino acids** for synthesis of:
   - Milk protein
   - Tissue protein
   - Enzymes, hormones, etc.
4. Supply **carbon** for glucose synthesis



Ever-Green-View My Gold-ET
(5 year scored EX-93, EX-95 udder)

Owned by the Tom Kestell

Set a 365-day record

- 77,480 lbs of milk
- 1,992 lbs of fat
- 2,055 lbs of protein

What Does My-Gold Consume?

- High chopped BMR corn silage (41% starch)
- Alfalfa haylage (170 to 190 RFV)
- High moisture corn, sugar, protein mix, roasted soybeans
- Other factors: tie stall barn, 3X, rBST

Factor 1: Evaluate Milk Components

Milk Fat and Milk Protein Relationship

(Hoard's Dairyman—August 2017)

	Fat %	Protein %	Protein vs Fat	Fat vs Protein
Ayrshire	3.87	3.11	80%	1.24
Brown Swiss	4.03	3.31	82%	1.22
Guernsey	4.56	3.34	73%	1.37
Holstein	3.84	3.03	81%	1.26
Jersey	4.84	3.65	76%	1.33

Holstein Components
(Fat% / True Protein%)

Milk yield	Lactation	1-40 days	41-100
30,000	3rd+	*4.0/2.9*	*3.4/2.8*
	1st	*3.9/2.9*	*3.5/2.8*
26,000	*3rd+*	3.9/2.8	3.4/2.7
	1st	3.8/2.8	3.5/2.8
23,000	3rd+	3.7/2.7	3.4/2.7
	1st	3.4/2.5	3.3/2.6

Pounds of Protein and Fat

Breed	Milk / Day	Fat	Protein	Total
	------------------------ Pounds ------------------------			
Ayrshire	18,886 / 50	1.97	1.61	3.6
Brown S.	22,509 / 61.6	2.48	2.04	4.5
Guernsey	16,229 / 44.5	2.02	1.47	3.5
Jersey	19,278/ 52.8	2.55	1.92	4.5
Holstein	25,476 / 70.0	2.61	2.24	4.9
	80	**2.98**	**2.42**	**5.4**
	90	**3.36**	**2.72**	**6.1**
	100	**3.73**	**3.02**	**6.8**

Value of Milk Components
(Prices for July, 2017)

- Holstein herd: 70 lb milk, 3.5% fat , and 2.9% true protein corrected to 3.7% fat and 3.0% true
- 70 lb x 0.2% point increase
  = 0.14 lb of milk fat x $2.96 / lb fat = $0.41
- 70 lb x 0.1% point increase milk protein
  = .07 lb protein x $1.22 / lb = $0.09
- Profit potential: $0.50 / cow / day

Wisconsin Transition Score Index

- **Cows over 1.4 milk fat : milk protein ratio or < 0.70 milk protein: milk fat at risk**
- **Values over 1.4 reflect fat mobilization and elevated NEFA (milk fat precursor)**
- **Examples:**
  - **4.2% fat% and 3.0% milk protein**
  - **4.5% fat% and 3.2% milk protein**
  - **> 4.5% fat test in Holstein (Hutjens bias)**

Milk Fat Test Inversions

- If true milk protein test is 0.2 units higher than the milk fat test, an inversion has occurred. For example 3.0% true protein and 2.8% milk fat is inverted.
- Review DHI individual cow records to count the number of inverted cows. If it is over 10% of the herd, look for rumen acidosis

Factor 2: Driving Dry Matter Intake

Why Is Dry Matter Key?

- Delivers the amount of nutrients (not percent or ppm; it is pounds, kilograms, and grams per animal per day).
- Dry matter = organic matter intake = digestible nutrients = microbial yield = energy and nutrients
- Rumen fill and rate of passage impact intake, rumen environment (such as SARA), and health (such as ketosis).
- Higher dry matter intake can:
  - Reduce feed cost/raise feed costs
  - Improve or reduce economics
  - Change feed efficiency (+ or -)

Dry Matter Intake (NRC 1989)

DMI in Pounds					DMI in Kilograms				
FCM in lbs	Body Weight in lbs				FCM in Kg	Body Weight in Kg			
	880	1,100	1,320	1,540		400	500	600	700
44	32	35	38	40	20	15	16	17	18
66	39	43	46	49	30	18	20	21	22
88	48	51	53	55	40	22	23	24	25
110		59	62	63	50		27	28	29
132			71	74	60			32	34

Dry Matter Intake at Week 17 of Lactation (NRC 2001)

DMI in Pounds (NRC 2001)					DMI in Kilograms				
FCM in lbs	Body Weight in lbs				FCM in Kg	Body Weight in Kg			
	880	1,100	1,320	1,540		400	500	600	700
44	35	39	42	45	20	16	17	19	20
66	43	47	50	53	30	20	21	23	24
88	52	55	58	61	40	23	25	26	28
110	60	63	66	69	50	27	29	30	32
132	68	71	75	78	60	31	32	34	35

$$DMI = (0.372 \times 4\%\ FCM + 0.0968 \times BW^{.75}) \times (1 - e^{(-0.192 \times (WOL + 3.67))})$$

Microbial Protein

- Estimated at 80 grams per pound of discounted TDN (energy driven)
- Contain 80 percent crude protein
- Assumed to be 80 percent digestible
- Bacteria protein/amino acid content is not constant, but….

Amino Acid Levels

(% of Essential AA—Schwab)

Product	Lysine	Methionine
Milk	16.0	5.5
Lean tissue	16.3	5.1
Rumen bacteria	15.8	5.2
Alfalfa	11.1	3.8
Corn silage	7.5	4.8
Corn	7.0	5.0
Soybean meal	13.7	3.1
Blood meal	15.7	2.1
Fish meal	17.0	6.3

Feed Efficiency

Pounds of fat corrected milk divided by pounds of DM consumed

High group, mature cows	> 1.7
High group, 1st lactation	> 1.6
Low group	> 1.3
One group TMR herds	> 1.5
Fresh cows	< 1.5
Concern (one group)	< 1.3

Example: 75 lb milk / 50 lb DMI = 1.5

Formula: 3.5% FCM = (0.4324 x lb of milk) + (16.216 x lb of milk fat)

Milk Yield Targets

1500 lb cow, 3.6% fat

Milk Yield (lb)	Feed Efficiency	Milk Yield (Kg)
55	1.25	25
60	1.32	27
65	1.38	29
70	1.44	32
75	1.49	34
80	1.54	36
85	1.58	39
90	1.63	41

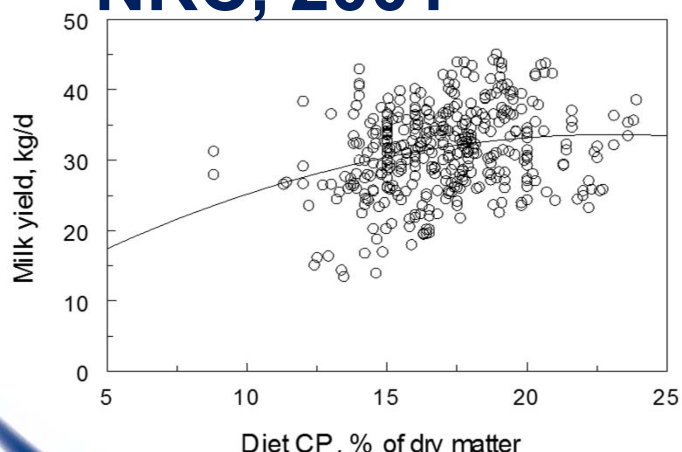
Source: The Ohio State University

Factor 3: Using A Rumen Model Program

Metabolizable Protein (MP) Major Sources of Amino Acids

- Microbial Protein (3 to 5 pounds of microbial protein produced per day)
- Rumen Undegradable Protein (RUP) is added as needed to compliment bacterial amino acid sources to meet animal requirements

NRC, 2001



Milk yield (kg/d) = 0.8 X DMI (kg/d) + 2.3 X CP (%) – 0.05 X CP^2 (%) – 9.8 (r^2 = 0.29) –provided by Dr. Varga, PSU

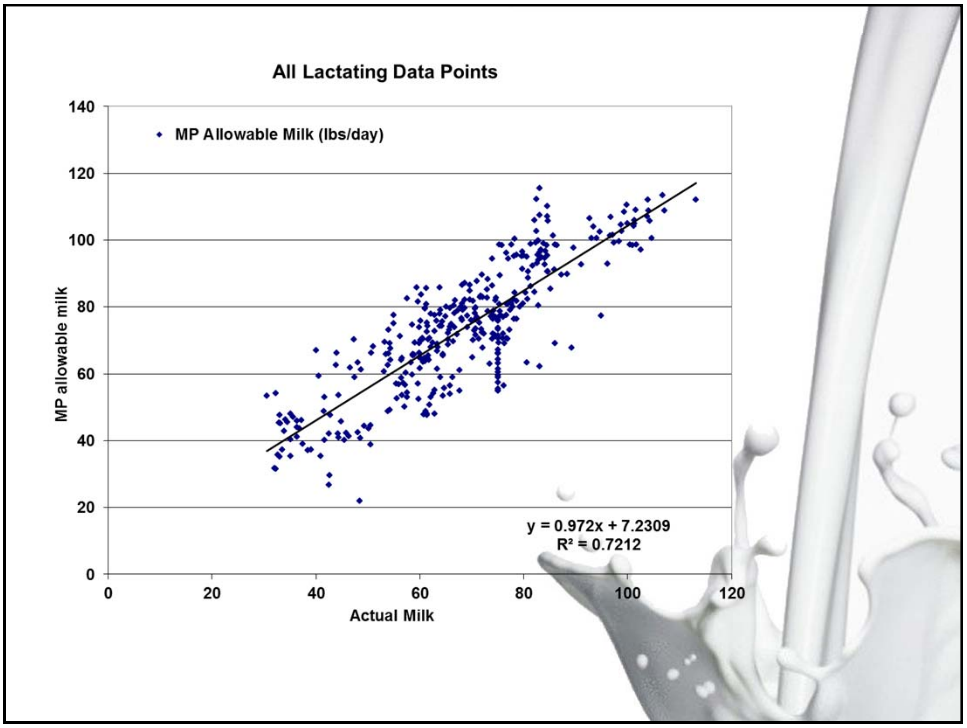
Then, why do we use crude protein?

