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Upcoming Conference Dates

June 11 & 12, 2014
June 10 & 11, 2015
June 15 & 16, 2016

Pre-Symposium
Improving Feed Efficiency in Dairy Cattle

Bill Braman, PhD, PAS
C. R. Hansen, Inc.

On behalf of Chr. Hansen and our employees, we welcome you to the Pre-Conference of the 4-State Dairy Nutrition Conference. Chr. Hansen is a global supplier of bioscience based ingredients to the food, health, pharmaceutical and agricultural industries. We are pleased to sponsor this pre-conference focused around feed efficiency for dairy cows.

Feed efficiency has been a major metric used in measuring production and profitability of poultry, swine, and feedlot cattle. Recently, feed efficiency has become a more important measurement in dairy production as feed prices increased from historical levels and with more focus on environmental implications with limited land bases. Dr. Mike Hutjens has spoken to this point for many years at this conference as well as other venues. Dr. Hutjens has used an optimal range of 1.4-1.8 lbs. FCM/lb. of dry matter intake as optimal. However, there are many other metrics which can be used that may more closely relate to a specific desired outcome.

Gross feed efficiency is some ratio of feed required to produce a certain amount of milk. How we define milk outputs and feed inputs leads to many different definitions of feed efficiency. Milk output can be defined in terms of yield (milk, fat, and/or protein), cheese yield, milk energy, and milk dollars. Feed inputs can be defined as gross, digestible, metabolizable, or net energy; dollars; and other methods. Our panel of consultants will explore these various metrics as well as other non-traditional measurements.

Measuring feed efficiency in an economic form is challenging and not constant. It involves fluctuating market conditions, biological issues related to feed production, and manipulating cattle biology and herd structure.

In this conference we will explore and identify biological tools to improve feed digestibility, animal performance and improve feed quality and preservation. Feed additives and silage inoculants are tools to increase dairy feed efficiency. As earlier mentioned, our panel of consultants will provide insight into putting feed efficiency to work on the dairy operation. Criteria such as collecting and measuring data, interpreting data, and implementation of measures to improve feed efficiency are addressed.

Changes in feed efficiency should be monitored to evaluate the impact of feeding and management changes on a dairy operation. However, comparisons between herds should be done very carefully.

On behalf of Chr. Hansen we thank you for participating in these pre-conference presentations. The use of dairy feed efficiency as a management decision tool will continue to evolve as a key metric for modern dairy production.

Chr. Hansen Welcomes You to the 4-StatePre-Conference

Improving Feed Efficiency in Dairy Cattle

Bill Braman, PhD, PAS
Chr Hansen, Inc.


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Every day millions of people consume products containing our ingredients
In food and beverages
And in other applications:
Probiotics for dietary supplements, infant formula and pharmaceuticals
Probiotic feed additives and silage inoculants
freeze dried cultures
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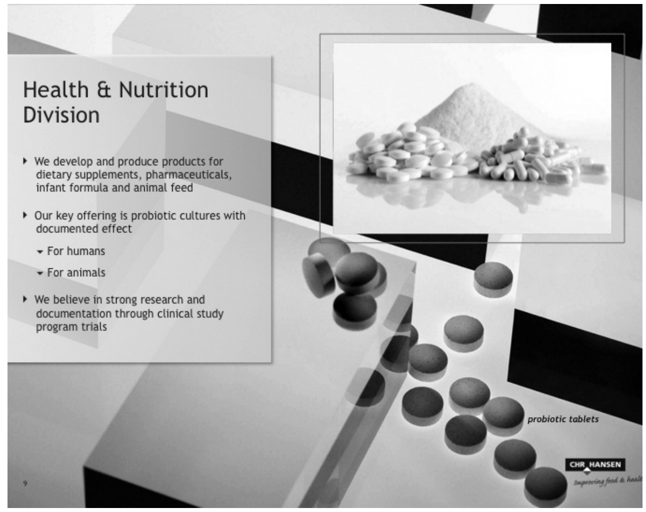
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We develop and produce products for dietary supplements, pharmaceuticals, infant formula and animal feed
Our key offering is probiotic cultures with documented effect
For humans
For animals
We believe in strong research and documentation through clinical study program trials
probiotic tablets
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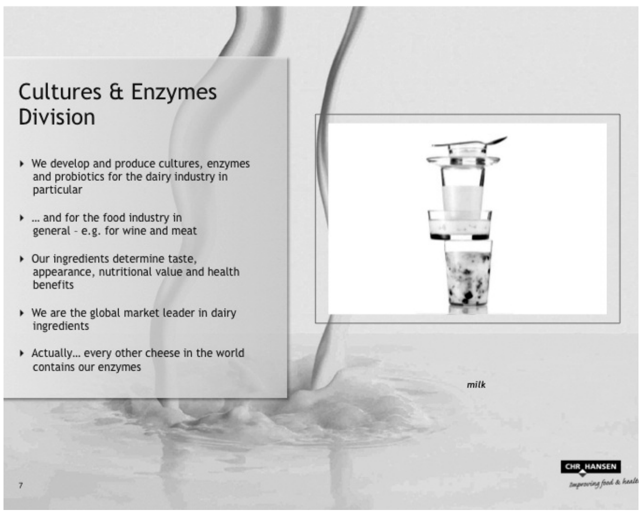
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We develop and produce cultures, enzymes and probiotics for the dairy industry in particular
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We are the global market leader in dairy ingredients
Actually… every other cheese in the world contains our enzymes
milk
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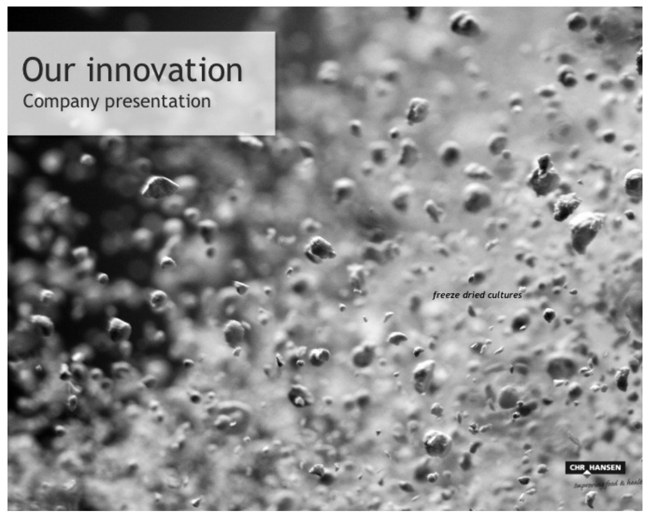
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Company presentation
freeze dried cultures
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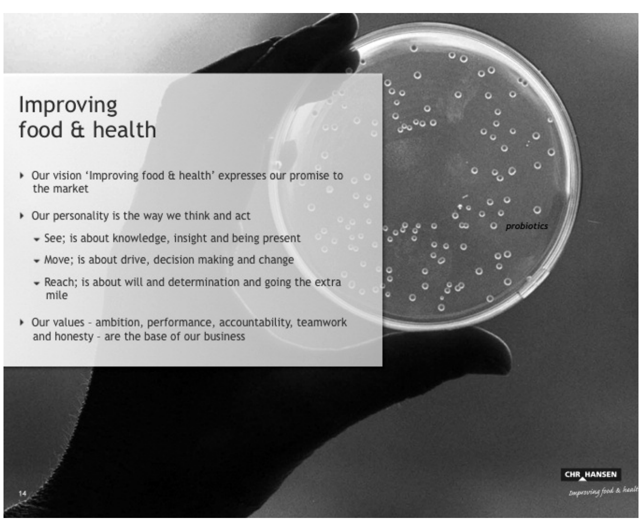

Improving Feed Efficiency in Dairy Cattle

Importance?

- Hutjens – Optimal range of 1.4-1.8 lbs. FCM/lb. DM intake
- Affected by days in milk, age, growth, changes in body condition score, body weight, forage quality,
- Influenced by feed additives and environmental factors that impact feed efficiency values.
- Feed efficiency has implications on the environmental-manure volume, N, P, etc.
- Improving feed efficiency almost always improves profitability

Defining Feed Efficiency in dairy cattle

- Gross feed efficiency is some ratio of feed required to produce a certain amount of milk
- How we define milk outputs and feed inputs leads to many different definitions of feed efficiency
- Milk output (yield) can be defined in many ways:
  - milk, fat, or protein yield
  - cheese yield potential (which in fact varies depending on what cheese is made!)
  - milk energy, etc.
  - milk dollars probably makes the most sense

Defining Feed Efficiency in dairy cattle

- Feed inputs can be defined in multiple ways:
  - Quantity of dry matter
  - Mcal gross energy (**GE**)
  - Predicted Mcal of digestible (**DE**),
  - Metabolizable (**ME**) or net energy (**NE**) estimated from combining some ration model with chemical composition
  - Dollars of feed might be the best, but least definable input.
  - Other methods?

Improving Feed Efficiency in dairy cattle

- Purpose of Pre-conference
  - Identify biological tools to improve:
    - Animal performance
    - Improve Feed Inputs
- Speakers
  - Dr. Mary Beth Hall- Improving rumen efficiency
  - Dr. Christer Ohlsson – Improving ensiled forage efficiency

Defining Feed Efficiency in dairy cattle

- Defining feed efficiency in an economic form is difficult, and not constant and involves:
  - Fluctuating market conditions
  - Biological issues related to feed production
  - Manipulations of cattle biology and herd structure.

Improving Feed Efficiency in Dairy Cattle

- Purpose of Pre-conference
  - Putting Feed Efficiency to work
- Panel– collecting/measuring, interpreting data, and implementing feed efficiency improvements on farm
  - Jim Barmore
  - Dr. Marty Faldet
  - Keith Sather

Protein and Carbohydrate Interactions in the Rumen (Protein Does WHAT?!?!)

Mary Beth Hall
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marybeth.hall@ars.usda.gov

Even though we've been at it for over 150 years, we keep finding out new things about the rumen, the cow, and feed that affect how animals perform. Some of this information can be useful for better formulation of rations, though it may take a while to fully understand what exactly we are working with.

Over the years, occasionally reports would come in from nutritionists that increasing protein over recommended levels gave better milk responses than predicted, or that excessive protein caused what looked like ruminal acidosis. The cows are always right, but what was going on? Was the protein in feed less available than usual or being used as an energy source? Even in the research literature, protein effects that look like what we usually think of as carbohydrate or energy effects have been reported, but often with little explanation. In this paper, we'll explore a relationship between ruminally degradable protein (RDP) and carbohydrates that are rapidly assimilated by rumen microbes. We may be able to use this information to improve feed efficiency and manipulate the nutrient supply to better meet the animal's needs.

Rumen Function

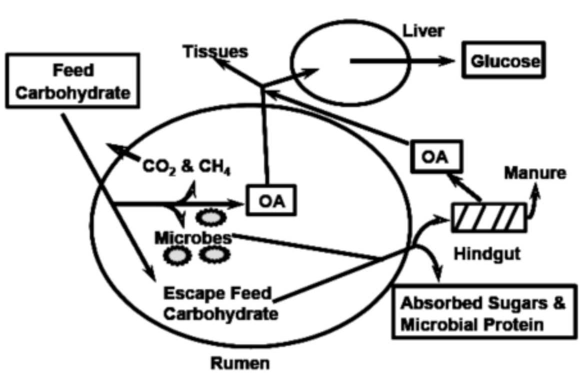


Figure 1. Digestion and fermentation of carbohydrates in cows. OA = organic acids, CO2 = carbon dioxide, CH4 = methane.

Carbohydrate is fermented in the rumen to produce organic acids (acetate, propionate, butyrate, lactate, valerate), gases (carbon dioxide and methane), and the energy to drive production of microbial cells (Figure 1). Availability of carbon skeletons and energy from fermentable carbohydrate are important to allow conversion of nonprotein nitrogen to microbial protein (Dellow et al., 1988). Microbes also incorporate carbohydrates into their cells as carbohydrate or for the synthesis of other molecules. The extent to which carbohydrate ferments in the rumen, or passes out unfermented is determined by competing rates of fermentation and passage. Carbohydrate fermentation can be depressed If RDP is limiting (Heldt et al., 1999), but no other ruminal effects of RDP on carbohydrate are typically discussed. Fermentation of carbohydrates in the rumen is perceived to be the main determinant of ruminal organic acid production.

Protein Effects on Carbohydrate Fermentations: In Vitro

Protein can affect formation of microbial products from carbohydrates in ways that may differ from our usual thinking. Increasing the supply of amino acids and peptides increased microbial yield of ruminal microbes linearly at each amount of carbohydrate tested (Figure 2; Argyle and Baldwin, 1989). How was it that the nitrogen sources were limiting to microbial cell synthesis at the lower amounts of protein, but still able to generate increasing yield responses as more carbohydrate was supplied? The study focused on protein effects, but begs the question of what was happening with the carbohydrate as microbial yields changed.

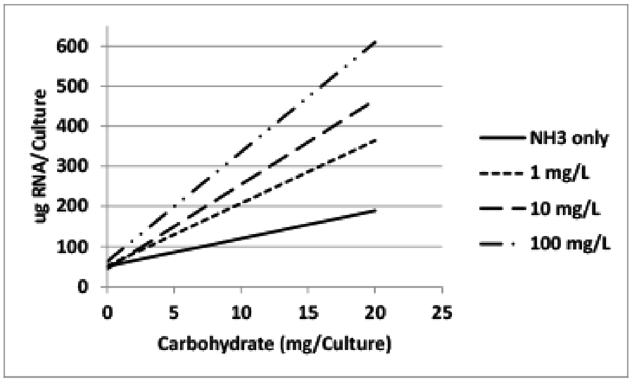


Figure 2. Microbial yields (as micrograms of RNA/mg of carbohydrate added) for mixed ruminal microbes after 6 hours of fermentation. The "mg/L" values are for the amount of amino acids + peptides added; media for all treatments contained 3.6 millimolar ammonia. (Argyle and Baldwin, 1989).

Glycogen is a microbial product that is often left out of discussion on carbohydrate fates, but it could help to explain a protein effect. For rapidly available carbohydrates such as glucose, fructose, sucrose, starch, and fructan (a water-soluble carbohydrate in cool season grasses), but not for lactose, rumen microbial products include:

Organic Acids + Gas + Microbial Cells + Glycogen (+ other microbial products like biofilms?)

Glycogen is a carbohydrate synthesized by bacteria and protozoa to store carbohydrate they've sequestered but have not yet fermented; it has essentially the same structure as starch. Glycogen storage increases with the amount of rapidly available carbohydrate present (Prins and Van Hoven, 1977), but decreases as dietary protein is increased (McAllan and Smith, 1974). Through an effect on glycogen accumulation, protein has potential to alter ruminal concentrations of organic acids by changing whether the carbohydrate is fermented immediately, or is stored and fermented more slowly (Figure 3). Protein supplementation has also been shown to increase lactic acid production (Malestein et al., 1984), possibly by increasing the flux of carbohydrate through glycolysis (Counotte and Prins, 1981) (Figure 3). When not produced in excessive quantities, lactic acid is not a problem per se. It is normally transient in the rumen, and is fermented to acetate and propionate.

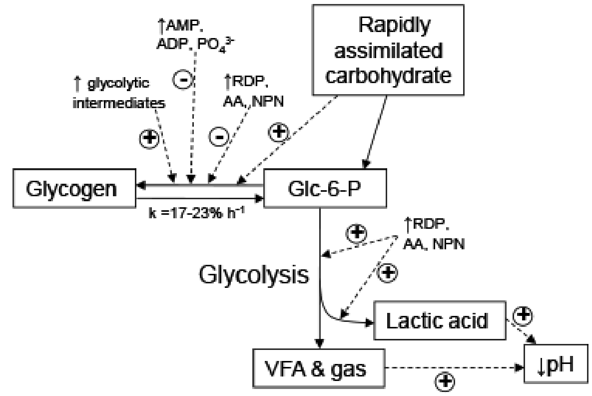
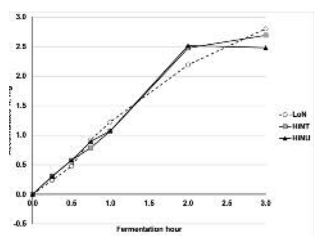


Figure 3. Proposed scheme describing factors affecting carbohydrate fates in the rumen. Solid lines indicate direction of reactions from substrate to product. Dashed lines designate effects on formation of products with "+" indicating an effect that increases and "-" indicating an effect that decreases product formation. The effect of RDP, amino acids and nonprotein nitrogen on glycolysis is assumed based on the negative effect of these sources of N on glycogen synthesis and positive effect on lactic acid production. (PO43- = orthophosphate, Glc-6-P = glucose-6-phosphate). (M.B. Hall, unpublished).

A



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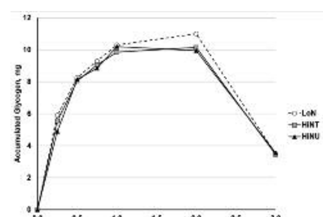

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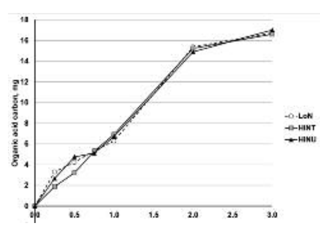


Figure 4A-C. Effect of amount and type of protein source on A) microbial growth (nitrogen accumulation), B) glycogen accumulation, and C) organic acid production in vitro with mixed ruminal microbes (Hall, 2012a). The LoN treatment contained ammonia and amino acids and peptides, but had 12.5% less N than the HiN treatments. The HiN treatments had added urea (HiNU) or amino acids and peptides (HiNT). Organic acids are presented as the amount of carbon in the acids.

In an experiment to investigate how protein amount and type affected the fate of a rapidly assimilated sugar (glucose), we found that offering mixed rumen microbes more urea or amino acids + peptides did result in less glycogen accumulation and in more microbial cell nitrogen (cell growth), at some time points (Figures 4A-C; Hall, 2012a). The response in cell growth depended on what time point was evaluated, with low nitrogen culture (LoN) having less growth at 2 h, but surpassing the greater nitrogen culture supplemented with urea (HiNU) at 3 hours. Organic acid production differed among the treatments in the very early time points, but not by the end of the fermentation, even though there was no difference in the rate of glucose disappearance. The organic acid response differs from results of the cow studies. It raises the question as to what other products microbes were making with the carbohydrate.

Protein Effects on Carbohydrate Fermentations: In Cows

For this alleged protein effect on carbohydrate to matter at all on the farm, does glycogen production by rumen microbes happen in cows? Measurements made on lactating dairy cows fed grass-clover silage and various supplements showed a net ruminal synthesis of "starch" that passed to the small intestine of 0.6 + 0.3 lb/day (value differed from zero, P=0.14; Larsen et al., 2009). That "starch" is microbial glycogen that would have been produced from other dietary carbohydrates. Accordingly, it is possible for cows to have something that digests like starch be produced in the rumen and flow to their small intestine, even if there was no starch in their diets.

Research studies with lactating cows have shown protein effects on what are usually considered carbohydrate-driven responses. Take for example a study in which cows given fresh-cut grass that had been fertilized with urea to give higher or lower nitrogen (N) contents (Table 1), and were or were not drenched 4 times daily with a 50:50 mix of dextrose and cornflour (starch) in water (Carruthers and Neil, 1997). The cows gave the expected ruminal ammonia responses: cows receiving the higher N grass or no carbohydrate supplement had greater ammonia concentrations than the opposing treatments (Table 2). This response was expected because ruminal degradation of a feed with greater protein content should give rise to greater production of ammonia, whereas increased amounts of available carbohydrate like that in sugar and starch allow microbes to capture the ammonia as microbial mass. Unexpectedly, the volatile fatty acid concentrations were greater on average, and 13 to 14 millimolar greater in later hours on the high N than low N grass ($P<0.001$), whereas carbohydrate supplementation only increased the concentration by 5 millimolar in later hours ($P<0.05$) (Table 2). There is potential for increased N fertilization of grasses to increase fiber digestibility, but the difference in organic acid concentrations found in this study is beyond what would be expected.

In another study investigating RDP by carbohydrate interactions, lactating cows were offered total mixed rations with greater or lesser concentrations of RDP and with more rapidly (high moisture corn) or more slowly (ground ear corn) available carbohydrate (Aldrich et al., 1993). Rumen pH of cows fed diets with high moisture corn were lower (6.28) when fed more RDP

Table 1. Chemical composition (% of dry matter unless stated) of high (HN) and low (LN) nitrogen grasses (Carruthers and Neal, 1997).

	HN	LN
Dry matter (% of fresh weight)	15.7	17.6
Organic matter	90.4	90.8
Crude protein	17.6	13.2
Soluble protein N	0.15	0.12
Soluble non-protein N	0.66	0.51
Neutral detergent fiber	46.0	45.7
Water-soluble carbohydrate	22.0	27.1

Table 2. Average ruminal ammonia-N, pH, and total volatile fatty acid concentrations of dairy cows offered fresh cut grass of high (HN) and low (LN) nitrogen content with (+NSC) and without (-NSC) non-structural carbohydrate supplementation (Carruthers and Neal, 1997).

	HN		LN			*p*-values		
	+NSC	-NSC	+NSC	-NSC	SED	N	NSC	NxNSC
NH3-N, mmol/L	13.2	17.6	5.4	7.5	0.60	<0.001	<0.001	<0.05
pH	6.05	6.19	6.11	6.17	0.022	NS	<0.001	<0.05
Total VFA, mmol/L	136	132	126	125	2.1	<0.001	NS	NS

As compared to less RDP (pH = 6.28 vs. 6.39, respectively, P<0.01). Cows fed more RDP also tended to have greater ruminal concentrations of organic acids (145.8 vs 137.1 mmol/L; P<0.08). In this study, there was no difference among protein treatments in organic matter digested ruminally, a change which could have altered organic acid production. In another lactating cow study, increasing dietary RDP gave greater average ruminal lactate concentrations, and tended to increase maximal lactate concentrations (Hall, 2012b).

Why Would This Happen?
Why would protein affect carbohydrate fates in the rumen? Protein may be having an effect by changing microbial energy demands (Figures 3 and 6). When added amino acids and protein increased microbial growth (Argyle and Baldwin, 1989; Figure 2), the total energy demands of the microbes also increased to support that growth. The microbes would shut down unnecessary processes that use ATP (Adenosine TriPhosphate, a major energy transfer molecule) to shunt the energy towards growth.

Storage of glycogen or energy spilling qualify as unnecessary processes when cell growth has higher priority. Storage of carbohydrate as glycogen costs 1 ATP per hexose (Stouthamer, 1973), which is 25 to 50% of the total ATP that bacteria may derive from the fermentation of a hexose (Russell and Wallace, 1988). Glycogen storage decreases with increased concentrations of breakdown products of ATP, which signal decreased energy status of the cell (Ball and Morell, 2003) and increased cellular demand for ATP. Energy spilling is the dissipation of "excess" ATP as heat; increased protein availability decreases energy spilling (Russell, 1993).

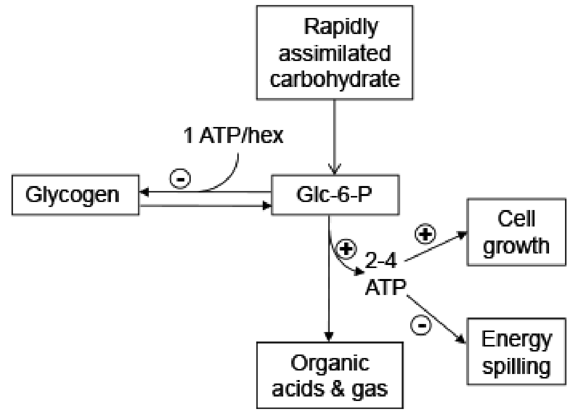


Figure 6. Effects of degradable protein or amino acids and peptide supplementation on ATP usage related to glycogen synthesis, flux of hexose through glycolysis, cell growth, and energy spilling. Nitrogen source effects on processes are designated as "+" (increase) or "-" (decrease). The effect on glycolysis is assumed based on the negative effect of N sources on glycogen synthesis and positive effect on lactic acid production. (Glc-6-P = glucose-6-phosphate). (M.B. Hall, unpublished).

When energy is not limiting, glycogen production or energy spilling utilize available ATP. These processes are apparently responsive to factors that affect energy status of the cell. Fundamentally, if cells have immediate need for energy, hexose is fermented and not stored as glycogen, if they do not, the storage of glycogen allows them to sequester substrate internally for future usage.

By shifting ATP use to production of microbial cells from glycogen synthesis or energy spilling, the efficiency of microbial growth per unit of carbohydrate fermented should be increased. An increase in the proportion of energy derived from carbohydrate that is used for growth would explain how the yield of microbes per unit of carbohydrate increased as more protein was provided (Argyle and Baldwin, 1989). To translate this increased microbial efficiency to increased amounts of microbial protein delivered to the cow, passage from the rumen would have to be such that more microbes flowed the small intestine than died and recycled in the rumen.

Thoughts On Application
The effect of ruminally degradable protein on fates of rapidly available carbohydrate seems to be a place where synchrony between protein and carbohydrate sources may give effects we can detect in cows. It also has potential to let us refine what we are doing

with diet formulation to improve feed efficiency and manipulate the nutrient supply to better meet the animal's needs. However, there's more that needs to be sorted out regarding practical application of this concept. In the meantime, some thoughts to consider:

- Don't overfeed total protein. If it's the rapidly available carbohydrates that are affected, you should only need rapidly available protein relative to the amount of that carbohydrate.
- Does it need to be nonprotein nitrogen or amino acids + peptides? We don't know, yet.
- Do you want glycogen, or organic acids + microbial protein? Hypothetically, if a herd is in a position where the corn has been in the silo all winter, the starch is fermenting more rapidly, and veering toward creating ruminal problems, would feeding less degradable protein help to slow down acid production in the rumen? It looks like it should; feeding some more NDF and/or effective fiber will also gain some margin of safety. Alternatively, greater efficiency of microbial growth with appropriately increasing the degradable protein could gain more microbial protein for the cow, given that passage rates supported that harvest.
- Rate of passage will decide whether the greater glycogen or microbial yield in the rumen ferments or recycles ruminally, or passes on to the small intestine where the cow can digest it and use the released glucose and amino acids. What are the options for changing rate of passage?
- No matter what you try, pay attention to the basics of good diet formulation.

References

Aldrich, J. M., L. D. Muller, G. A. Varga, and L. C. Griel, Jr. 1993. Nonstructural and carbohydrate effects on rumen fermentation, nutrient flow, and performance of dairy cows. J. Dairy Sci. 76:1091-1105.

Argyle, J. L., and R. L. Baldwin. 1989. Effects of amino acids and peptides on rumen microbial growth yields. J. Dairy Sci. 72:2017-2027.

Ball, S. G., and M. K. Morell. 2003. From bacterial glycogen to starch: understanding the biogenesis of the plant starch granule. Annu. Rev. Plant Biol. 54:207-233.

Carruthers, V. R., and P. G. Neil. 1997. Milk production and ruminal metabolites from cows offered two pasture diets supplemented with non-structural carbohydrate. N.Z. J. of Agric. Res. 40:513-521.

Counotte, G. H. M., and R. A. Prins. 1981. Regulation of lactate metabolism in the rumen. Vet. Res. Comm. 5:101-115.

Dellow, D. W., Y. Obara, K. E. Kelly, and B. R. Sinclair. 1988. Improving the efficiency of utilisation of pasture protein by sheep. Proc. N. Z. Soc. Anim. Prod. 48:252-255.

Hall, M. B. 2012a. Nitrogen concentration and source alter products from fermentation of glucose by mixed ruminal microbes. J. Dairy Sci. 95 (Suppl. 2): 434 (abstract).

Hall, M. B. 2012b. Corn source and dietary protein degradability: effects on ruminalmeasures and proposed mechanism for degradable protein effects. J. Dairy Sci. 95 (Suppl. 2): 613 (abstract).

Heldt, J. S., R. C. Cochran, G. L. Stokka, C. G. Farmer, C. P. Mathis, E. C. Titgemeyer, and T. G. Nagaraja. 1999. Effects of different supplemental sugars and starch fed in combination with degradable intake protein on low-quality forage use in beef steers. J. Anim. Sci. 77:2793-2802.

Larsen, M., P. Lund, M. R. Weisbjerg, and T. Hvelplund. 2009. Digestion site of starch from cereals and legumes in lactating dairy cows. Anim. Feed Sci. Technol. 153:236-248.

Malestein, A., A. T. van't Klooster, R. A. Prins, and G.H.M. Counotte. 1984. Concentrate feeding and ruminal fermentation. 3. Influence of concentrate ingredients on pH, on DL-lactic acid concentration in the rumen fluid of dairy cows and on dry matter intake. Neth. J. Agric. Sci. 32:9-21.

McAllan, A. B., and R. H. Smith. 1974. Carbohydrate metabolism in the ruminant: Bacterial carbohydrates formed in the rumen and their contribution to digesta entering the duodenum. Br. J. Nutr. 31:77-88.

Prins, R. A., and W. Van Hoven. 1977. Carbohydrate fermentation by the rumen ciliate Isotricha prostoma. Protistologica 13:549-556.

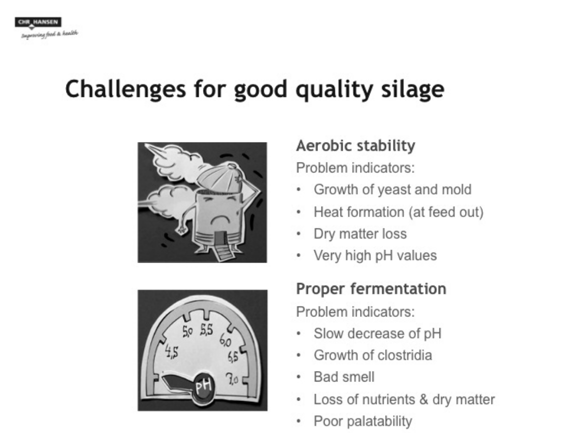
Russell, J. B. 1993. Effect of amino acids on the heat production and growth efficiency of Streptococcus bovis: balance of anabolic and catabolic rates. Appl. Environ. Microbiol. 59:1747-1751.

Russell, J. B., and R. J. Wallace. 1988. Energy yielding and consuming reactions. Pages 185–215 in The Rumen Microbial Ecosystem. P. N. Hobson, ed. Elsevier Applied Science, London, UK.

Stouthamer, A. H. 1973. A theoretical study on the amount of ATP required for synthesis of microbial cell material. Antonie van Leeuwenhoek 39:545–565.

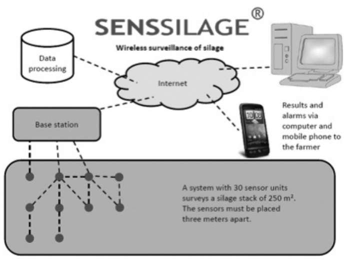
Effects of SiloSolve Inoculants on Silage Quality, Dairy Performance, and Production Efficiency

Christer Ohlsson and Bill Braman
C. R. Hansen, Inc.



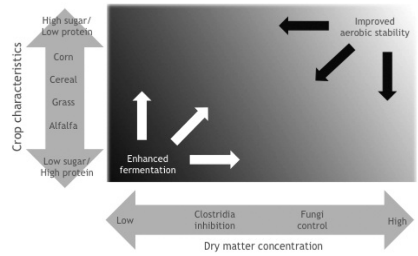
SensSilage

Mean temperature of all the sensors is found. If one sensor temp increases with 2 °C (3.6 °F) → alarm to the farmer!

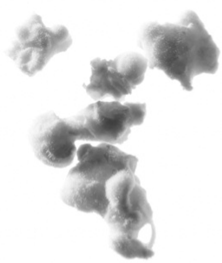


Type of Inoculant?

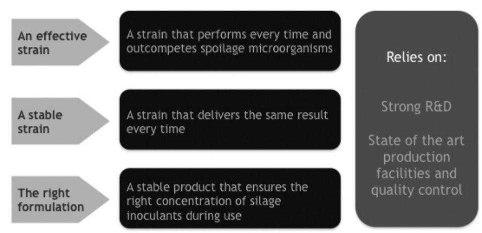
Crop and dry matter conditions determine the product selection



Bacterial inoculants



Success factors for an effective ensiling with bacterial silage inoculants



Focusing on function

Improved aerobic stability

Improved fermentation and production

Reduction of *Clostridium*, yeast, and molds

Freeze dried culture

A good silage inoculant starts with bacteria selection

Bacterial strains are selected due to their unique functions

Chr. Hansen are experts in strain research, and we are using robot technology to screen strains

Inoculant bacteria differences

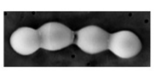
Homofermenter vs. Heterofermenter

- **Homofermenter** *-L. plantarum* → Most efficient
  - 1 6-C Sugar → 2 Lactic Acid

Less efficient ↓

- **Heterofermenter** *-L. buchneri*
  - 1 6-C Sugar → 1 Lactic Acid + 1 Acetic Acid + CO_2
  - 1 6-C Sugar → 1 Lactic Acid + 1 Ethanol + CO_2
  - 1 Lactic Acid → 1 Acetic Acid + CO_2 (*L. buchneri*, not all heteros)

Production of bacterial silage inoculants

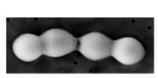


End Product Comparison

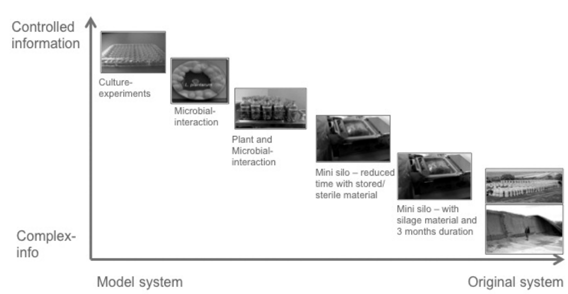
- Lactic acid- strong acid, weak spoilage inhibitor, fermented in rumen to primarily propionate (very efficient)
- Acetic acid- weak acid, good spoilage inhibitor, not fermented in rumen
- Ethanol- neutral, good spoilage inhibitor, partially fermented in rumen
- Carbon dioxide- lost dry matter

Lactic acid bacteria

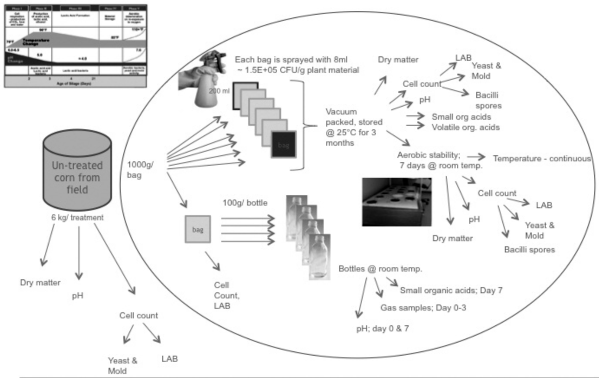
- Produce lactic acid from sugars
- Are acid tolerant – out-compete other bacteria (e.g. pathogens)
- Well documented bio-preservatives in fermented dairy products, meats, vegetables and silage
- Preservation of the nutritional value of silage
- Rapid and efficient fermentation
- Long lasting effect (beyond silo opening)
- No safety risk
- Small volumes



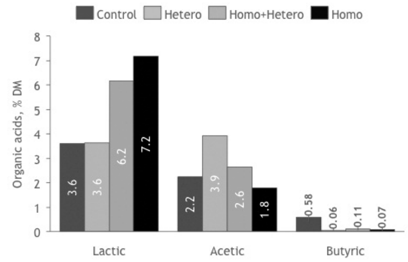
Silage competence platform



Mini-silos – What do we measure

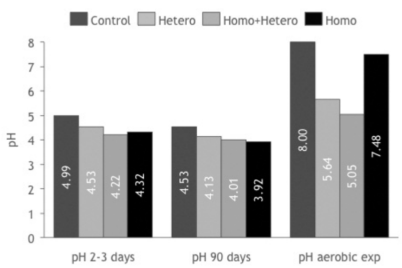


Additives and organic acid



Chr Hansen data from trials 80046, 80057, 80059, 80086, 80087, 80088, 80089

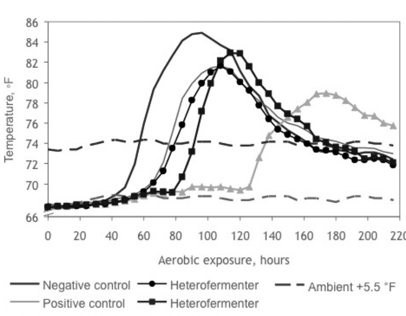
Additives and pH value



Chr Hansen data from trials 80046, 80057, 80059, 80086, 80087, 80088, 80089

How does your silage smell?