Feeds are tested for crude protein

Feed tags list crude protein and NPN levels

Cannot test feed ingredients for metabolizable protein (MP)

Need a model to estimate amino acid yield and MP due to rumen degradation, rate of passage, and dry matter intake



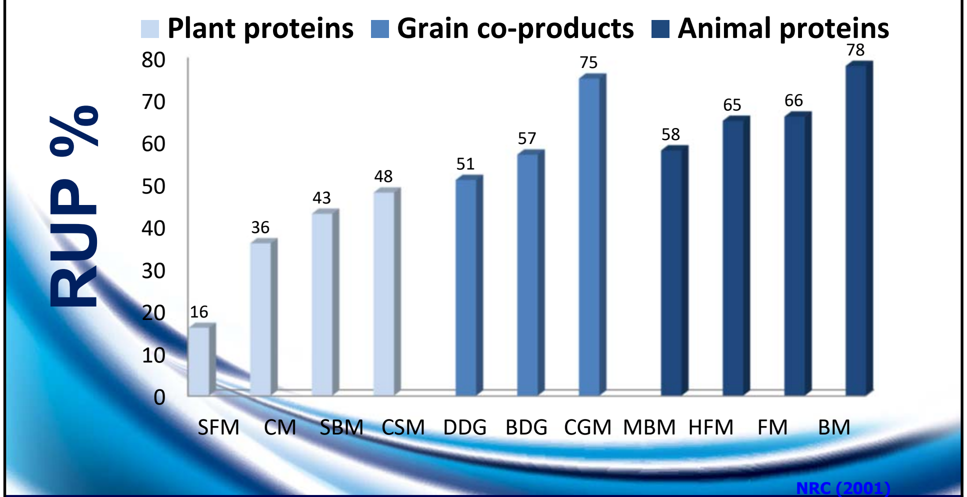
Target formulation levels for percentages of Lys and Met in MP

(Whitehouse et al., 2009)

	Optimal Lys	Optimal Met	Optimal Lys/Met
	NRC Model		
Content of milk protein	6.80	2.29	2.97
Yield of milk protein	7.10	2.52	2.82
Average	6.95	2.41	**2.90**
Target	**6.60**	**2.28**	
	CPM Model		
Content of milk protein	7.46	2.57	2.90
Yield of milk protein	7.51	2.50	3.00
Average	7.49	2.54	**2.95**
Target	**7.11**	**2.41**	
	AMTS/DNS (CNCPS 6.1 biology)		
Content of milk protein	6.68	2.40	2.78
Yield of milk protein	6.74	2.31	2.92
Average	6.71	2.36	**2.85**
Target	**6.38**	**2.24**	

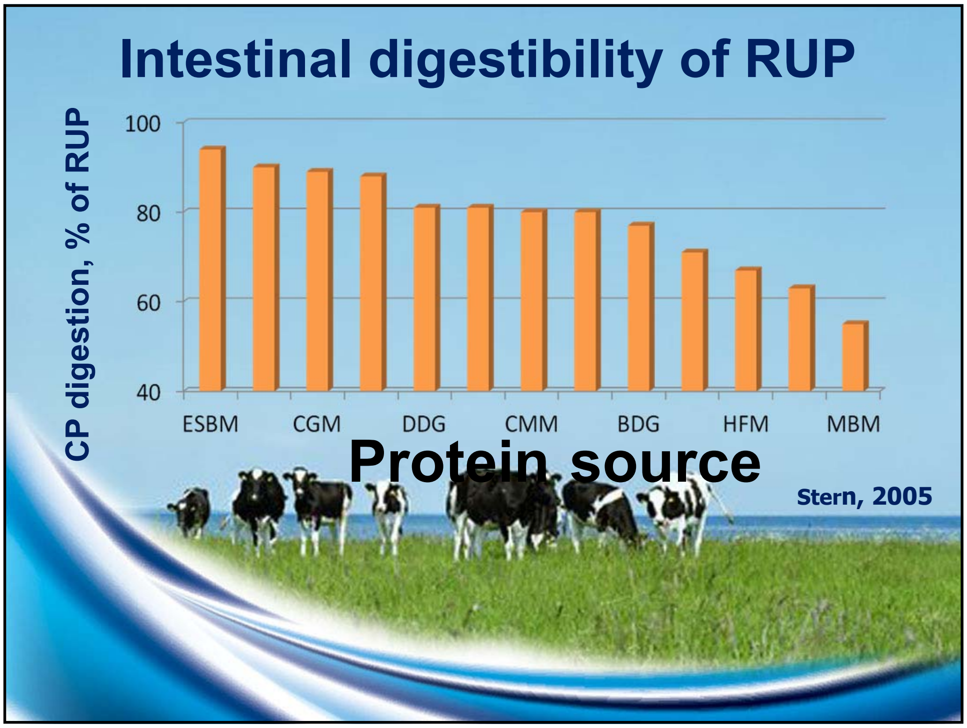
Factor 4:
Feed Selection
Based on RUP

Ruminal undegradable protein (RUP) content of various feedstuffs



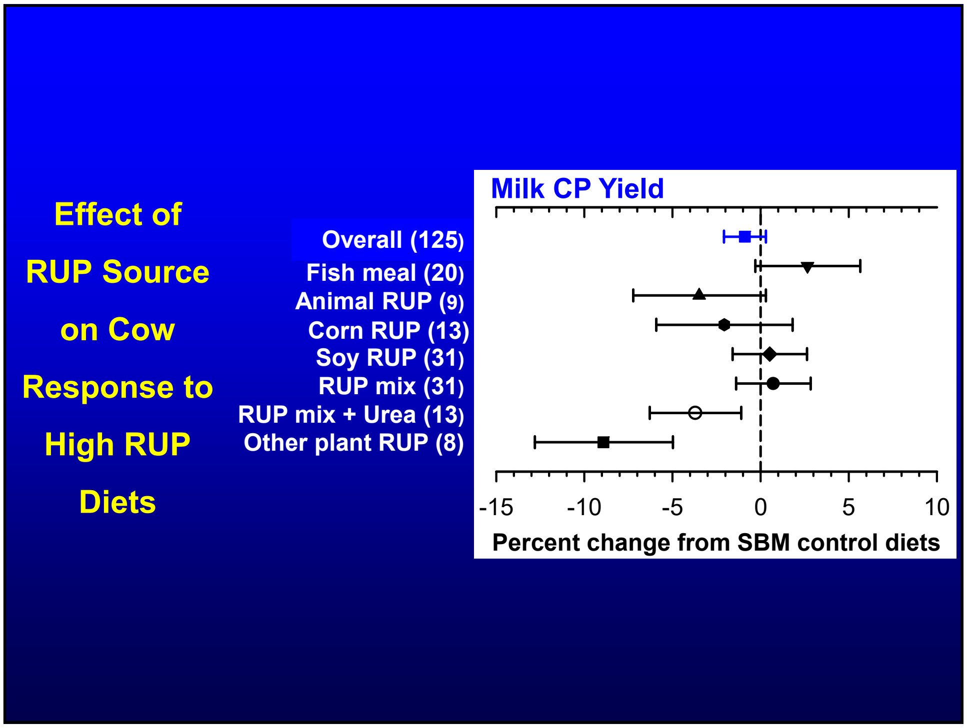
RUP Feed Values Change

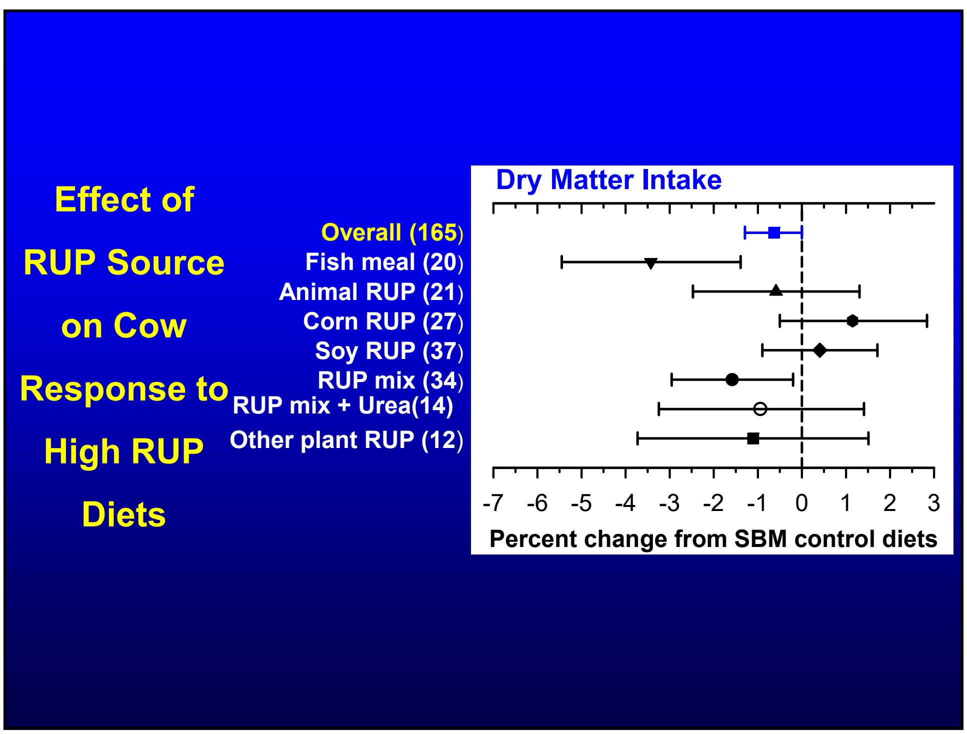
Feed	Percent of CP 2% BW	4% BW
Blood meal	71	77
Distillers grain	42	50
Soybean meal	31	43
Soybeans, roasted	29	39
Alfalfa hay, immature	20	21
Corn silage	33	35



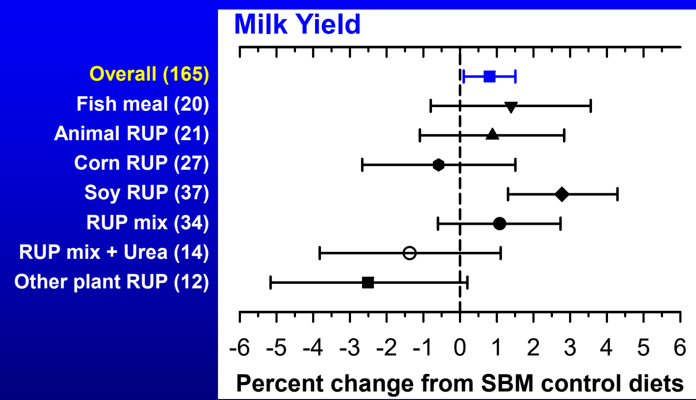
Responses to Sources of RUP
(Dr. Jimmy Clark, U of IL)