Aerobic stability of corn silage

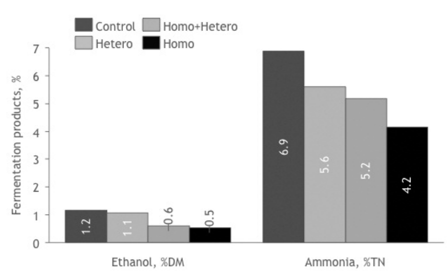


Temp increase above ambient, °F	Dry matter loss, %
2	3
3.5 - 11	10
> 11	15

(McDonald et al 1991)

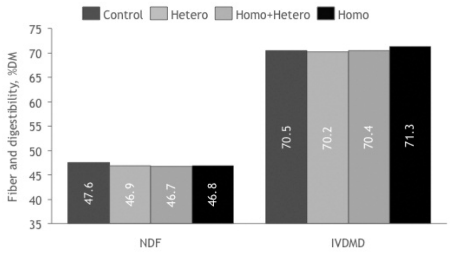
Whole-crop maize ensiled at ca. 27% DM (73% moisture), Baisogala 2010. Jonas Jatkauskas. Trial 80088.

Additives and ethanol and ammonia



Chr Hansen data from trials 80046, 80057, 80059, 80086, 80087, 80088, 80089

Additives and NDF and digestibility



Chr Hansen data from trials 80046, 80057, 80059, 80086, 80087, 80088, 80089

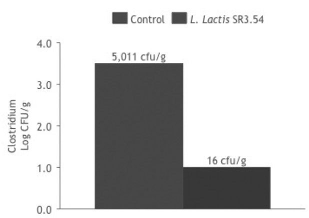
Homofermentative Silage Inoculants-Summary of Published Trial Results (Muck, 2012)

- Dry Matter Recovery
  - Improved in 38% of trials (Muck and Kung, 1997)
  - Improvement when successful: 8% absolute
  - On average of all trials, 2-3% absolute improvement
  - Increased dry matter recovery will usually pay for the inoculant

Reduction of *Clostridia*

Wet silage is at risk for undesired clostridial fermentation causing protein breakdown and subsequent reduced palatability

Bacteria strains which reduce clostridia

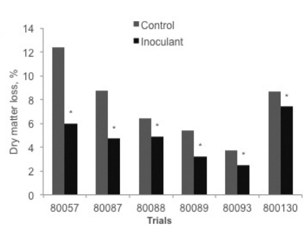


Swedish patent nr 511828.

Bacteria inoculants reduce dry matter loss

Chr Hansen research: decreases dry matter loss - on average 35 %

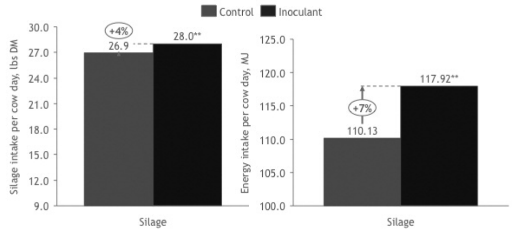
Preservation of dry matter is essential in obtaining a good feed utilization and profitability



Six trials with grass, corn and alfalfa

Inoculants result in higher Intake

As a consequence of reducing undesired conversions in the silage, both feed intake and the overall energy intake will increase



Grass 34.2% DM. Trial 80087   Grass 34.2% DM. Trial 80087

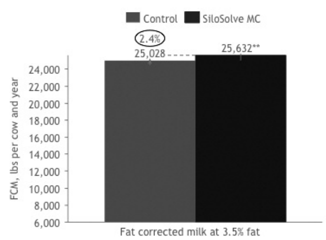
Does inoculant affect cow performance?

"The effects of inoculants on gain or milk production in livestock have been greater than expected (Weinberg and Muck, 1996). In fact, there are a significant number of reported cases where animal performance has been increased even though there was either no or only minor changes in pH or silage fermentation products. ….. However, beyond scientific curiosity, <u>improvements in animal performance provide a bigger return to the farmer than improvements in DM recovery.</u> So there is incentive both scientifically and in helping farmers choose effective inoculants to understand how LAB silage inoculants affect livestock."

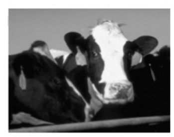
Quote by Dr. Richard Muck-USDA Forage Lab, Madison, WI
International Silage Conference, 2012

Inoculants improve milk production

Improved feed conversion (FCM/DMI): 1.72 vs. 1.54
Increased milk fat:
2.93 lbs/day vs 2.86 lbs/day
Same milk protein:
2.42 lbs/day
Increased milk lactose:
4.20 lbs/day vs. 4.00 lbs/day



Corn silage fed to cows for >90 days. Trial 80148, Florida. Assumed 305 milking days



Silage Inoculants and Fiber Digestibility and Fermentation of Corn Silage

Treatment	pH	Lactic Acid	Acetic Acid	Soluble Protein	Lactate: Acetate	NDF Digestibility
		------------ % DM	------------		Ideal >3:1	%
Control	3.91	4.1	1.60	3.65	2.6	52,8
Inoculant	3.79	4.6	1.41	3.42	3.3	55.6

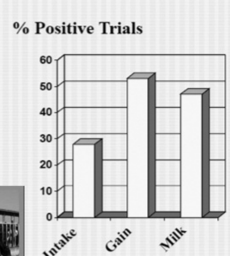
+ 5.3% in vivo NDF Digestibility

K.S. Bolsen - Kansas State University

Homofermentative Silage Inoculants - Results

Animal Performance

- Typical improvements when worked: 3 to 5%



Ref. Muck and Kung, 1997

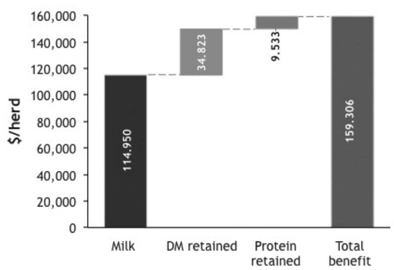
Economic value of silage inoculants - Assumptions

Parameters	Value
Dairy herd size	1000
Milk price, $/100 lbs	19
Price of silage, $/wet ton	90
Price of 49% SBM, $/ton	400
Price of silage additive, $/ton	0.90 - 1.20

Parameters	Control	Inoculant
Dry matter, %	34.5	36.5
DM loss, %	5	2
CP, %DM	8.05	8.25
NH_3-value, %TN	9.1	7.8
FCM, lbs/cow year	25,028	25,632

Corn silage treated with SiloSolve MC and used in a dairy trial at the University of Florida, Gainsville

Benefits of using inoculant, 1000 cows



ROI ranges between 7.7 and 10

Additive cost ranges between $13,582 and $15,293

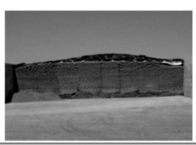
Future challenges

- Better knowledge of mode of action of lactic acid bacteria in silage
- Better prediction of changes in silage quality during fermentation
- Improve consistency of bacterial efficacy
- Better correlation between silage analyses and animal performance

Conclusions-Science-based Bacteria Inoculants will:

- Provide consistent performance
- Increase in silo dry matter recovery on average of 2-3%
- Increases production by 3-5%
- Increase fiber digestibility

Most money in using inoculants from increased milk yield



How I Measure & Utilize Feed Intake Data
Panel Discussion

Dr. Marty Falder, Keith Sather and Dr. Jim Barmore

Low Protein Feeding

Dr. Steve Woodford
Nutrition Professionals, Inc.

Nutrition Professionals, Inc

- Nine nutritionists
- Located in upper midwest, doing business midwest to southern US.
- Do not have a standard guideline when it comes to ration formulation.
- Different models used, but tend to have same general philosophy.

Herd	Milk lb/d	Ration CP%	Fat%	Protein, %	MUN	DMI, lb
A	95+	15-15.5	3.4-3.6	3.0-3.1	8-10	56
B	90-95	15	3.7-3.8	3.15+	~10	60
C	110-120	15.5	3.5-3.6	3.10+	7-9	51
D	90+	15.5	3.6-3.9	3.0-3.10	8-10	54
E	95-100	15-15.5	3.4-3.3	3.00+	7-9	52

Nitrogen balance, intake= economics

- In 2012 in Wisconsin, average price paid for milk protein was $3.04/lb.
- For 80 lb tank milk, 1/10th point milk protein is worth 24 cents/head/day
- If 10-12 grams protected AA costs 20+ cents and soybean meal ~ 22-25 cents/lb, easy to not make money.

Thought process to low protein rations

1. Look at AA balance first.
   1. Target Lys >6.8% MP, Met >2.2% MP, Lys:Met ratio >3.0.
      - Response should be easy to judge
   2. Try and get MUN in target range, 8-10, verify MUN if necessary.
   3. From this point on monitoring cow response critical, not sure models tell me when this works. Previous rations all deficient in MP.

- Dry matter intake
- Tank milk and components
- Peak milk
- Milk components, especially 50-100 DIM
- Makes more difficult to analyze during summer heat and feed changes.

Requirements for low protein rations

1. High quality, consistent forage.
2. Multiple grain sources.
    - One lb SBM would buy two pounds corn, wheat, oats
3. Individual milk components.
4. Digestibility, fecal starch data.

Ultimately key to low protein feeding is a carbohydrate and energy issue.

Low Protein Feeding

John Koepke, Koepke Farms

Current Herd Statistics

- RHA 29,858 lb milk, 4.1 fat, 2.99 protein
- Current Bulk tank 97 lb per cow
- 95,000 SCC
- Milk 3 and 4x.
- No BST since Jan 2011
- Over 100 cows over 200,000 lb milk lifetime.

Koepke Farms

- **Milks 330 cows**
- **Raises 275 replacement heifers**
- **Markets 40+ head of quality replacement animals per year**
- **Markets approximately 15 breeding age bulls per year**
- **Farms 1100 acres of cropland utilizing all no-till methods, producing feed and commodities for sale**
- **Manages 2 rental homes on the farm**
- **Market a small percentage of milk directly as cheese**

N Management Goals

- Maximize animal performance
- Reduce input costs, both feed and fertilizer
- Minimize environmental impact

CP Objectives

Finding balance on the farm as well as feed bunk, reduce N excretion, lower MUNs

- Utilize lower cost feed ingredients (may contradict the goal above)
- Minimize environmental footprint, measured at ration guidelines, bulk tank, manure spreader, waterways, and tile line outlet.

Methods and Materials

- Use multiple group feeding, grouping by stage of lactation
  1. 3 lactating cow diets
  2. 4 heifer diets
  3. 1 dry cow diet
- Utilize multiple forage storage options to separate and categorize feeds
- Measure everything: milk weights, DMs, quantities of forage
- Utilize homegrown feedstuffs and affordable byproducts to keep feed costs down, attempt to use them to maximize protein and amino acid balance

So About N Management….

- Use CNCPS to minimize protein waste, but not reduce animal performance
- Current CP levels for different diets:
- 17.1 % CP for <70 days fresh
- 15.9 % CP for 70 days till 200 days
- Low 15's for "low" herd.

More M and M's

- Have utilized CNCPS or equivalent since 1996
- Try to make consistent, quality forage. Goal (and net result) is complete boredom for nutritionist!!!
- Diet goals- keep MP positive, but not by much.

Our diet CP could be lower, but…

- CNCPS shows I could lower diet CP more by utilizing a higher % Corn Silage in lactating diets (Currently 55% CS, 45 % haylage)
- Alfalfa very important part of our no-till crop rotation
  1. Forage source
  2. Fertilizer for a following corn crop
  3. Erosion control
  4. Tillage tool
  5. Discovery Farm data on our farm indicated less N loss to drain tile under alfalfa than corn or beans

What's Worked

- Utilizing model software to reduce CP levels in diet has been effective.
- Reducing input variability by categorizing forages and targeting their use has made things even more successful- i.e. top forages to top cows, etc.
- Tools such as AA balancing important and appear successful, but only after quality and variability in feeds are controlled.

What Hasn't Been Perfect

- Putting too many new ideas together can be counter-productive.
- High forage diets can be effective. So can low protein, or low starch. Putting all 3 together makes a diet look like a "low string" diet… and is!
- As always, watch and listen to the cows, they know better than we do. And when things are right with them, document what is going on, and best to just keep out of their way.

Thank You!

Delac from AMPI

30% DM replaces corn

Make labor more efficient

- Added lockups
- Streamlined our processing barn
- Added sand free stalls
- Custom chopping for 4 other dairies

SDSU Feed Cost Calculator App

Match intakes with their requirements

Our philosophy on dairy heifers is "spring of rib" tease them with energy and let them eat until they are physically full.

Identify the realizers

Ask yourself, can I

- Increase what I charge?
- Improve my feed quality?
- Protect my feed investment?
- Procure by-products?
- Identify the realizers?
- Make labor more efficient?

Panel on low protein feeding

Dr. Steve Woodford, Dr. Dave LaCount and John Koepke

Update to Approaches to Reduce Nitrogen Intake and Improve N Efficiency of Use in Lactating Dairy Cattle

Dr. Mike Van Amburgh, Larry Chase, Ryan Higgs,and Debbie Ross
Department of Animal Science, Cornell University, Ithaca, NY

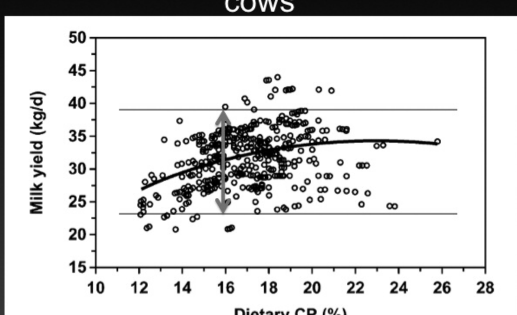
Outline

- Perspectives on protein and nitrogen balancing in high producing cows – limits to efficiency
- Nitrogen metabolism and some modeling discussion
  - what we have learned and why cows can do this
- Herd data related to lower N diets
- Where it might not work and possibly why
- Summary

Improving Efficiency of Use of Intake Nitrogen

- Opportunities exist – need refining
- On farm N efficiencies (milk N:feed N) 20 to 32%
- Theoretical efficiency limit 40 to 45% in lactating dairy cattle (Van Vuuren and Meijs, 1987; Hvelplund and Madsen, 1995)
- Practical limit is ~ 38 to 40% (groups are achieving this)
- Requires refinement of current ration formulation models – balancing for rumen N and post-ruminal amino acids
- Requires refinement of feeding management – reduce variation associated with feed, management

Impacts of source and amounts of CP on intestinal supply of N and performance of cows



Ipharraguerre and Clark, 2005

There are cows within groups approaching the theoretical limits of protein efficiency

Hardie Family Farm, Lansing NY

High group average production: 119 ± 35 lb/d

Average DMI: 60.2 lb/d, 15.8% CP

Average N efficiency: 38% (productive:intake N)

Cows at high end of production: ~168 lb/d milk

At estimated intake, N efficiency: 41%

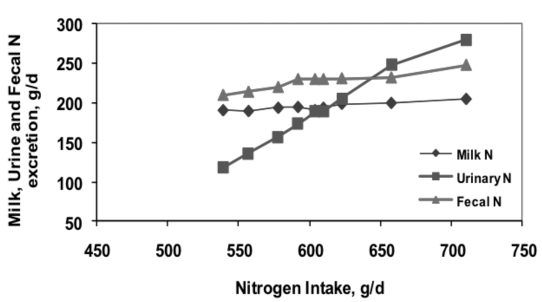
Improving Efficiency of Nitrogen Use

- Milk protein output is a function of energy supply and amino acid balance
- Urine N is variable and is a function of excess nitrogen intake and recycling
- Urine N is most volatile form – so reducing it will reduce the environmental impact and improve efficiency
- High levels of urinary N indicate:
  - Overfeeding total protein
  - High rumen N balance relative to microbial demand

Urinary N is main form of excreted N Fecal N is fairly constant

Reference	Intake N (g/d)	Fecal N (g/d)	Urinary N (g/d)
Kauffman and St-Pierre, 2001	429	178	93
	460	184	101
	572	198	190
Hristov and Ropp, 2003	658	208	233
	754	176	279

Nitrogen excretion in milk, feces and urine based on N intake in lactating dairy cattle – under controlled conditions of energy as first limiting: 88 lb milk/d @53 lb DMI range in CP intake 14 to 18.7%



CNCPS v6.1 Nutrient Excretion – Manure and Manure Nitrogen

Excretion	
Fecal	44 kg
Urine	23 kg
TotalManure	67 kg
Fecal N	255 g
Urine N	227 g
Total Manure N	482 g
Productive N/Total N	30%
Productive N/Urinary N	0.91:1
Manure N/Total N	70%

Improving Efficiency of Nitrogen Use

- Milk protein output and overall protein efficiency is a function of energy supply
- Amino acid balance enhances efficiency of N use – not always direct
- Urine N is variable and is a function of excess nitrogen intake and recycling
- Urine N is most volatile form – so reducing it will reduce the environmental impact and improve efficiency
- Can use monitoring tools like milk urea nitrogen to diagnose independent of production responses or predict it with formulation

Fecal and Urinary N Excretion Predictions

- New equations were added and some modified to the urine and fecal nitrogen predictions
- This was based on the M.S. work of Ryan Higgs
- J. Dairy Sci. 95:2004-2014

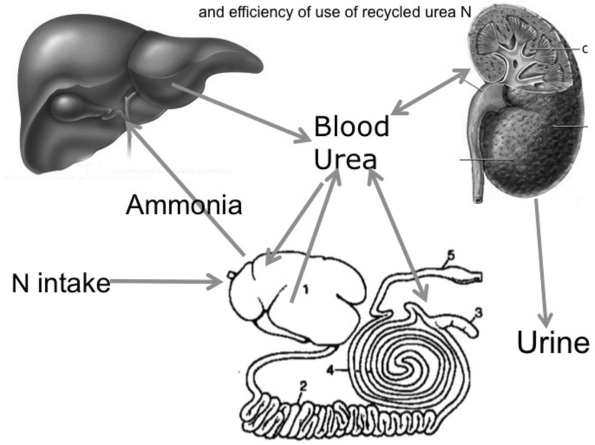
Fecal, Urinary and Total Manure Excretion

Equation	Slope	R^2	MSE	Variance component, (%)		
				Study	Slope	Residual
Fecal N	1.00	0.97	107.66	85.33	0.01	14.66
Urinary N	0.93	0.97	162.17	70.79	0.01	29.20
Manure N	0.97	0.99	154.14	56.82	0.00	43.17
Total N	1.00	1.00	0.05	72.20	0.00	27.80

Recent work quantifying nitrogen recycling (Ouellet et al., 2004)

- 6 cows, 3x3 Latin square
- Diets:
  - 60% forage, 40% concentrate (14.5% CP) fed 12x/d
  - 3 different forages:
    - Sun-cured hay, 10.1% CP
    - Formic acid-treated silage (12.0% CP)
    - Microbial inoculated silage (12.2% CP)

We have underestimated the amount and efficiency of use of recycled urea N



Urea Production and Recycling

	Intake N	Urea-N synthesis		Urea-N entering GIT	
Diet	gN/d	gN/d	% of intake N	gN/d	% of intake N
Hay	295	172	58%	123	42%
Formic acid treatment	341	171	50%	122	36%
Inoculated silage	351	200	57%	140	40%

Ouellet et al., 2004

Nitrogen recycling and efficiency of use

- The dairy cow is particularly adapted to use as much intake N as possible
  - Ruminant system highly adapted for N retention for the microbial population
  - 50-70% of intake N is converted to urea
  - 30-45% of intake N is recycled into the GIT
  - Need diets and management that improve utilization of capture of the recycled N

Anabolism = microbial capture

	Intake N	Urea-N used for anabolic purposes		
Diet	gN/d	gN/d	% of intake N	% of recycled urea-N
Hay	295	55	19%	45%
Formic acid treatment	341	56	16%	46%
Inoculant	351	64	18%	46%

Ouellet et al., 2004

Treatments

- CPM Dairy v3.0 was used to formulate diets
  - 1,400 lb cow, 80 lb milk/d, 3.70% fat, 2.95% protein
- Diets:
  - LoMP = 14.1% CP, adequate ruminal N, deficient MP (-145 g MP)
  - LoRumN = 14.1% CP, negative ruminal N (-39 g N or 79% of requirement), adequate MP
  - Control = 16.3% CP, adequate ruminal N and MP
- TMR was approximately 45% corn silage, 2% wheat straw, and 53% concentrate mix specific to treatment
  - Fed 1x/d at 8:00 a.m.
  - 300 mg Rumensin®•cow^{-1}•d^{-1}
  - bST per label (Posilac, Elanco Animal Health)

CPM Dairy Predictions at 50 lb/d Formulated Dry Matter Intake

	Control	LoMP	LoRumN
ME allowable milk, lb/d	89.5	89.9	89.0
MP allowable milk, lb/d	95.9	77.4	88.0
CP, % DM	16.6	14.2	14.2
RDP, % DM	9.9	9.6	7.7
Ruminal:			
Peptide balance, g/d	24(106%)	14(103%)	-50(88%)
Peptide and NH3, g/d	10(105%)	0(100%)	-52(77%)
MP bacteria, g/d	1529	1494	1345
MP feed, g/d	824	848	1207

Diet Ingredients

Ingredient (% of DM)	Control	LoMP	LoRumN
Corn silage	46.14	45.24	45.34
Wheat straw	2.10	2.05	2.06
Ground corn	11.11	11.31	10.92
Cottonseed	8.39	8.23	8.45
Citrus pulp	5.24	9.25	9.27
Ground barley	4.19	8.23	6.18
Confectioners sugar	2.62	0.82	3.09
Soybean hulls	4.19	4.11	4.12
Soybean meal 47.5% solv.	5.77	7.81	0
SoyPLUS	6.29	0	5.15
Mepron	0.05	0	0.05
ProvAAI	1.05	0	2.27
Nitroshure	0.38	0.41	0.35
Vitamin and mineral mix	2.47	2.53	2.76

Infusion cows: n = 12	Control	LoMP	LoRumN	SEM	Diet effect
Milk yield, lb/d	71.6	72.7	60	7.2	0.28
Milk fat %	3.16	3.17	2.71	0.24	0.33
Milk protein %	3.04	2.87	2.87	0.17	0.72
Milk fat yield, lb/d	2.20	2.27	1.66	0.21	0.10
Milk protein yield, lb/d	2.05	1.94	1.94	0.14	0.71

Full lactation study results: n = 88, 100 days

	Control	LoMP	LoRumN	SEM	Diet effect
Milk yield, lb/d	**99[a]**	**94[b]**	**95[ab]**	1.7	0.06
Milk fat %	2.68	2.67	2.54	0.08	0.37
Milk protein %	2.93	2.92	2.90	0.04	0.85
Milk fat yield, lb/d	**2.65[a]**	**2.47[ab]**	**2.40[b]**	0.06	0.09
Milk protein yield, lb/d	**2.91[a]**	**2.71[b]**	**2.73[b]**	0.04	0.01

[a,b]Different subscripts indicate significant differences within a row, $P < 0.05$

Diet composition	Control	LoMP	LoRumN
Dry matter, %	48.43	48.83	48.80
Crude protein, % DM	16.30	14.30	14.20
Soluble protein, %CP	29.80	35.47	30.29
RDP, %DM	9.52	9.43	7.70
NDF, % DM	34.50	34.67	34.81
Starch, % DM	24.64	26.13	25.37
Sugar, % DM	5.50	5.01	6.18
Soluble fiber, % DM	7.81	8.79	8.27
Ether extract, %DM	4.61	4.37	4.54
Calcium, % DM	0.75	0.75	0.72
Phosphorus, % DM	0.33	0.34	0.33

Urea-N recycling kinetics

	Control	LoMP	LoRumN	SEM	P
N intake, g/d	659	583	521	66.0	0.35
UER (g N/d)	293.3 (0.44)	221.6 (0.38)	253.8 (0.49)	44.0	0.49
UER to urine	0.374	0.375	0.254	0.09	0.62
UER to GIT	0.626	0.625	0.746	0.09	0.62
GER (g N/d)	184.6	137.4	204.8	45.6	0.57
GER to ROC	0.485	0.488	0.393	0.10	0.80
GER to UFE	0.007	0.006	0.003	0.002	0.53
GER to UUA	0.508	0.506	0.604	0.104	0.79

UER = urea-N entry rate; GER = gastrointestinal (GIT) urea-N entry rate; ROC = urea-N re-entering ornithine cycle; UFE = urea-N to fecal excretion; UUA = urea-N utilized for anabolism

CPM Dairy and NRC 2001 predictions based on milk yield and components

		Ctrl	LowMP	LowRumN
Actual milk, lb/d		101	93	95
CPM	ME milk, lb/d	99	97	92
	MP milk, lb/d	98	78	89
NRC	NEl milk, lb/d	99	97	94
	MP milk, lb/d	97	78	69
	NEl balance, Mcal/d	-0.8	1.4	-0.4
	MP balance, g/d	-89	-290	-499

What do you get when you add a rumen protected amino acid like methionine?

Milk Protein Synthesis - Basics

- Is an energy driven event
  - Relies on an adequate supply of amino acids
  - Driven by propionate production in the rumen
    - Propionate converted to glucose in the liver – which in turn stimulates insulin secretion
    - Intestinal glucose absorption also supplies energy substrate but there is a discount on energy for lactose synthesis – based on the data of Reynolds et al, about an 18% discount due to tissue use

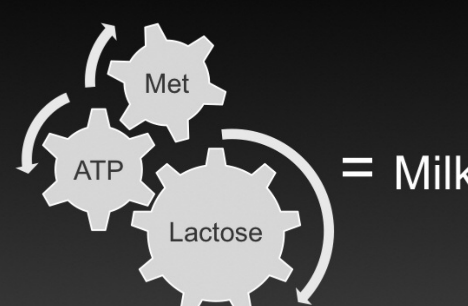
Is that a change in protein efficiency or energetic efficiency?

- Suggest it is a change in the efficiency of use of energy
- If Energy Corrected Milk increases, then it is really an energy effect – especially if the amount of amino acid supplied in the diet was less than the total amount of excreted in the milk
- More nutrients were secreted in the milk, making the overall diet more energetically efficient

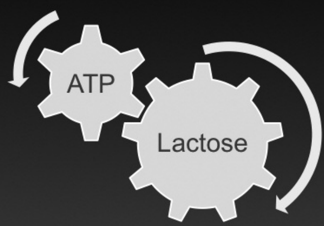
Milk Protein Synthesis - Basics

- Insulin secretion stimulates protein synthesis in the mammary gland
- Energy intake stimulates IGF-I secretion from the liver
- Protein supply per se is not an activator of milk protein output but can modulate some of the signaling – IGF-I, mTOR, elongation factors (methionine, leucine and others)

Efficiency Example

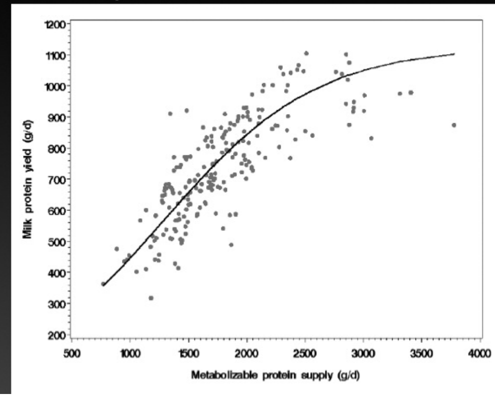


Reduced efficiency due to lack of needed amino acid



≠ Milk

MP Supply and Milk Protein Yield – From data of Doepel et al., 2004



NRC 2001/CNCPS v6.1- Efficiency of use of Protein for Milk Protein Synthesis – Factorial approach

The efficiency of use of absorbed protein for milk protein synthesis was increased from 0.645 to 0.67 based on NRC 2001

$$\mathrm{LE} = \mathrm{Milk}(0.0929 \times \mathrm{MF}) + \left(\frac{0.0547 \times \mathrm{MTP}}{0.93}\right) + (0.0395 \times \mathrm{ML}) \quad (7)$$

$$\mathrm{LP} = \mathrm{Milk}\left(\frac{(\mathrm{MTP}/100)}{0.67}\right) \times 1000 \quad (8)$$

where LE is net energy for lactation (Mcal/d); Milk the milk production (kg/d); MF the milk fat (g/100 g milk); MTP the milk true protein (g/100 g milk); ML the milk lactose (g/100 g milk); and LP is metabolizable protein for lactation (g/d).