- Research review by Illinois researchers and published in Journal of Dairy Science
- Analysis based on published research using soybean meal as the control protein source
- Values that do not cross the zero line are statistically difference


Effect of
RUP Source
on Cow
Response to
High RUP
Diets
Milk CP Yield
Overall (125)
Fish meal (20)
Animal RUP (9)
Corn RUP (13)
Soy RUP (31)
RUP mix (31)
RUP mix + Urea (13)
Other plant RUP (8)
-15
-10
-5
0
5
10
Percent change from SBM control diets


Effect of
RUP Source
on Cow
Response to
High RUP
Diets
Dry Matter Intake
Overall (165)
Fish meal (20)
Animal RUP (21)
Corn RUP (27)
Soy RUP (37)
RUP mix (34)
RUP mix + Urea(14)
Other plant RUP (12)
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
Percent change from SBM control diets

Effect of RUP Source on Cow Response to High RUP Diets



FeedVal v6.0 Protein Feeds (U of WI)

(August, 2017)

	Price	Breakeven
• Soybean meal (48%)	$321	$386
• Blood meal	$1125	$968
• Canola meal	$249	$330
• Wet brewers (25%)	$45	$70
• Distillers grain	$ 96	$289
• Cottonseed meal	$248	$336
• Corn gluten meal	$535	$590
• Raw soybeans	$320	$318
• Heat treated soybeans	na	$480

Factor 5:
Milk Urea Nitrogen (MUN) Applications

Action in the Rumen

- RDP and soluble protein degrades in the rumen at variable rates and amounts to ammonia
- If ammonia is too high or the bacteria can not capture, the ammonia is absorbed/transferred to the blood
- Liver converts toxic ammonia to urea and it appears as blood urea nitrogen

Action in the Blood

- BUN (blood urea nitrogen) can be recycled via saliva or excreted in the urine or milk
- MUN levels lags BUN levels by two hours
  - Relationship of feeding to milk time is critical
  - Variation in feed intake and feeding time will influence MUN

Interpreting MUN Values

- Normal values range from 10 to 14 (Illinois 8 to 12)
- Values under 7 and over 16 may be an indication of a potential problem
- Develop a "normal" MUN profile for the herd (lab, milking, and feeding pattern)
- Normal variation: + / - 3 MUN units

MUN Management Factors

- If MUN are over 16 mg/dl
  - Check level of protein
  - Amount of degraded /soluble protein
  - Level of rumen fermentable carbohydrates
  - May reduce fertility in cows
- If less than 8 mg/dl
  - Manure scores (should be number 3)
  - Milk protein percentage (> 3% for Holsteins)
  - Level and forms of protein and carbs

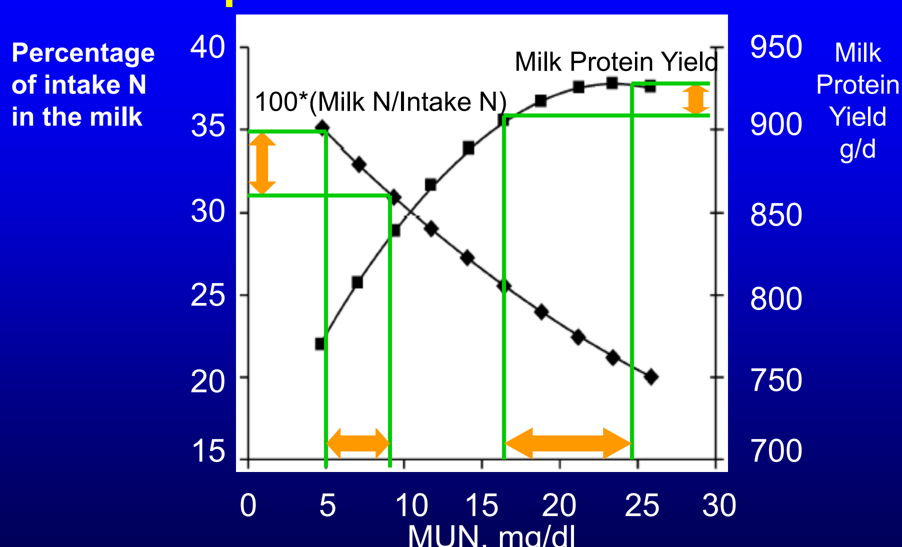
Confirming MUN Values

- Check ration total protein, RDP, and soluble protein levels
- Measure ration sugar and starch levels
- Evaluate milk protein levels and ratio between fat and protein test
- Review manure consistency

Economics of MUN (Wisconsin)

- **Urinary excretion of nitrogen: B.W. x 0.0129 x MUN**
- **1500 cow with 14 MUN excretes 271 grams of nitrogen**
- **1500 cow with 10 MUN excretes 194 g of N**
- **Difference of 77 gram of nitrogen = 2.2 lb SBM-48%**
- **Value of 2.2 pounds of soybean meal can be 40 to 50 cents per cow per day**

Optimal MUN for What ?



Nousiainen et al., 2004

Factor 6: Impacting Milk Protein Production

Causes of Low Milk Protein
(Protein Considerations)

- Lack of rumen degradable protein (RDP) in the diet
  - Decreases synthesis of microbial protein and VFA
- Low in rumen undegraded protein (RUP) in the diet
  - Cows become deficient in metabolizable protein (absorbed amino acids)
- Poor quality RUP
  - Metabolizable protein not balanced for amino acid levels

Causes of Low Milk Protein
(Energy Considerations)

- Overfeeding fermentable starch and sugars /underfeeding *pe*NDF
  - Decreases rumen pH
  - Decreases production of microbial protein
  - Decreases RDP in diet
- Overfeeding fat (particularly unprotected oils)
  - Inhibitory to bacterial activity…decreases production of microbial protein

Causes of Low Milk Protein
(Non-Nutrient Factors)

* Spoiled and/or contaminated feed (elevated mycotoxins, molds, and yeast counts)
  - Inhibitory to bacterial activity…decreases production of microbial protein and VFA
- Inconsistent feeding frequency or poor bunk management
  - Constantly challenging rumen bacteria and preventing maximal growth

Factor 7: Amino Acid Balancing Considerations

Amino Acid Supplementation

Herds / cows producing over 2.5 lb of true protein per day

- 80 lb x 3.1%--Holsteins
- 60 lb x 4.1%--Jerseys

Possible benefits of feeding rumen-protected amino acids

1. Milk protein increase
   - About 0.1 percentage unit
   - Usually occurs within 3 days
   - Usually occurs when ruminally undegradable protein is low in Met &/or Lys
2. Milk yield increase
   - 0 to 5lb/cow/day
   - Usually occurs only during early lactation
3. Milk fat increase
   - 0 to 0.2 % unit when RPMet is fed
   - Response may be restricted to RPMet products that are partially degraded in the rumen

Rumen Protected Methionine

- Field cost varies from 2.0 to 2.6 cents per gram of RPMeth
- Bioavailability varies from 60 to 80% based on rumen protection and intestinal digestibility
- Market share is controlled by two major suppliers totaling 74%
- Estimated that 15 to 25% of the cows in the U.S. are supplemented with RPMeth—more in the Midwest

Rumen Protected Lysine

- Field cost varies from 2.6 to 2.8 cents per gram of RPLy
- Bioavailability varies from 50 to 52% based on rumen protection and intestinal digestibility
- Estimated that 15 to 20% of the cows in the U.S. are supplemented with RPLy

Factor 8: Breeding for Pounds of True Protein

Take Home Messages

- Metabolizable protein is an improvement over crude or digestible protein.
- Need a computer rumen based modelling program to calculate metaboliizable protein (MP).
- Meeting amino acid requirements is more important than metabolizable protein.
- RUP values vary based on dry matter intake, rate of feed passage, and source.
- Check other factors that can impact amino acid yield (dry matter, environment, and genetics)

Milk Fatty Acids: The Building Blocks of Fat

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SilagePro®
American Farm Products

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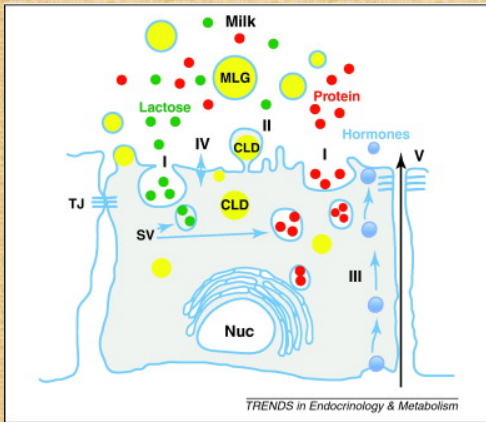
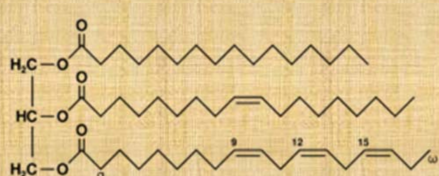
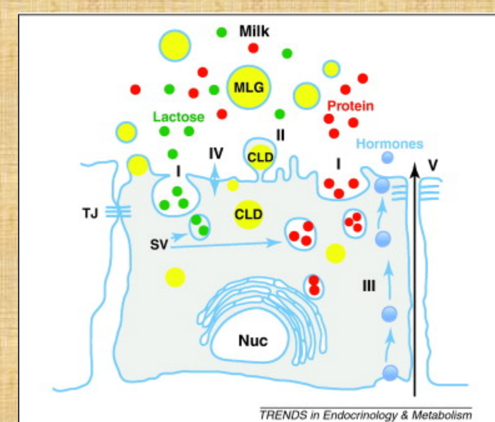
The mammary cell has evolved to provide nourishment for the calf

 2

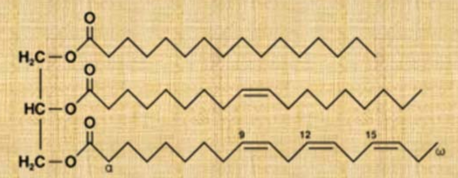


Milk fat is encased in membrane to ensure it passes to the small intestine

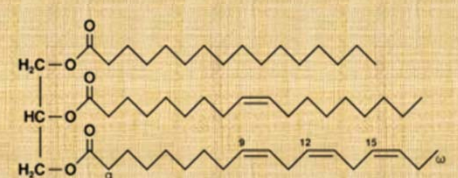




Most fat in milk is in the form of triglycerides



The mammary cell is a very big place. How do FA come together?



The mammary cell is a very big place. How do FA come together?

MS ID#: JBC/2017/781815
Title: Acute Acinar Pancreatitis Blocks Vesicle-Associated Membrane Protein 8 (VAMP8)-Dependent Secretion Resulting in Intracellular Trypsin Accumulation

Elaina K. Jones, PhD Candidate
University of Wisconsin
FARME Institute Board member

Fatty acid trafficking is poorly understood

There may be a hormone component to this

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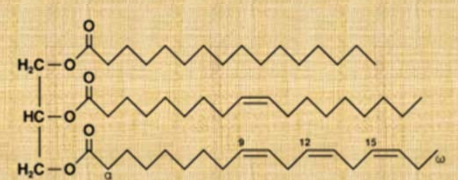
Table 4. Average triglyceride composition of milk fat, expressed as total carbon number.[1]

Total fatty acid carbon number	Average range (wt%)
C26	0.1–1.0
C28	0.3–1.3
C30	0.7–1.5
C32	1.8–4.0
C34	4–8
C36	9–14
C38	10–15
C40	9–13
C42	6–7
C44	5–7.5
C46	5–7
C48	7–11
C50	8–12
C52	7–11
C54	1–5

[1]Adapted from Kaylegian and Lindsay (1995). Note lowering effect of 4:0 to 10: on carbon numbers.



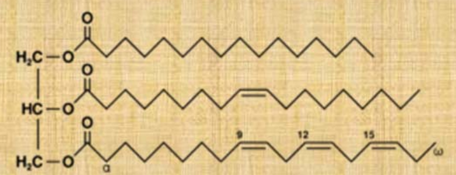
There are a small number of triglycerol molecules that make up milk fat

 8

sn-1
- 56.2% of 18:0
- 59.3% of 18:1
- 44.4% of 16:0

sn-2
- 43.5% of 8:0
- 51.4% of 10:0
- 59.8% of 12:0
- 62.2% of 14:0
- 43.1% of 16:0

sn-3
- 98.1% of 4:0
- 93.2% of 6:0
- 52.5% of 8:0
- 27.8% of 18:0
- 41.3% of 18:1



The distribution of FA on the triglyceride are not random

Chain Length	*sn1*	*sn2*	*Sn3*
34	16	14	4
36	16	14	6
38	16	14	8
40	16	14	10
42	16	8	18
44	18	8	18
48	18	16	14
50	18	16	16
52	18	16	18

25%	C4-C14
37.5%	C16
37.5%	C18

In this case, if you add more C18, do you expect more milk fat?

Chain Length	*sn1*	*sn2*	*sn3*
34	16	14	4
36	18	14	4
38	16	14	8
40	18	14	8
42	16	8	18
44	18	8	18
48	18	16	14
50	18	16	16
52	18	16	18

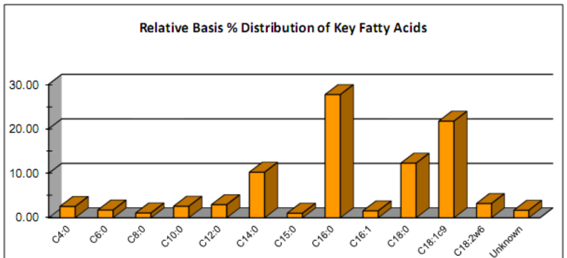
Additional C18, limited C4-C16

26% C4-C14
35% C16
39% C18

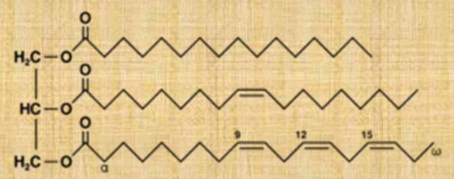
Less C16, more C4-C14

Chain Length	*sn1*	*sn2*	*sn3*
34	16	14	4
36	18	14	4
38	16	14	8
40	18	14	8
42	16	8	18
44	18	8	18
48	18	16	14
50	18	16	16
52	18	16	18

The cell does not make random triglycerides!

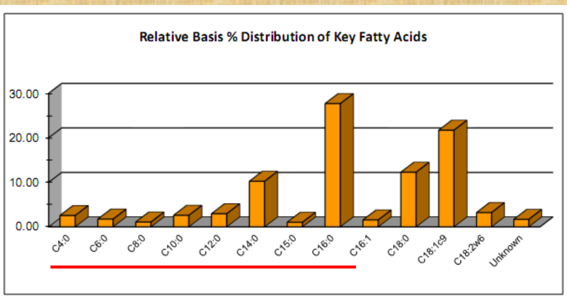


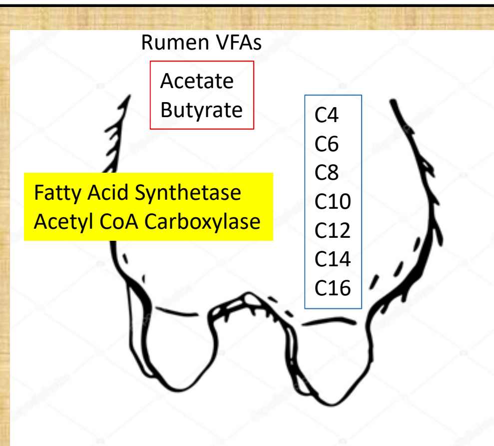
CVAS Milk Fatty Acid Graph



What are the sources of milk fatty acids?

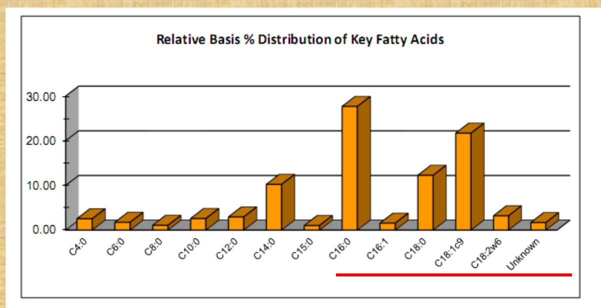
 13

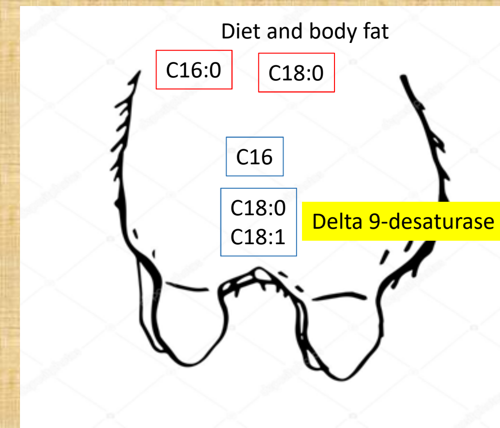




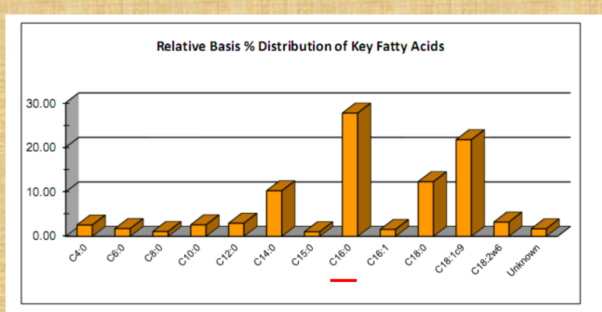
De novo – made in the mammary gland

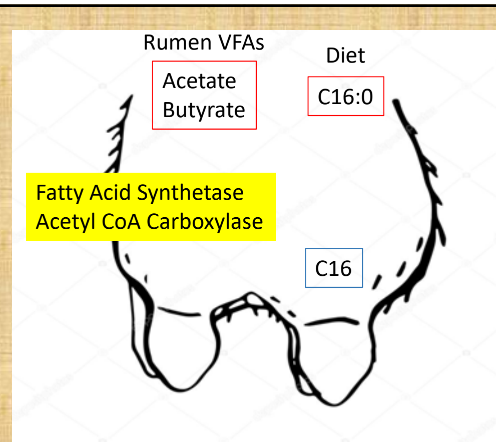
 14



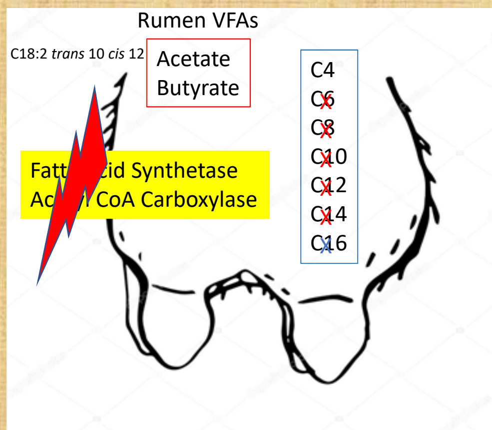


Preformed – made outside mammary gland





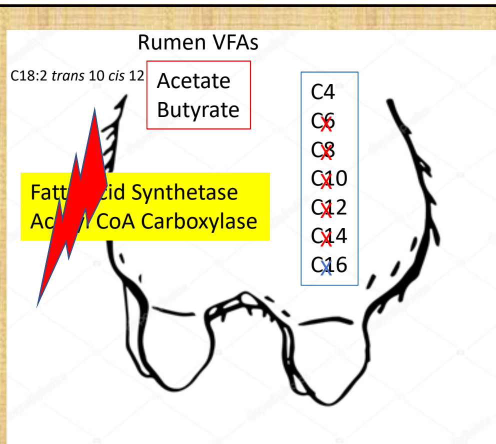
Mixed – C16 both *de novo* and preformed



Chain Length	*sn1*	*sn2*	*Sn3*
34	16	14	4
36	16	14	6
38	16	14	8
40	16	14	10
42	16	8	18
44	18	8	18
48	18	16	14
50	18	16	16
52	18	16	18

Classical Milk Fat Depression

 17



Chain Length	*sn1*	*sn2*	*Sn3*
34	16	14	4
36	16	14	6
38	16	14	8
40	16	14	10
42	16	8	18
44	18	8	18
48	18	16	14
50	18	16	16
52	18	16	18