Efficiencies of Use of Absorbed Amino Acids after Discounting the Maintenance Requirements from Total AA Supply - Calculated by Linear and Non-Linear Solutions and Compared with CNCPS (Doepel et al. 2004)

		Logistic model				
	Linear model	% Optimum Supply				CNCPS
	(Fixed)	50	75	100	125	(fixed)
Arg	0.59	0.71	0.57	0.49	0.44	0.35
His	0.95	1.09	0.88	0.76	0.68	0.96
Ile	0.74	0.86	0.72	0.65	0.58	0.66
Leu	0.70	0.83	0.70	0.61	0.55	0.72
Lys	0.77	0.90	0.76	0.68	0.60	0.82
Met	0.80	0.89	0.75	0.66	0.59	1.00
Phe	0.64	0.75	0.61	0.53	0.48	0.98
Thr	0.69	0.82	0.67	0.60	0.55	0.78
Val	0.76	0.86	0.71	0.62	0.56	0.62

Efficiency of Use of Absorbed Protein (MP for milk)

- Is variable based what is most limiting, ME or MP
- A recent evaluation of the AFRC value of 0.68 suggested that value is appropriate if MP was limiting (Metcalf et al. 2008)
- If MP was equal to or in excess of ME, then 0.62 to 0.64 provided better solutions for actual MP allowable milk (Metcalf et al. 2008)
- Data from Doepel et al. (2004) calculated 0.67 when protein was limiting and 0.60 to 0.62 when ME and MP were in balance

Optimal absolute and relative amounts of digestible AA supply estimated from curve fitting from a database from Doepel et al. 2004

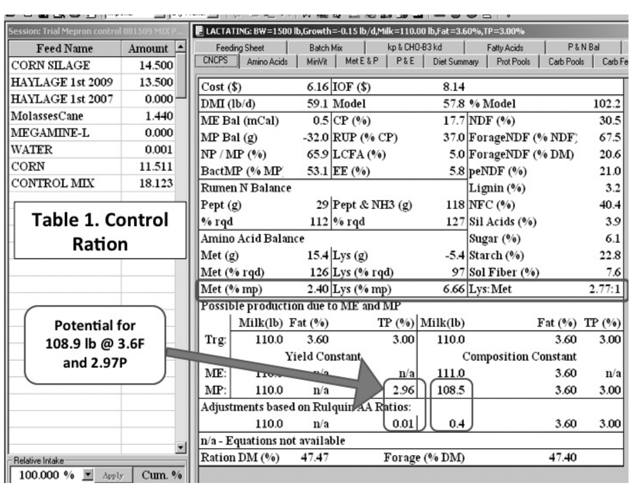
Amino acid	Grams per day	% Essential Amino Acid	% Metabolizable protein
Arg	91	9.6	4.6
His	48	5.1	2.4
Ile	105	11.1	5.3
Leu	175	18.5	8.9
Lys	142	15.0	7.2
Met	50	5.3	2.5
Phe	108	11.4	5.5
Thr	98	10.4	5.0
Val	129	13.6	6.5

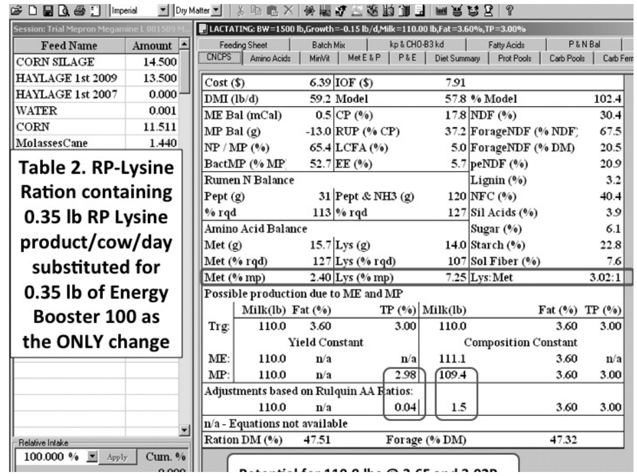
Amino acid recommended levels, % MP

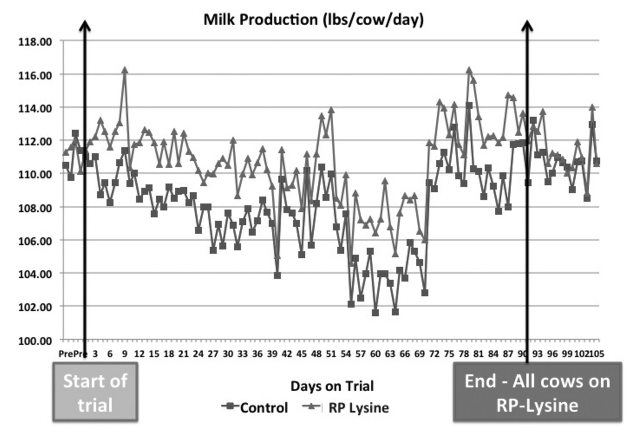
Amino acid	Sniffen et al. 2001	Rulquin et al., 2001	Doepel et al., 2004	Rulquin 2008 Ideal to Lysine	NRC, 2001
Met	2.02	2.5	2.5	2.48	2.38
Lys	7.05	7.3	7.2	7.30	7.24
Arg	6.22	>4.3	4.6		
Thr	4.54	>4.3	5.0	4.02	
Leu	8.37	<8.8	8.9	8.91	
Ile	4.73	>5.0	5.3		
Val	5.75	>5.3	6.5	5.91	
His	2.72	3.2	2.4	3.07	
Phe	5.10	4.95	5.5	4.6	
Trp	1.37	---	--		

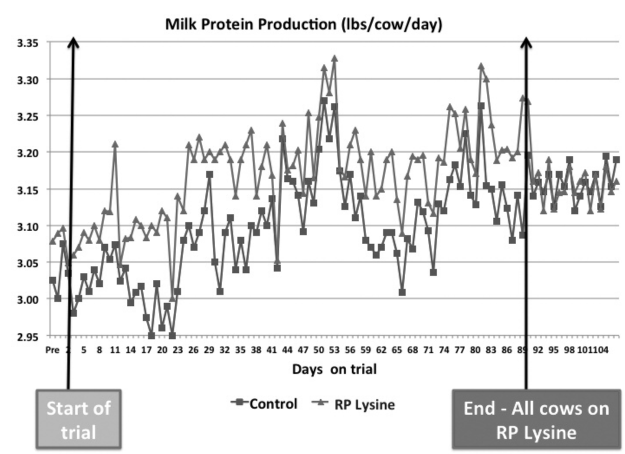
Field Trial Completed

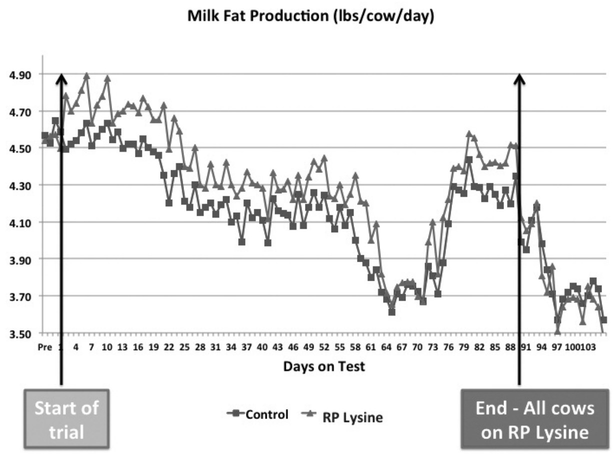
- 3,200-cow dairy
- 4 High Pens (2 Control; 2 RP Lysine)
- Control diet (CPM Dairy for formulation)
  - Balanced for 113 lbs. milk @ 3.6% F, 3.0% True Protein
  - -225g/d MP Balance, 0 Mcal/d ME balance
  - Methionine at 2.4% of MP; Lysine at 6.7% of MP
- Rumen Protected Lysine diet
  - Same as Control except replaced 0.3 lbs. of fat with 0.3 lbs. Rumen Protected Lysine to bring Lysine to 7.2% of MP











Efficiency – Protein or Feed?

- Dry matter intake of cows on feed: 59.1 lb/d
  - Didn't change during study
- Milk volume increased ~3 lb/d
- Milk protein increased ~ 0.15 lb/d
- Milk fat increased ~ 0.1 lb/d
- Energy corrected milk change: 3.44 lb/d
- Overall feed efficiency improved 3.3%

Formulating for AA

- Should formulate on Energy Corrected Milk
  - This will capture milk volume, protein and or fat yield changes
  - Under most conditions, this is easier to detect than a particular milk composition change
  - As in this particular data set, many factors were affected
  - Energy corrected milk provides greater information for this type of outcome

Example Herd A – 54 lb DMI, 92 lb Milk

% DM basis	CNCPS v6.1
CP	14.4
RDP	8.6
Sol CP	4.9 (34)
Rumen NH3, % req	134
NDF	31.6
Lys:Met	3.29
ME allowable, lb	99
MP allowable, lb	90

Example Herd Ingredients – 54 lb DMI, 92 lb Milk

Ingredient	DM amount, lb
Corn silage	17
Grass haylage	12
Dry hay	3
Ground corn	13.3
Soybean Meal	4.0
Roasted soybean	1.6
Cane molasses	0.46
Sugar	0.70
Provaal	0.44
Urea	0.097
Meta smart	0.012
Min. & Vitamins	1.59
Total	54.2

Herd C – Whole herd, 1100 cows, no Rumensin, no bST, 2 x milking – was not AA balancing – these are final values

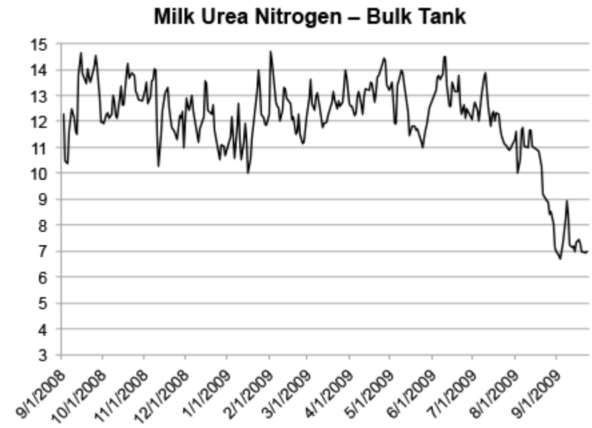
<u>Final stats at end of evaluation</u>

DMI	50 lb
CP	15.8%
NDF	30.2%
Actual milk	84 lb kg
ME allowable	85 lb
MP allowable	91 lb
True protein	3.1%
Fat	3.7%
Met	2.3% MP
Lys	6.77% MP

Herd C Ration

Ration Fed				
			DM	AF
Ingredient	$/hd	%DM	lbs/day	lbs/day
2009 2nd Haylage-CNCPS-04051	0.42	44.4	5.98	13.49
Canola Meal Solvent-CNCPS-02006	0.53	90.2	3.28	3.64
Corn Grain Ground Medium-CNCPS-01040	0.75	88.0	8.83	10.04
2008 Corn Silage-CNCPS-03019	1.32	31.1	21.94	70.66
Citrus Pulp Dry-CNCPS-01031	0.54	88.6	4.07	4.59
Soybean Rolled Roasted-CNCPS-02028	0.24	93.2	1.09	1.17
Old SHF Lact-CNCPS-C071546	0.00	91.8	4.81	5.24

New concentrate mix contained rumen protected methionine and Alimet



Herd C – Manure excretion profile

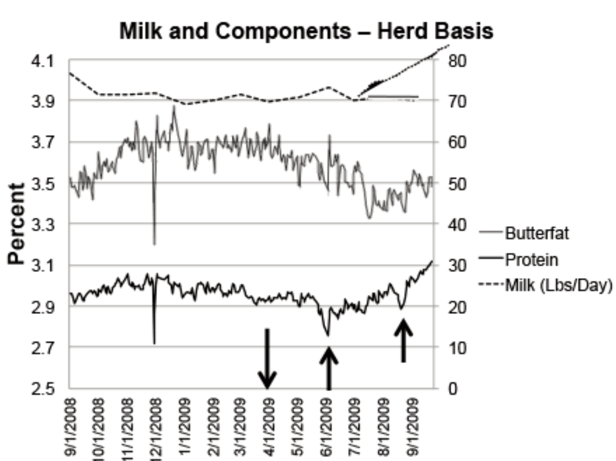
Fecal N	217 g
Urine N	154 g
Total Manure N	371 g
Productive N/Total N	35%
Productive N/Urinary N	1.30:1
Manure N/Total N	65%

What was the impact on N excretion?

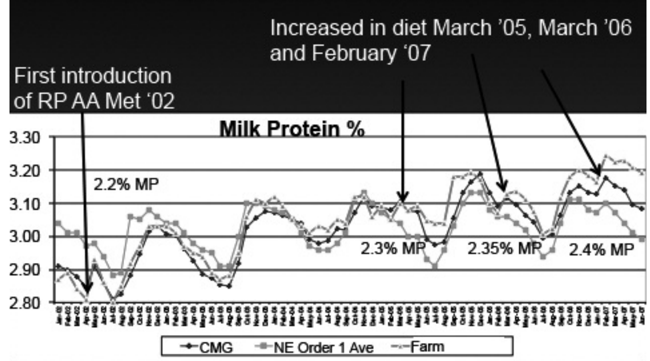
Our calculations indicate ~60 g N/cow/d less urinary excretion

1,100 cows = ~26.5 tons N less in the environment over 365 d lactation

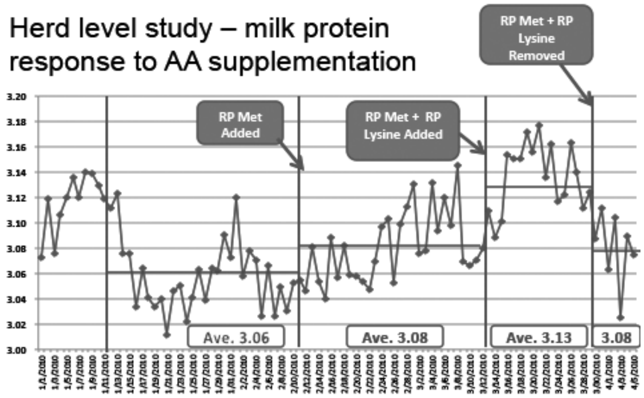
In 2009, that was $0.40/cow/d reduced feed costs



Milk Protein Content – NE Order 1, Management Group (28,000 cows) and Local Dairy (900 cows)



Herd level study – milk protein response to AA supplementation



Summary

- Opportunities to formulate for amino acids are increasing
- Need to reduce the non-functional protein in the diet (reduce urinary N excretion)
- Replace that protein with amino acids
- Maintain the Lys:Met ratio that fits with the software/system you are using
- Balance on energy corrected milk to capture the overall effect

Early Life Nutrition and Management and the Impact on Lifetime Productivity of Calves

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INTRODUCTION

Research, publications and farm level management related to the topic of calves and calf management over the last 40 years traditionally involved dry cow management, colostrum, diarrhea, rumen development and early weaning. In the last ten years, the concept of "intensified feeding or accelerated growth" has become a topic of interest among calf raisers and researchers and is being applied on farms in various management systems. The various management approaches involve differences in to best manage and deliver nutrition and nutrient intake for the pre-weaned calf to optimize the specific farm management capability. There are teleological arguments for providing a greater supply of nutrients from milk or milk replacer, e.g. what would the dam provide, and there are also arguments for improving the welfare status of calves by following that concept (Jasper and Weary, 2002; de Paula Vieira et al., 2008). Further, data generated over the last ten years has documented positive responses in productivity of calves as adult cattle when fed greater nutrient intake from milk or milk replacer prior to weaning. The implications of this productivity will be discussed.

EARLY DEVELOPMENT AND PRODUCTIVITY

Lactocrine Hypothesis

It has been well recognized that the phenotypic expression of an individual is affected by both genetic composition as well as environment. The environment contains multiple external signals that affect the development and expression of the genetic composition of an animal. While in the womb, the mother controls the environment in which the fetus is developing, influencing in this way the expression of the genetic material. The effect and extent of maternal influence in the offspring's development does not end at parturition, but continues throughout the first weeks of life through the effect of milk-born factors, including colostrum in this definition, which have an impact in the physiological development of tissues and functions in the offspring. This concept has been recently described as the "lactocrine hypothesis" (Bartol et al., 2008). Conceptually, this topic is not new but the terminology is useful and the ability of several groups to make a direct connection from a factor in milk to a developmental function at the tissue or behavior level is significant (Nusser and Frawley, 1997; Hinde and Capitanio, 2010). Data relating to this topic has been described and discussed by others in neonatal pigs (Donovan and Odle, 1994; Burrin et al., 1997) and calves (Baumrucker and Blum, 1993; Blum and Hammon, 2000; Rauprich et al. 2000). The implication of this hypothesis and these observations are that the neonate can be programmed maternally and post-natally to alter development of a particular process.

Colostrum's role

Colostrum, in comparison with milk, is known to be rich in immunoglobulins (60x cow), as well as hormones and growth factors such as relaxin (>19x pig), prolactin (18x cow), insulin (65x cow), IGF-1 (155x cow), IGF-2 (7x cow), and leptin (90x humans) (Odle et al., 1996; Blum and Hammon, 2000; Wolinski et al., 2005; Bartol et al., 2008) among many other factors that have biological activity in the neonate. For a long period of time, colostrum has been known to have a major effect on the development of the gastrointestinal tract, but the exact mechanisms are still not well understood. During the first few days of life in neonatal piglets, a notable increase in the length, mass, DNA content, and enzymatic activities of certain enzymes (lactase) occurs in the small intestine for neonates fed colostrum/milk versus a control of water (Widdowson et al. 1976, Burrin et al., 1994). This was originally thought to be mediated by differences in nutrient intake between milk and water (Burrin et al. 1992). However, other studies have demonstrated differences between animals fed colostrum that is rich in growth factors, versus milk with comparable energy values (Burrin et al., 1995).

To maximize calf survival and growth, plasma immunoglobulin (Ig) status and thus colostrum management is of utmost importance. This is obviously not a new concept and there are hundreds of papers describing the management and biology surrounding colostrum quality, yield and Ig absorption by the calf although some recent research in colostrum handling and management suggest we can still make improvements (Godden, 2008). Until recently, the primary reason colostrum has been of interest in neonatal ruminants is due to the importance of supplying Ig's to calves born without any and lacking a mature immune system (Weaver et al., 2000). Thus, without sufficient levels of Ig's, morbidity and mortality rates are increased. While Ig's are important, colostrum provides the newborn calf with much more than Ig's. There is an abundance of literature describing some of these other factors in colostrum and the role these compounds can have in the development of the calf. Given that calves over time can produce their own Ig's through exposure to bacteria and viruses, maternal antibodies from colostrum are transient and an argument could be made that they are not absolutely necessary. Minimizing the bacterial load of colostrum is probably one of the major management concerns with many farms and is usually a factor not considered or analyzed for. Data demonstrate that the presence of bacteria in the gut prior to colostrum ingestion or in the colostrum reduces the uptake of Ig, thus increasing the incidence of failure of passive transfer (James et al. 1981, Godden, 2008). Thus excellent udder health and proper post-harvest colostrum handling is as important, or even more important than vaccination programs to minimize neonatal and post weaned calf diseases and death loss.

Of interest are the studies that have described decreased growth rate and increased morbidity of calves with low serum immunoglobulin status (Nocek, et al., 1984; Robinson et al., 1988) and some have even indicated that milk yield during first lactation can be affected (DeNise et al., 1989). Robinson et al. (1988) demonstrated that calves with higher Ig status were able to inactivate pathogens prior to mounting a full immune response which allows them to maintain energy and nutrient utilization for growth, whereas calves with low Ig status must mount an immune response which causes nutrients to be diverted to defense mechanisms. How severe is this difference or for how long does it persist? The data of DeNise et al., (1989) demonstrated that for each unit of serum IgG concentration, measured at 24 to 48 hr after colostrum feeding, above 12 mg/mL, there was an 18.6 lb increase in mature equivalent milk. The implication was that calves with lower IgG concentration in serum were more susceptible to immune challenges which impacted long term performance. As with all longitudinal and epidemiological studies there are inconsistencies. Donovan et al. (1998) found indirect effects of colostrum status on growth and performance of calves, but concluded it was caused by increased morbidity and not a direct effect. The calculations of growth and feed efficiency should in many cases include the calves that were lost to study, thus providing a more applicable value.

Work from Faber et al. (2005) using Brown Swiss calves demonstrated that the amount of colostrum provided to calves at birth significantly influenced pre-pubertal growth rate by over 0.45 lb per day and the calves receiving greater colostrum showed a trend for an additional 2,263 lb of milk throughout the second lactation. The growth rate observation was not unique to this study, but begs the question if the response was due to greater feed intake or better feed conversion efficiency, which was not measured in the study. Further, Jones et al. (2004) examined the differences between maternal colostrum and serum-derived colostrum replacement. In that study, two sets of calves were fed either maternal colostrum or serum-derived colostrum replacement with nutritional components balanced. The serum-derived colostrum replacer was developed to provide essential IgG's to a neonatal calf; however the colostrum replacer does not generally contain the other bioactive factors native to colostrum. These two groups were then further separated into calves fed milk-replacer with or without animal plasma, yielding four different groups. The results demonstrated that calves fed maternal colostrum had significantly higher feed efficiency compared to calves fed serum-derived colostrum replacement. The IgG status of the calves on both treatments were nearly identical, suggesting that other factors in colostrum other than IgG's were important in contributing to the differences.

Some of the other components in colostrum, such as insulin, IGF-I, relaxin and other growth factors and hormones, might be important factors in developmental processes; likewise, a lack or shortage of them in early life might alter developmental functions, leading to a change in nutrient utilization and efficiency. To examine this concept, Soberon and Van Amburgh (2011) examined the effect of colostrum status on pre-weaning ADG and also examined the effects of varying milk replacer intake after colostrum ingestion. Calves were fed either high levels (4 liters) or low levels (2 liters) of colostrum, and then calves from these two groups were subdivided into two more groups being fed milk replacer at limited amounts or ad libitum. In this study, none of the calves exhibited failure of passive transfer. Comparing calves fed 4 liters of colostrum and ad libitum intake of milk replacer versus 2 liters of colostrum and ad libitum intake of milk replacer, calves fed the 4 liters of colostrum demonstrated an 8.5% increase in milk replacer intake, an 18% increase in pre-weaning ADG, a 12% increase in post-weaning feed intake, and a 25% increase in post-weaning ADG through 80 days of life, indicating that colostrum potentially affects appetite regulation, which enhances growth and possibly feed efficiency (Table 1). Therefore, it can be logically concluded that if colostrum induces changes in feed efficiency, then the first feeding can also potentially affect future milk production.

Table 1. Effect of high (4+2 L) or low (2L) colostrum and ad-lib (H) or restricted (L) milk replacer intake on feed efficiency and feed intake in pre and post-weaned calves (Soberon and Van Amburgh, 2011).

Treatment	HH1	HL	LH	LL	
	Mean	Mean	Mean	Mean	SD
ADG birth to 80 d, lb	1.72^{a}	1.30^{bc}	1.45^{b}	1.17^{c}	0.07
Hip height gain, birth to 80 d, cm/d	0.214^{a}	0.157^{b}	0.184^{c}	0.148^{b}	0.008
Total milk replacer intake, lb DM	97.8^{a}	44.5^{b}	90.1^{c}	44b	2.4
Grain intake pre-weaning, lb	4.8^{a}	26.4^{b}	4.6^{a}	21.3b	3.3
ADG/DMI, pre-weaning	0.60	0.61	0.67	0.61	0.042
ADG post-weaning, lb	2.4^{a}	2.1^{ab}	1.76^{b}	2.02^{b}	0.13
DMI post-weaning, lb/d	6.4^{ab}	2.0^{a}	5.7^{c}	$5.3b^{c}$	0.23
ADG/DMI post-weaning	0.359	0.345	0.335	0.358	0.020

[1]HH = high colostrum, high feeding level, HL = High colostrum, low feeding level, LH = Low colostrum, high feeding level,LL = Low colostrum, low feeding level. Rows with different superscripts differ P < 0.05.

Nutrient status

There are several published studies and studies in progress that have both directly and indirectly allowed us to evaluate milk yield from cattle that were allowed more nutrients up to eight weeks of age (Table 2). The earliest of these studies investigated either the effect of suckling versus controlled intakes or ad-libitum feeding of calves from birth to 42 or 56 days of life (Foldager and Krohn, 1994; Bar-Peled et al, 1997; Foldager et al, 1997). In each of these studies, increased nutrient intake prior to 56 days of life resulted in increased milk yield during the first lactation that ranged from 1,000 to 3,000 additional pounds compared to more restricted fed calves during the same period (Table 2). Although they are suckling studies, milk is most likely not the factor of interest, but nutrient intake in general and this is demonstrated in the more recent data.

A meta-analysis was conducted to evaluate the data presented in Table 2 using Comprehensive Meta-Analysis software (CMA, v2.2.064, Biostat, Englewood, NJ; Borenstein et al., 2005). In the first analysis, the treatment calves, or those calves that received more nutrients from milk or milk replacer prior to weaning, were estimated to produce 429 ± 106 lb more milk in first lactation ($P < 0.001$) compared to control calves. This analysis did not include ADG or any other predictor and was simply an evaluation of treatment effect. It should be immediately recognized that within these data sets, starter intake was not well described and any starter intake or additional nutrient intake would enhance the outcome, but is difficult to quantify. In the paper by Soberon et al. (2012) the role of starter intake was discussed and based on recent studies investigating starter intake and growth rates, it would be very difficult for calves to achieve the nutrient intakes and associated growth rates in the first 4 to 6 wk of life necessary to realize the milk yield outcome identified in this analysis. Equally important was the odds ratio from this analysis of 2.09 ($P = 0.001$) which indicated that a calf receiving more nutrients during the pre-weaning period was two times more likely to produce more milk that a calf that is restricted during the same period.

Table 2. Milk production differences as adults among treatments where calves were allowed to consume approximately 50% more nutrients than the standard feeding rate prior to weaning from either milk or milk replacer.

Study	Milk yield, lb
Foldager and Krohn, 1991	$3,092^{s}$
Bar-Peled et al., 1998	998^{t}
Foldager et al., 1997	$1,143^{t}$
Ballard et al., 2005 (@ 200 DIM)	$1,543^{s}$
Shamay et al., 2005	$2,16^{2s}$
Rincker et al., 2006 (proj. 305@ 150 DIM)	$1,100^{ns}$
Drackley et al., 2007	$1,841^{s}$
Raith-Knight et al., 2009	$1,582^{ns}$
Terre et al., 2009	$1,375^{ns}$
Morrison et al., 2009	0^{ns}
Moallem et al., 2010	$1,600^{s}$
Soberon et al., 2011	$1,216^{s}$

Milk response is the difference between treatment milk yield minus controls P < 0.05, t P < 0.1, ns P > 0.1

Each study offered different quantities and qualities of nutrients to treatment groups, thus to help evaluate the outcome of milk yield, ADG was included in the analysis to account for the effect of nutrient intake and nutrient quality. In order to evaluate the effect of ADG on first lactation milk yield, ADG was included in the analyses as a predictor variable and analyzed by meta-regression. In that analyses, a prediction equation was generated where first lactation milk yield = -106 lb + 1,551.4 (± 637) lb*ADG (Low limit 301 lb, upper limit 2,801 lb; Z value 2.41; P = 0.01), where ADG is lb pre-weaning average daily gain. This means that for every kg of pre-weaning ADG, calves produced 1,551 lb more milk during their first lactation (Soberon and Van Amburgh, 2013). This was a higher but consistent response to what was observed among two herds of 850 lb and 1,113 lb per lb of ADG (Soberon et al., 2012) indicating that the response to pre-weaning nutrient intake is not constant among herd and most likely varies with the management and environment of the herd along with the herd genetic potential for milk yield.

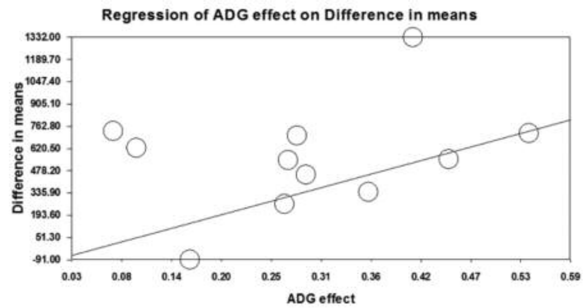

Figure 1. Meta regression of the ADG effect on milk yield response from calves offered more nutrients pre-weaning. Regression equation: Difference in milk yield means = -106 lb + 1,551.4 lb*ADG (P = 0.01) (From Soberon and Van Amburgh, J. Anim. Sci. 2013)

The responses in the studies of Shamay et al. (2005) and Moallem et al. (2010) are significant, specifically because they suggest that milk replacer quality is important to achieve the milk response, as is protein status of the animal post weaning. In that study, the calves were fed a 23% CP, 12% fat milk replacer containing some soy protein or whole milk. Further, post-weaning the calves were fed similarly until 150 days of gain, and the diets were protein deficient (~13.5% CP). Starting at 150 days calves from both pre-weaning treatments were supplemented with 2% fish meal from 150 to 300 days of life. The calves allowed to consume the whole milk (ad libitum for 60 minutes) and supplemented with the additional protein produced approximately 1,613 lb more milk in the first lactation indicating that the early life response could be muted by inadequate protein intake post-weaning.

Finally the data of Drackley et al. (2007) again demonstrate a positive response of early life nutrition on first lactation milk yield. In this study, calves were fed either a conventional milk replacer (22:20; i.e. 22% protein, 20% fat) at 1.25% of the body weight (BW) or a 28:20 milk replacer fed at 2% of the BW for week one of treatment and then 2.5% of the BW from week 2 to 5 and then systematically weaned by dropping the milk replacer intake to 1.25% of the BW for 6 days and then no milk replacer. All calves were weaned by 7 weeks of age and after weaning all calves were managed as a single group and bred according to observed heats. The heifers calved between 24 and 26 months of age with no significant difference among treatments. Calving BW were also not different and averaged 1,278 lb. Milk yield on average was 1,841 lb greater for calves fed the higher level of milk replacer prior to weaning.

The Cornell University Dairy Herd started feeding for greater pre-weaning BW gains many years ago and we have over 1,200 weaning weights and 3+ lactations with which to make evaluations outside of our ongoing study. What makes our approach to this unique is the application of a Test Day Model (TDM) (Everett and Schmitz. 1994; Van Amburgh et al., 1997) for the analyses of the data. This approach allows us to statistically control for factors not associated with the variables of interest and is the same approach that has been used to conduct sire summaries and daughter evaluations and develop heritabilities for genetic traits. Thus, the outcome is mathematically more robust and allows us to look within a herd over time with less bias and to look at herd responses independent of formal treatments. The resulting residuals are standardized which makes them additive over the life of the animal and they can be calculated for individual test days or over the lactation. The power of this type of analyses is much more significant compared to comparing daily milk or even ME305 milk and helps us partition out variance not associated with the variables of interest.

We analyzed the lactation data of the 1,244 heifers with completed lactations using the TDM approach and statistically analyzed several factors related to early life performance and the TDM milk yield residuals (Soberon et al. 2012). The factors analyzed were birth weight, weaning weight, height at weaning, BW at 4 weeks of age and several other related and farm measurable factors. From a management perspective the most interesting observation was the relationship among two factors, growth rate prior to weaning and intake over maintenance and first lactation milk yield. In these analyses, the strongest relationship associated with first lactation milk production was growth rate prior to weaning and the findings are consistent with the data presented in Table 4. In our data set, for every 2.2 lb of average daily gain (ADG) prior to weaning (or at least 42 to 56 days of age), the heifers produced approximately 1,216 lb more milk ($P < 0.01$). The range in pre-weaning growth rates among the 1,244 animals were 0.53 to 2.76 lb per day which, when analyzed against other farm level data is consistent but was puzzling to us. Our feeding program at the research farm is straightforward: 1.5% BW dry matter from day 2 to 7 and then 2% of BW dry matter from day 8 to 42 of a 28:15 or 28:20 milk replacer mixed at 15% solids. Free choice water is offered year around and starter is offered from day 8 onward. At that feeding rate, we are offering twice the industry standard amount and had assumed it was enough for overcoming the maintenance requirement and provide adequate nutrients for growth, even in the winter. However, when we analyzed the TDM residuals by temperature at birth, a very significant observation was made (Figure 2).

These data very much suggest that although we are meeting the maintenance requirements of the calves from a strict requirement calculation, we are not providing enough nutrients above maintenance to optimize first lactation milk production. We need to remember that the thermoneutral zone for calves is 20° to 28° C and that when the temperature drops below that level, intake energy will be used to generate heat instead of growth. In addition, when we analyzed the data by lactation, the response increased as the animals matured (Table 3).

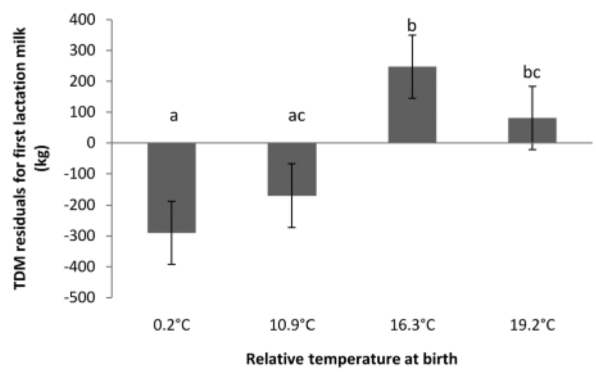

Figure 2. Test Day Model residuals in kg of milk, averaged by temperature at time of birth with mean temperature in Celsius. Columns with different superscripts differ ($P < 0.05$).

Taken together, these data demonstrate there are development or programming events being affected in early life that have a lifetime impact on productivity. When the data were evaluated for the 450 animals that had completed a third lactation, we found a lifetime milk effect of pre-weaning average daily gain of over 2,279 lb of milk depending on pre-weaning growth rates. Further, 22% of the variation in first lactation milk production could be explained by growth rate prior to weaning. This suggests that colostrum status and nutrient intake and or pre-weaning growth rate have a greater effect on lifetime milk yield and account for more variation in milk yield of the calf than genetic selection. Generally, milk yield will increase 150 to 300 lb per lactation due to selection whereas the effect of management is three to five times that of genetic selection

Health effects: In the Cornell herd, the effect of diarrhea or antibiotic treatment on ADG was not significant and ADG differed by approximately 30 g/d for calves that had either event in their records (P > 0.1). However, for calves that had both events recorded, ADG was lower by approximately 50 g/d (P < 0.01). Over the eight year period, approximately 59% of all of the calves had at least one of the recorded events. In the data from the Cornell herd, first lactation milk yield was not significantly affected by reported cases of diarrhea. Antibiotic treatment had a significant effect on TDM residual milk and calves that were treated with antibiotics produced 493 lb less milk in the first lactation (P > 0.01) than calves with no record of being treated.

Table 3. Predicted differences by TDM residual milk (lb) for 1st, 2nd, and 3rd lactation as well as cumulative milk from 1st through 3rd lactation as a function of pre-weaning average daily gain and energy intake over predicted maintenance for the Cornell herd.

Lactation	n	Predicted difference in milk pre lb of pre-weaning ADG, lb	P valu	Predicted difference in milk for each additional Mcal intake energy above maintenance, lb	P value
1st	1244	850	< 0.01	235	< 0.01
2nd	826	888	< 0.01	108	0.26
3rd	450	48	0.91	351	< 0.01
1st - 3nd	450	2,279	0.01	902	< 0.01

Regardless of antibiotic treatment, the effect of ADG on first lactation milk yield was significant in all calves (P < 0.05). Calves that were treated with antibiotics produced 623 lb more milk per lb of pre-weaning ADG while calves that did not receive antibiotics produced 1,407 lb more milk per kg of pre-weaning ADG. The effect of increased nutrient intake from milk replacer was still apparent in the calves that were treated, but the lactation milk response was most likely attenuated due to factors associated with sickness responses and nutrient partitioning away from growth functions (Johnson, 1998; Dantzer, 2006).

An analysis of all the lactation data and the pre-weaning growth rates, when controlled for study, suggests that to achieve these milk yield responses from early life nutrition, calves must double their birth weight or grow at a rate that would allow them to double their birth weight by weaning (56 days). This further suggests that milk or milk replacer intake must be greater than traditional programs for the first 3 to 4 weeks of life in order to achieve this response.

What changes in the animal are allowing for these differences? There is no one answer to that question but investigations are looking for several factors. Although mammary development as previously measured is probably not the appropriate factor (Meyer et al., 2006a, 2006b), it is intriguing to look at very specific cells within the mammary gland. There are a couple sets of data that demonstrate increased mammary cell growth based on early life nutrient intake. Brown et al. (2005) observed a 32 to 47% increase in mammary DNA content of calves fed approximately 1 versus 0.5 kg of milk replacer powder per day through weaning. Just like the milk production increases discussed earlier, this mammary effect only occurred prior to weaning. In fact, this increase in mammary development was not observed once the calves were weaned, indicating the calf is more sensitive to level of nutrition prior to weaning and that the enhancement mammary development cannot be "recovered" once we wean the animal.

Meyer et al. (2006a) observed a similar effect in mammary cell proliferation in calves fed in a similar manner. The calves on their study demonstrated a 40% increase in mammary cell proliferation when allowed to consume at least twice as much milk replacer as the control group before weaning (Meyer et al., 2006a). Sejrsen et al (2000) observed no negative effect on mammary development in calves allowed to consume close to ad libitum intakes. A more specific attempt to look at stem cell proliferation did not find increased stem cells in calves fed higher levels of nutrient intake (Daniels et al., 2008) and it was hypothesized that the stem cell proliferation might lead to greater secretory cells once the animal becomes pregnant.