Classical Milk Fat Depression

This will not respond to supplemental fat (c16 or C18)

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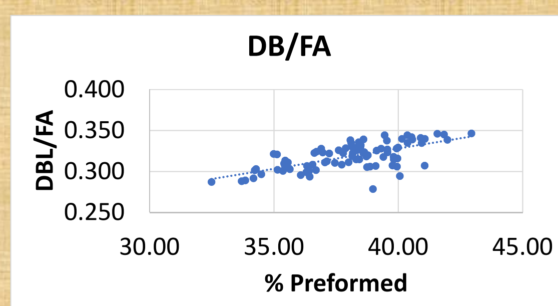
	Fat	Lactose	Protein	De Novo	Mixed	Preformed	De Novo	Mixed	Preformed		
Milk	g/100 g milk						g/100 g FA			# carbons	dbl/FA
85	3.3	4.65	2.94	0.73	1.07	1.31	23.34	34.41	42.25	14.73	0.33
85	3.4	4.63	2.90	0.74	1.13	1.37	22.76	34.87	42.37	14.73	0.33
85	3.9	4.6	3.09	0.88	1.31	1.44	24.15	36.26	39.59	14.73	0.32
85	3.9	4.7	3.04	0.81	1.28	1.54	22.28	35.17	42.56	14.8	0.34
85	4.1	4.63	2.99	0.85	1.35	1.63	22.19	35.26	42.55	14.81	0.33
85	3.9	4.67	2.84	0.84	1.3	1.60	22.36	34.91	42.73	14.76	0.33
85	3.5	4.33	2.96	0.75	1.21	1.37	22.56	36.2	41.25	14.79	0.33

Bulk Tank Milk Fatty Acid Analysis

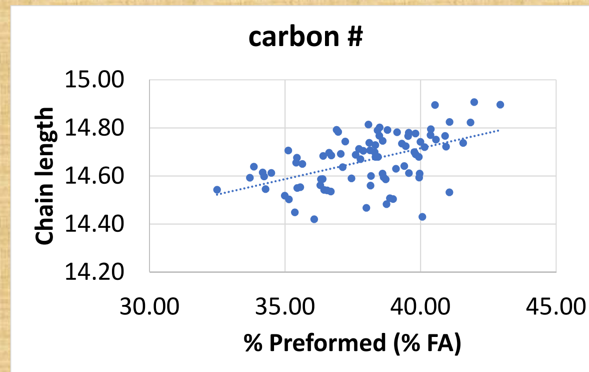
dbl/FA
0.33
0.33
0.32
0.34
0.33
0.33
0.33



Double Bonds per FA is a function of % Preformed

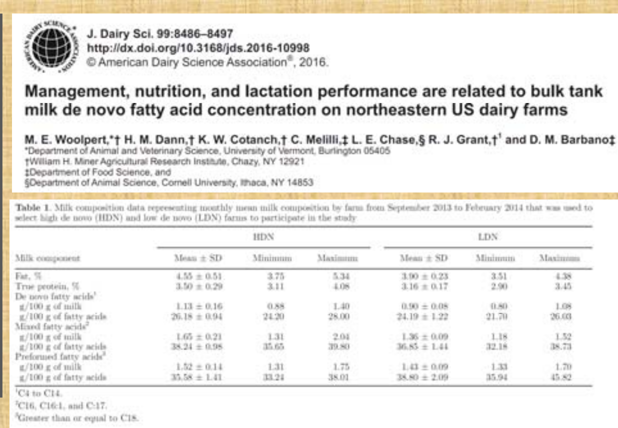
90% of C18:1 *cis* 9 is made by the mammary gland

carbons
14.73
14.73
14.73
14.8
14.81
14.76
14.79



Chain length is a function of % Preformed FA

De Novo	Mixed	Preformed
g/100 g FA		
23.34	34.41	42.25
22.76	34.87	42.37
24.15	36.26	39.59
22.28	35.17	42.56
22.19	35.26	42.55
22.36	34.91	42.73
22.56	36.2	41.25



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Management, nutrition, and lactation performance are related to bulk tank milk de novo fatty acid concentration on northeastern US dairy farms

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Table 1. Milk composition data representing monthly mean milk composition by farm from September 2013 to February 2014 that was used to select high de novo (HDN) and low de novo (LDN) farms to participate in the study

Milk component	HDN Mean ± SD	HDN Minimum	HDN Maximum	LDN Mean ± SD	LDN Minimum	LDN Maximum
Fat, %	4.55 ± 0.51	3.75	5.34	3.90 ± 0.23	3.51	4.38
True protein, %	3.50 ± 0.29	3.11	4.08	3.16 ± 0.17	2.90	3.45
De novo fatty acids[1]						
g/100 g of milk	1.13 ± 0.16	0.88	1.40	0.90 ± 0.08	0.80	1.08
g/100 g of fatty acids	26.18 ± 0.94	24.20	28.00	24.19 ± 1.22	21.70	26.03
Mixed fatty acids[2]						
g/100 g of milk	1.65 ± 0.21	1.31	2.04	1.36 ± 0.09	1.18	1.52
g/100 g of fatty acids	38.24 ± 0.98	35.65	39.80	36.85 ± 1.44	32.18	38.73
Preformed fatty acids[3]						
g/100 g of milk	1.52 ± 0.14	1.31	1.75	1.43 ± 0.09	1.33	1.70
g/100 g of fatty acids	35.58 ± 1.41	33.24	38.01	38.80 ± 2.09	35.94	45.82

[1] C4 to C14.
[2] C16, C16:1, and C17.
[3] Greater than or equal to C18.

Fatty acids as a percent of fatty acids

A + B + C = 100%, If A increases, C must decrease

	Fat	Lactose	Protein	De Novo	Mixed	Preformed
Milk	g/100 g milk					
85	3.3	4.65	2.94	0.73	1.07	1.31
85	3.4	4.63	2.90	0.74	1.13	1.37
85	3.9	4.6	3.09	0.88	1.31	1.44
85	3.9	4.7	3.04	0.81	1.28	1.54
85	4.1	4.63	2.99	0.85	1.35	1.63
85	3.9	4.67	2.84	0.84	1.3	1.60
85	3.5	4.33	2.96	0.75	1.21	1.37

Core Bulk Tank Milk Fatty Acid Analysis

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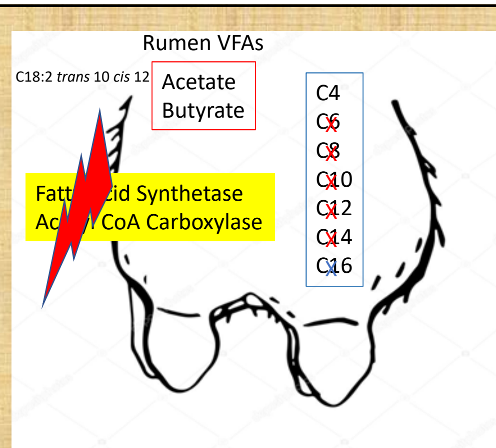
	Fat	Protein	de novo	Mixed	Preformed
Average	3.15	3.02	0.71	1.08	1.17
Expected based on fat	3.15	2.92	0.69	1.14	1.14
Goal	3.57	3.02	.81	1.28	1.28



Low fat, normal protein

CLA induced MFD, no rumen effect

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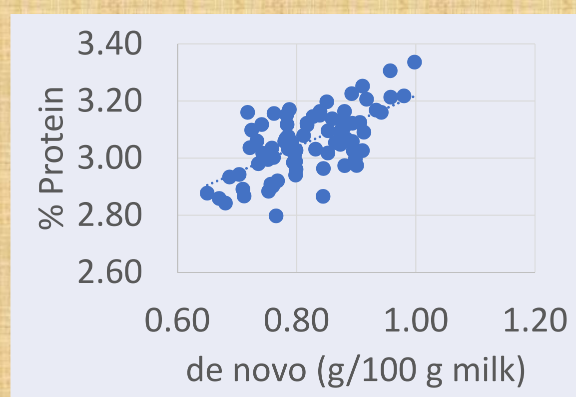
%(m/m) Fat D	%(m/m) Lactose	%(m/m) Protein	Denovo g/100 g	Mixed g/100 g	Preformed g/100 g
3.98	4.65	3.09	0.92	1.44	1.36
3.84	4.64	3.05	0.88	1.40	1.29
3.79	4.63	3.05	0.88	1.40	1.25
3.89	4.70	3.07	0.90	1.43	1.31
3.97	4.71	3.08	0.92	1.47	1.33
3.90	4.67	3.07	0.90	1.43	1.31
Benchmarks		3.30	0.92	1.38	1.38

Supplemental C16 will reduce C16 made *de novo*, thereby increasing the C4-C14 fatty acids.

High fat compared to protein, high C16

High Palm Fat

	% Protein	% Fat	% de Novo	% Mixed	% Preformed
Mean	2.98	3.66	0.74	1.26	1.42
Reference	3.10	3.93	0.90	1.41	1.41



Low fat and low protein, CLA not suspected

Need more acetate and butyrate from the rumen

			Denovo	Mixed	Preformed
	Fat	Protein	g/100 g		
Mean	3.52	3.14	0.86	1.28	1.15
Goal	3.71	3.14	0.88	1.31	1.31

Mammary cells need more long chain fatty acids for higher milkfat. These need to be supplemented or spared!

Low fat, normal protein, low preformed

Competition between liver and mammary gland for energy

Severe milk fat depression is usually caused by "toxic" trans fatty acids inhibiting *de novo* fatty acid synthesis

Mild milk fat depression with equally depressed protein is usually a poor rumen fermentation.

Fatty Acids are the building blocks of milk fat

Cause #1 - Poor *de novo* synthesis

Adding Palm Fat (C16) will usually reduce *de novo* synthesis of C16. Acetate and butyrate will be spared to build more C4-C14

Feeding Palm Fat often masks poor rumen fermentation. Protein usually does not respond. IOFC usually goes down.

Fatty Acids are the building blocks of milk fat

High Palm Fat supplementation can artificially support milk fat

Preformed fatty acids are low when long chain fatty acids are used elsewhere. Or not supplied.

Preformed fatty acids will be high when cows are losing weight.

Fatty Acids are the building blocks of milk fat

Low Preformed Fatty acids are caused by a low energy status

Milk Fatty Acids:
The Building Blocks of Fat

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Canola Meal versus Soybean Meal in Dairy Cow Diets

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Spencer A. E. Moore, University of Wisconsin, Madison, WI

The past decade has given rise to a shift in the paradigm around feeding protein to dairy cattle. This can be attributed to a greater understanding of dairy cattle protein requirements, desire to reduce ration costs through increased efficiency, and reduction in the environmental impact of dairy cattle waste. The use of oilseed crop by-products as animal feed is an effective way to feed dairy cattle and supply required nutrients, specifically protein. Two of these popular oilseed by-products used in dairy systems include canola and soybean meals. While soybean meal has long been a staple in North American dairy rations, the popularity of canola meal inclusion is on the rise due to an increase in canola production, particularly in Canada. The increased availability of this quality animal feed has necessitated research efforts to evaluate its value in dairy production systems. To fully utilize canola meal in an optimized system, there is a knowledge gap surrounding amino acid function, supply, and interactions within dairy cow physiology.

Canola is a variety of rapeseed. A member of the *Brassica* genus, it is bred to produce an edible oil fraction and protein feed suitable for livestock. Two endemic compounds to rapeseed, glucosinolates and erucic acid, negatively impact the use of oil and meal fractions for human or animal consumption via toxicity and decreased palatability (Tripathi and Mishra, 2007). It was not until the mid-1970s that Canadian plant breeders were able to develop cultivars low in these 2 compounds, increasing the use of canola products (Stefansson and Kondra, 1975). The nomenclature “canola,” “double-low” rapeseed, or “double-zero” rapeseed is used to identify these improved varieties from their less desirable counterparts. Meal glucosinolate levels of <30 μmol/g and oil erucic acid levels of <2% denote high quality rapeseed (Canola Council of Canada, 2015).

Canola meal has been shown to be a quality protein by-product when used as an animal feedstuff. Its position in the marketplace and use in dairy cow rations will be supported by evaluating the production response of cows fed canola meal compared directly to other protein by-products and how the nutrient fractions of canola meal behave in the dairy cow. In an evaluation of solvent-extracted canola meal from 11 different North American plants, crude protein ranged from 40.6 to 43.7% of DM over a 4-year period (Table 1; Adewole et al., 2016). Soybean meal values, on the other hand, tended to fall between 46.3 ans 55.9% DM (Table 1; Dairy One, 2016). Canola has a considerably larger NDF fraction (Table 1; 27.4 to 30.9% of DM; Adewole et al., 2016), whereas soybean meal tends to fall within 7.8 to 19.2% NDF, % of DM (Table 1; Dairy One, 2016). The RUP fraction of canola ranged from 32.3 to 46.1% of CP, with a mean of 41.0% RUP, % of CP when evaluated in situ (Table 1; Jayasinghe et al., 2014). A comparison sample of solvent extracted soybean meal was tested, and the RUP fraction was 31.0% of CP (Table 1; Jayasinghe et al., 2014).

Table 1. Canola versus soybean meal nutrient composition and digestibility.

	Canola meal		Soybean meal	
Item	**Mean**	**Range**	**Mean**	**Range**
Crude protein	41.7[a]	40.6 - 43.7[a]	51.1[b]	46.3 - 55.9[b]
Ether extract	3.5[a]	2.8 - 4.0[a]	4.38[b]	0.0 - 9.1[b]
Ash	7.5[a]	7.2 - 8.0[a]	7.3[b]	5.9 - 8.6[b]
NDF	29.4[a]	27.4 - 30.9[a]	13.5[b]	7.8 - 19.2[b]
RDP, % of CP	59.0[c]	53.9 - 67.7[c]	69.0[c]	-
RUP, % of CP	41.0[c]	32.3 - 46.1[c]	31.0[c]	-
IDP[1], % of RUP	74.8[c]	71.6 - 77.4[c]	94.5[c]	-

[1]Indigestible protein.
[a]Adewole et al. (2016).
[b]Dairy One (2016).
[c]Jayasinghe et al. (2014).

When similar samples were evaluated in vitro the mean RUP was slightly higher; approximately 44.0% RUP, % of total N for canola meal compared to solvent extracted soybean meal with 34.9% RUP, % total N (Broderick et al., 2016). While a higher proportion of canola meal CP reaches the small intestine, the availability of this protein fraction is less than soybean meal. Intestinally digestible protein (IDP) ranged from 71.6% to 77.4% when evaluated using a modified 3-step in situ/in vitro procedure, whereas soybean meal was 94.5% IDP, % of RUP (Table 1; Jayasinghe et al., 2014). These values are similar to those determined by the National Research Council, 75% for canola meal and 93% for soybean meal (NRC, 2001).

AMINO ACIDS

Our current understanding stipulates the inclusion of lysine (Lys) and methionine (Met), the first 2 limiting amino acids (AA), at a ratio of 3:1 to maximize the use of metabolizable protein for milk production (NRC, 2001; Liu et al., 2013). The AA profile of canola meal includes a ratio of Lys to Met of 3.01:1, whereas soybean meal has a ratio of 4.37:1 (NRC, 2001). Additionally, enriching diets with Lys and Met during the transition period (3 weeks prepartum to 3 weeks postpartum) increased daily milk yield 0.68 kg/d and milk protein 80 g/d throughout the first 16 weeks of lactation (Garthwaite et al., 1998; Grummer, 1995; Liu et al., 2013). Formulating diets for AA pre-calving resulted in an even greater production response, 2.27 kg/d milk, 112 g/d milk protein, and 115 g/d milk fat, than for animals not supplemented with additional AA (Garthwaite et al., 1998; Liu et al., 2013). This indicates further evaluation of ration AA profiles during the pre-calving and early-lactation periods is needed. While there is considerable research surrounding Lys and Met balances in dairy cows, there is growing evidence suggesting AA interactions contribute to performance responses and efficiencies. Formulating for AA reduces dietary requirements for RUP and may improve health status (Liu et al., 2013; Schwab, 2017). In terms of AA nutrition, Lys and Met balance in early lactation has increased glutathione and carnitine concentration in liver, thereby increasing beta-oxidation capacity and antioxidant prevalence (Osorio et al., 2014; Schwab, 2017). In addition, Met supplementation affects methyl donor (i.e. S-adenosylmethionine) and antioxidant (glutathione) availability (Osorio et al., 2014). S-adenosylmethionine is an active methyl donor, responsible for gene regulation and expression. In addition, there is increased liver inflammation during early lactation negative energy balance, and this decreases productive efficiency. Understanding the relationships between AA and their contributions to health and efficiency is important to delineating the production response observed when feeding canola meal and its value in the industry. Understanding this phenomenon will be advantageous in leveraging the favorable essential AA profile of canola meal to meet dairy cow requirements and efficiency of protein feeding. This could prove especially vital when intakes are low and animals are particularly responsive to essential AA supplies, such as in early lactation.

In the 2011 meta-analysis, which included 292 treatment means from 122 peer-reviewed studies, DMI, milk yield, and energy-corrected milk were greater for canola meal-fed cows, compared to those fed soybean meal (Huhtanen et al., 2011). Dry matter intake was 2.6 ± 0.03 kg/d greater with canola meal vs. soybean meal. Milk yield and energy-corrected milk increased 3.6 ± 0.25 kg/d and 5.0 ± 0.29 kg/d, respectively (Huhtanen et al., 2011). When feeding isonitrogenous rations that compared soybean meal and canola meal, an increase in milk yield tended to fall in the range of 0.59 to 1.32 kg/d with canola meal in mid-lactation animals (Broderick and Faciola, 2014; Broderick et al., 2015; Marostegan de Paula et al., 2015). The effect of feeding canola meal to cows in early lactation has been limited until recently.

EARLY LACTATION

During the transition period, AA and glucogenic compounds are not consumed in adequate quantities resulting in negative nutrient balances (Drackley, 1999; Ji and Dann, 2013). In addition, the adoption of lower energy and protein diets in early lactation necessitates the evaluation of metabolizable protein quality for transition cow health (Overton and Burhans, 2013). The ability of the cow to make a shift from pregnancy to lactation, efficiently and without incident, will contribute dramatically to her production potential. We conducted an experiment with 79 multiparous Holstein cows that received high protein (17.6% CP, % of DM) or low protein (15.4% CP, % of DM), where the main protein supply was provided by either canola or soybean meal. Diets were formulated to contain 55.0% forage (39.6% corn silage, 15.4% alfalfa silage) and 45% concentrate mix on DM basis. Canola meal was included at 19.4% and 11.9% DM, whereas soybean meal was included at 14.5% and 8.9% DM. Cows were enrolled at calving and production was followed for 16 weeks of lactation. Cows fed canola meal out performed those that received soybean meal, producing (mean ± SEM) 55.7 vs 51.2 ± 0.97 kg/d of milk, respectively (Table 2; Moore and Kalscheur, 2016). This additional production was not supported by a commensurate intake response. Canola meal-fed cows only tended to have higher DMI with 25.8 vs 25.0 ±

0.34 kg/d (Moore and Kalscheur, 2016). This suggests that nutrient utilization efficiency or body reserve turnover contributed to the additional energy required for greater milk production. The source of CP did not affect milk fat, protein, lactose, or total solids percentage. Decreasing dietary CP concentration increased milk fat (4.09 vs 3.90 ± 0.07% and total solids 12.8 vs 12.5 ± 0.95% (Moore and Kalscheur, 2016). Cows fed high protein diets produced greater milk urea N (MUN) than cows fed low protein diets (12.6 vs 9.82 ± 0.22 mg/dL). Milk urea N tended to be lower for cows fed canola meal compared to cows fed soybean meal (10.9 vs 11.4 ± 0.22 mg/dL), consistent with others (Martineau et al., 2014; Broderick et al., 2015). Milk fat, protein, lactose, and total solids were greater for cows fed canola meal in agreement with increased milk production. Energy-corrected milk (ECM) was greater for cows fed canola meal compared to soybean meal (57.6 vs 53.6 ± 0.95 kg/d). Cows fed canola meal exhibited a trend for improved feed efficiency (ECM/DMI) compared to cows fed soybean meal (2.27 vs 2.16 ± 0.38). These data suggest that fluid milk production and efficiency of nutrient conversion to milk can be improved in early lactation with the inclusion of canola meal in dairy rations.

Table 2. Production performance (Moore and Kalscheur, 2016).