SUMMARY

Early life events appear to have long-term effects on the performance of the calf. Our management approaches and systems need to recognize these effects and capitalize on them. We have much to learn about the consistency of the response and the mechanisms that are being affected. Given the amount of variation accounted for in first and subsequent lactation milk yield, there are opportunities to enhance the response once we know and understand those factors. The bottom line is there appears to be a positive economic outcome to improving the management of our calf and heifer programs starting at birth.

REFERENCES

Ballard, C., H. Wolford, T. Sato, K., Uchida, M. Suekawa, Y. Yabuuchi, and K. Kobayashi. 2005. The effect of feeding three milk replacer regimens preweaning on first lactation performance of Holstein cattle. J. Dairy Sci. 88:22 (abstr.)

Bar-Peled, U., B. Robinzon, E. Maltz, H. Tagari, Y. Folman, I. Bruckental, H. Voet, H. Gacitua, and A. R. Lehrer. 1997. Increased weight gain and effects on production parameters of Holstein heifers that were allowed to suckle. J. Dairy Sci. 80:2523-2528.

Bartol, F. F., A. A. Wiley, and C. A. Bagnell. 2008. Epigenetic programming of porcine endometrial function and the lactocrine hypothesis. Reprod. Domest. Anim. 43:273-279.

Bascom, S. A., R. E. James, M. L. McGilliard, and M. Van Amburgh. 2007. Influence of dietary fat and protein on body composition of Jersey bull calves. J. Dairy Sci. 90:5600–5609.

Baumrucker , C. R., and J. W. Blum. 1993. Secretion of insulin-like growth factors in milk and their effect on the neonate. Livest. Prod. Sci. 35:49-72.

Blum, J. W., and H. Hammon. 2000. Colostrum effects on the gastrointestinal tract, and on nutritional, endocrine and metabolic parameters in neonatal calves. Livest. Prod. Sci. 66:151-159.

Borenstein M, Hedges L, Higgins J, Rothstein H. Comprehensive Meta-analysis Version 2, Biostat, Englewood NJ. 2005. Comprehensive Meta Analyses software. www.Meta-Analysis.com

Brown, E. G., M. J. VandeHaar, K. M. Daniels, J. S. Liesman, L. T. Chapin, D. H. Keisler, and M. S. Weber Nielsen. 2005a. Effect of increasing energy and protein intake on body growth and carcass composition of heifer calves J. Dairy Sci. 88: 585-594.

Brown, E. G., M. J. VandeHaar, K. M. Daniels, J. S. Liesman, L. T. Chapin, J. W. Forrest, R. M. Akers, R. E. Pearson, and M. S. Weber Nielsen. 2005b. Effect of increasing energy and protein intake on mammary development in heifer calves J. Dairy Sci. 88: 595-603.

Burrin, D. G., R. J. Shulman, R. J. Reeds, T. A. Davis, and K. R. Gravitt. 1992. Porcine colostrum and milk stimulate visceral organ and skeletal muscle protein synthesis in neonatal piglets. J. Nutr. 122:1205-1213.

Burrin, D. G., M. A. Dudley, P.J. Reeds, R. J. Shulman, S. Perkinson, and J. Rosenberger. 1994. Feeding colostrum rapidly alters enzymatic activity and the relative isoform abundance of jejunal lactase in neonatal pigs. J. Nutr. 124:2350-2357.

Burrin, D. G., T. A. Davis, S. Ebner, P. A. Schoknect, M. L. Fiorotto, P. J. Reeds, and S. McAvoy. 1995. Nutrient-independent and nutrient-dependent factors stimulate protein synthesis in colostrum-fed newborn pigs. Pediatr. Res. 37:593-599.

Burrin, D.D., T.A. Davis, S. Ebner, P.A. Schoknecht, M.L. Fiorotto, and P.J. Reeds. 1997. Colostrum enhances the nutritional stimulation of vital organ protein synthesis in neonatal pigs. J. Nutr. 127:1284-1289.

Daniels, K. M., A. V. Capuco, R. E. James, M. L. McGilliard, and R. M. Akers. 2008. Diet does not affect putative stem cells in pre-weaned Holstein heifers. J. Dairy Sci. 91 (E-Suppl. 1): 121 (Abstr.)

Dantzer, R. 2006. Cytokine, sickness behavior, and depression. Neurol. Clin. 24:441 460.

Davis Rincker L. E., M. J. VandeHaar, C. A. Wolf, J. S. Liesman, L. T. Chapin, and M. S. Weber Nielsen. 2011. Effect of intensified feeding of heifer calves on growth, pubertal age, calving age, milk yield, and economics. J. Dairy Sci. 94 :3554–3567.

DeNise, S. K., J. D. Robison, G. H. Stott and D. V. Armstrong. 1989. Effects of passive immunity on subsequent production in dairy heifers. J. Dairy Sci. 72:552-554.

de Paula Vieira, A., V. Guesdon. A. M. de Passille, M. A von Keyserlingk and D. M. Weary. 2008. Behavioral indicators of hunger in dairy calves. Applied Anim. Behavior Sci. 109:180-189.

Donovan, G.A., I. R. Dohoo, D. M. Montgomery and F.L. Bennett. 1998. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. Prev. Vet.Med. 34:31-46

Donovan, S. M., and J. Odle. 1994. Growth factors in milk as mediators of infant development. Annu. Rev. Nutr. 14:147-167.

Drackley, J.K., B. C. Pollard, H. M. Dann and J. A. Stamey. 2007. First lactation milk production for cows fed control or intensified milk replacer programs as calves. J. Dairy Sci. 90:614. (Abstr.)

Everett, R. W., and F. Schmitz. 1994. Dairy genetics in 1994 and beyond. Cow and sire evaluation using test-day records, DairyGene, and DairyView for farm management. Pages 4–39 in Mimeo Ser. No. 170, Cornell Coop. Ext., Cornell Univ., Ithaca, NY.

Faber, S. N., N. E. Faber, T. C. McCauley, and R. L. Ax. 2005. Case Study: Effects of colostrum ingestion on lactational performance. Prof. Anim. Scientist 21:420-425.

Foldager, J. and C.C. Krohn. 1994. Heifer calves reared on very high or normal levels of whole milk from birth to 6-8 weeks of age and their subsequent milk production. Proc. Soc. Nutr. Physiol. 3. (Abstr.)

Foldager, J., C.C. Krohn and Lisbeth Morgensen. 1997. Level of milk for female calves affects their milk production in first lactation. Proc. European Assoc. Animal Prod. 48th Annual Meeting. (Abstr.)

Godden, S. 2008. Colostrum management for dairy calves. Vet. Clin. Food Anim. 24:19-39.

Hill, T.M, H.G. Bateman, J. M. Aldrich, and R. L. Schlotterbeck. 2009 Effects of changing the essential and functional fatty acid intake of dairy calves. J. Dairy Sci. 92:670-676.

Hinde, K., and J. P. Capitanio. 2010. Lactational Programming? Mother's milk energy predicts infant behavior and temperament in rhesus macaques (Macaca mulatta). Amer. J. of Primatology. 72:522-529

James, R. E., C. E. Polan, and K. A. Cummins. 1981. Influence of administered indigenous microorganisms on uptake of [Iodine-125] -Globulin in vivo by intestinal segments of neonatal calves. J Dairy Sci. 64: 52-61.

Jasper, J. and D. M. Weary. 2002. Effects of ad libitum milk intake on dairy calves. J. Dairy Sci. 85:3054-3058.

Johnson, R. W. 1998. Immune and endocrine regulation of food intake in sick animals. Domest Anim. Endocrinol. 15:309–319.

Jones, C. M., R. E. James, J. D. Quiqley, III, and M. L. McGilliard. 2004. Influence of pooled colostrum or colostrum replacement on IgG and evaluation of animal plasma in milk replacer. J. Dairy Sci.87:1806-1814.

Meyer, M. J., A. V. Capuco, D. A. Ross, L. M. Lintault, and M. E. Van Amburgh. 2006a. Developmental and nutritional regulation of the prepubertal heifer mammary gland: I. Parenchyma and fat pad mass and composition. J Dairy Sci. 89: 4289-4297.

Meyer, M. J., A. V. Capuco, D. A. Ross, L. M. Lintault, and M. E. Van Amburgh. 2006b. Developmental and nutritional regulation of the prepubertal bovine mammary gland: II. epithelial cell proliferation, parenchymal accretion rate, and allometric growth. J. Dairy Sci. 89:4298–4304

Moallem, U., D. Werner, H. Lehrer, M. Kachut, L. Livshitz, S. Yakoby and A. Shamay. 2010. Long-term effects of feeding ad-libitum whole milk prior to weaning and prepubertal protein supplementation on skeletal growth rate and first-lactation milk production. J. Dairy Sci. 93:2639-2650.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. 7th rev. Ed., Natl. Acad. Sci., Washington, D. C.

Nocek, J. E., D. G. Braund, and R. G Warner. 1984. Influence of neonatal colostrum administration, immunoglobulin, and continued feeding of colostrum on calf gain, health and serum protein. J. Dairy Sci. 67:319-333.

Nusser, K. D., and S. Frawley. 1997. Depriving neonatal rats of milk from early lactation as long-term consequences on mammotrope development. Endocrine 7:319-323.

Odle, J., R. T. Zijlstra, and S. M. Donovan. 1996. Intestinal effects of milkborne growth factors in neonates of agricultural importance. J. Anim. Sci. 74:2509-2522.

Raeth-Knight, M., H. Chester-Jones, S. Hayes, J. Linn, R. Larson, D. Ziegler, B. Ziegler and N. Broadwater. 2009. Impact of conventional or intensive milk replacer programs on Holstein heifer performance through six months of age and during first lactation. J Dairy Sci. 92:799-809.

Rauprich, A. B., H. M. Hammon, and J. W. Blum. 2000. Influence of feeding different amounts of first colostrum on metabolic, endocrine, and health status and on growth performance of neonatal calves. J. Anim. Sci. 78:896-908.

Robinson, J. D., G. H. Stott and S. K. DeNise. 1988. Effects of passive immunity on growth and survival in the dairy heifer. J. Dairy Sci. 71:1283-1287.

Sejrsen, K., S. Purup, M. Vestergaard, and J. Fodager. 2000. High body weight gain and reduced bovine mammary growth: physiological basis and implications for milk yield. Domes. Anim. Endo. 19:93-104.

Shamay, A., D. Werner, U. Moallem, H. Barash, and I. Bruckental. 2005. Effect of nursing management and skeletal size at weaning on puberty, skeletal growth rate, and milk production during first lactation of dairy heifers. J. Dairy Sci. 88:1460–1469.

Soberon F., E. Raffrenato, R. W. Everett and M. E. Van Amburgh. 2012. Early life milk replacer intake and effects on long term productivity of dairy calves. J. Dairy Sci. 95:783–793.

Soberon F., and M. E. Van Amburgh. 2011. Effects of colostrum intake and pre-weaning nutrient intake on post-weaning feed efficiency and voluntary feed intake. J. Dairy Sci. 94:69-70 (Abstr.).

Soberon F., and M. E. Van Amburgh. 2013. The effect of nutrient intake from milk of milk replacer of pre-weaned dairy calves on lactation milk yield as adults: a meta-analysis of current data. J. Anim. Sci. 91:706-712.

Terré, M., C. Tejero, and A. Bach. 2009. Long-term effects on heifer performance of an enhanced growth feeding program applied during the pre-weaning period. J. Dairy Res. 76:331–339.

Van Amburgh, M. E. and J. K. Drackley. 2005 Current perspectives on the energy and protein requirements of the pre-weaned calf. Chap. 5 in "Calf and heifer rearing: Principles of rearing the modern dairy heifer from calf to calving". Nottingham Univ. Press. P.C. Garnsworthy, ed. Pp.67-82.

Van Amburgh, M. E., D. M. Galton, D. E. Bauman, and R. W. Everett. 1997. Management and economics of extended calving intervals with use of bovine somatotropin. Livest. Prod. Sci. 50:15–28.

.Weaver, D. M., J. W. Tyler, D. C. VanMetre, D. E. Hostetler, and G. M. Barrington. 2000. Passive transfer of colostral immunoglobulins in calves. J. Vet. Intern. Med. 14:569-577.

Wolinski, J., M. Biernat, P. Guilloteau, B. R. Weström. 2003. Exogenous leptin controls the development of the small intestine in neonatal piglets. J. Endo. 177:215-222.

Widdowson, E. M., V. E. Colombo, and C. A. Artavanis. 1976. Changes in the organs of pigs in response to feeding for the first 24 h after birth. II. The digestive tract. Biol. Neonate 28:272-281.

Feeding the Organic Dairy Herd During 2013 and Beyond

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Introduction
The number of organic dairy producers in Minnesota and the Upper Midwest continues to grow. Over an eight-year period from 2000 to 2008, the number of organic farms in Minnesota grew by 42 percent. Currently, there are over 750 organic dairy farms in the Upper Midwest. Between 2000 and 2005, the number of organic milk cows in the United States increased from 38,000 to more than 86,000 cows (ERS, 2012; McBride and Greene, 2009), thus slowing the decline of smaller dairy operations in the Upper Midwest. Despite the slow-moving economy over the past several years, consumers continue to purchase organic dairy products. Organic milk can cost considerably more than conventional milk; the national price premium for organic milk averages $2.50 per gallon. Interest in organic dairying is on the increase because of the growing organic market, premium prices for organic milk, and a preference by consumers and some farmers for a less intensive production system. To maintain the viability of organic dairy operations, best management practices and a consistent season-long supply of high quality forage need to be provided to ensure animal health and milk production.

Organic Dairy Production
Many people may be confused about the use of the term “organic”. Organic, unlike “natural” is defined by federal law and regulated through a certification process. According to the National Organic Program (NOP) of the USDA (NOP, 2013), organic is a production system that is managed to respond to site-specific conditions by integrating cultural, biological and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity. To sell milk as organic, a farm must be certified and inspected annually to verify that an organic plan is followed. Rules are incorporated in the NOP with oversight provided by a certification agency (Riddle and Gulbranson, 2010).

For dairy operations, organic certification requires an Organic Livestock Plan, outdoor access for livestock, pasture for all dairy animals over 6 months of age during the grazing season (at least 30% of dry matter intake from pasture for at least 120 days), no antibiotics, growth hormones or GMOs, 100% organic feed, and no rotation of animals between organic and conventional management. Furthermore, dairy cows are to have had one year of organic management prior to production of organic milk, and manure must be managed to prevent contamination of crops, water, and soil, and to optimize recycling of nutrients. According to the NOP rules, it is forbidden to withhold medical treatment from a sick animal in order to keep it organic (NOP, 2012; NOP, 2013).

Organic livestock must consume organic feed, and therefore, rules apply to certified organic crop acres and pastures. Fields and pastures must have three years with no application of synthetic fertilizers or pesticides prior to the first harvest of organic crops or pasture. A producer must use organic seeds and an organic systems plan must be followed to include proactive soil fertility, and weed and pest management. Land transition begins at the date of the last application of a prohibited substance, and there must be a buffer zone between organic and conventional land. Organic crop and dairy producers must be certified, and annul certification is an evaluation system that validates the authenticity of products sold as organic (NOP, 2013).

Organic milk price is the biggest incentive for producers to transition from conventional to organic production. Based on spring 2012 prices, conventional milk base price was about $16 versus $26/cwt. for organic milk. Therefore, organic dairy production is very attractive to producers when the milk price spread is high. During the summer of 2011, the milk price spread between conventional and organic ranged from $3 to $5/cwt. making organic production not that attractive. However, supply management and a sustainable and persistent milk price for dairy producers are two incentives for producers to consider organic production.

For 2013, Midwest pay price data from CROPP cooperative (aka Organic Valley, www.farmers.coop) reports a base component price of $26.55/cwt., which is, based on 3.5% fat, 3.05% protein, and 5.65% other solids. Organic processors also pay significant premiums for somatic cell count, standard plate count (SPC), preliminary incubation count (PI), and lab pasteurization count (LPC). For somatic cell count, there is an adjustment of $0.48 cents per 100,000 cells. The limit for somatic cell count is 350,000. The deduction is $0.48 per 100,000 over 350,000 cells. The organic payment information for all regions of the United States is available at the Organic Valley website at http://www.farmers.coop/producer-pools/dairy-pool/pay-price/. Finally, organic processors incorporate a seasonal pay price premium to provide an incentive for persistent milk production across the year. For Organic Valley, there is a $3/cwt. increase for milk produced during the months of December, January, and February. Typically, most organic producers calve animals in the spring, and therefore, this incentive is in place for more production during the winter months.

Organic Grain Prices

Currently, in 2013, the biggest factor affecting the profit and bottom line of organic dairy herds in the United States is the high price of organic grains. During 2010, organic corn prices hovered around $6/bushel. However, in 2011, organic corn and soybean price rapidly climbed to $14/bushel and early 2013 prices indicate that organic corn will be high. Speculation is that most of the organic corn is going to the western United States for organic poultry production. Figure 1 and 2 are from the May 1, 2013 National Organic Grain and Feedstuffs report of the USDA (AMS, 2013). Additionally, the report stated that organic soybean meal averaged $1,150 per ton, which is not economical to feed to organic dairy cattle.

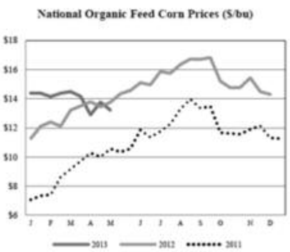

Figure 1. National Organic Corn Price 2011 - 2013

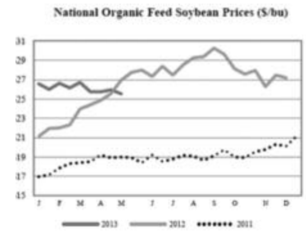

Figure 2. National Organic Soybean Price 2011 - 2013

Supplementing Diets on Pasture

Feed costs are a high proportion of the total production costs on dairy farms. With grain prices expected to increase in the future, dairy farms will feel pressure to increase the feeding of high quality, but low cost forages. Pastures and perennial forages that can be preserved for winter feeding will be a good source of high quality forage on many farms.

Supplementation of feeds is designed to complement pasture forage at a reasonable cost (Hamilton et al., 2012). Table 1 shows that grasses and legumes benefit from different supplement formulations. Neither grass nor legume pasture will meet the energy requirement of the high producing dairy cow. Levels of Neutral Detergent Fiber (NDF), especially in grasses, will limit the ability of the cow to maximize dry matter intake. High quality legumes or grasses provide adequate levels of protein, although requirements for rumen undregradable protein (RUP) may not be met.

Table 1. Nutrient recommendations for cows in early lactation and nutrient composition of pastures.

Nutrient	Recommendation	Grass	Grass-Legume	Legume
NEL, Mcal/lb	0.70	0.65-0.70	0.66-0.72	0.68-0.74
Crude protein,% of DM	16.1	27	19	26.5
Bypass protein (RUP)	6.4	4.3-4.6	4.2-5.7	4.6-5.0
NDF, % of DM (min)	25-33	46	45	33
NFC, % of DM	36-44	15-20	15-20	20-25

1989 and 2001 National Research Council Recommendations (NRC, 2001)

There remain unanswered questions on appropriate supplementation for grazing cows. Cows on all forage diets should respond to supplementation with high-energy feeds. Unfortunately, grains replace forage in the diet. A typical energy supplement consists of 10 to 16 lb of finely ground shelled corn with salt and minerals. That works out to 1 lb of supplement for every 4 to 5 lb of milk produced each day (Hoffman, 2000). Stored forage or additional grain may be provided to adjust for seasonal changes in pasture performance. Therefore, during the summer of 2012, we conducted a study that would develop practical strategies for organic dairy producers to enhance the profitability of their farm by evaluating organic grain supplementation levels, and its effect on economics, behavior, and pest management of organic dairy cows.

Organic Grain Supplementation

Organic dairy cows at the University of Minnesota's West Central Research and Outreach Center (**WCROC**), Morris, MN, that calved during fall 2011 and spring 2012 calving seasons were used to evaluate production, reproduction, grazing behavior, and pest management of organic dairy cattle supplemented with three levels (none, low, and high) of organic grain. Cows were assigned to one of three supplementation levels and were blocked by lactation number, breed, and previous lactation milk production. Breed groups of cows included pure Holsteins and various crossbreds of Jersey, Normande, Holstein, Montbéliarde, and Scandinavian Red.

During the 2012 grazing season, 96 lactating Holstein and crossbred organic dairy cattle were randomly assigned to a grain supplementation treatment (no grain, low grain, and high grain). Cows were fed the following dietary supplementation levels, 1) no grain supplementation (100% pasture, **GRS**), 2) low grain (6 lb of grain supplementation per day, **LOW**), or 3) high grain (12 lb per day, **HI**). Supplement was fed with a total mixed ration of an organic grain mix (corn and minerals). The TMR was 25 lb of organic corn silage, 20 lb of organic alfalfa silage, and 1.5 lb of organic minerals. Furthermore, at least 30% of their diet consisted of high-quality organic pasture during the grazing season. All feed consumption was recorded daily with Feed Supervisor software utilized by the WCROC dairy. Supplemented cows were fed TMR in a compost barn after the morning milking and were allowed to graze during the afternoon and evening. The GRS cows were continually on pasture except during milking. Pasture herbage production was assessed for each group of supplemented cows during the grazing season with an electronic rising plate meter. Pasture herbage samples were analyzed for dry matter, ash, crude protein, neutral detergent fiber, acid detergent fiber, starch, and minerals using wet chemistry by Dairyland Laboratories, Inc. (St. Cloud, MN).
For statistical analysis of production, body weight, and body condition score, independent variables were fixed effects of days in milk, season of calving, lactation number, breed group, and supplementation group, and cow within breed was a random effect. For pasture herbage mass and fatty acids, the fixed effect was supplementation group and collection date was a random effect. The MIXED procedure of SAS (SAS Institute, 2012) was used to obtain solutions and conduct the ANOVA. All treatment results are reported as least squares means and significance was declared at $P < 0.05$.

The distribution of cows by breed group and supplementation group is in Table 2. Breed groups of cows were Holsteins (n = 32) maintained at 1964 breed average level, Holstein-sired crossbreds (n = 27), Jersey-sired crossbreds (n = 26), and Scandinavian Red-sired crossbreds (n = 11).

Table 2. Distribution of organic dairy cows by breed group and supplementation group.

Breed group	Grass (N)	Low Supplement (N)	High Supplement (N)
1964 Holstein	10	11	11
Holstein-sired crossbreds	10	8	9
Jersey-sired crossbreds	9	9	8
Scandinavian Red-sired crossbreds	3	4	4
Total cows	32	32	32

The GRS cows had ($P < 0.05$) lower milk, fat, and protein production than the LOW and HI cows (Table 3). However, LOW and HI cows were not different for milk, fat, and protein production. Surprisingly, there were no differences in production between the two supplemented groups of organic cows, but the HI cows may have been partitioning the extra 6 lbs. of grain into body condition, and these results are presented in Table 5.

Table 3. Means of production by supplementation group during the grazing season for organic dairy cows.

Measurement	Grass Mean	SE	Low Supplement Mean	SE	High Supplement Mean	SE
Milk (lb)	32.2a	2.1	40.4b	1.9	39.4b	1.9
Fat (lb)	1.23a	0.1	1.53b	0.1	1.33a,b	0.1
Fat (%)	3.82a	0.2	3.78a,b	0.2	3.38b	0.2
Protein (lb)	1.03a	0.1	1.31b	0.1	1.26b	0.1
Protein (%)	3.20a	0.1	3.24a	0.1	3.20a	0.1
Somatic cell score	3.66	0.32	3.26	0.27	3.03	0.27
Milk urea nitrogen (mg/dl)	14.25a	0.3	10.06b	0.2	7.33c	0.3
Energy-corrected milk(lb)	32.2a	1.2	37.2b	1.1	36.3b	1.1

a,b,c = Means within a row without common superscripts are different at $P < 0.05$

As expected, the GRS cows had higher milk urea nitrogen (MUN) than the LOW and HI groups of cows. The concentration of MUN in milk provides an idea of how cows utilize crude protein from the feedstuffs they consume. Typical dairy cow MUN ranges from 10 to 12 mg/dl, but values are higher when excess rumen degradable and undegradable protein is fed. The interpretation of MUN values may be influenced by many different variables, i.e. season, breed, level of production, and feedstuffs. When correcting for the fat and protein content in milk, the difference between the GRS and LOW and HI cows was reduced, but the GRS cow were still lower for energy-corrected milk.

Means for body weight for cows by 14-d period and across the grazing season are in Table 4. Across the grazing season, there were no differences for body weight for the GRS (1,079 lb), LOW (1,080 lb), and HI (1,089 lb) organic cows. The GRS cows had greater body weight change (+109 lb) compared to the LOW (+80 lb) and HI (+86 lb) cows.

Table 4. Means of body weight by supplementation group during the grazing season for organic dairy cows.

Measurement for 14-d period	Grass Mean	SE	Low Supplement Mean	SE	High Supplement Mean	SE
1	1,022	27.3	1,043	26.4	1,050	26.1
2	1,093	27.2	1,062	26.4	1,064	26.1
3	1,043	27.2	1,071	26.4	1,087	26.0
4	1,074	27.2	1,059	26.4	1,066	26.1
5	1,067	27.2	1,090	26.5	1,081	26.1
6	1,071	27.2	1,078	26.5	1,095	26.1
7	1,116	27.2	1,105	26.5	1,116	26.1
8	1,093	27.5	1,092	26.6	1,105	26.3
9	1,131	27.7	1,123	26.8	1,136	26.4
Mean of 14-d periods	1,079	26.6	1,080	25.8	1,089	25.5

Body weights for groups were not different for specific 14-d periods ($P < 0.05$)

For BCS across the grazing season, the GRS (2.98) cows had lower body condition scores than the LO (3.09) and HI (3.15) cows (Table 5). During the early period of the grazing season (May), GRS cows were not different from the supplemented cows for body condition score. These results may be attributed to fact that there was an adjustment period for the GRS cows moving from TMR to 100% pasture. However, during the latter period of the grazing season, the GRS cows were ($P < 0.05$) lower for body condition score than the LO and HI cows. Although not significantly different, the HI cows had numerical higher body condition scores than the LO cows.

Table 5. Means of body condition score by supplementation group during the grazing season for organic dairy cows.

	Grass		Low Supplement		High Supplement	
Measurement for 14-d period	Mean	SE	Mean	SE	Mean	SE
1	3.12	0.08	3.12	0.07	3.23	0.07
2	3.28	0.07	3.25	0.07	3.20	0.07
3	3.14a	0.07	3.34b	0.07	3.37b	0.07
4	2.86a	0.07	3.00a,b	0.07	3.06b	0.07
5	2.86a	0.07	2.97a,b	0.07	3.06b	0.07
6	2.86a	0.07	2.97a,b	0.07	3.07b	0.07
7	2.91a	0.08	3.12b	0.07	3.12b	0.07
8	2.87 a	0.08	2.98 a,b	0.08	3.04 b	0.08
9	2.90a	0.08	3.03a,b	0.08	3.17b	0.08
Mean of 14-d periods	2.98a	0.06	3.09a,b	0.06	3.15b	0.06

a,b,c = Means within a row without common superscripts are different at P < 0.05

Potentially, the LOW and HI cows in this study devoted more of the energy they consumed to maintain and restore BCS compared than GRS cows and this, in turn, may have resulted in the enhanced reproductive cyclicity of the LOW and HI cows.

Pasture herbage mass results (Table 6) for cows found the GRS (562 lb) cows consumed more dry matter intake per acre per day than the LO (465 lb) or HI (472) cows on pasture, as expected. The GRS cows may have had higher dry matter intake on pasture, if the digestibility of the grass would have remained constant throughout the grazing season. The NDF digestibility was high during May and June, decreased during July and August, and was the lowest in September even though crude protein was constant from June to September. The GRS cows were simply not consuming enough quality dry matter intake from pasture during the latter part of the grazing season, and this may be one of the reasons for the lower milk production that was observed for the GRS cows compared to the LO and HI cows

Table 6. Means of pasture herbage mass by supplementation group during the grazing season for organic dairy cows.

	Grass	Low Supplement	High Supplement
Grazing measurement	Mean	Mean	Mean
Pre-grazing herbage mass (lb/DM/acre)	3,389[a]	3,377[b]	3,426[b]
Post-grazing herbage mass (lb/DM/acre)	2,140[a]	2,329[b]	2,374[b]
Forage intake (lb/DM/acre)	1,252[a]	1,080[b]	1,091[b]
Dry matter/acre/day	562[a]	465[b]	472[b]

[a,b,c] = Means within a row without common superscripts are different at P < 0.05

The results for fatty acid profile analysis across the grazing season are in Table 7. The most beneficial fatty acids to human health are Stearic (18:0), Oleic (18:1), Linoleic (18:2), and Linolenic (18:3), and those fatty acids were all (P < 0.05) higher in milk from the GRS cows compared to milk from the LOW or HI cows. Furthermore, the GRS cows had milk than was lower in Lauric (12:0), Myristic (14:0), and Palmitic (16:0) acid than the LOW and HI cows. Lauric, Myristic, and Palmitic acid have been shown to be of greater risk to human health (Daley et al, 2010). Additionally, the GRS cows had milk that was (P < 0.05) higher for mono-unsaturated fat and Omega-3 fatty acid than milk from LOW and HI cows. No difference was found for supplementation groups for Omega-6 fatty acid.

Total mixed ration cost were lower ($0.00 versus $3.18 versus $4.21), pasture cost were higher ($1.02 versus $0.86 versus $0.87), and production revenue from milk were lower ($5.02 versus $6.35 versus $5.53) for GRS, LOW, and HI cows, respectively. Although the LOW cows consumed lower amounts of concentrate, they had similar production to the HI cows. Income over feeds costs ($/cow/day) was higher for the GRS and LOW cows compared to the HI cows ($3.61 versus $2.20 versus $0.38, respectively). For profitability, grain costs were substantially higher for the HI cows, and therefore, resulted in a reduced income over feed cost for HI cows. The higher cost of production for the HI cows is due to the extremely high value of organic corn ($13.21/bushel, April 2013). The GRS cows had the highest income over feed costs compared to the other supplementation groups because of lower feed costs, mainly pasture. Therefore, a low grain ration may reduce feed costs without sacrificing profit in an organic dairy system.

Table 7. Means of specific fatty acids by supplementation group during the grazing season for organic dairy cows.

	Grass		Low Supplement		High Supplement	
Measurement	Mean	SE	Mean	SE	Mean	SE
	------------ (%) weight of total fat --------------					
C12:0 Lauric	2.28[a]	0.2	3.15[b]	0.2	3.43[b]	0.2
C14:0 Myristic	8.78[a]	0.4	10.70[b]	0.4	11.00[b]	0.4
C16:0 Palmitic	24.83[a]	0.8	29.18[b]	0.8	29.08[b]	0.8
C18:0 Stearic	13.63[a]	0.6	12.23[b]	0.6	11.85[b]	0.6
C18:1 Oleic	24.48[a]	1.0	21.58[b]	1.0	21.60[b]	1.0
C18:1T Elaidic	6.58[a]	0.3	4.03[b]	0.3	3.93[b]	0.3
C18:2 Linoleic	1.48[a]	0.09	1.63[a,b]	0.09	1.83[b]	0.09
C18:2T Linoelaidic	1.35[a]	0.1	1.13[a,b]	0.1	0.95[b]	0.1
C18:3 Linolenic	0.90[a]	0.07	0.73[a,b]	0.07	0.65[b]	0.07
----------------------- (%) in sample of milk -----------------------						
cis-Monounsaturated Fat	1.14a	0.07	0.94[b]	0.07	0.93[b]	0.07
cis-Polyunsaturated Fat	0.12	0.01	0.11	0.01	0.12	0.01
Omega 3 Fat	0.05a	0.0	0.04[b]	0.0	0.03[b]	0.0
Omega 6 Fat	0.08	0.0	0.07	0.0	0.08	0.0
Saturated Fat	2.61	0.2	2.61	0.2	2.63	0.2
Total Fat Triglycerides	4.46	0.2	4.07	0.2	4.10	0.2
trans Fat	0.37[a]	0.02	0.21[b]	0.02	0.22[b]	0.02

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

Table 8. Means of profitability by supplementation group during the grazing season for organic dairy cows.

	Grass		Low Supplement		High Supplement	
Measurement	Mean	SE	Mean	SE	Mean	SE
TMR cost ($)	0.0[a]	0.06	3.18[b]	0.06	4.21[c]	0.06
Pasture cost ($)	1.02[a]	0.03	0.87[b]	0.03	0.86[b]	0.03
Production revenue ($)	5.02[a]	0.3	6.35[b]	0.3	5.53[c]	0.3
Income over feed cost ($)	3.61[a]	0.3	2.20[b]	0.3	0.38[c]	0.3

[1] = All revenue and costs are in dollars per cow per day

[a,b,c] = Means within a row without common superscripts are different at $P < 0.05$

Conclusions

The dairy segment of the organic food industry is rapidly growing. More consumers are choosing organic dairy products and organic dairy consumption is on the increase. For organic dairy production, feed must be 100% organic, antibiotics and hormones are not allowed, pasture is mandated, and extensive records must be maintained on feed and animal health. There are many challenges associated with organic dairy production and extensive planning is needed for producers considering a transition to organic dairy production. Some challenges include fewer health products allowed, higher costs of feed, less research information available on organic dairy production, high costs of certification ($500 to $1,500 per year), and the extensive paperwork and records that must be maintained on all aspects of the farm.

Pasture can be a cost effective source of feed and housing for dairy animals. The pastures should utilize productive and high quality legumes and grazes organized in paddocks that are intensively grazed with rest periods of three to four weeks before being grazed again. Animals should be monitored regularly to determine the need for supplementation and general health. During the first year of our organic grain supplementation project, cows that consumed 100% pasture had lower milk production, lower body condition scores, but had milk that was higher in beneficial fatty acids. This information can be significant to organic dairy producers, as well as conventional producers, who are looking to reduce input costs during high grain prices. Producers who have a handle on their feed costs in an organic dairy production system can make informed decisions that reduce financial loss. The most important point for reducing inputs and increasing profits in organic dairy systems is to produce high quality forages and maximize dry matter intake on pasture.

Acknowledgements

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References

Agricultural Marketing Service (AMS). 2013. USDA Livestock and Grain Market News, www.ams.usda.gov/LSMarketNews. Accessed: May 1, 2013.

Daley, C.A., A. Abbott, P.S. Doyle, G.A. Nader, S. Larson. 2010. A review of fatty acid profiles and antioxidant content in grass-fed and grain-fed beef. Nutrition Journal, 9:10.

Economic Research Service/USDA (ERS). 2012. Organic Production Data. Table 5. Certified Organic Livestock. http://www.ers.usda.gov/Data/Organic/ Accessed: May 1, 2013.

Hamilton, S. A., G. J. Bishop-Hurley, and R. Young. 2012. Economics of pasture-based dairies. M192. University of Missouri Extension. http://extension.missouri.edu/p/M168

Hoffman, K., R. DeClue, and D. L. Emmick. Prescribed grazing and feeding management of lactating dairy cows. New York State Grazing Lands Conservation Initiative in Cooperation with the USDA-NRCS, Syracuse, New York, January 2000.

McBride, W.D., and C. Greene. Characteristics, Costs, and Issues for Organic Dairy Farming, ERR-82, U.S. Department of Agriculture, Economic Research Service, 2009.

National Organic Program (NOP). 2013. http://www.ams.usda.gov/AMSv1.0/nop

National Organic Program Standards. 2012. United States Department of Agriculture,

Agricultural Marketing Services, 205.239. http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=3f34f4c22f9aa8e6d9864cc2683cea02&tpl=/ecfrbrowse/Title07/7cfr205_main_02.tpl

Nutrient Requirements of Dairy Cattle. Washington, DC: 6th rev. ed. Natl. Acad. Sci.; 1989

Nutrient Requirements of Dairy Cattle. Washington, DC: 7th rev. ed. Natl. Acad. Sci.; 2001

Riddle, Jim and Lisa Gulbranson. 2011. Minnesota Guide to Organic Certification. Minnesota Institute for Sustainable Agriculture. http://www.misa.umn.edu

SAS Institute. 2012. SAS/STAT Software, Release 9.3. SAS Inst. Inc., Cary, NC.

The Metabolic Profile of Transition Dairy Cows

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Introduction

- Transition period
  - Most stressful time in lactation
  - 75% of all illness occurs within this period (LeBlanc et al., 2006)
  - Focus of much research and management
- Necessary to utilize all tools available for proper diagnosis or treatment of illness in transition period

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Profile Components

- Reference values - based upon data from laboratory analysis over time
  - Adapted from earlier profiles
- Specific for breed?
- Specific for stage of lactation?

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Metabolic Profile

- Compton Metabolic Profile (CMP) (Payne, 1970)
  - Monitor metabolic health of herd
  - Help diagnose metabolic problems and production diseases
  - Glucose, urea, P, Ca, Mg, Na, K, albumin, globulin, hemoglobin, and Cu
- Selected components differ based upon demands
  - Diagnosis of illness or deficiency

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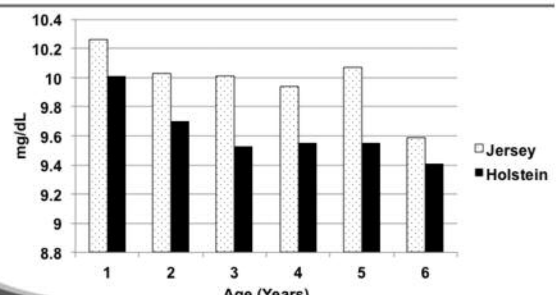
Calcium - Two Breeds



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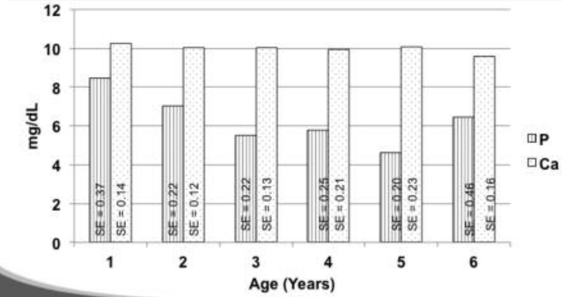
Roussel et al., 1982; Roussel et al., 1982

Ca and P Levels for Jersey Cows



Roussel et al., 1982

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Impact of Lactation Number

Analyte	Precalving Cows	Postcalving cows
BHBA	None	L2 < L3+
Cholesterol	L2 < L3+	None
Glucose	L2 < L1, L3+ < L1	L2 < L3+ < L1
Urea	L1 < L2; L1 < L3	L1 < L2; L1 < L3
Calcium	L2 < L1, L3+ < L1	L3+ < L2 < L1
Phosphorus	None	L2 < L1, L3+ < L1

Quiroz-Rocha, 2009

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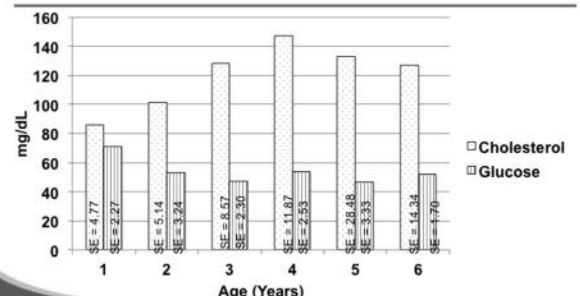
Cholesterol and Glucose - Jersey



Roussel et al., 1982

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Seasonal Effect

	Season			
	Summer		Winter	
Parameter	Mean	CI	Mean	CI
Phosphorus	1.8	1.4-2.3	1.7	1.3-2.2
Sodium	135	131-139	137	131-143
Chloride	98	90-106	100	92-108

(Cozzi, 2011)

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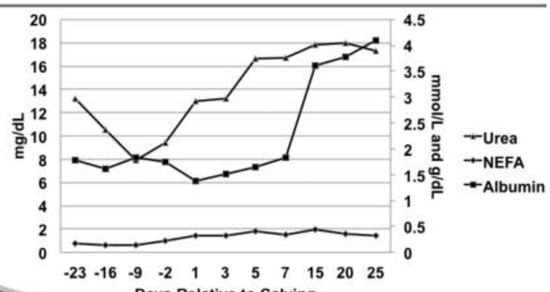
Variation Over Time



Park et al., 2010

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Extended Profile: Recent Research

- Breed difference (Jersey vs. Holstein)
  - Ca, P, Mg, albumin, urea, cholesterol, NEFA, Na, K (Lager et al., 2012)
- Seasonal difference (winter vs. summer)
  - Ca, P, Mg, albumin, urea, glucose, cholesterol, NEFA, K, Cl (Lager et al., 2012)

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Key: Sampling and Interpretation

- Old adage: garbage in garbage out
  - Lab results only as good as sample received (e.g. sample handling, animal classification)
- Sample collection location
  - Variation between coccygeal, jugular, mammary for certain analytes
- Stage of lactation relative to calving

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Interpretation of Results

- Analyze results in relation to reference range from laboratory
  - Lab range separated by stage of lactation?
- Breed differences
- Seasonal effects

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Profile, Select Locations

		Analyte				
		Alb	Urea	Chol.	Glucose	NEFA
Source	Class	g/dL	mg/dL	mg/dL	mg/dL	mEq/L
SW USA	close-up	3.0-3.6	9.4-16.6	39-123	51-65	<0.6
	<14 DIM	3.0-3.6	9.4-16.6	39-123	51-65	<0.6
NE USA	close-up	3.3-3.7	-	65-114	51-74	0.03-0.46
	fresh	3.2-3.6	-	63-253	42-68	0.01-0.52
NW USA	Cattle	3.2-4.1	8.0-27	43-331	51-77	0.04-0.34

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Conclusion

- Metabolic profile used in full or its components can be used as an additional tool for management
- Differences for breed, season, and variability over time; accounting for differences?
- Proper sampling and interpretation of results are imperative to effective use

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Mineral Profiles, Select Locations

		Analyte					
		Ca	P	Mg	K	Na	Cl
Source	Class	mg/dL	mg/dL	mEq/dL	mEq/dL	mEq/dL	mEq/dL
SW USA	close-up	8.3-9.7	4.9-7.1	1.5-2.1	4.0-5.0	139-147	99-107
	<14 DIM	8.0-10	4.9-7.1	1.5-2.1	4.0-5.0	138-146	97-105
NE USA	close-up	8.7-11	4.5-8	2-3.5	3.8-5.2	137-148	-
	fresh	-	-	-	-	-	-
NW USA	Cattle	8.2-10	5.2-7.9	2-3.9	3.8-5.2	137-148	96-110

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3-R Transition Period: Recovery, Reproduction and Results

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TAKE HOME MESSAGE

- Cows that received controlled energy (**CE**) diets during the last 4 weeks (**wk**) prepartum had higher hazard ratio for difference in days to pregnancy (**DTP**). Such a finding may be explained by the increased net energy for lactation intake (**NE_{LI}**) in the first 4 wk postpartum, lower incidence of diseases (**DISE)**, and lower incidence of multiple diseases (**MDISE)**.
- Lower body condition score (**BCS**) loss in the first 6 wk and slightly greater glucose concentrations at wk 3 may have contributed to improved reproductive performance. Energy-limited cows had lower liver triglyceride (**TG**) concentrations at wk −2, which led to fewer DTP.
- Cows that received CE diets during the dry period yielded the same amount of milk as cows that received high energy (**HE**) diets.
- Cows fed HE during the close-up (**CU**) period had higher milk fat and milk protein during early lactation.
- Cows fed HE during the far-off (**FO**) period lost more body weight (**BW**) in the first 6 wk after calving, which might be related to higher MUN concentration in wk 3 for those cows.
- Cows fed CE during the dry period had less odds for developing displacement of abomasum (**DA**) or clinical ketosis (**KET**).

INTRODUCTION

During the transition period from late gestation through early lactation, the dairy cow undergoes tremendous metabolic adaptations (Bell, 1995). The endocrine changes during the transition period are necessary to prepare the dairy cow for parturition and lactogenesis. As peak milk yield increases, the transition period for dairy cows becomes much more challenging with most infectious diseases and metabolic disorders occurring during this time (Drackley, 1999; Grummer, 1995). Decreased dry matter intake (DMI) during late gestation influences metabolism leading to fat mobilization from adipose tissue and glycogen from liver.

Nutrient demand for milk synthesis is increased in early lactation; if no compensatory intake of nutrients is achieved to cope with the requirement, reproductive functions (i.e., synthesis and secretion of hormones, follicle ovulation, and embryo development) may be depressed. Milk production increases faster than energy intake in the first 4 to 6 wk after calving, and thus high yielding cows will experience negative energy balance (NEB).

Therefore, strategies that stimulate DMI around parturition are of grant advantage for the dairy cow. Based on previous reports (Kunz et al., 1985) and on field observations from experienced professionals such as Dr. Gordie Jones, Drackley's group at the University of Illinois was motivated to better understand the possible effects of controlled energy feeding during the transition period.
Controlling energy with high fiber rations seems to improve DMI after parturition, thereby avoiding excessive adipose tissue lipid mobilization. One can hypothesize that the benefits of the controlled energy diet prepartum could have a positive effect on cows' fertility. In order to best evaluate pregnancy risk to assess fertility of dairy cows, statistical inferences should be based on survival analysis.

NUTRITION

Common dietary recommendations for close-up cows following publication of the NRC (2001) include feeding diets containing relatively high (36 to 44%) concentrations of nonfiber carbohydrate (NFC) to promote DMI during the peripartum period in an attempt to increase dietary energy intake and thus decrease the cow's reliance on NEFA. However, compared with diets lower in NFC content, excessive concentrations of starch-based NFC (>40%) in the prepartum diet may result in a greater decrease in DMI immediately before calving (Rabelo et al., 2005) and could potentially be detrimental to postpartum health and performance.

In a review, Grummer (1995) suggested that prepartum DMI was positively correlated with postpartum DMI and that prepartum DMI should be maximized to improve postpartum performance and health. This author also suggested that increasing the nutrient density of the diet could increase DMI and thus nutrient intake.
Cows that were overfed during the entire dry period had higher serum insulin concentration and lower basal lipolytic rates in adipose tissue during the last

week prepartum than cows that were feed restricted (Rukkwamsuk et al., 1998). Conversely, VandeHaar et al. (1999) increased dietary protein and energy density during the prepartum period and observed a reduction in liver TG concentration (2.4 vs. 1.5%, wet basis) on day 1.

Dann et al. (2006) concluded that during the first 10 days in milk (DIM), far-off treatments had significant carryover effects on DMI, energy balance, serum NEFA concentration, and serum BHBA concentration. Cows with the lower energy balance during the far-off period had higher DMI and energy balance and lower serum NEFA and BHBA during the first 10 DIM. There were no effects of close-up diet and no interactions of far-off and close-up treatments.

Drackley (1999) suggested that dietary fat or elevated NEFA from decreased nutrient intake in the studies of Grum et al. (1996) and Douglas et al. (1998) may have increased expression and action of peroxisome proliferator-activated receptor, leading to increased hepatic oxidation and decreased esterification of FA observed in liver tissue. Both starvation and increased dietary fat intake lead to increases of acyl-CoA concentrations in rat liver (Ney et al., 1989). Increases in NEFA during the last few days before calving may contribute to decreased DMI due to hepatic oxidation of NEFA and neural signaling from the liver via the vagus nerve (Allen et al., 2005). Hayirli et al. (1998) observed that over-conditioned cows experienced a gradual decline in DMI during the transition period; whereas, thin cows maintained DMI longer prior to experiencing a more abrupt decrease in DMI shortly before parturition.

CONTROLLED ENERGY

Feeding diets with 1.30 Mcal NEL/kg of DM accommodates energy requirements for maintenance, pregnancy, and mammary growth in mature cows during the dry period (NRC, 2001). Usually at dry-off, cows are fed high forage diets containing high fiber compared to the lactation diet. The diet change affects bacterial population, the absorptive capacity and size of the rumen papillae, and therefore the capacity for absorption of volatile fatty acids in the rumen (Goff and Horst, 1997). During the close-up period (usually 3 wk before parturition) rations of higher energy and nutrient density are fed ("steam-up" diets) with the objective to adapt the rumen microbial population and papillae to the high-energy content of the lactation diet just after calving (Grummer, 1995). However, there is evidence that cows can over consume energy relative to their energy requirement independent of diet adjustments (Dann et al., 2006, Janovick and Drackley, 2010). Even though steam-up diets are frequently used in dairy farms, research had not demonstrated that they improved milk production, body condition, or the immune status of the cow during the transition period.

Based on previous reports (Kunz et al., 1985) and on field observations from experienced professionals such as Dr. Gordie Jones, Drackley's group at the University of Illinois was motivated to better understand the possible effects of controlled energy feeding during the transition period. The strategy developed was to formulate and feed rations with relatively low energy density (1.30 to 1.39 Mcal NEL/kg of DM) during the entire dry period. The incorporation of low energy ingredients (straw or low quality grass hays) allows cows to consume ad libitum without exceeding their daily energy requirements (Janovick and Drackley, 2010). Controlling energy with high fiber rations seems to improve DMI after parturition, avoiding excessive adipose tissue mobilization (Douglas et al., 2006). Milk production appears to be similar when compared to higher energy close-up programs (Douglas et al., 2006, Janovick and Drackley, 2010). Benefits of feeding controlled energy (CE) diets prepartum to dairy cows have been reported (Dann et al., 2006; Douglas et al., 2006; Janovick and Drackley, 2010). Recently, Janovick et al. (2011) suggested that cows fed CE during the dry period had fewer diseases and disorders than cows fed high-energy (HE) diets. Also, Beever (2006) stated that farmers have repeatedly observed easier calving and greater DMI around parturition when energy intake is controlled prepartum. Excess energy consumption prepartum also seems to result in a larger decline in DMI prepartum compared with cows having controlled intake prepartum (Janovick et al., 2011). Such steep changes in DMI prepartum have been associated with increased deposition of lipid in liver postpartum (Drackley et al., 2005). From a practical standpoint, the CE approach may simplify dry cow management by avoiding social stress due to group changes (Cook and Nordlund, 2009) and allowing a single group feeding instead of the two-group approach (Dann et al., 2006).

REPRODUCTION AND NUTRITION

Nutrient demands for milk synthesis are increased in early lactation, and if no compensatory intake of nutrients is achieved to cope with requirements reproductive functions (i.e., synthesis and secretion of hormones, follicle ovulation, and embryo development) may be depressed. The incidence of diseases and disorders can be high during this time period and have a negative impact on reproductive performance. The risk of pregnancy was reduced if cows had retained placenta (RP; i.e., presence of fetal membranes 12 hours or more following parturition –

Radostitis et al., 2007) or lost one body condition score (BCS) unit (Goshen and Shpigel, 2006; Santos et al., 2008).

Milk production increases faster than energy intake in the first 4 to 6 wk after calving. High yielding cows will experience NEB where blood concentrations of NEFA increase, while concentrations of insulin-like growth factor-I (IGF-I), glucose, and insulin are low. If extreme, these changes in blood metabolites and hormones may compromise ovarian function and fertility. In addition, energy balance and DMI can decrease plasma concentrations of progesterone (Vasconcelos et al., 2003; Villa-Godoy et al., 1988), possibly interfering with follicle development and pregnancy maintenance.
Improved management of herds and genetic selection during the last decades have increased milk production of dairy cows, at the same time that fertility has decreased (Butler, 2003). Selection for increased milk yield in the dairy cow has changed endocrine profiles of those animals, including increased blood concentrations of bovine somatotropin and prolactin and decreased insulin (Bonczeck et al., 1988). The difference in the metabolite and hormonal profile together with increased nutrient demands for milk production might have a negative impact on reproduction of the dairy cow. Nevertheless, good management and adequate nutrition have been shown to alleviate the depression of fertility on herds with average milk production exceeding 12,000 kg/cow annually (Nebel and MacGilliard, 1993; Jordan and Fourdraine, 1993). Different nutritional strategies have been proposed to improve reproduction of the dairy cow with no detrimental effect on lactation performance. Feeding high quality forages, increasing the concentrate:forage ratio, or adding supplemental fat to diets are some of the most common ways to improve energy intake in cows. Reproduction of dairy cattle may be benefited by maximizing DMI during the transition period, minimizing the incidence of periparturient problems, and promoting increased concentrations of insulin in early lactation.

UTERINE HEALTH AND FERTILITY

A large number of epidemiological studies have demonstrated strong relationships between diseases postpartum and subsequent reproductive performance in dairy cattle. Cows identified with clinical hypocalcemia were 3.2 times more likely to experience RP than cows that did not have clinical hypocalcemia (Curtis et al., 1983). Whiteford and Sheldon (2005) also found an association between hypocalcemia and occurrence of uterine disease in lactating dairy cows. Markusfeld (1985) suggested that 80% of cows with ketonuria developed metritis (i.e., cows with abnormally enlarged uterus and a purulent uterine discharge detectable in the vagina, within 21 d postpartum – Sheldon et al., 2006).

Usually, cows with RP have increased risk of developing metritis compared with cows without RP. Both metritis and RP double the risk of cows remaining with uterine inflammation at the time of first postpartum insemination (Rutigliano et al., 2008). Both RP and metritis have a negative impact on reproductive success in lactating dairy cows, with reduced conception rates and extended intervals to pregnancy (Goshen and Shpiegel, 2006). Furthermore, not only does the clinical disease negatively affect fertility, but subclinical endometritis, a disease characterized by increased proportion of neutrophils in uterine cytology without the presence of clinical signs of inflammation of the uterus, has deleterious effects on conception rates of lactating dairy cows at first postpartum insemination (Sheldon et al., 2006).

Feed intake and feeding behavior around parturition might mediate some of the increased risk for uterine diseases in dairy cattle (Hammon et al., 2006; Huzzey et al., 2007; Urton et al., 2005). Hammon et al. (2006) observed that cows developing uterine disease postpartum experienced reduced DMI beginning 1 wk before parturition. In concordance, cows diagnosed with severe metritis after calving were already consuming less DMI 2 wk prior to calving (Huzzey et al., 2007). In the same study, cows that subsequently developed mild metritis had reduced DMI 1 wk before calving compared with cows with healthy uterus. Urton et al. (2005) observed that cows subsequently developing metritis spent significantly less time eating before and after calving than cows that did not develop metritis. Therefore, diminished intake of nutrients or alterations in feeding behavior prior to calving may be major risk factors for development of metritis postpartum.

Since intake of nutrients influences energy status and immune function of dairy cows, both being related to the risk of uterine diseases, one could suggest that nutritional and management strategies that optimize nutrient intake around parturition should improve uterine health and subsequent fertility of dairy cows.

NUTRITIONAL REGIMEN, METABOLIC DISORDERS, REPRODUCTION, AND PRODUCTION IN DAIRY COWS DURING THE TRANSITION PERIOD

Negative energy balance (NEB) during the first weeks postpartum is associated with reduced reproductive performance in dairy cows. A meta-analysis approach was conducted to investigate the association between prepartum energy feeding regimen and reproductive performance. Days to pregnancy (DTP) was used as the dependent variable to assess reproductive performance. The database was developed from 7 experiments completed in our group from 1993 to 2010. Individual data for 408 cows (354 multiparous and 54 primiparous) were included in the analysis. The net energy for lactation (NEL) intake was determined from each cow's average DMI and calculated dietary NEL density. Treatments were applied prepartum and were classified as either controlled energy (CE; median NE_{LI} = 13.7 Mcal/d) or high energy (HE; median NE_{LI} = 22.1 Mcal/d) diets fed during the far-off (FO) or close-up (CU) dry periods. Cow was the experimental unit.

The Cox proportional hazard model revealed a significant difference in DTP between HE and CE during the CU period (median = 167 and 157 d; hazard ratio (HR) = 0.696; Figure 1). Cows fed HE diets during the last 4 wk prepartum lost more BCS in the first 6 wk postpartum than those fed CE (−0.43 and −0.30, respectively). Cows with 3 or more lactations lost more BCS than cows with one or two lactations (−0.42 and −0.33, respectively). Cows fed CE during the FO period had lower nonesterified fatty acids (NEFA) concentrations in wk 1, 2, and 3 of lactation compared with cows fed HE. Higher NEFA concentration in wk 1 postpartum was associated with a greater probability of diseases (n = 251; OR = 1.176).

Cows on the CE regimen during the FO period had greater plasma glucose concentrations during wk 1 and 3 after calving than cows fed the HE regimen. Higher plasma glucose (HG) concentration compared with lower glucose (LG) in wk 3 (HG n = 154; LG n = 206) and wk 4 (HG n = 71; LG n = 254) after calving was associated with greater HR for DTP (wk 3: median = 151 and 171 d for HG and LG, HR = 1.334; wk 4: median = 148 and 167 d, HR = 1.394). In the first 2 wk after calving, cows that received HE in the FO period had higher concentrations of total lipids and triglyceride and greater ratio of triglyceride to glycogen in liver than did CE. In conclusion, cows fed CE during the CU period had greater HR for DTP, meaning a shorter interval between parturition and conception. The positive effect of CE may be explained by increased NEL intake during the first 4 wk postpartum and lower incidence of peripartal diseases. In addition, lower BCS loss during the first 6 wk postpartum and slightly higher glucose concentration at wk 3 likely contributed to improved reproductive performance.

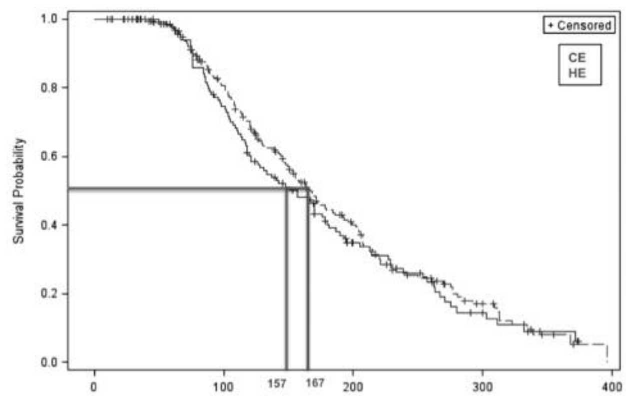

Figure 1. Survival function curves for days to pregnancy (DTP) for 332 Holstein cows fed either controlled energy (CE = blue) or high energy (HE = red) during the last four weeks before calving. Blue and red lines represent median values for DTC when 50% of the cows were pregnant.

Additionally, to investigate the association between prepartum energy feeding regimen and productive performance and health, the same dataset was analyzed. Milk production, milk components, BW, cholesterol, displacement of abomasum (DA), and ketosis (KET) were the variables used to assess productive performance and health status. The net energy for lactation (NEL) intake (NE_{LI}) was calculated from the cow's respective dietary NEL density and average DMI.

There was no statistical difference for milk production in the first 4 wk postpartum between cows fed CE or HE prepartum. Cows fed HE during CU had greater milk fat concentration in wk 2, 3 and 4 than cows fed CE. Cows fed HE during CU had higher protein concentration during wk 3 and 4 then cows fed CE. Cows that were fed HE during CU lost more BW either as absolute amounts (kilograms) or as percentage loss during the first 6 wk postpartum (38.5 vs 19.7 kg, SEM 8.9, and 5.6 vs 2.9 %, SEM = 1.2, respectively). In addition, cows that were fed HE during the dry period had greater odds of experiencing DA or KET when compared to cows that received CE.

REFERENCES

Allen, M. S., B. J. Bradford, and K. J. Harvatine. 2005. The cow as a model to study food intake regulation. Annu. Rev. Nutr. 25:523-547.

Bell, A. W. 1995. Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. J. Anim. Sci. 73:2804-2819.

Bonczeck, R. R., C. W. Young, J. E. Wheaton, and K. P. Miller. 1988. Responses of somatotropin, insulin, prolactin, and thyroxine to selection for milk yield in Holsteins. J. Dairy Sci. 71:2470-2478.

Butler, W. R. 2003. Energy balance relationships with follicular development, ovulation and fertility in postpartum dairy cows. Livest. Prod. Sci. 83: 211-218.

Cook, N. B., and K. V. Nordlund. 2009. The influence of the environment on dairy cow behavior, claw health and herd lameness dynamics. Vet. J. 179:360-369.

Curtis, C. R., H. N. Erb, C. J. Sniffen, R. D. Smith, P. A. Powers, M. C. Smith, M. W. White, R. B. Hillman, and E. J. Pearson. 1983. Association of parturient hypocalcemia with eight periparturient disorders in Holstein cows. J. Am. Vet. Med. Assoc. 183:559-561.

Dann, H. M.; N. B. Litherland, J. P. Underwood, M. Bionaz, A. D'Angelo, J. W. McFadden, and J. K. Drackley. 2006. Diets during far-off and close-up dry periods affect periparturient metabolism and lactation in multiparous cows. J. Dairy Sci. 89:3563-3577.

Douglas, G. N., T. R. Overton, H. G. Bateman, H. M. Dann, and J. K. Drackley. 2006. Prepartal plane of nutrition, regardless of dietary energy source, affects periparturient metabolism and dry matter intake in Holstein cows. J. Dairy Sci. 89:2141-2157.

Douglas, G. N., J. K. Drackley, T. R. Overton, and H. G. Bateman. 1998. Lipid metabolism and production by Holstein cows fed control or high fat diets at restricted or ad libitum intakes during the dry period. J. Dairy Sci. 81(Suppl. 1):295. (Abstr.).

Drackley, J. K., H. M. Dann, N.A. Janovick, N. B. Litherland, J. P. Underwood, and J. J. Loor. 2005. Physiological and pathological adaptations in dairy cows that may increase susceptibility to periparturient diseases and disorders. Ital. J. Anim. Sci. 4:323-344.

Drackley, J. K. 1999. Biology of dairy cows during the transition period: the final frontier? J. Dairy Sci. 82:2259-2273.

Goff, J. P., and R. L. Horst. 1997. Physiological changes at parturition and their relationship to metabolic disorders. J. Dairy Sci. 80:1260-1268.

Goshen, T., and N. Y. Shpigel. 2006. Evaluation of intrauterine antibiotic treatment of clinical metritis and retained fetal membranes in dairy cows. Theriogenology 66:2210-2218.

Grum, D. E., J. K. Drackley, R. S. Younker, D. W. LaCount, and J. J. Veenhuizen. 1996. Nutrition during the dry period and hepatic lipid metabolism of periparturient dairy cows. J. Dairy Sci. 79:1850-1864.

Grummer, R. R. 1995. Impact of changes in organic nutrient metabolism on feeding the transition dairy cow. J. Anim. Sci. 73:2820-2833.

Hammon, D. S., I. M. Evjen, T. R. Dhiman, J. P. Goff, and J. L. Walters. 2006. Neutrophil function and energy status in Holstein cows with uterine health disorders. Vet. Immun. Immunopathol. 113:21-29.

Hayirli, A., R. R. Grummer, E. Nordheim, P. Crump, D. K. Beede, M. J. VandeHaar, and L. H. Kilmer. 1998. A mathematical model for describing dry matter intake of transition cows. J. Dairy Sci. 81(Suppl. 1):296 (Abstr.).

Huzzey, J. M., D. M. Veira, D. M. Weary, and M. A. von Keyserlingk. 2007. Prepartum behavior and dry matter intake identify dairy cows at risk for metritis. J. Dairy Sci. 90:3220-3233.

Janovick, N. A., Y. R. Boisclair and J. K. Drackley. 2011. Prepartum dietary energy intake affects metabolism and health during the periparturient period in primiparous and multiparous Holstein cows. J. Dairy Sci. 94:1385-1400.

Janovick, N. A., and J. K. Drackley. 2010. Prepartum dietary management of energy intake affects postpartum intake and lactation performance by primiparous and multiparous Holstein cows. J. Dairy Sci. 93:3086-3102.

Jordan, E. R., and R. H. Fourdraine. 1993. Characterization of the management practices of the top milk producing herds in the country. J. Dairy Sci. 76:3247-3256.

Kunz, P. L., J. W. Blum, I. C. Hart, H. Bickel, and J. Landis. 1985. Effects of different energy intakes before and after calving on food-intake, performance and blood hormones and metabolites in dairy-cows. Anim. Prod. 40:219-231.

Markusfeld, O. 1985. Relationship between overfeeding, metritis and ketosis in high yielding dairy cows. Vet Rec. 116:489-491.

Ney, D. M., J. B. Lasekan, T. Spennetta, M. Grahn, and E. Shrago. 1989. Effect of dietary fat on individual long-chain fatty acyl-CoA esters in rat liver and skeletal muscle. Lipids 24:233-235.

Nebel, R. L., and M. L. McGilliard. 1993. Interactions of high milk yield and reproductive performance in dairy cows. J. Dairy Sci. 76:3257-3268.

National Research Council. 2001. Nutrient Requirements of Dairy Cattle. National Academy Press, Washington, DC.

Rabelo, E., R. L. Rezende, S. J. Bertics, and R. R. Grummer. 2005. Effects of pre- and postfresh transition diets varying in dietary energy density on metabolic status of periparturient dairy cows. J. Dairy Sci. 88:4375-4383.

Radostits, O. M, C. C. Gay, D. C. Blood, K. W. Hinchcliff, and P. D. Constable. 2007. Veterinary Medicine: A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses, 10th ed. London: Saunders Elsevier.

Rukkwamsuk, T., T. Wensing, and M. J. Geelen. 1998. Effect of overfeeding during the dry period on regulation of adipose tissue metabolism in dairy cows during the periparturient period. J. Dairy Sci. 81:2904-2911.

Rutigliano, H. M., F. S. Lima, R. L. A. Cerri, L. F. Greco, J. M. Villela, V. Magalhães, F. T. Silvestre, W. W. Thatcher, and J. E. P. Santos. 2008. Effects of method of presynchronization and source of selenium on uterine health and reproduction in dairy cows. J. Dairy Sci. 91:3323-3336.

Santos, J. E. P., T. R. Bilby, W. W. Thatcher, C. R. Staples, and F. T. Silvestre. 2008. Long chain fatty acids of diet as factors influencing reproduction in cattle. Reprod. Dom. Anim. 43 (Supp. 2):23-30.

Sheldon, M., G. S. Lewis, S. LeBlanc, and R. O. Gilbert. 2006. Defining postpartum uterine disease in cattle. Theriogenology 65:1516-1530.

Urton, G., M. A. von Keyserlingk, and D. M. Weary. 2005. Feeding behavior identifies dairy cows at risk for metritis. J. Dairy Sci. 88: 2843-2849.

VandeHaar, M. J., G. Yousif, B. K. Sharma, T. H. Herdt, R. S. Emery, M. S. Allen, and J. S. Liesman. 1999. Effect of energy and protein density of prepartum diets on fat and protein metabolism of dairy cattle in the preiparturient period. J. Dairy Sci. 82:1282-1295.

Vasconcelos, J. L. M., S. Sangsritavong, S. J. Tsai, and M. C. Wiltbank. 2003. Acute reduction in serum progesterone concentrations after feed intake in dairy cows. Theriogenology 60:795-807.

Villa-Godoy, A., T. L. Hughes, R. S. Emery, T. L. Chaplin, and R. L. Fogwell. 1988. Association between energy balance and luteal function in lactating dairy cows. J. Dairy Sci. 71:1063-1069.

Whiteford, L. C., and I. M. Sheldon. 2005. Association between clinical hypocalcaemia and postpartum endometritis. Vet. Rec. 157:202-203.

Forage Substitutes and By-Products: Feeding Cows When Forage Is Scarce & Corn Is High

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Take Home Message: Use of forage substitutes in low starch / high byproduct diets can maintain good milk production and components in late lactation cows. Intakes increased, and feed efficiency and income over feed costs were lower than on a high forage/higher starch TMR. Dietary phosphorus contents were also greater than with the high forage TMR because of the byproducts used. There was a suggestion that feeding the highest amount of wheat straw may have increased mobilization of body tissues, so body condition should be watched carefully with these types of rations.

The drought has made 2012 a challenging year. Feed prices were high and forage was limited in both quality and quantity in some areas. So, what are our options for feeding cows? We know that dairy cows need fermentable and physically effective feeds to provide nutrients and maintain good rumen function. Common forage substitutes such as sugar beet pulp or straw provide either very fermentable or very physically effective fiber sources, respectively. In dealing with high feed prices, replacement of purchased corn grain or soybean meal with less expensive by-product feeds could reduce cost of the ration. However, a challenge is that formulating rations based largely on forage substitutes and byproducts has not been well explored. Do they need more effective fiber to keep byproduct fiber in the rumen to be digested? We ran an experiment to test some of the possibilities.