Item	LO[1]		HI[1]		SEM	P [2]
	SBM[1]	CM[1]	SBM[1]	CM[1]		
DMI, kg/d	24.6	26.1	25.4	25.6	0.50	ST
Milk yield, kg/d	50.1	54.8	52.3	56.5	1.41	S
ECM,[3] kg/d	53.1	57.4	54.1	57.8	1.36	S
Feed efficiency[3]	2.16	2.22	2.17	2.31	0.06	ST
Milk components						
Fat, %	4.12	4.05	3.89	3.91	0.09	C
Protein, %	2.88	2.85	2.90	2.77	0.05	NS
Fat, kg/d	2.04	2.18	2.04	2.18	0.05	S
Protein, kg/d	1.45	1.54	1.50	1.54	0.05	S
MUN, mg/dL	10.0	9.6	12.9	12.2	0.30	C, ST

[1]LO = 16.3% CP, HI = 18.2% CP, CM = canola meal, SBM = soybean meal.
[2]C = main effect of protein concentration (LO or HI) $P \leq 0.05$, S = main effect of protein source (SBM or CM) $P \leq 0.05$, ST = main effect trend of protein source $0.05 \leq P \leq 0.10$, NS = No significant effect.
[3]Feed efficiency = ECM/DMI where ECM = [0.327 × milk (kg)] + [12.95 × fat (kg)] + [7.20 × protein (kg)].

While canola meal did not affect circulating glucose or beta-hydroxybutyrate concentrations in cows compared to those fed soybean meal, circulating triglyceride concentration was greater for cows fed canola (0.125 vs 0.118 ± 0.002 mM; Moore and Kalscheur, 2017). Efficiency of nitrogen utilization favored canola meal vs soybean meal-fed cows for both circulating plasma urea nitrogen (0.37 vs 0.40 ± 0.01 mM) and concentration of MUN (10.7 vs 11.4 ± 0.24 mg/dL). The increase in milk yield can be attributed in part, to an increase in circulating triglycerides and nitrogen utilization. However, further investigation into the canola meal vs soybean meal milk disparity in early lactation is needed.

ENVIRONMENT

There is a growing interest in mitigating the impact of dairy systems on the environment. Two waste products of particular interest are methane (CH_4) and ammonia (NH_3). While these are 2 inherent by-products of biological systems, there may be strategies to affect dairy cow rumination and nitrogen excretion through feeding strategies. In addition, the positive implications resulting from the inclusion of canola meal use in dairy cow diets will increase use and demand. Therefore, it is important to consider the ancillary implications of greater inclusion of this feedstuff, including if it affects greenhouse gas emissions by the dairy cow. Dietary forage concentration has a great impact on CH_4 production in dairy cattle. Increasing forage to concentrate ratio from 47:53 to 68:32 increased CH_4 production 20% in Wisconsin Holstein cows (Aguerre et al., 2011). When studied in Swedish Red cattle fed grass-based TMR diets, there was a greater reduction in g of CH_4/kg ECM when increasing CP in the diet with heat-treated canola meal vs soybean meal (Gidlund et al., 2015). However, protein source effect on greenhouse gas emission has not been evaluated in traditional Midwestern corn-forage based diets with Holstein cattle. Urinary urea N excreted by the cow increases with increasing concentrations of CP in the diet, resulting in an increase in N loss to the environment in the form of NH_3 and N_2O (Hristov, et al., 2011; Powell et al., 2015). While reducing these waste products is environmentally advantageous, it is important to maintain exceptional milk production. Following the 16-week evaluation of production, 6 blocks (24 cows total; 120.5 ± 2.24 DIM were evaluated in environmental emissions chambers. Cows fed either source or CP concentration of protein did not differ in DMI (26.67

± 0.75 kg/d) or 4% fat-corrected milk (FCM; 53.89 ± 2.04 kg/d; Moore et al., 2016). There was a source by CP concentration interaction for CH_4 emission. Cows fed high protein canola meal diets produced less CH_4 than those consuming high protein soybean meal and low protein canola meal diets (465.7 vs 528.5 and 537.9 ± 28.7 g/d; Moore et al., 2016). Methane expressed per unit of DMI (19.3 ± 1.24) or FCM (9.23 ± 0.71) did not differ among treatments (Moore et al., 2016). Ammonia excretion did not differ between protein sources, contrary to the increased nitrogen use efficiency reflected in the MUN values. Milk N (g/d) was not affected by protein source and NH_3 emission expressed per unit of milk N was not affected by diet. The mechanism by which methane release is lower with canola meal fed diets has yet to be determined. One possibility may include a shift in fiber digestion. Dry matter, organic matter, CP, and NDF digestibility were all greater when feeding canola vs soybean meal at 11.6% and 8.6% of DM on an isonitrogenous basis in multiparous Holstein cows (Marostegan de Paula et al., 2016).

CONCLUSIONS

While changes in markets dictate when canola or soybean meal can be favorably incorporated into dairy cow diets, we have outlined the potential benefits for using canola as a protein source. As further research is needed, canola meal may provide a cost-favorable source of essential AA, specifically in early lactation.

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Replacing Starch with Non-Forage Fiber Sources in Dairy Cow Diets

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INTRODUCTION

Lower dietary inclusion of costly grains can improve income over feed costs and potentially spare cereal grains for other more profitable uses. Non-forage fiber sources (NFFS) have been traditionally recommended to decrease cereal grain starch in the diet since they contain monosaccharides (Miron et al., 2001) and highly digestible fiber that can maintain or even improve the performance of dairy cattle (Bradford and Mullins, 2012). However, the effect of decreasing dietary starch concentration by partially replacing cereal grains with NFFS on the productivity of lactating dairy cows remains debatable.

Previous reviews have described nutritional approaches when NFFS were included into diets of lactating dairy cows. Firkins (1997) described the digestion kinetics of NFFS and determined that dietary NDF from NFFS had more contribution to the total tract NDF digestibility when compared to forage NDF. In addition, Firkins (1997) stated that replacing starch with NFFS increased fiber digestibility because of reduced negative associative effects. More recently, Bradford and Mullins (2012) concluded that when NFFS replaced forages, DMI in cows increased, but physical effectiveness of the diet decreased. The authors specified that the partial replacement of starch with NFFS could optimize nutrient utilization in the cows without compromising animal health.

Published papers from 1982 to 2016 indicated that the replacement of starch in lactating dairy cow diets was achieved mainly by reducing a portion of cereal grains with two or more NFFS – although there are a few studies where cereal grains were replaced with a single NFFS. Therefore, we decided to pool information from 39 peer-reviewed papers to evaluate the relationship between decreased dietary starch intake and performance, rumen fermentation, and total tract nutrient digestion using meta-analysis techniques (Sanchez-Duarte, 2017). In these studies, the NFFS used to replace cereal grain starch included: beet pulp, brewers dried grains, citrus pulp, distillers dried grains with solubles (DDGS), hominy feed, potato pulp, soybean hulls, wheat bran, and wheat middlings. Average dietary starch intake was 5.1 kg/d with a range of 0.32 to 9.08 kg/d. Average intake of CP and NDF were 3.87 kg/d (0.90 to 5.29 kg/d) and 7.35 kg/d (2.42 to 13.82 kg/d), respectively. Regression analysis was performed according to the meta-analysis methodology proposed by St-Pierre (2001).

DAIRY COW PERFORMANCE

Cow performance included DMI, milk production, and concentrations and yields of milk fat and protein (Table 1). Dry matter intake responded quadratically to the increase of dietary starch intake, but milk production increased linearly with starch intake. Increasing dietary starch intake reduced milk fat concentration linearly but increased milk protein concentration linearly. Milk fat yield responded quadratically and milk protein yield increased linearly with increased dietary starch intake. Responses for milk component yields resulted from the combination of increased milk production and their respective milk component concentration.

Figure 1 shows a graphic representation of the relationship between dietary starch intake and production variables. Higher starch intake corresponded to cows fed diets with greater inclusion of grain (27.5% grain inclusion ± 11.5% on DM basis) compared to those cows fed NFFS (25.9% NFFS inclusion ± 11.5% on DM basis). However, as dietary starch intake increased, DMI decreased (Figure 1a), which could be because of subclinical/clinical acidosis (Oetzel, 2003). It is important to point out how increasing the inclusion rate of NFFS in the diets affected the production variables. Cows fed diets with greater NFFS to reduce dietary starch concentration had the lowest DMI (Figure 1a), milk production (Figure 1b), and milk protein concentration (Figure 1d), whereas the same diets increased milk fat concentration (Figure 1c). Lower DMI and milk yield have been observed when sources of NFFS such as wet corn gluten feed (Staples et al., 1984), soybean hulls plus

Table 1. Linear and quadratic regression equations used to measure response to different dietary starch intakes by partially replacing cereal grain with non-forage fiber sources.

Response variable	n[1]	Parameter	Estimate	SE	*P*-value	RMSE
DMI (kg/d)	114	Intercept	19.152	0.9034	<0.0001	0.0292
		Starch	1.105	0.3016	0.0005	
		Starch^2	-0.077	0.0297	0.01	
Milk yield (kg/d)	114	Intercept	31.869	1.1164	<0.0001	0.0261
		Starch	0.339	0.0935	<0.0001	
Milk fat (%)	112	Intercept	3.942	0.0827	<0.0001	0.0388
		Starch	-0.047	0.0106	<0.0001	
Milk fat yield (kg/d)	103	Intercept	1.074	0.0724	<0.0001	0.0224
		Starch	0.047	0.0213	0.03	
		Starch^2	-0.005	0.0020	0.03	
Milk protein (%)	116	Intercept	3.012	0.0437	<0.0001	0.0470
		Starch	0.017	0.0053	0.003	
Milk protein yield (kg/d)	107	Intercept	0.946	0.0368	<0.0001	0.0375
		Starch	0.019	0.0044	0.0003	

[1]Number of observations.

brewer's dried grains (Batajoo and Shaver, 1994), and DDGS (Schingoethe et al., 1999) were used to replace highly digestible carbohydrates. Similar to the effect in the present analysis, the replacement of corn grain with NFFS improved milk fat concentration (Weiss, 2012). The positive response of dietary starch on microbial protein synthesis has been well-documented (Herrera-Saldana et al., 1990; Clark et al., 1992). Cows with high dietary starch intake produce high amounts of microbial protein, which may contribute to increased milk production and milk protein concentration.