The objective of the feeding trial was to evaluate performance of lactating dairy cows offered different combinations of forage substitutes (wheat straw = more effective fiber, and sugar beet pulp = more fermentable) in diets that were relatively low in forage and supplemented solely with byproducts (no corn, no soy). Forty-eight late lactation cows, including 8 that were ruminally cannulated were used; cows averaged 1.3 lactations, 71 lb milk, 1442 lb body weight, and 280 days in milk at the start of the trial. Cows were offered a high forage TMR (covariate diet) in the first 2 weeks of the study, and then switched to 1 of 4 experimental diets for 4 straight weeks of feeding (Table 1). The experimental diets contained only 40% true forage (corn & alfalfa silages), and differed in the amount of chopped wheat straw or sugar beet pulp pellets they contained, ranging from 0% straw + 12% beet pulp to 9% straw + 3% beet pulp. All other ingredients were kept in the same proportions in all diets. Molasses was included to bind the rations together and reduce sorting. Diets contained monensin.

When analyzing the results, the cow responses from the initial 2 week feeding period on a common TMR was used to adjust the responses on the experimental diets so that results took into account the relative change in performance of individual cows. One of the cannulated cows was omitted from the performance evaluations because of low milk production (12 lb / day) and she was used only for rumen and fecal pH measures.

Results

Compared to the "normal" higher forage/higher starch TMR, the experimental rations contained a lower proportion of NDF from forage (NDF from corn & alfalfa silages, and chopped wheat straw). Ranges of 0.8 to 0.95 of bodyweight as forage NDF have been recommended; the experimental diets were below and above these values. Starch content of the experimental diets was less than half as much as is commonly included in lactating dairy cow diets in the Midwest and two-thirds higher in phosphorus (Table 1).

Dry matter intake was 9 lb greater overall on the high byproduct/low forage diets as compared to the high forage TMR (57.4 vs 48.4 lb, respectively, simple averages). Intake declined as straw replaced sugar beet pulp (Table 2). Milk production tended to decline, but the total decrease was 3 lb of milk as straw increased from 0 to 9%. Butterfat % tended to decline and then increased as straw increased; milk protein % did not change across diets. With the changes in milk and component production, fat yield did not change across diets, whereas milk protein yield declined. Milk urea nitrogen rose as straw increased; the MUN at 9% straw was or tended to be greater than the responses at lesser amounts of straw. Despite the slight increase at 3% straw, 3.5% fat- and protein-corrected

Table 1. Feed and chemical compositions of study diets (% of dry matter).

	Covariate	---Chopped Wheat Straw %---			
Feed	Diet	0	3	6	9
Corn Silage	28.6	20	20	20	20
Alfalfa Silage	32.4	20	20	20	20
Chopped wheat straw	---	0	3	6	9
Sugar beet pulp	---	12	9	6	3
Distillers grains	4.0	8	8	8	8
Corn gluten feed	---	25.5	25.5	25.5	25.5
Whole cottonseed	---	5	5	5	5
Vitamin & Minerals	2.4	2.5	2.5	2.5	2.5
Molasses 80:20 cane:whey	---	7	7	7	7
High moisture corn	20.7	---	---	---	---
Roasted soy beans	7.9	---	---	---	---
High protein soybean meal	3.7	---	---	---	---
Sodium bicarbonate	0.25	---	---	---	---
Salt	0.13	---	---	---	---
Diet dry matter, %	45.8	52.6	54.8	53.8	54.0
As % of diet dry matter					
Crude protein	16.4	16.9	16.6	16.4	16.2
NDF	30.4	33.1	34.4	35.6	36.9
Starch	27.8	10.7	10.8	10.8	10.8
Nonfiber carbohydrate	41.5	33.1	31.8	30.6	29.3
Ca	1.06	0.98	0.95	0.92	0.90
P	0.38	0.60	0.60	0.60	0.60
K	1.72	1.63	1.67	1.70	1.73
Mg	0.44	0.46	0.45	0.45	0.44
S	0.24	0.36	0.35	0.34	0.34
Forage	61	40	43	46	49
Forage NDF/Diet NDF, %	80	51	56	61	66
Forage NDF % of BW	0.85	0.66	0.72	0.84	0.98

NDF = neutral detergent fiber analyzed with sulfite and amylase, BW = body weight

Table 2. Production performance and efficiency on experimental diets.

	------Chopped Wheat Straw %-------					P-values	
Measure	0	3	6	9	SED	linear	quadratic
Dry matter intake, lb	59.4	57.1	57.1	56.1	1.4	0.03	0.51
Dry matter intake, % BW	3.96	3.83	3.88	3.80	0.09	0.12	0.70
Milk, lb	70.9	72.0	69.4	68.0	1.95	0.08	0.37
Fat, %	4.26	4.17	4.19	4.53	0.16	0.11	0.06
Protein, %	3.31	3.27	3.27	3.27	0.05	0.44	0.65
3.5% FPCM, lb	78.7	79.2	76.3	75.7	2.9	0.20	0.79
MUN, mg/dl	10.0	10.9	10.6	12.0	0.46	<0.01	0.48
Fat, lb	3.04	3.04	2.91	3.02	0.14	0.67	0.58
Protein, lb	2.34	2.36	2.28	2.16	0.07	0.02	0.18
3.5% FPCM/DMI	1.34	1.41	1.34	1.35	0.052	0.83	0.48
Milk N/Intake N	0.23	0.24	0.24	0.23	0.008	0.97	0.08
Body weight change, lb	70	59	55	55	14	0.27	0.56

3.5% FPCM = 3.5% fat- and protein- corrected milk, DMI = dry matter intake, N = nitrogen, SED = standard error of the difference.

milk production efficiency did not differ across experimental diets. Milk nitrogen efficiency tended to increase and then decrease with increasing wheat straw. Body weight increased on all diets, but we don't know to what extent this was due to increased gut fill. No major, obvious condition score changes were noted, but body condition was not monitored in this study.

Cows were fed the covariate and forage substitute/high byproduct diets a month apart, so the change in DIM had to be taken into account, but, even so, 3.5% fat- and protein-corrected milk did not differ between them (75.3 vs 76.2 lb, least squares means, P=0.48). Because of the large difference in dry matter intake, the efficiency of production for 3.5% fat- and protein-corrected milk (1.50 vs. 1.28, P<0.01) and milk N/feed N (0.27 vs 0.23, least squares means, P=0.02) were greater for cows on the higher forage covariate diet.

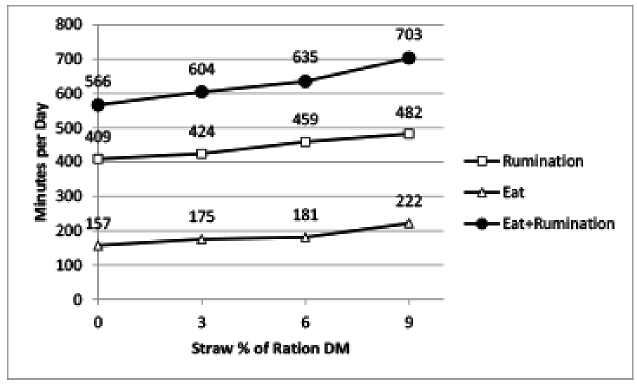

Figure 1. Minutes per day that cows spent ruminating or eating.

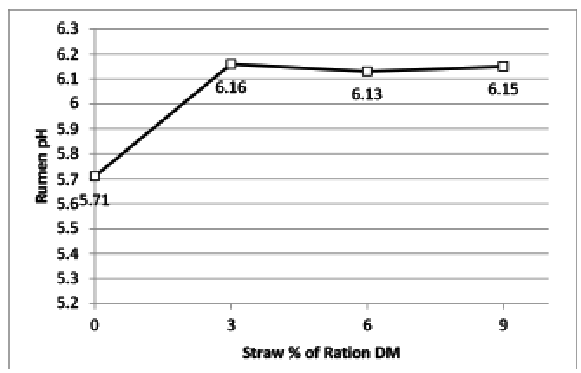

Figure 2. Rumen pH (average of 0 and 4 hour sampling times; these did not differ from each other).

Speaking to the influence of effective fiber sources, the amount of time cows spent ruminating and eating increased as the amount of straw increased (linear increase in both, P<0.01; Figure 1).

Increased rumination/ chewing would deliver more saliva and buffer to the rumen. That affected ruminal pH (Figure 2), where the pH of the 0% straw diet was lower or tended to be lower than for the other diets (diet effect P<0.01; 0% straw different from other diets, P<0.02). What was strange was that rumen pH did not change between right before and 4 hours after feeding on the experimental diets (P=0.73). This is different than what we normally see with diets that are higher in starch; rumen pH declines after feeding and usually hits its low point within 6 hours. The low pH noted on the 0% straw diet would likely slow down but not stop rate of fiber digestion. Fecal pH did not differ by diet (P>0.24) suggesting that ruminal escape of carbohydrates that ferment appreciably in the hindgut were not an issue and not different among diets (6.39, 6.52, 6.43, and 6.48 for 0, 3, 6, and 9% straw, respectively; 6.51 for covariate diet).

Income over feed costs increased as straw inclusion increased: cows largely maintained production and intakes declined, and wheat straw is less expensive than sugar beet pulp. Although the 9% straw diet gave a $0.49 advantage over the 6% straw diet, caution is urged; the increase in butterfat % and MUN as intake declined on the 9% diet may suggest body condition mobilization greater than

Table 3. Income over feed costs for study diets.

Item	0% straw	3% straw	6% straw	9% straw	Covariate
DM Intake, lb	59.4	57.1	57.1	56.1	48.4
Ration DM $/cwt	14.44	14.14	13.84	13.54	14.57
Ration Cost, $	8.58	8.07	7.90	7.60	7.05
Milk, $/cwt	19.59	19.28	19.32	20.00	19.50
Milk value	13.89	13.88	13.41	13.60	14.08
Income/Feed	5.31	5.81	5.51	6.00	7.03

As fed feed prices/ton: corn silage, $60; alfalfa silage, $85; chopped wheat straw, $115; distillers grains with solubles, $287; sugar beet pulp, $293; corn gluten feed, $245; whole cottonseed, $359; molasses 80:20 cane:whey blend, $295; high moisture shell corn, $202; roasted soy, $530; high protein soybean meal, 492; vitamin and mineral mix, $900; salt, $98; sodium bicarbonate, $315.

Milk prices per hundredweight calculated on milkpay.com using milkfat and protein percentages from each treatment and Midwest area prices.

with the other diets. That could be a problem if done over an extended period of time. Verification of what was actually happening with the 9% straw diets is needed to understand whether the diet formulation needs to change to support late lactation production, reproduction, and maintenance or increase in body stores. Although the high forage covariate diet had the greatest ration cost per hundredweight, the milk production similar to cows on the forage substitute/high byproduct diets and lower intakes combined to give the highest income over feed costs.

Summary

Late lactation cows maintained performance on the low forage, low starch diets based on byproduct feeds. Using up to 6% wheat straw gave good performance without noticeable body weight loss/condition change. If such diets are tried, cows should be carefully observed to assure that body weight is maintained. The high phosphorus content of the byproducts elevated phosphorus content in the diet; not desirable long term for nutrient management issues and impact on the environment. On the 60% forage "more standard" lactating cow diet, cows gave similar milk production performance, had lower intakes, more efficient production, and better income over feed costs than cows on the experimental diets. However, the forage substitute/high byproduct diets are viable substitutes to feed lactating dairy cows when other more traditional feeds are in short supply.

Additional Information

Additional feed analyses are being done to provide data needed to evaluate these rations with the CNCPS and NRC models. Forage and TMR particle size data are also available.

Acknowledgements

We wish to thank the Archer Daniels Midland Company for their donation of a tractor trailer load of corn gluten feed for use in this study. Other support for this study came from the USDA-Agricultural Research Service.

Heat Stress: Practical Lessons Learned in 2011

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Introduction
Heat stress negatively impacts a variety of dairy parameters including milk yield, milk quality and composition, rumen health, growth and reproduction and therefore is a significant financial burden (~$900 million/year for dairy in the U.S.; St. Pierre et al., 2003; Baumgard and Rhoads, 2013). Advances in management (i.e. cooling systems; VanBaale et al., 2006) and nutritional strategies (West, 2003) have alleviated some of the negative impact of heat stress on cattle, but productivity continues to decline during the summer.

The entire 2011 summer was particularly warm and 78% of the summer days in Champaign IL had an average THI greater than 68 (Table 1); 68 is the THI threshold for modern dairy cows (Zimbleman et al., 2009). July 2011 was the 4th hottest July on record and the national average was 2.67°F warmer than the 1901-2000 average (Ripley et al., 2011). There were 8,926 daily heat records broken in July 2011 in the continental USA and only 31% of these were for daily maximums while 69% were record daily minimum temperatures (i.e. nighttime temperatures; National Weather Service: www.noaa.gov). The mid-July heat wave which blanketed the upper-Midwest was especially hard on animal agriculture and the dairy industry in particular. The combination of heat and humidity a few days before and after July 20th was dubbed the "Dome of Doom" by the popular press (Ripley, 2011). Interestingly, the daily high ambient temperatures during July 18th-23rd were not noteworthy compared to the rest of the summer. For example, in Minneapolis the departure from the normal temperature was 10°F less during the July 20th heat wave compared to the early June heat wave (Figure 2). This is also easily observed when evaluating the maximum hourly temperature humidity index (THI) in Ames IA, Champaign IL, St. Paul MN and Madison WI (Figure 1A-D). In other words, neither the maximum daily ambient temperature nor the maximum hourly THI were unusually remarkable during the July 20th heat wave.
The environmental characteristic of the July 20th heat wave that severely affected the upper-Midwest dairy industry was the lack of night-time cooling coupled with high relative humidity. On July 17th and 18th, the dew-point was 80 and 83°F in Green Bay WI and Rochester MN, respectfully (Ripley et al., 2011). The minimum hourly THI on July 20th was 73, 75, 74 and 72 for Ames IA, St. Paul MN, Champaign IL and Madison WI, respectively (Figure 1A-D). This lack of night-time cooling (not daytime highs) was associated with the severe decreases in milk production that accompanied the July 20th heat wave. This agrees with recent environmentally-controlled experiments indicating that the daily minimum THI is closely associated with decreased milk yield (Zimbleman et al., 2009).

Milk yield almost certainly decreased in every dairy in the four-state area during the July 20th heat wave, but considerable variation apparently existed within the industry (personal communication with dairymen, university extension personnel, nutritionists, and consultants). Not only did the acute milk yield response vary, the "recovery" or long term effects of the heat wave also markedly differed amongst producers. Presumably, much of the variation can be explained by differences in facilities, barn design and the utilization of heat stress abatement strategies (i.e. fans, soakers, etc.). However, there are a variety of non-facility management decisions that likely influence a herd's immediate and long-term response to a heat wave. Therefore, objectives of our project were to identify management practices (nutritional, heat abatement strategies, cow comfort indices etc.) associated with the heat stress response. Although admittedly not causal, these correlations may help identify management approaches to help mitigate future heat stress events.

Material and Methods
A full data set of 590 direct patrons of First District Association (FDA), Litchfield, Minnesota was analyzed from July and August, 2011. Average milk received by FDA from the patrons during four distinct time periods were utilized: (A) average milk

received from July 1st through 4th represented the baseline milk yield prior to the heat wave; (B) average milk received during July 20th through 23rd represented the acute milk production response during the heat event; (C) average milk received during July 28th through 31st represented milk yield after the heat wave as the first phase of recovery; and (D) milk received during August 28th through 31st represents milk received five-weeks after the heat wave as long-term recovery of milk production. Patron data with extreme decreases or increases in total milk sold during the heat event were eliminated from this analysis as the data could reflect changes due to herd expansion/reduction or seasonal calving. Nine herds that dropped more than 40% and 42 herds that increased more than 10% during periods A to B were removed.

Individual patron data was assigned into milk drop categories of high (H) or low (L) and subsequent milk recovery categories of (H) or (L). Percentage of milk drop from (period B compared to period A) was used to assign the milk drop treatment. Herds with greater than 10.0% milk drop were assigned to a drop treatment of H and those with less than 10.0% milk drop were assigned to a drop treatment of L. Herds that were on the cusp of the H or L milk drop treatment assignment (had a drop of greater than 8.5 % and less than 12.5%) were eliminated from the data set.

Milk recovery assignments were calculated as the change from period D compared to period A. Herds recovering to 95.0% or more of their baseline milk during this period were assigned to high recovery treatment (H). Herds that recovered less than 95.0% of their baseline were assigned to a low milk recovery treatment (L). Herds that were on the cusp of the H or L milk recovery treatment assignment (had a recovery within 92.5 to 96.5% of their baseline milk) were eliminated from the data set. In addition, herd data indicating an increase of more than 20.0% from the period of A to D were eliminated to account for herds that may have increased production due to seasonal calving.

From the treatment assignments, there were 365 patrons eligible for the survey data and were assigned into H or L drop and H or L recovery (Table 2). From this set, 206 herds were randomly surveyed by trained personnel with no knowledge of the herd's previous production history. A survey pertaining to heat abatement, facilities, nutrition, and management practices were presented to the owner/managers. Questions were presented orally to the herd manager by personnel trained to ask consistent questions. Survey questions were presented to the patron herd managers during the months of June and July, 2012.
The survey consisted of questions regarding housing type and relevant, commonly practiced heat abatement and nutritional management strategies. Along with lactating and dry cow housing type, these six main areas of concern were addressed based on the Form-A-Feed (FAF) Dairy Heat Stress Risk Snapshot©[2] (Kohls and Baumgard, 2012): 1) monitoring systems, 2) drinking water, 3) air and ventilation, 4) evaporative cooling, 5) shade and cow comfort and 6) nutritional and metabolic management practices. Results were compiled and analyzed utilizing two distinct statistical models to evaluate the use (or nonuse) of each questioned heat abatement practice for milk drop to the acute heat stress event and subsequent milk recovery, each as an independent variable.

From this set, 108 herds agreed to share their reproduction and culling data from records obtained from Minnesota Dairy Herd Improvement Association (MNDHIA), Buffalo, MN (Table 2). Herd data was downloaded and analyzed for reproduction and culling event data.

Chi-Square analysis was utilized to test for differences in responses to the questions (category's H or L) using the Proc Freq function of SAS. Responses were also evaluated by analysis of variance (ANOVA) using the Proc Mixed procedure of SAS. Monthly reproductive, culling and death data were analyzed as repeated measures (month was the repeated variable) using Proc Mixed procedure of SAS. Results are considered significant if $P < 0.10$ and considered a trend from $P < 0.20$.

RESULTS
Regardless of facility design, management practices etc., the average FDA patron had a 20.2% decrease in milk production during July 20th to 23rd (compared to July 1st benchmark; Figure 3). By August 31st, the average patron's milk production was still 5.1% less than it was on July 1st. Lactation barn type did not influence the acute response to heat stress, but the open-lot grazing producers had a much lower persistency (the milk production at the end of August compared to the beginning of July) compared to the others and this is especially true for the bedded-pack

and free-stall farms (Table 3). From a recovery standpoint, free-stall barns tended to be in the high recovery category much more than the tie-stall barns (Table 3).

Acute Response to heat stress: July 1-4 milk production

Dairy producers that invested in monitoring systems (bulk tank changes, body temperature indices, etc.) generally had or tended to have (P < 0.20) less of a decrease (15.5 vs. 18.7%) in milk yield during the acute response to heat stress (Table 4). Surprisingly, there were no differences in any of the drinking water quality/availability responses (Table 4). The only variable in the *Shade and Comfort* section that tended to differ (P = 0.13) was the stocking density that indicated overstocking was associated with a more severe decrease (17.4 vs. 12.0%) in the acute response to heat stress (Table 4). Ensuring wind-speed over the resting/loafing areas was associated with small but significant improvement in the acute response (15.9 vs. 18.8%; P < 0.05). Not surprisingly, utilizing evaporative cooling strategies ameliorated (P < 0.05; 17.4 vs. 13.4%) the acute milk yield response to heat stress. The location of the soakers/sprinklers also tended (P < 0.20) to influence the acute response, as having them in the feed lane and holding pen benefited milk production (11.9 vs. 16.5%; Table 4). The only question in the *Feed and Nutrition* section associated with an improved (P < 0.05; 17.3 vs. 12.4%) acute response was the feeding of Sweet Energy (Table 4). Sweet Energy/Sweet Dairy Liquid Blends are liquid sources of sugar and macrominerals derived from cheese whey byproducts.

Short Term Recovery: Percentage of milk production increases one week following the heat wave

In contrast to the acute response, none of the *Monitoring Systems* variables were associated with the short term recovery (P > 0.29; Table 5). Similar to the acute response, no *Drinking Water* quality/quantity was associated with the short term recovery (P > 0.40; Table 5). Fly control and surface grooming tended (P < 0.20) to differ in No and Yes responders, but stocking density was no longer (P > 0.82) affiliated with the short term recovery (Table 5). Having the sidewalls completely open decreased the short term recovery by over 2 fold (5.9 vs. 13.0%; P < 0.06) and was the only influencer in the *Air-Quality/Quantity* category (Table 5). Interestingly, there were no questions from the *Evaporative Cooling* section associated with an improved short term recovery (Table 5). Having rations balanced by a professional nutritionist improved the short term recovery (P < 0.10; 9.3 vs. 13.8%; in other words, herds utilizing a nutritionist produced 13.8% more milk following the heat wave than they did during the heat wave) and feeding Hydro-Lac® prior to and following the heat wave tended (P < 0.20) to improve (17%) the short term recovery (Table 5). Hydro-Lac® is a product designed to provide essential nutrients necessary to maintain homeostasis and performance in cattle during periods of stress.

Long Term Recovery: ***Percentage of milk production increase five weeks following the heat wave.***

Monitoring environmental conditions was actually associated with a reduced long term recovery (15.3 vs. 11.1%: P<0.05; Table 6) but this is likely due to the fact that producers who did not monitor THI had a more severe decrease in milk production during the heat wave and thus had mathematically more production opportunity for an increase. Testing water quality within the last 2 years tended (P< 0.20) to be associated with an increase in the long term response. Providing access to shade tended to increase (P <0.20 14.0 vs. 5.9%) the long term recovery (Table 6). Having a thermostat and setting it to start at 68°F was affiliated with an increase in long term recovery (10.0 vs.14.9%; P < 0.10; Table 6). Utilizing evaporative cooling in the holding pen tended to be correlated with a reduced recovery, but this is also probably due to the same issue as monitoring environmental conditions (mentioned above). Producers utilizing rbST (Posilac ®) also had increased long term recovery (12.8 vs. 18.5%; P < 0.05; Table 6). Again, utilizing a professional nutritionist tended to be associated with an improved long term recovery (8.2 vs. 14.2%; P = 0.11) and feeding a rumen modifier was also correlated with an improved long term recovery response (11.4 vs. 15.0%; P = 0.11; Table 6).

Persistency: Percentage decrease in milk production at the end of August compared to July 1st.

Similar to the acute response, improved persistency was associated with a variety of monitoring systems associated with DMI, milk yield and water intake (Table 7). There were little or no differences in Drinking Water variables other than producers who had their water quality tested were to be more persistent (-7.0 vs. -3.3%; $P < 0.05$; Table 7). Having a thermostat on the fans, and locating fans above the resting area and ensuring that the fans provided at least 5+ mph were all associated ($P < 0.10$) with an improved persistency (Table 7) following the heat wave. Utilizing evaporative cooling strategies like soakers and sprinklers was affiliated with an improved persistency ($P<0.10$: -6.4 vs. -2.4%; Table 7). Herds on rbST also had improved ($P < 0.10$) persistency (-6.5 vs. -2.5%; Table 7). Feeding Sweet Energy, utilizing rumen modifiers and incorporating HydroLac® were all associated with or tended to be affiliated with improved persistency (Table 7).

Reproduction, Culling and Death

As expected, both conception rate and pregnancy rate were markedly affected by month and the severity of the summer was most pronounced during July (Figure 4 A & B). Interesting, culling was not influenced by month, but death percentage was doubled during July compared to the rest of the year (Figure 4 C &D).

Summary

This project attempted to identify management characteristics associated with an improved herd-level response to heat stress. It is important to remember that the responses (yes or no) are simply affiliated with a response and not necessarily causal. However, there are some areas that clearly highly associated with good heat stress management. It is interesting to note that several more factors were positively correlated with milk persistency than with acute loss or recovery. From a barn type perspective, the acute response to the heat wave was fairly similar amongst barn types, but grazing dairies did not have near the persistency as compared to the others and this is especially true when compared to free-stall barns. Clearly, utilizing intensive heat stress abatement strategies was associated with an improved response during the acute heat wave and markedly affiliated with long term recovery and persistency. Avoiding over-stocking was also associated with an improved acute heat stress response and long term response. From a nutrition perspective, clearly the producers who employ professional nutritionist fared better at almost all of the parameters measured. Further, producers who fed Sweet Energy had multiple improved production variables during and following the heat wave. In addition, utilizing rumen modifiers and HydroLac® was associated with an improved recovery and persistence following the heat wave.

References

Baumgard, L.H., and R.P. Rhoads. 2013. Effects of heat stress on post-absorptive metabolism and energetics. Ann. Rev. Anim. Biosci. 1: 311-337.

Kohls, D.S., and Baumgard, L.H. 2011. Form-A-Feed Dairy Heat Stress Risk Snapshot. Form-A-Feed, Inc. Stewart, MN

Ripley, B., J.B. Halverson, H. Angeloff, B. Moore, T. Fathauer, A Prechtel and R. Thoman. 2011. Weatherwatch: July/August, Weatherwise 64:6, 42-57.

St. Pierre, N.R., B. Cobanov, G. Schnitkey. 2003. Economic losses from heat stress by US livestock industries. J. Dairy Sci. 86 (Issue E):E52-E77.

VanBaale, M., J. Smith, C. Jamison, R. Rodriguez, and L.H. Baumgard. 2006. Evaluate the efficacy "heat stress audits" of your cooling system through core body temperature. Proc. Southwest Nutr. Conf. 174-180.

West, J.W. 2003. Effects of heat-stress on production in dairy cattle. J. Dairy Sci. 86:2131-2144.

Zimbleman, R.B., R.P. Rhoads, L.H. Baumgard and R.J. Collier. 2009. Revised temperature humidity index (THI) for high producing dairy cows. J. Dairy Sci. 92. E-Suppl. 1:347.

Table 1. Temperature humidity index (THI) indices during June, July and August of 2011

City	# days Avg THI was >68	% days Avg THI > 68
Ames IA	67	72.8%
Champaign IL	72	78.3%
Madison WI	57	62.0%
St. Paul MN	58	63.0%

Table 2. Number of herds eligible, surveyed, and providing reproduction and cull data within milk drop and recovery treatment assignments.

	Herd Classification			
Variable	HH	HL	LH	LL
Total Patrons Eligible	19	167	62	17
Herds Surveyed	74	86	40	6
Repro/Cull records	45	39	21	3

HH: High drop and High recovery
HL: High drop and Low recovery
LH: Low drop and High recovery
LL: Low drop and Low recovery

Table 3: Milk production categories based upon lactation barn design.

Lactation Barn Type	Herds (n)	Avg Drop	Persistency	High Drop	Low Drop	High Recovery	Low Recovery
Bedded Pack-Compost	13	-13.67%	-3.68%	n=8 (62%)	n=5 (38%)	n=8 (62%)	n=5 (38%)
Freestall	37	-15.19%	-3.94%	n=27 (73%)	n=10 (27%)	n=27 (73%)	n=10 (27%)
Open Lot-Grazing	10	-12.71%	-12.98%	n=5 (50%)	n=5 (50%)	n=5 (50%)	n=5 (50%)
Tie Stall	146	-17.78%	-6.00%	n=120 (82%)	n=26 (18%)	n=74 (51%)	n=72 (49%)*
			Totals	160 (78%)	46 (22%)	114 (55%)	92 (45%)

Table 4, Acute Decrease in Milk Yield (percentage) on July 20-23 compared to July 1-4

Question	Obs	Response No	Response Yes	SEM	P
Monitoring Systems		% Decrease			
Utilize thermometer, humidity or measure THI in the facility?	206	-17.4	-15.8	0.9	0.20
Were rectal temperatures, respiration rates, or skin temperatures measured?	206	-17.5	-15.4	0.9	0.11
Was day-to-day variation in dry matter intake measured?	206	-17.3	-15.6	0.9	0.21
Were day-to-day changes in bulk tank milk yield measured?	206	-24.1	-16.6	2.0	0.03
Was water intake measured on a daily basis?	206	-17.0	-14.2	1.4	0.20
Drinking Water					
Was a drinking water quality test conducted in the last 2 years?	206	-17.1	-16.1	0.9	0.45
Was there a 10+ gal/minute flow rate at all drinking waterers?	206	-16.2	-16.9	1.3	0.71
Was there at least 1.5"/hd water space for all milking cows?	206	-13.6	-17.0	1.7	0.22
Were water troughs/cups checked daily for fill and contamination?	206	-17.1	-16.7	1.1	0.81
Were water troughs/cups cleaned at least once per week?	206	-16.7	-16.9	0.9	0.90
Shade and Comfort					
Did livestock have access to shade during daylight hours?	206	-15.2	-16.9	2.1	0.66
Did 100% of the livestock fit in shaded areas at any given time?	206	-16.8	-16.8	1.8	0.99
Were cattle bedded at least twice weekly?	204	-15.0	-17.0	1.6	0.44
Did you have a fly control program?	206	-16.8	-16.8	1.2	0.98
Were surfaces groomed daily to provide dry, easily accessed resting areas?	203	-13.5	-17.0	2.1	0.34
Were freestalls stocked < 110% of stalls? Bedded pack barns >80'/hd?	203	-17.4	-12.0	1.4	0.13
Air-Quality-Quantity					
Natural Ventilation – Did A-frame buildings have an open ridge-vent?	52	-18.2	-14.6	3.1	0.47
Sidewall - Were sidewalls completely open with operable curtains?	48	-14.6	-10.4	2.3	0.22
Were fans or mechanical air equipment used to improve air movement?	206	-13.9	-17.0	1.7	0.27
Were Thermostats/Humidistats set to start fans at 68^0F or less?	195	-17.2	-16.9	1.1	0.89
Were circulating fans operating over the resting area?	206	-17.6	-16.5	0.9	0.42
Was wind-speed over the resting /loafing areas 5+ mph?	206	-18.8	-15.9	0.9	0.03
Evaporative Cooling					
Were Sprinklers or Soakers used to enhance evaporative cooling?	206	-17.4	-13.6	1.1	0.03
Were sprinklers/soakers used with fans or mechanical air movement?	206	-17.3	-13.3	1.2	0.04
Were High Pressure Misters or "Cool Cells" used in power ventilated barns?	9	-9.9	-5.3	6.3	0.63
Were water and timing systems for evaporative cooling maintained regularly?	33	-15.3	-13.2	2.6	0.58
Location of Sprinklers or Soakers:					
Feed Lanes	33	-14.5	-13.5	2.5	0.78
Holding Pens	33	-16.2	-11.3	2.3	0.15
Parlor Exit	33	-13.7	-18.3	5.7	0.64
Loafing/Resting Areas	33	-18.2	-12.4	2.6	0.15
Did your dairy use rBST on lactating cows at that time?	206	-16.8	-16.9	1.1	0.94
Feed and Nutrition					
Did you have your rations balanced by a professional nutritionist?	206	-14.9	-17.0	1.4	0.37
Did you alter feeding schedule and/or amounts during summer months?	206	-16.6	-17.0	0.9	0.79
Were preservatives used on either wet feeds or TMRs to increase stability?	206	-17.0	-16.5	0.9	0.71
Did you feed Sweet Energy or a Sweet Energy/Sweet Dairy Liquid Blend?	206	-17.3	-12.4	1.3	0.02
Did your nutritionist use Buffers/DCAD buffering in lactation rations?	206	-17.1	-16.7	1.0	0.82
Did you feed a live DFM, yeast culture, ionophores or other rumen modulator?	205	-17.5	-16.5	0.9	0.46
Did you feed Hydro-Lac® at any time during July or August 2011?	206	-17.3	-15.6	0.9	0.21
Prior to July 20th, 2011?	206	-17.2	-16.1	0.9	0.40
After July 20th, 2011?	206	-17.3	-15.6	1.0	0.24

Table 5, Short Term Recovery: percentage recovery on July 28-31 from the milk production of July 20-23

Question	Obs	Response No	Response Yes	SEM	P
Monitoring Systems		% Increase			
Utilize thermometer, humidity or measure THI in the facility?	206	13.7	13.1	1.1	0.67
Were rectal temperatures, respiration rates, or skin temperatures measured?	206	14.0	12.3	1.1	0.29
Was day-to-day variation in dry matter intake measured?	206	13.3	14.0	1.4	0.65
Were day-to-day changes in bulk tank milk yield measured?	206	13.4	13.5	2.4	0.98
Was water intake measured on a daily basis?	206	13.5	12.8	1.7	0.79
Drinking Water					
Was a drinking water quality test conducted in the last 2 years?	206	13.5	13.3	1.1	0.90
Was there a 10+ gal/minute flow rate at all drinking waterers?	206	12.3	13.6	1.6	0.58
Was there at least 1.5"/hd water space for all milking cows?	206	14.7	13.4	2.0	0.71
Were water troughs/cups checked daily for fill and contamination?	206	12.1	13.8	1.3	0.40
Were water troughs/cups cleaned at least once per week?	206	14.0	13.3	1.1	0.66
Shade and Comfort					
Did livestock have access to shade during daylight hours?	206	8.0	13.6	2.6	0.21
Did 100% of the livestock fit in shaded areas at any given time?	206	11.6	13.6	2.2	0.59
Were cattle bedded at least twice weekly?	205	11.2	13.6	1.9	0.44
Did you have a fly control program?	206	15.9	13.1	1.4	0.19
Were surfaces groomed daily to provide dry, easily accessed resting areas?	203	5.1	13.8	2.6	0.06
Were freestalls stocked < 110% of stalls? Bedded pack barns >80'/hd?	203	13.5	14.1	1.7	0.82
Air-Quality-Quantity					
Natural Ventilation – Did A-frame buildings have an open ridge-vent?	52	11.6	12.6	3.7	0.87
Sidewall - Were sidewalls completely open with operable curtains?	48	13.0	5.9	2.4	0.06
Were fans or mechanical air equipment used to improve air movement?	206	12.5	13.5	2.0	0.77
Were Thermostats/Humidistats set to start fans at 68^{0}F or less?	195	14.9	13.2	1.3	0.42
Were circulating fans operating over the resting area?	206	12.8	13.8	1.1	0.57
Was wind-speed over the resting /loafing areas 5+ mph?	206	14.6	12.9	1.1	0.30
Evaporative Cooling					
Were sprinklers or soakers used to enhance evaporative cooling?	206	13.6	12.6	1.4	0.60
Were sprinklers/soakers used with fans or mechanical air movement?	206	13.7	11.7	1.5	0.38
Were High Pressure Misters or "Cool Cells" used in power ventilated barns?	9	13.0	11.0	5.6	0.81
Were water and timing systems for evaporative cooling maintained regularly?	33	14.0	11.8	3.2	0.64
Location of Sprinklers or Soakers:					
Feed Lanes	33	12.8	12.3	3.1	0.91
Holding Pens	33	15.0	9.8	2.9	0.22
Parlor Exit	33	12.0	25.7	7.0	0.27
Loafing/Resting Areas	33	14.2	11.9	3.4	0.64
Did your dairy use rBST?	206	13.1	15.1	1.3	0.34
Feed and Nutrition					
Did you have your rations balanced by a professional nutritionist?	206	9.3	13.8	1.7	0.10
Did you alter feeding schedule and/or amounts during summer months?	206	13.3	13.6	1.1	0.83
Were preservatives used on either wet feeds or TMRs to increase stability?	206	13.3	13.9	1.1	0.67
Did you feed Sweet Energy or a Sweet Energy/Sweet Dairy Liquid Blend?	206	13.5	13.0	1.2	0.83
Did your nutritionist use Buffers/DCAD buffering in lactation rations?	206	14.1	13.3	1.3	0.65
Did you feed a live DFM, yeast culture, ionophores or other rumen modulator?	205	13.0	13.8	1.1	0.63
Did you feed Hydro-Lac® at any time during July or August 2011?	206	12.8	14.9	1.1	0.21
Prior to July 20th, 2011?	206	12.7	14.9	1.1	0.17
After July 20th, 2011?	206	12.9	15.1	1.2	0.19

Table 6, Long Term Recovery: Recovery on August 28-31 from milk production on July 20-23 (percentage increase)

Question	Obs	Response No	Yes	SEM	P
Monitoring Systems		% Increase			
Utilize thermometer, humidity or measure THI in the facility?	206	15.3	11.1	1.4	0.04
Were rectal temperatures, respiration rates, or skin temperatures measured?	206	14.2	12.9	1.5	0.54
Was day-to-day variation in dry matter intake measured?	206	13.1	15.3	1.5	0.32
Were day-to-day changes in bulk tank milk yield measured?	206	15.1	13.7	3.3	0.81
Was water intake measured on a daily basis?	206	13.5	16.8	2.3	0.38
Drinking Water					
Was a drinking water quality test conducted in the last 2 years?	206	12.8	15.9	1.5	0.14
Was there a 10+ gal/minute flow rate at all drinking waterers?	206	15.9	13.5	2.1	0.48
Was there at least 1.5"/hd water space for all milking cows?	206	15.7	13.7	2.7	0.66
Were water troughs/cups checked daily for fill and contamination?	206	12.1	14.2	1.7	0.42
Were water troughs/cups cleaned at least once per week?	206	14.7	13.4	1.5	0.56
Shade and Comfort					
Did livestock have access to shade during daylight hours?	206	5.9	14.0	3.5	0.18
Did 100% of the livestock fit in shaded areas at any given time?	206	11.7	13.9	2.9	0.66
Were cattle bedded at least twice weekly?	205	11.3	14.1	2.5	0.51
Did you have a fly control program?	206	12.5	14.0	1.9	0.60
Were surfaces groomed daily to provide dry, easily accessed resting areas?	203	0.8	14.1	3.5	0.27
Were freestalls stocked < 110% of stalls? Bedded pack barns >80'/hd?	203	13.3	17.7	2.2	0.23
Air-Quality-Quantity					
Natural Ventilation – Did A-frame buildings have an open ridge-vent?	52	16.2	12.5	4.2	0.59
Sidewall - Were sidewalls completely open with operable curtains?	48	12.3	8.2	3.1	0.38
Were fans or mechanical air equipment used to improve air movement?	206	8.8	14.0	2.7	0.24
Were Thermostats/Humidistats set to start fans at 68^{0}F or less?	195	10.0	14.9	1.8	0.07
Were circulating fans operating over the resting area?	206	12.0	14.5	1.5	0.26
Was wind-speed over the resting /loafing areas 5+ mph?	206	13.2	14.0	1.5	0.69
Evaporative Cooling					
Were Sprinklers or Soakers used to enhance evaporative cooling?	206	13.7	13.9	1.8	0.94
Were sprinklers/soakers used with fans or mechanical air movement?	206	14.0	12.0	2.0	0.53
Were High Pressure Misters or "Cool Cells" used in power ventilated barns?	9	12.8	9.5	7.0	0.75
Were water and timing systems for evaporative cooling maintained regularly?	33	10.0	14.9	3.8	0.37
Location of Sprinklers or Soakers: Feed Lanes					
Feed Lanes	33	14.6	12.8	3.7	0.72
Holding Pens	33	16.7	10.0	3.5	0.18
Parlor Exit	33	13.2	21.2	8.5	0.59
Loafing/Resting Areas	33	14.3	13.2	4.0	0.86
Did your dairy use rBST on lactating cows at that time?	206	12.8	18.5	1.7	0.03
Feed and Nutrition					
Did you have your rations balanced by a professional nutritionist?	206	8.2	14.2	2.3	0.11
Did you alter feeding schedule and/or amounts during summer months?	206	12.6	14.8	1.4	0.30
Were preservatives used on either wet feeds or TMRs to increase stability?	206	13.9	13.5	1.5	0.84
Did you feed Sweet Energy or a Sweet Energy/Sweet Dairy Liquid Blend?	206	13.4	16.9	2.1	0.30
Did your nutritionist use Buffers/DCAD buffering in lactation rations?	206	12.6	14.1	1.7	0.55
Did you feed a live DFM, yeast culture, ionophores or other rumen modulator?	205	11.4	15.0	1.5	0.11
Did you feed Hydro-Lac® at any time during July or August 2011?	206	13.0	15.5	1.5	0.26
Prior to July 20th, 2011?	206	13.0	15.2	1.5	0.31
After July 20th, 2011?	206	13.1	15.6	1.5	0.26

Table 7, Persistency: Percentage difference of milk production on August 28-31 compared to July 1-4

Question	Obs	Response No	Yes	SEM	P
Monitoring Systems		% difference			
Utilize thermometer, humidity or measure THI in the facility?	206	-5.3	-6.7	1.2	0.42
Were rectal temperatures, respiration rates, or skin temperatures measured?	206	-6.2	-5.0	1.3	0.50
Was day-to-day variation in dry matter intake measured?	206	-6.8	-3.3	1.3	0.06
Were day-to-day changes in bulk tank milk yield measured?	206	-13.0	-5.6	2.7	0.11
Was water intake measured on a daily basis?	206	-6.3	-1.0	1.9	0.09
Drinking Water					
Was a drinking water quality test conducted in the last 2 years?	206	-7.0	-3.3	1.2	0.04
Was there a 10+ gal/minute flow rate at all drinking waterers?	206	-3.5	-6.1	1.7	0.35
Was there at least 1.5"/hd water space for all milking cows?	206	-1.1	-6.1	2.2	0.18
Were water troughs/cups checked daily for fill and contamination?	206	-7.6	-5.4	1.4	0.32
Were water troughs/cups cleaned at least once per week?	206	-5.1	-6.1	1.3	0.58
Shade and Comfort					
Did livestock have access to shade during daylight hours?	206	-10.0	-5.7	2.9	0.39
Did 100% of the livestock fit in shaded areas at any given time?	206	-7.5	-5.8	2.5	0.68
Were cattle bedded at least twice weekly?	205	-6.3	-5.7	2.1	0.87
Did you have a fly control program?	206	-7.3	-5.6	1.6	0.46
Were surfaces groomed daily to provide dry, easily accessed resting areas?	203	-12.6	-5.7	2.9	0.17
Were freestalls stocked < 110% of stalls? Bedded pack barns >80'/hd?	203	-6.7	2.0	1.8	<0.01
Air-Quality-Quantity					
Natural Ventilation – Did A-frame buildings have an open ridge-vent?	52	-5.2	-4.6	3.4	0.91
Sidewall - Were sidewalls completely open with operable curtains?	48	-4.7	-3.8	2.4	0.81
Were fans or mechanical air equipment used to improve air movement?	206	-6.7	-5.8	2.2	0.80
Were Thermostats/Humidistats set to start fans at 68^{0}F or less?	195	-9.3	-5.0	1.5	0.06
Were circulating fans operating over the resting area?	206	-8.3	-4.8	1.3	0.06
Was wind-speed over the resting /loafing areas 5+ mph?	206	-8.5	-4.6	1.2	0.03
Evaporative Cooling					
Were Sprinklers or Soakers used to enhance evaporative cooling?	206	-6.4	-2.4	1.5	0.08
Were sprinklers/soakers used with fans or mechanical air movement?	206	-6.1	-3.6	1.7	0.33
Were High Pressure Misters or "Cool Cells" used in power ventilated barns?	9	0.1	2.8	1.8	0.33
Were water and timing systems for evaporative cooling maintained regularly?	33	-7.4	-1.2	2.5	0.09
Location of Sprinklers or Soakers:					
Feed Lanes	33	-2.7	-3.3	2.5	0.86
Holding Pens	33	-2.9	-3.2	2.4	0.94
Parlor Exit	33	-3.1	-1.0	5.8	0.83
Loafing/Resting Areas	33	-6.8	-1.9	2.6	0.22
Did your dairy use rBST on lactating cows at that time?	206	-6.5	-2.5	1.5	0.07
Feed and Nutrition					
Did you have your rations balanced by a professional nutritionist?	206	-7.8	-5.7	1.9	0.50
Did you alter feeding schedule and/or amounts during summer months?	206	-6.6	-5.2	1.2	0.41
Were preservatives used on either wet feeds or TMRs to increase stability?	206	-5.9	-5.7	1.3	0.92
Did you feed Sweet Energy or a Sweet Energy/Sweet Dairy Liquid Blend?	206	-6.6	1.3	1.7	<0.01
Did your nutritionist use Buffers/DCAD buffering in lactation rations?	206	-7.1	-5.5	1.4	0.44
Did you feed a live DFM, yeast culture, ionophores or other rumen modulator?	205	-8.5	-4.6	1.3	0.03
Did you feed Hydro-Lac® at any time during July or August 2011?	206	-6.9	-3.4	1.3	0.05
Prior to July 20th, 2011?	206	-6.8	-4.0	1.2	0.12
After July 20th, 2011?	206	-6.8	-3.4	1.3	0.07

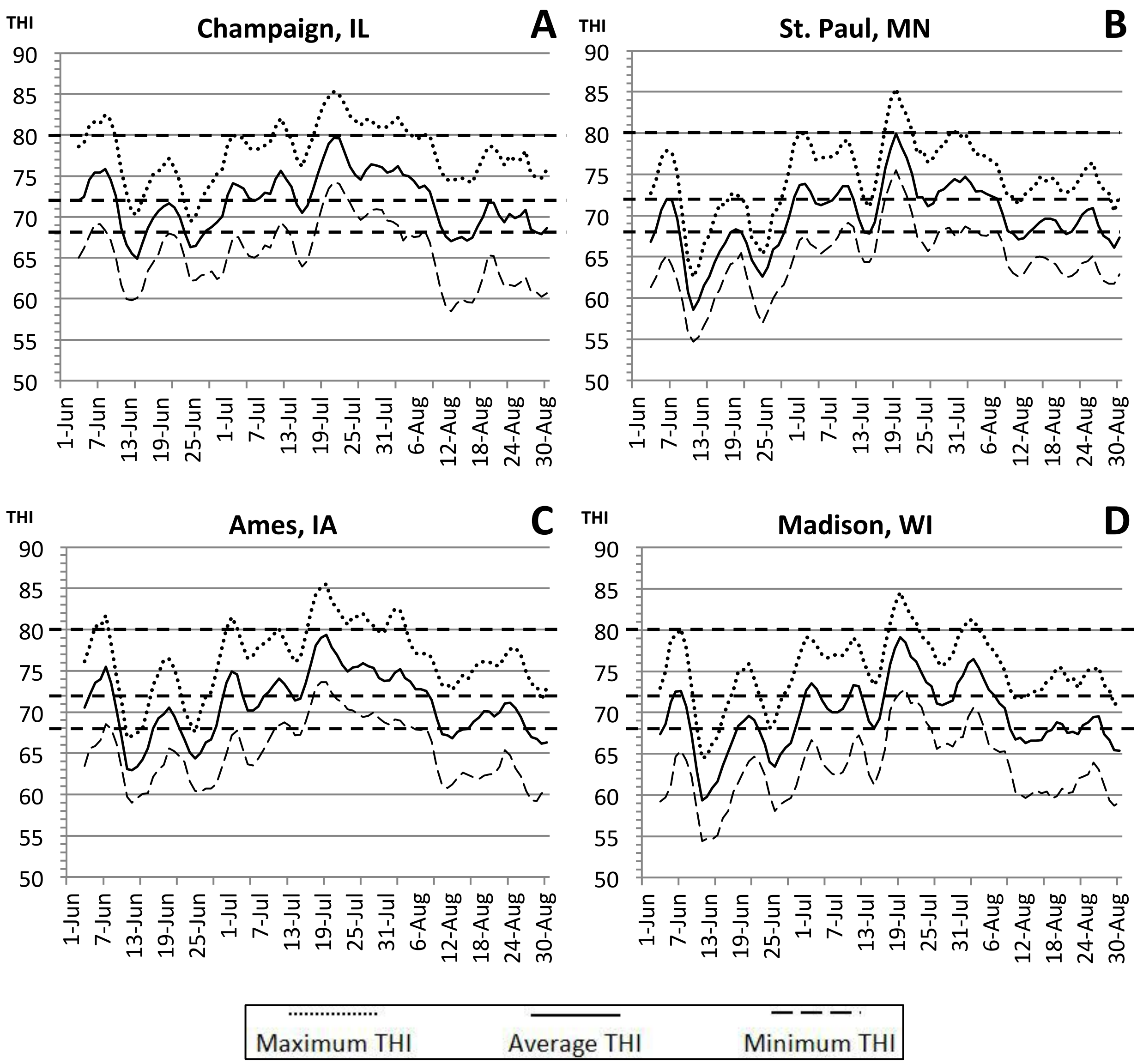

Figure 1. Four day moving average temperature humidity index (THI) of Champaign, IL (A), St. Paul, MN (B), Ames, IA (C), and Madison, WI (D). Stress threshold, moderate stress threshold, and severe stress threshold are shown by horizontal dashed lines at 68, 72, and 80 THI, respectively.

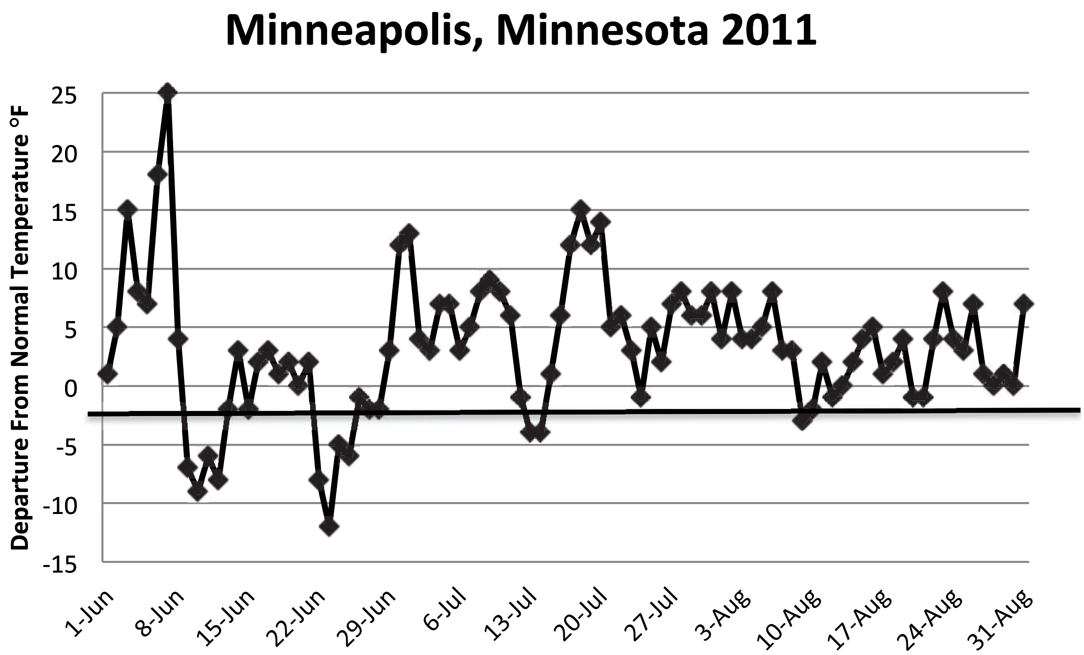

Figure 2. Deviation of daily temperatures compared to historical average.

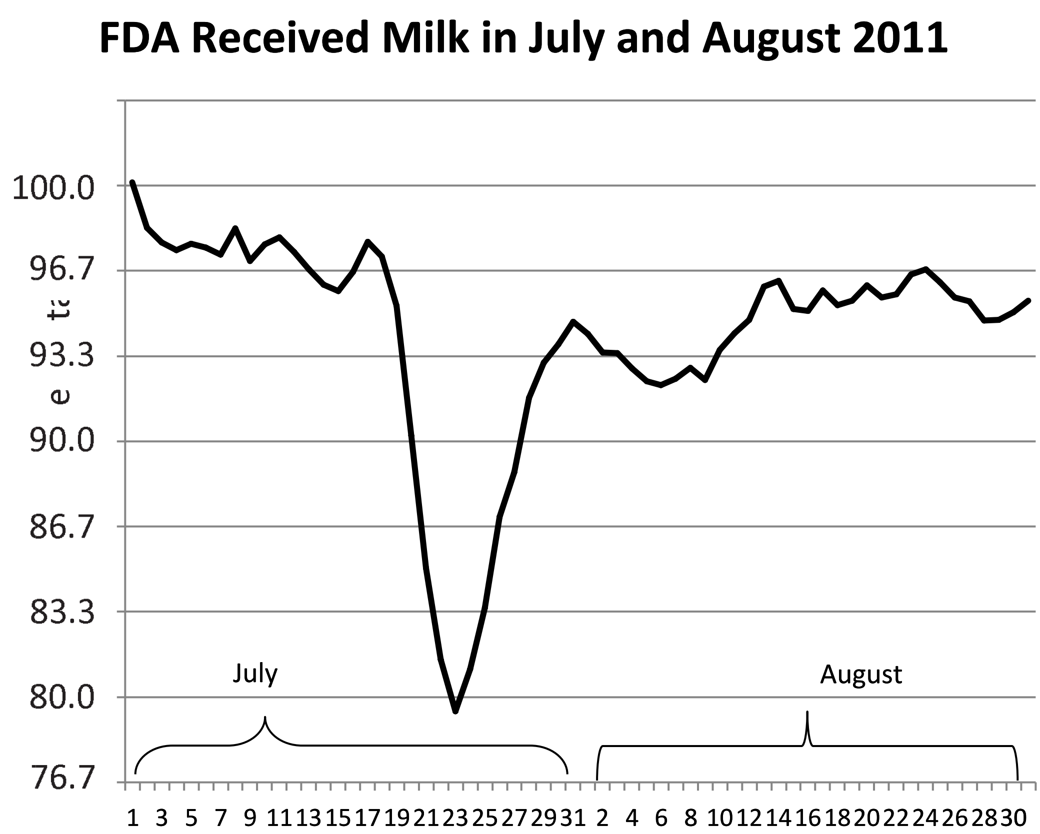

Figure 3. Milk received at First District Association for the months of July and August 2011

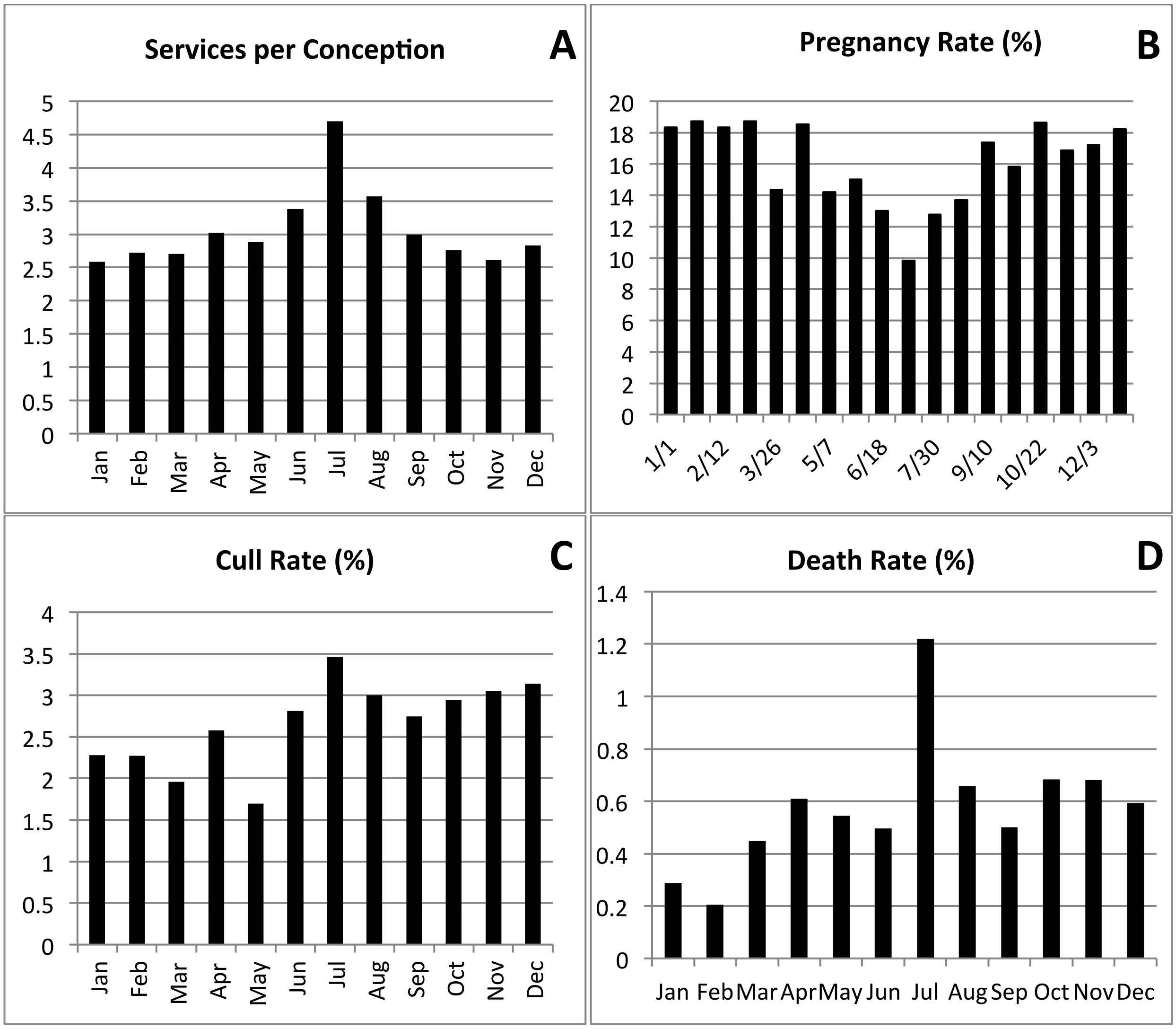

Figure 4. Monthly reproductive indices (A & B) and culling rate (C) and death percentage (D) for dairies completing the questionnaire.

Troubleshooting Mixed Rations: Observations From the Field About What Can Go Wrong and What to Look For

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Troubleshooting a problem on a dairy is a multi-faceted endeavor. Usually not one specific area will tell the whole story and most of the time the problem started weeks ago. Since feed continues to consume roughly 70 percent of total gross revenue on the dairy and because it's linked to many different issues that arise it becomes the target of many troubleshooting schemes. Every aspect of day to day feed management should be closely monitored.

Mixer wagons and the employees that operate them are the heart of any total mixed ration (TMR). Mixing equipment (wagon, tractor, loader) can cost in excess of $250,000. This equipment is critical to the success of the dairy. There are many different brands of wagons and each has their own specific engineering details. As consultants and dairyman, we should strive to properly educate the employees in every area involved with proper feed management. The area of feed management that receives the least attention, but should require the most: is constant analysis of the mixer wagon and feeder.

Mixer Wagon Analysis

Look inside. Make a habit of looking in the mixer wagon prior to the first load of the day. The feeder needs a basic understanding of what the components (knives/kicker plate) look like and how they function. He should be aware of how many knives there should be on each auger and what they look like when they need to be replaced. By checking often enough the feeder can establish maintenance guidelines on the equipment. Notice how the wagon cleaned out the last load of the day. Is there a lot of feed left around the edges? Is there feed clinging to the augers? If the wagon doesn't clean out well there could be a couple of issues happening. First examine the kicker plate and the leading edge of the auger. The leading edge of the auger should be very close to the side wall. This leading edge coupled with the kicker plate is very critical for feed movement up the auger. It is also very important during clean out at the end of every load. Since there is a lot of pressure placed on the bottom of the augers from weight and cutting pressure, the kicker plate, leading edge, and any knives along the bottom will wear out quicker than knives at the top of the auger.

Look inside, again. Safely climb up the manufactures ladder/platform to visually appraise the inside of the mixer box when mixing a TMR. The most obvious thing to look for is "dead spots", meaning feed that is not moving. Specifically look at areas around the discharge door(s). If the door area is worn out it will create a depression for feed to get caught and will stop feed from being picked up by the kicker plates and augers. Pay careful attention to *ALL* discharge doors. It's harder to see, but watch the back of the wagon if there is a discharge door there. Examining the load from start to finish will allow you to pinpoint where the dead spot is forming since feed moves around differently as more weight is added. Usually when the mixer is one-quarter full, feed will still flow around in a circular motion from front to back: back to front. As more weight is added the movement shifts from circular to a "boiling" motion. The auger's purpose is to bring feed from the bottom to the top and boil over back down the wall of the wagon. All the while shifting feed from front to back and back again. It's a must to look inside at different time points during mixing, since a dead spot might not be apparent until sufficient weight is added. If a dead spot is apparent first make sure the tractor RPM's are high enough. In the past couple of years since budgets have tightened drastically on the dairy, the idea of saving fuel has forced a decrease in the RPM's while mixing. This practice will dramatically affect the mixing capability of the augers. Simply increase tractor RPM by 500 and inspect the difference in feed agitation. Remember to keep air filters clean when running higher RPMs. Establish a visual of how your mixer is working when all the components are new. .

Monitor loading technique. The best way to see how the load is mixing is by watching it from start to finish. Many times feeders get in a hurry to load the mixer. There also have been situations of feeders that load the mixer with all ingredients before turning the

PTO on. The explanation was "to prevent over-mixing" or "to prolong the life of the components". Even when the load gets 10 minutes of mixing after stratifying the feed, it does not mix properly. Therefore, it is highly recommended to keep the mixer turning while loading the ration. When loading wet ingredients or ingredients with small inclusion rates, it's best to load down the side wall of the wagon instead of dumping the ingredient directly over the augers. Ingredients have a tendency tol stick to the augers and if you follow a wet ingredient with a fine meal feed it will tend to stick to that wet auger. If this is a small load (i.e. Pre-fresh diet) it will be a problem since the wagon will never get full enough to work feed over the entire auger. Always have some sort of spreader bar for loading liquid ingredients and allow at least 3-5 minutes of mixing time after the last ingredient. There isn't a "perfect time" to mix every ration. Careful monitoring while mixing and the cows at the feed bunk will tell the proper mixing time.

Choosing a mixer wagon. The most popular question I get when visiting a dairy is "what is the best mixer wagon"? This is not a simple answer. I've compiled a list of questions to aid management in making this decision. When determining what mixer will work best for your dairy, use this simple checklist:

1) ***Where is the closest dealer*?** If you don't have a dealer close by for parts and repairs or for allowing you to demo the machine, I have a hard time recommending that mixer. A dealership that has a replacement mixer in case of a major breakdown is a huge asset.

2) ***How much dry hay is in your ration*?** This will determine the need for a vertical mixer or a horizontal. Horizontal wagons still do an excellent job of mixing feed when low inclusion rates of dry hay are used.

3) ***Is there a brand that you are familiar/comfortable with*?** It's human nature to wonder why your neighbor uses a specific brand. The more familiar you are with a brand the quicker you will recognize problems and keep the equipment running more efficiently.

4) ***How often do you service your equipment*?** Let's be honest with this question. All mixer wagons work as intended when they are new. There is a tremendous amount of feed that goes through your mixer every day. For example, a 1000 cow dairy will run approximately 6-8 loads of feed/day. Assuming a 15,000 lb batch size, (8 loads*15,000 lbs = 120,000 lbs TMR daily). Therefore, in 6 months' time, roughly 432 semi-truck loads of feed are going through the box. The internal components will wear out and require periodic servicing or replacement. Bottom line: after 6 months, don't expect the wagon to perform like the day it arrived to the dairy.

Feed bunk management. As a nutritionist , I was always concerned with how much feed was left in the bunks at a certain point in time, when was the next feeding, what did it smell and look like, how often was it being pushed to the cows, etc. Teaching the feeder the critical art of feed bunk management will ensure that you are getting consistent dry matter intake. There are many different scenarios as to how well a TMR unloads from the wagon. What I recommend to the feeders is to find the most *efficient* method to unload. This includes proper tractor RPM to keep the feed moving in the mixer. Feed is in constant motion from front to back and tractor RPM is important for proper clean out at the end of the load. Feeders need to monitor speed and proper discharge- door control to provide a consistent flow of feed to the feed bunk. Teach the feeder to never drive over the TMR. With a narrow feed lane and trying to feed everything once per day or before the last load can be eaten down, this essentially decreases the amount of drivable space in the feed lane and it's very difficult not to drive over feed, especially when backing up. The feeder also needs to understand proper feed distribution. He will soon learn where the majority of the feed needs to be placed in order to minimize left-over or stale feed. Amount of feed, feed distribution and timing of feeding is critical to managing the feed bunk.

Silage management. Silage management gets a lot of attention and rightfully so. The dairy is spending large sums of money to get many tons of feed properly grown, chopped, packed, and covered for a consistent product throughout the entire year. After all of this hard work, it's disturbing to see improper handling of the silage during feed out. Silage facing and uncovering the pile is very important. Whether you have silage facing equipment or shave the pile with the loader, use a technique that allows moving across the face of the pile in three days or less. Don't allow the feeder to jab and dig from the bottom to loosen the silage. This produces jagged edges that allow for maximum oxygen infiltration and subsequent heating and mold growth.

Commodity management. Just as important as silage management, we should be concerned with and try to measure the amount of commodity shrink that is taking place at the dairy. Preliminary results (personal research) are indicating anywhere from 3-10% shrink loss with ground corn kept in a traditional commodity bay. Having the feeder be conscious about pushing feed to the back of the bays and minimizing spillage from full buckets will help put more feed to the cows and ultimately save the dairy money.

Conclusions. Staying ahead of the game in terms of feed management is critical to the success of a dairy. When we are confident and comfortable that the mixer wagon is being maintained properly and that the feeder understands his importance to the entire scheme, troubleshooting problems when they occur will happen more quickly and efficiently. As in most corporate structures, training sessions happen all the time. Training and retraining employees should be a part of every management system. A solid employee training structure and excellent communication between employees and the owner will almost always lead to a successful business. This along with maintaining a tightly managed feed operation should be top on the list of priorities.

Precision Feeding Dairy Heifers

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Dairy heifers represent a large expense of resources including feed, buildings, and labor; yet return no money to the dairy farm until they calve. Thus our overall objective must be to minimize costs while maximizing the returns on those costs incurred. Our overall management of these heifers must be handled in a manner that yields the best quality heifer, with the highest potential to be productive, profitable, with a minimal cost to the farm and the environment.

Feed represents the largest component to the cost of heifer production and is such a large proportion that it clearly represents the major way to control heifer costs. We are often reminded of the importance of feed efficiency (lb milk/lb feed) for lactating dairy cows; yet the concept is seldom mentioned for the growing heifer. However, dairy animals spend over half of their life on most farms as a calf or heifer, which means that their feed efficiency is critical as well. There are many factors that can impact feed efficiency in the dairy heifer, including: genetics, forage quality (fiber and dry matter digestibility), feed intake level, growth rate or stage of growth, body condition or change in body composition, gestation, heat or cold stress (environmental stresses), and exercise level. Precision feeding heifers is really only about feed efficiency and utilizing the principles of feed efficiency to grow heifers at the rates that we need and desire.

Diet type and amount fed can be large factors that affect feed efficiency and are the major aspects that we use in precision feeding heifers. Forage and ration digestibility are also obviously important. The more digestible the feedstuffs used in the ration, the more efficient the heifer will be. In addition, the greater the dry matter intake fed as a percent of body weight, the lower will be the feed efficiency.

There has been a great deal of research done about precision feeding heifers, and virtually all since 2000. Much of the research has been done looking at precision feeding highly digestible diets to dairy heifers for improving feed efficiency and reducing nutrient waste. Feeding dairy heifers a balanced diet is always important. In the case of precision feeding, no additional free choice forages are fed, and the balanced diet is likely fed in the form of a TMR or mixture of forage and grain, fed once daily. Based on current published research for precision-fed dairy heifers, nutrient specifications as currently understood are as follows:

Protein: Balance primarily for crude and soluble protein.

- 14 to 15% CP for pre-pubertal heifers based on 2.15% BW DMI/d.
- 13 to 14% CP for post pubertal heifers based on 1.65% BW DMI/d.
- Maintain at least 30 to 35% soluble CP in the rations at all times.
- Rumen undegradable CP levels in excess of 25 to 30% are not required; use only standard feed sources based on price and availability and not feeds specifically designed for high bypass protein.