RUMEN FERMENTATION

The response of rumen fermentation variables to dietary starch intake is presented in Table 2. Rumen pH and NH_3 concentration were not affected by increasing dietary starch intake, but increased starch intake tended to linearly reduce total VFA and the acetate to propionate ratio. Similarly, acetate concentration in the rumen decreased linearly as dietary starch intake increased. In contrast, increasing starch intake resulted in a linear increase of the concentrations of propionate, isobutyrate, isovalerate, and valerate. It is well known that starch fermentation increases the concentration of propionate (Raun, 1961; Rémond et al., 1995) but decreases acetate concentration in the rumen (Rémond et al., 1995; Gao and Oba, 2016). The increased propionate concentration might have affected DMI since it has been suggested to play an important role in feed intake regulation by affecting satiety and hunger (Oba and Allen, 2003). The increased propionate, valerate, and isobutyrate may explain the increase in milk production in the current meta-analysis. These metabolites are glucogenic precursors for the net synthesis of glucose (Reynolds et al., 2003; Larsen and Kristensen, 2009) used to synthesize lactose, the main determinant of milk production (Aschenbach et al., 2010).

TOTAL TRACT NUTRIENT DIGESTION

The relationship of dietary starch intake and total tract nutrient digestion variables is shown in Table 3. The digestion of DM and CP responded quadratically to dietary starch intake. The digestion of NDF decreased linearly with the increase of starch intake. No relationship was observed between dietary starch intake and digestion of organic matter and starch. The quadratic effect of DM digestibility helps explain the quadratic effect of DMI as dietary starch increased. Even though the NDF digestibility of many NFFS is very high, that fiber contributes to limit feed intake in reduced starch diets, and it may contribute to reduced rate of passage when NFFS are included. In fact, it has been demonstrated that rate of passage of numerous NFFS in lactating dairy cows is similar to the rate of passage from forages (Erdman et al., 1987). The quadratic response of CP intake contributed partially to the increase of milk production when dietary starch intake increased. The negative effect of increasing starch intake on NDF digestibility is well known (Mertens and Loften, 1980), and it is the result of decreasing the fibrolytic activity in the rumen with low pH as dietary starch increases (Hoover, 1986; Lechartier and Peyraud, 2011) – although it was not possible to detect changes in rumen pH in the present analysis. Therefore, the digestibilities of DM, CP, and NDF also help explain the effect of replacing starch with NFFS on DMI, milk production, and milk composition in lactating dairy cows.

CONCLUSIONS

This meta-analysis indicates that reducing starch from cereal grain with NFFS significantly affected cow performance, rumen fermentation, and total tract nutrient digestion. As dietary starch intake increased, DMI responded quadratically, but milk production and milk protein concentration increased linearly. Milk fat concentration however, decreased as dietary starch intake increased. Yields of milk fat and protein responded quadratically and linearly, respectively, as a result of the combination of increased milk production and the respective milk component concentration. This also showed that cows fed diets formulated with NFFS had lower DMI, milk production, and milk protein concentration than cows fed diets high in cereal grains, although those cows produced higher milk fat concentration. Dry matter intake is partially explained by the quadratic effect of DM digestibility in response to increased starch intake, while increased milk production was explicated with the increase of propionate, isobutyrate, isovalerate, valerate, and CP digestibility as an effect of increased dietary starch intake. Milk fat concentration on the other hand, may be an effect of decreasing NDF digestibility in response to increased dietary starch intake. Therefore, cow performance measurements observed in this meta-analysis along with feed cost must be considered when NFFS are used to replace cereal grain starch in diets.

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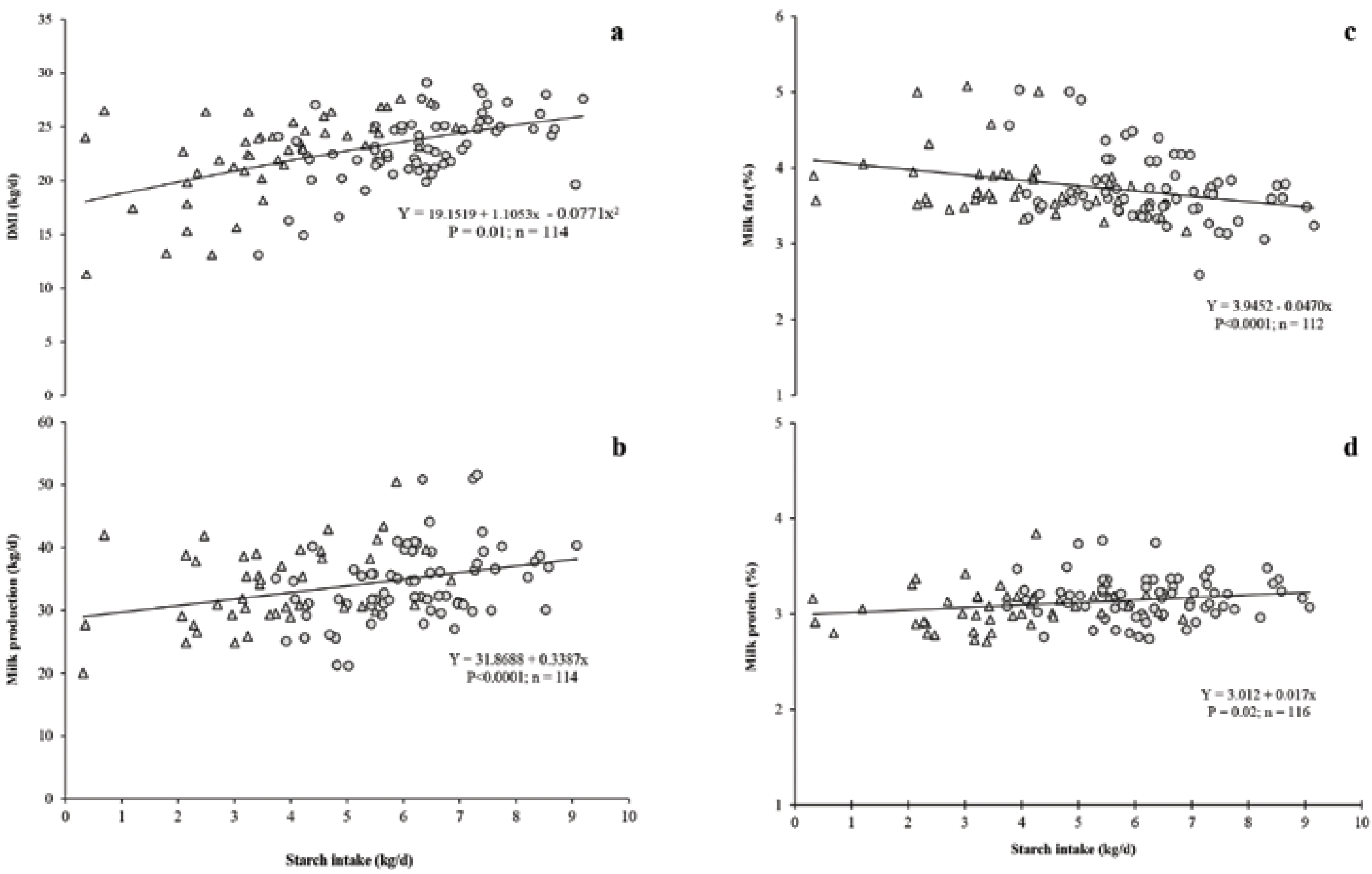

Figure 1. Response of DMI (a), milk production (b), and concentrations of fat (c) and protein (d) in milk to increased dietary starch intake in dairy cows. Observations were adjusted to the random effect of trial. Triangles indicated diets formulated with non-forage fiber sources [25.9 ± 11.5% on DM basis (reduced dietary starch diets)] and circles diets formulated with cereal grains [27.5 ± 11.5% as fed (high dietary starch diets)].

Table 2. Equations for linear regression of rumen fermentation response to different dietary starch intake by partially replacing cereal grains with non-forage fiber sources.

Response variable	n[1]	Parameter	Estimate	SE	*P*-value	RMSE
pH	52	Intercept	6.299	0.0775	<0.0001	0.0373
		Starch	-0.009	0.0073	0.24	
NH_3 (mg/dL)	51	Intercept	12.220	1.7748	<0.0001	0.0735
		Starch	0.026	0.1943	0.89	
Total VFA (*Mm*)	79	Intercept	114.470	4.6885	<0.0001	0.0312
		Starch	-0.810	0.4629	0.09	
Acetate (mol/100 mol)	83	Intercept	66.153	1.3566	<0.0001	0.0416
		Starch	-0.584	0.1430	0.0004	
Propionate (mol/100 mol)	83	Intercept	20.171	0.8907	<0.0001	0.0361
		Starch	0.305	0.1187	0.01	
Butyrate (mol/100 mol)	83	Intercept	12.117	0.5307	<0.0001	0.0314
		Starch	-0.024	0.0663	0.72	
Acetate:propionate	55	Intercept	3.296	0.1139	<0.0001	0.0631
		Starch	-0.049	0.0256	0.06	
Isobutyrate (mol/100 mol)	57	Intercept	0.950	0.1723	<0.0001	0.0233
		Starch	0.039	0.0178	0.03	
Isovalerate (mol/100 mol)	49	Intercept	1.059	0.1859	<0.0001	0.0335
		Starch	0.050	0.0151	0.002	
Valerate (mol/100 mol)	61	Intercept	1.875	0.2528	<0.0001	0.0352
		Starch	0.104	0.0498	0.04	

[1]Number of observations.

Table 3. Linear and quadratic regression of total tract nutrient digestion response to different dietary starch intake by partially replacing cereal grains with non-forage fiber sources.

Response variable (%)	n[1]	Parameter	Estimate	SE	*P*-value	RMSE
DM	69	Intercept	63.059	1.8300	<0.0001	0.0779
		Starch	1.648	0.6879	0.02	
		$Starch^2$	-0.139	0.0651	0.04	
Organic matter	60	Intercept	69.331	1.2163	<0.0001	0.0559
		Starch	0.002	0.1636	0.98	
Starch	45	Intercept	94.485	1.5167	<0.0001	0.0843
		Starch	-0.173	0.2157	0.43	
CP	55	Intercept	61.657	2.3380	<0.0001	0.0368
		Starch	2.286	0.8360	0.01	
		$Starch^2$	-0.229	0.0770	0.005	
NDF	63	Intercept	64.390	1.8187	<0.0001	0.0692
		Starch	-2.351	0.3737	<0.0001	

[1]Number of observations.

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