Heifers require a specific amount of crude protein daily, and for heifers total protein has been shown to be equally as important as the various protein fractions. Research has shown that added rumen undegradable protein (RUP) is of limited value to the heifer beyond what is found in common feedstuffs. In situations where high RUP feedstuffs are more economical than lower RUP feeds, they may be used; however they should not be used for the added RUP. Soluble (SP) and rumen degradable crude protein (RDP) are efficiently utilized by dairy heifers. In studies with SP added as urea, improved nitrogen retention in rations with SP approaching 40% has been observed. It appears that nitrogen utilization in the precision-fed dairy heifer is efficient, allowing for efficient rumen microbial protein production throughout the day despite feed access being limited to a few hours. In various published research trials, maximum protein efficiency has been demonstrated when heifers are fed diets containing 14 to 14.5% CP.

Energy: The energy requirement of the heifer will be influenced by the size, growth rate, and environment of the heifer. There are two feeding strategies to meet the energy requirements of growing dairy heifers. First, diets can be formulated at variable energy densities and fed ad-libitum to allow the heifer to select her energy consumption. In the second strategy, heifers' diets can be formulated at a fixed (generally higher) energy content and precision-fed to specifically meet the heifers' energy requirement. Regardless of feeding strategy, heifers should be fed energy to allow 1.75 to 2.00 pounds of average daily gain or approximately 130 kcal of metabolizable energy per pound of metabolic body weight ($BW^{0.75}$).

Fiber (NDF or ADF): The current NRC levels for fiber for dairy heifers may not be warranted based on recent precision-feeding experiments. Traditionally, high levels of fiber or low quality forage are fed to dairy heifers to control dietary energy; however precision feeding high concentrate, low fiber diets effectively accomplishes the same goal. Economics and the mix of forages available to a farm usually drive the forage level to feed. Much of our recent precision feeding work has been done with 70 to 90% forage diets.

Vitamins and minerals: In precision feeding systems balance for current NRC specifications. At present there are no data to suggest vitamin and mineral requirements are altered when heifers are precision-fed diets.

Monitor Heifer Weight

Weighing heifers is a relatively simple means to monitor animal performance, ***and this practice is a must for precision feeding dairy heifers successfully***. Weighing heifers is increasingly important when precision feeding dairy heifers since an inappropriate level of diet restriction can lead to rapid gains and fat heifers or gains lower than desired. Electronic scales can be placed in alleys or some other easy to handle location to make heifer weighing less of a chore. Basically any time a heifer is handled, she should be weighed. With a precision feeding system heifers must be weighed to allow you know what amount of feeding is required, while maintaining the growth rates needed for breeding at a given age or for calving at a given body weight.

Recommendations:

- Weigh heifers at the same time of day (relative to feeding), otherwise alterations in gut fill can impact ADG calculations.
- Weighing heifers once per month is best, but once your system is stable, less frequent weights can work as long as you at least observe body condition.
- It is best to weigh all heifers; however, on some farms it may not be realistic, as heifer numbers may be labor prohibitive. In this case, weighing a representative group of heifers in a pen each time will suffice. It is important to be sure that this group is representative of the entire group and that the same heifers are weighed each time.
- Monitor individual heifer and group gains against benchmark weights, and alter management, specifically feed intake strategies, as needed.

Group Sizes

In any group-housed heifer facility minimizing variation in size and age of heifers in each group is important, and it remains important in precision feeding system management. Typically, beyond 4 months of age, heifers should be housed with other heifers as close to the same age as possible and always in groups with less than 200 pounds (90 kg) of weight variation within the group. Often this means having groups with 2 to 4 months of age variation at the most. Post breeding, this number can be increased to 300 pounds (136 kg) weight spread between animals within a group.

Feed Bunk Space

In precision feeding systems, heifers will need 14 to 24 inches of feed bunk space per heifer as they progress from 4 months of age to pre-calving or 22 months of age.

Precision-fed heifers will not have access to feed at all times of day, thus all heifers in a pen must have access to the feed bunk. Overly aggressive and timid heifers are very susceptible to over- or under-nutrition when feed bunk space is limited.

There are three strategies that can be used when feed bunk space is limited. The first is clearly grouping animals with peers having similar body weight. The second strategy is to have impediments to free motion at the feed bunk, such as headlocks or closely placed divider posts. This will likely be effective to some degree, but not completely. The third is to feed twice daily at close intervals. For example, feed two-thirds of the daily allotment at 7 a.m. and the remaining third at 9 a.m.; in this way the larger animals can eat more freely at the early feeding and the more timid animals at the second feeding.

Hungry, But Growing

At the initial implementation of the precision feeding protocol, the heifers will likely vocalize immediately prior to feeding, with the frequency and magnitude increasing toward the next feeding. Research experiences are that this behavior will diminish and virtually disappear by between 10 and 14 days after the implementation of the precision feeding strategy. This is due to a moderate reduction in rumen and gut size needed to accommodate a reduced digestive load, which is one of the reasons for the improved efficiency in precision-fed heifers.

The transition to precision feeding requires time and commitment in a manner similar to the time it takes to increase gut capacity after calving. As long as the heifers are growing according to the ADG goals of your operation and receiving a correctly balanced ration, they are adequately fed.

Transition to Pre-freshening and Post-freshening Diets

Precision feeding should be discontinued and heifers adapted to normal pre-freshening diets 30 to 45 days before calving. Precision feeding heifers until 30 to 45 days before calving has had no adverse effects on calf birth weight, dystocia, metabolic problems, early lactation intakes, or first lactation milk production, as has been reported in several peer-reviewed journal publications. Changes in rumen and gut volume have been shown to occur rapidly and do not limit postpartum dry matter intake.

Nutrient Specifications

Listed below are some of the nutrient recommendations that have been determined under experimental and practical situations. It should be noted that both high forage and high concentrate rations contributed to these recommendations, both types of diets were precision-fed to produce a level of growth to meet ADG objectives. Precision feeding highly digestible, high concentrate diets is still under development for dairy heifers, and knowledge is still incomplete. But this information can serve as a starting point for those interested in precision feeding dairy heifers. ***The final determination for the success of a precision feeding program is the animal herself, and careful and frequent monitoring of heifer progress is the key to successful application of this nutritional approach.***

A strategy for practical ration balancing is to formulate a least-cost diet based on the feeds available, meeting the required specifications, and then feed an amount of dry matter to meet the nutrient requirements. That is, assuming energy is most limiting for growth, determine the ME required by a heifer for a specific rate of gain (from the NRC, for instance) and divide the requirement by the formulated ration energy density (Mcal/d ÷ Mcal/pound DMI).

Table 1. Nutrient recommendations for precision-feeding dairy heifers.

Values are for Holstein heifers growing 1.9 pounds per day. These are starting values based on precision feeding experiments; actual performance should be monitored and dietary alterations should be made accordingly.

Age, mo	Body Weight, pounds	DMI, pounds/d	ME, Mcal/d	CP, pounds/d	NDF, %
4	250	5.72	7.8	0.9	23
6	350	7.45	10.1	1.1	24
7	450	9.07	12.2	1.4	26
9	550	10.62	14.1	1.6	27
11	650	12.11	16.0	1.8	28
13	750	13.55	17.9	2.0	29
14	850	14.95	19.6	2.2	30
16	950	16.32	21.3	2.4	30
18	1050	17.65	23.0	2.6	31
20	1150	18.96	24.6	2.8	32
21	1250	20.24	26.2	2.9	32
23	1350	21.51	27.7	3.1	33

Feed efficiency in the dairy heifer can therefore be optimized by selecting animals that have the genetic propensity for high dry matter intake in first lactation and have the ability to grow at uniform rates to meet the body size requirements for calving at 22 to 24 months of age. Maintaining optimal body size during the growing phase is important to minimize heifer maintenance requirements. Finally, feeding precise amounts of highly digestible and perhaps higher concentrate rations will minimize energy and protein requirements of the heifer as the heifer will efficiently digest and utilize the feeds that she is fed.

On-Farm Genomics Testing and Dairy Cattle Replacement Decisions

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Introduction
The availability of affordable sexed semen since the fall of 2005 and improvements in reproductive efficiency in the last decade have led to an abundance of dairy heifers on many farms in 2013. Historically, most dairy farmers have raised all their heifer calves to replace culled cows. The ability to create more dairy heifers than are needed for culling and herd expansion has many dairy farmers wondering how many dairy heifer calves are needed. Many options need to be considered, such as increasing the cull rate of cows to make room for the extra heifers, limiting the number of heifers entering the herd through sales of surplus dairy calves or surplus heifers, or limiting the number of heifer calves born through breeding decisions such as reduced use of sexed semen, the use of beef semen, or delaying or not breeding certain animals at all. The best policy could be a combination of these options. These options have both consequences for breeding decisions of animals that are kept, and selling decisions for cows and (surplus) heifers. These decisions are interdependent when maximizing herd profitability.

The other new technology that became commercially available to dairy farmers in 2009 was genomic testing. Genomic testing allows dairy farmers to more accurately identify generically superior females (and males) shortly after birth. For a relatively small fee (about $40 for the low density test per animal) we can better identify the superior females for the traits we desire. Genomic testing helps to make better informed breeding and culling decisions, but questions remain about which animals to test and the expected profitability of the best use of the test.

The objective of this paper is twofold. First, we'll describe (optimal) genomic testing policies for heifers including which animal to test and which not, and the expected genetic progress if the bottom portion of all heifers is sold. The genetic value of the kept heifers depends on how many animals are sold vs. born. Second, we'll explore in a whole-farm cost-benefit analysis how many dairy calves the herd should create in order to allow for the sale of surplus dairy calves and capture genetic progress from the kept dairy calves. For example, increasing the use of sexed semen creates more dairy calves but also affects fertility, culling, and breeding cost. Several scenarios will be presented. Other uses of genomic testing have value, for example to find elite animals as embryo donors, but these are not considered in this paper.

Genomic testing principles
Genomic testing implies that money is spent on a test to learn something about the animal. Such an expense makes only sense if it affects what we do with the animal. If genetic testing does not lead to alternate breeding or culling decisions, then there is no value in the test. In the analysis that follows, we'll assume that the dairy farmer is interested in ranking heifer calves for genetic merit. The farmer will sell the lowest ranked animals if they are not needed to be kept on the farm. Genomic testing alters (improves) the ranking and therefore makes a difference in the decision which animals to keep and which ones to sell.

A genomic test measures single-nucleotide polymorphism (SNPs) in the DNA of animals. This DNA is made available through for example a sample of blood or hair. One SNP implies that a single nucleotide (A, T, C or G) in the 3 billion possible nucleotides of dairy animals differs between animals. Biologically, one SNP, or a more likely a number of SNPs, may lead to a different biological performance, such as higher milk yield or lower fertility. The current low density genomic tests measure approximately 8,000 known SNP locations. Each tested animal's SNP pattern then is compared with the SNP patterns in the predictor population of dairy animals and the associated estimated breeding values for various traits. Each genomic test therefore gives insight into the actual DNA of an animal and its associated breeding values. The collective breeding values of traits of interest are referred to as genetic merit.

Genetic progress in a group of selected animals depends on natural genetic variation in a population, the reliability of the ranking for genetic merit of the trait of interest, and the fraction animals that are selected (= kept). The natural genetic variation is basically given and is not easily changed. A greater reliability means that we are better at ranking animals for their true genetic merit, based on their predicted genetic merit. That means that the selected group of animals is more likely to consist of the genetically truly best animals in the population. Finally, the average genetic progress of the selected group is greater when fewer animals are selected then when more animals are selected.

The key equation that captures this idea is where is the additive genetic standard deviation (natural genetic variation), is the accuracy of the prediction calculated as the square root of the reliability, and is the selection intensity factor which depends on the fraction of animals that are selected (Van Vleck et al.,1987).

Genomic testing improves the reliability of the estimate of genetic merit of individual animals. That means that we are more sure that the estimate is close to the true genetic merit of the animals. In a population, genomic testing improves the accuracy of the prediction and therefore genetic merit of the selected (best) animals. For example, the reliability for the predicted transmitting ability (PTA) milk increases from about 42% with just parent average information, to about a 65-70% reliability for animals that have been genomically tested with the a low density SNP test.

For example, in a herd with only sire identification, we might have a standard deviation (a measure of the variation) of $350 lifetime Net Merit dollars (NM$) and a reliability of NM$ of only 20% because only the sire is identified. The low reliability means that the ranking of the animals for genetic merit is not very good, so the selected animals may or may not be the truly genetically best animals. It is convenient to work with NM$ because this selection index represents the increases in profit in an adult cow's lifetime, which is approximately 3 years. The current NM$ includes 10 traits such as milk fat, protein, and yield, daughter pregnancy rate, productive life, somatic cell score, feed and legs etc. (Cole et al., 2009). So an increase in NM$ of $120 means that the average profit per cow per year is expected to be increased by approximately $40 due to a combination of altered fertility, milk components, feed and legs composite, etc.

Using the key equation with the above assumptions, if the best 10% of the animals are selected, the average NM$ of this group of animals is $275 better than the population average of $0. If the best 90% of the animals are selected, their average is only $31 better than the population average. The best 90% of the animals consists of all animals in the population, except the ones that are predicted to be the worst 10%. If the reliability increases say from 20% to 60%, for example because all animals are genomically tested, the average of the predicted best 90% increases from $31 to $53. The reason is that we now identified the genetically truly best animals with more accuracy. **Table 1** shows increase in NM$ for various reliabilities and selection intensities calculated from the key equation.

The NM$ is the expected increase in profit during a lifetime, but a genetically better female is expected to also have better daughters, grant daughters etc. Therefore, the NM$ is probably an underestimate of the value of a genetically improved animal. On the other hand, the expected gain in NM$ from a breeding decision today is not realized until the calf born starts lactating and later has offspring of her own. This future profitability should be discounted into today's dollars. Collectively, the value of

+$1 greater NM$ of the decision to keep a better heifer calf is about $1.40 in net present value of all profit resulting from the higher genetic merit realized in the future. The 1.4 is referred to as the number of discounted expressions. Further assuming a cost of $40 per genomic test and that an animal is tested only once in her lifetime, **Table 2** shows the increase in the net present value of this cumulative profit for various reliabilities and selection intensities. It turns out that genomic testing is very often profitable if no prior information is available. At 60% reliability, if fewer than 95% of the best animals are kept, the net present value starts to be positive. The only exception is when very few animals are selected but all animals are tested.

Table 1. Increase in lifetime Net Merit dollars (NM$) for various reliabilities and selection intensities calculated from the key equation assuming an additive genetic standard deviation of $350.

	Reliability				
% Best animals selected	20%	40%	60%	80%	100%
100%	0	0	0	0	0
90%	31	43	53	61	68
80%	55	77	95	110	122
60%	101	143	175	202	225
40%	151	214	262	302	338
20%	219	310	380	438	490
1%	417	590	723	834	933

Table 2. Increase in net present value per selected animal for various reliabilities and selection intensities assuming an additive genetic standard deviation for lifetime Net Merit of $350, 1.4 discounted expressions, and $40 cost per genomic test. All animals are tested, either selected or not.

	Reliability				
% Best animals selected	20%	40%	60%	80%	100%
100%	-40	-40	-40	-40	-40
90%	-1	16	$30	41	51
80%	27	58	$83	104	121
60%	75	134	$178	216	248
40%	111	200	$267	323	373
20%	107	234	$332	413	486
1%	-3416	-3174	-2988	-2832	-2694

Which animals to test

Genomic testing with a low density test is likely profitable if nothing is known about the animals. However, the value of the genomic testing is less when animals can already be pre-ranked by other means, for example by parent average. If we know the PTAs for NM$ for the sire and dam, for example, we already have some idea about an animal's own genetic merit for NM$. A genomic test will change the value and improve the reliability of that NM$ estimate, but less than when nothing is known.

Secondly, if animals can be pre-ranked, there is often no need to test all animals with a genomic test. For example, when most of the animals need to be selected, it is often economically to test only the lower pre-ranked animals. The animals with the highest parent averages do not need to be genomically tested because they most likely will be selected anyway. The advantage of genomic testing is the greatest when animals cannot be pre-ranked and when a small fraction of animals is selected, provided we use a smart testing policy.

Weigel et al. (2012) studied the economic feasibility of genomic testing for various reliabilities of pre-ranking and depending on whether all animals, the pre-ranked top 50%, the pre-ranked middle 50%, or the pre-ranked bottom 50% were tested. Testing all animals was most cost-effective if ancestry of the animals was not known and when fewer animals were selected. Selective testing of pre-ranked animals was most profitable when animals could be pre-ranked and a relatively small proportion of animals were to be selected of culled. They concluded that routine genotyping of heifer calves or yearling heifers could be cost-effective strategy for enhancing the genetic level of replacement females on commercial farms.

We also explored the concept of selective testing of animals based on pre-ranking information (De Vries et al., 2011). Compared to Weigel et al. (2012), who studied testing all animals and 3 variations of testing 50% of the candidates, we varied the fraction of animals to test in 10% increments. For example, we compared testing the middle 30%-80% range of pre-ranked animals (thus not testing the top 30% and not testing the bottom 20%). The number of discounted expressions was set to 1.4 and cost per genomic test was $40.

A SAS macro was created which simulated 36,000 scenarios varying in pre-ranking reliability, genomic test reliability, bottom fraction of animals genomically tested, upper fraction of animals genomically tested, and a standard deviation of $350 NM$. Calculation of the gain in NM$ through genomic testing was performed by conditional normal distributions. Each scenario was evaluated 1 million times with different random numbers.

Figure 1 shows the value of a genomic test with 60% reliability and no pre-ranking of animals. Five testing policies are shown, in addition to not using any genomic testing. The values are directly comparable to **table 2**. Testing all animals was the optimal policy for all selection intensities, except when very few or very many animals were selected. When 90% or 10% of animals were selected, the optimal policy was to test about 50% of the animals. There is a much value in genomic testing all animals when about half of the animals are to be selected.

Figure 2 shows the value of a genomic test with 60% reliability and 20% reliability when pre-ranking all animals. The value of the various genomic testing policies is very close, except when few animals are selected. **Figure 3** shows the best policy. When many animals are selected, the bottom third of pre-ranked animals should be tested. When few animals are tested, the top third of pre-ranked animals should be tested. Otherwise, pre-ranked animals in the middle should be tested. When the pre-ranking reliability is 40%, the value of selection is shown in **figure 4**. The best policy is similar to the one for a 20% pre-ranking reliability (**figure 3)**, but the bottom and top bands move closer together so fewer animals should be tested.

The difference between the best policy and the policy with no genomic testing becomes smaller when the pre-ranking reliability increases, as can be seen in **figures** 1, 2, and 4. For example, when the top 70% of animals are selected, the expected value of the best genomic testing policy is $131, $36, and $14 per selected animals, given a pre-ranking reliability of 0%, 20%, and 40%, respectively.

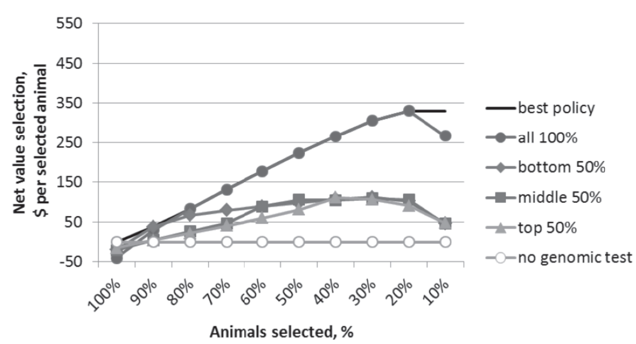


Figure 1. Value of selection with a genomic test with 60% reliability and no pre-ranking of animals. Genomic test cost was $40 per animal. Five testing policies are shown.

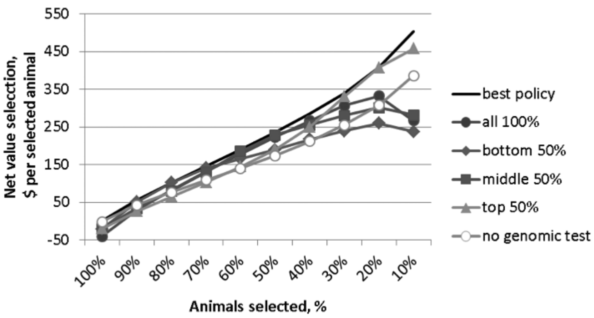


Figure 2. Value of selection with a genomic test with 60% reliability and all animals are pre-ranked with 20% reliability. Genomic test cost was $40 per animal. Five testing policies are shown in addition to selection without a genomic test.

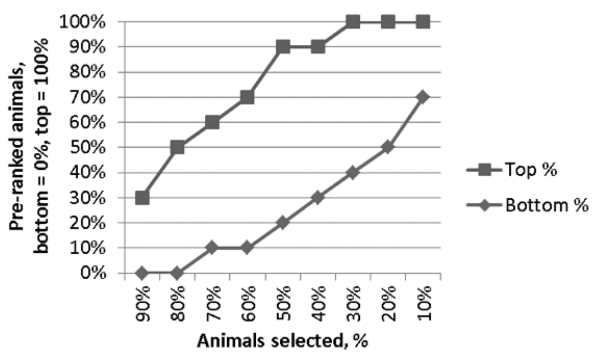


Figure 3. Best genomic testing policy with 60% reliability and 20% reliability when pre-ranking all animals. Genomic test cost was $40 per animal. The non-smooth lines are caused by random sampling error. For example, when 60% of all animals are selected, the best genomic testing policy is to test all animals except the top 30% and the bottom 10%.

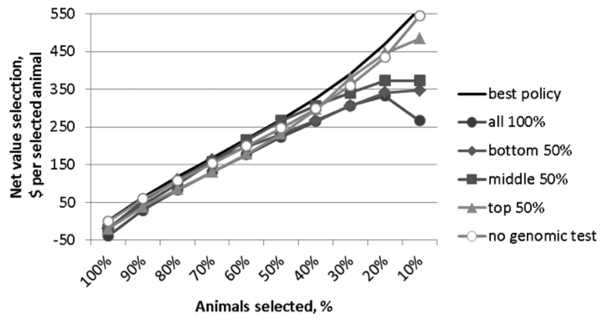


Figure 4. Value of selection with a genomic test with 60% reliability and all animals are pre-ranked with 40% reliability. Genomic test cost was $40 per animal. Five testing policies are shown in addition to selection without a genomic test.

It is convenient to capture the value of the best testing policies in simple regression equations. **Table 3** shows the regression coefficients from simple linear regressions fit on the value of the best testing policy per selected animals for 50% to 100% of animals selected. For example, when the pre-ranking reliability is 20% and the genomic test reliability is 60% with a cost per test of $40, then the value per selected animal is 469.6 – 463.5 * animals selected %. If the top 80% of the animals are selected after the best testing policy, then the increase in value per selected animal is 469.6 – 463.5 * 0.8 = $99 during her lifetime and her offspring through discounted expressions. This is compared to selecting animals randomly which yields no genetic progress.

Table 3. Simple linear regression equations that capture the value of the best testing policy from 50% to 100% of all animals selected. Net value of selection per selected animal = b0 + b1 * animals selected%[1]

Pre-ranking reliability	Genomic test reliability	Genomic test cost	b1	b0
0%	40%	$40	-340.4	335.7
20%	40%	$40	-403.1	408.0
0%	60%	$40	-452.5	448.1
20%	60%	$40	-463.5	469.6
40%	60%	$40	-532.2	538.5
0%	80%	$40	-546.1	542.5
20%	80%	$40	-536.5	542.6
40%	80%	$40	-573.6	581.2
60%	80%	$40	-620.4	629.6

[1]At 100% animals selected, the theoretical value of selection is $0. A regression equation with quadratic terms gave a slightly better fit in the order of at most a few dollars.

The analysis above assumes that the value of the best genomic testing policy is expressed through an increase in NM$ of the animals that are kept for the herd, for example through higher milk production, greater daughter pregnancy rate, and/or better feed and legs. It is also assumed that the not selected animals are sold and that their sale price is independent of the testing policy. One can imagine that the sale price might decrease if it is known that the animals for sale are in the bottom half for genetic merit.

Genomic testing generally has value when surplus heifer calves can be sold. One question therefore is how many more heifer calves should be created (by using sexed semen or reduced culling) than are needed to replace culled cows. The use of sexed semen and keeping non-pregnant cows longer typically comes at a cost to the herd, but that loss could be offset by the increased genetic value of the kept heifer calves because selection intensity is high.

Further, better knowledge of the genetic merit of heifers and cows might lead to additional gain through altered breeding polices, for example by deciding which dams should be bred (with conventional or sexed semen) to become the mothers of the next generation of heifer calves. In some markets, it could be advantageous to breed the bottom end of heifers and cows with beef semen and sell the crossbred calves. This policy would decrease the number of dairy heifer calves born and consequently reduce the value of selection, but extra value would be captured from selling crossbred calves. These combined options of genomic testing policy, breeding policy, and culling policy should be considered simultaneously. This is a non-trivial problem, however, and probably best analyzed with simulation.

We used a comprehensive linear program model to evaluate a few of the possible strategies. Briefly, there are 10 parities (heifers and 9 cow parities) in the model. For open heifers there are 4 breeding opportunities where for open cows there are at most 15 breeding opportunities. Pregnant animals are always kept and not subject to decision making although a risk of forced culling is included. The timing between the breeding opportunities depends on the 21-day service rates set by the user. At each breeding opportunity, the animal can be culled, not inseminated, or inseminated with (if not restricted) 3 types of semen: conventional dairy, sexed dairy, or conventional beef. The model also decides for every breeding if the dairy heifer calf that may be born should be kept or sold. Seven levels of NM$ breeding values are assumed for all animals which represent genetic diversity and affect the value of their calves and hence breeding decisions. The NM$ also declines with age. Among cows, an additional 7 levels of milk production are considered. The model has approximately 40,000 decision states. The model further has transition probabilities between levels of milk yield and NM$. Animals are subject to risks of involuntary culling anytime. Many other relevant inputs are modeled such as functions for feed dry matter intake, milk production, body weights, probabilities of conception, as well as prices for milk, feed, inseminations, calves, cull cows, and other variable and fixed costs.

The key advantages of this model are that herd demographics of a herd with groups of cows and heifers can be generated while allowing enough flexibility for optimizing breeding, culling, and calf keeping decisions for reach group. The linear program makes it possible to apply constraints, such as for example that enough heifer calves are kept to keep a constant herd size. Another constraint option is to require the model to generate a certain number of surplus heifer calves. The model than optimizes all decisions to generate the requested number of surplus heifer calves, while optimizing profit per cow (or per milking slot) per year.

In our scenarios shown below, we optimized breeding, culling, and calf keeping decisions while maximizing (pre)profit per milking cow per year. The maximum number of milking cows was set at 1000. In addition to let the model decide on the number of heifer calves to sell, we also forced the model to sell 0, 150, 300, 450, 525, or 600 heifer calves per year. These heifer calves to sell plus the heifer calves to keep determined the selection intensity. The income per heifer calf sold was $150, regardless of selection intensity. The value per kept heifer calf depended on the genetics of her dam, but did not include the value of the best genomic testing and selection policy as described above. This value was added separately. Therefore, the value of selection as outlined above was converted to an annual value per milking cow and added to the (pre-)profit per milking cow per year to obtain the bottom line profit per milking cow per year. We assumed that sexed semen cost $10 more than conventional semen and reduced the conventional probability of conception by 20%. Beef semen and conventional dairy semen had the same cost and fertility. Dairy bull calves were sold at $50 per head and crossbred calves at $175 per head. The model included many other inputs and costs with the intention to represent an average herd in the US, but these inputs are not described here.

Table 4 shows some key statistics for the default inputs when only conventional and sexed semen were allowed as breeding choices. The results show a herd with 1000 milking cows and a slightly variable numbers of dry cows and heifers. The optimal, unconstrained, number of heifer calves sold per year was 68. More sexed semen was used when more heifer calves had to be created. An attempt to generate 600 dairy heifer calves for sale per year was not feasible, even with 100% sexed semen use and as little culling as possible.

As expected, the (pre)profit per milking cow per year decreased from $648 when other than 68 dairy heifer calves were sold. When 68 dairy heifer calves were sold (11% of the total number born), the added genetic value per kept heifer calf was $36 from the regression equation with 20% pre-ranking reliability and 60% genomic test reliability. This was the equivalent of $10 per milking cow per year for a bottom line profit of $648 + $10 = $658. Judging the bottom line, the optimal number of heifer calves to sell was approximately 150 for a profit of $663. Therefore, it was beneficial to create a larger surplus of dairy heifer calves to capture the value of genetic selection through the increased selection intensity. On the other hand, selling more than 150 dairy heifer calves cost more than was captured by increased genetic progress of the kept dairy calves.

Table 5 shows results when conventional, sexed, and beef semen all were allowed as breeding choices. Again a pre-ranking reliability of 20% was assumed with 60% reliability from genomic testing. The value of crossbred calves ($175 per head) was enough to trigger the use of beef semen, even when 150 dairy heifer calves had to be sold. Under these assumptions it was not profitable to create a surplus of dairy heifer calves.

Tables 4 and 5 also show annual cull rate for cows and the fraction inseminations with either conventional, sexed, or beef semen. When more heifer calves were sold and beef semen was not an option, the annual cull rate generally decreased which implied that cows were kept longer. Also, more sexed semen was used. Within the herd, sexed semen was used primarily in heifers and early lactation cows with high genetic levels. The breeding policy is a balance between the probability to generate a high valuable (heifer) calf and the need to keep a high producing cow in the herd. These complex optimal policies are not easily captured in simple guidelines.

In **summary**, genomic testing with a low density test at $40 per test was generally valuable when fewer than about 95% of the dairy heifer calves were kept. Generally only the bottom third to half of all heifer calves needed to be tested when animals can be pre-ranked, for example by parent average, and when the majority of the animals need to be kept. A whole herd analysis showed that that it was valuable to use sexed semen to create a greater surplus of heifer calves to capture extra genetic progress from the kept heifers. This may not be valuable if a market for crossbred calves exist. The results showed that

Table 4. Effect of variations in the number of heifer calves sold on herd statistics including profitability and the value of genetic progress from selection among heifer calves. Only conventional and sexed semen were allowed as breeding choices.

	Heifer calves sold (N/yr)					
Herd statistic	0	Optimal	150	300	450	525
Milking cows present (N)	1000	1000	1000	1000	1000	1000
Dry cows present (N)	124	126	126	124	120	123
Dairy heifer calves kept (N/yr)	602	563	550	557	554	404
Dairy heifer calves sold (N/yr)	0	68	150	300	450	525
Dairy bull calves born (N/yr)	649	596	513	338	161	127
Crossbred calves born (N/yr)	0	0	0	0	0	0
Heifers present (N)	1167	1093	1069	1087	1077	783
Conv. semen breedings (%)	99%	91%	74%	40%	4%	0%
Sexed semen breedings (%)	1%	9%	26%	60%	96%	100%
Beef semen breedings (%)	0%	0%	0%	0%	0%	0%
Annual cull rate (%)	47%	44%	42%	42%	41%	29%
Pregnancy rate (%)	19%	19%	18%	17%	15%	15%
(Pre)profit ($/milking cow/yr)	643	648	644	625	591	521
From best calf selection policy:						
Heifer calves kept (%)	100%	89%	79%	65%	55%	43%
Added value ($/selected calf)	0	56	105	168	214	268
Added value ($/milking cow/yr)	0	10	19	31	40	36
Bottom line ($/milking cow/yr)	643	658	663	656	631	557

Table 5. Effect of variations in the number of heifer calves sold on herd statistics including profitability and the value of genetic progress from selection among heifer calves. Conventional, sexed, and beef semen were allowed as breeding choices.

	Heifer calves sold (N/yr)					
Herd statistic	0	Optimal	150	300	450	525
Milking cows present (N)	1000	1000	1000	1000	1000	1000
Dry cows present (N)	126	126	124	124	120	123
Dairy heifer calves kept (N/yr)	550	550	553	557	554	404
Dairy heifer calves sold (N/yr)	0	0	150	300	450	525
Dairy bull calves born (N/yr)	206	206	224	338	161	127
Crossbred calves born (N/yr)	449	449	270	0	0	0
Heifers present (N)	1071	1071	1080	1087	1077	783
Conv. semen breedings (%)	24%	24%	23%	40%	4%	0%
Sexed semen breedings (%)	40%	40%	55%	60%	96%	100%
Beef semen breedings (%)	36%	36%	22%	0%	0%	0%
Annual cull rate (%)	42%	42%	42%	42%	41%	29%
Pregnancy rate (%)	18%	18%	17%	17%	15%	15%
(Pre)profit ($/milking cow/yr)	670	670	649	625	591	521
From best calf selection policy:						
Heifer calves kept (%)	100%	100%	79%	65%	55%	43%
Added value ($/selected calf)	0	0	105	168	213	268
Added value ($/milking cow/yr)	0	0	19	31	40	36
Bottom line ($/milking cow/yr)	670	670	668	656	631	557

genomic testing, breeding, culling, and calf keeping decisions for cows and heifers are interdependent and not easily summarized in easy rules.

Acknowledgments

We thank Dr. John B. Cole, Animal Improvement Programs Laboratory, ARS, USDA, Beltsville, MD, for clarification of several concepts presented in this paper.

References

Cole, J. B., P.M. Van Raden, and Multi-State Project S-1040. 2009. Net merit as a measure of lifetime profit: 2010 revision. AIPL Research Reports. NM$4 (12-09). Available at http://aipl.arsusda.gov/reference/nmcalc.htm

De Vries, A., D. T. Galligan, and J. B. Cole. 2011. The use and economic value of the 3K SNP genomic test for calves on dairy farms. Univ. Florida EDIS publ. AN270. Available at http://edis.ifas.ufl.edu/an270

Van Vleck, L. D., E. J. Pollak, and E. A. Branford Oltenacu. 1987. Genetics for the Animal Sciences. W. H. Freeman and Company, NY.

Weigel, K. A., P. C. Weigel, W. Herring, and T. J. Lawlor. 2012. Potential gains in lifetime net merit from genomic testing of cows, heifers, and calves on commercial dairy farms. J. Dairy Sci. 95:2215-2225.

Heifer Feeding Realties

Ron Holty, Foundation Feeders, Inc.

Ron Holty

- Ron graduated from the University of Minnesota in fall of 1993 and married Kimberly. He continued to study animal nutrition and worked for Farmland Industries as a nutrition consultant. Ron later worked as a private consultant while embarking on a career in Dairy heifer raising. Ron started Foundation Feeders in 1995 with a fellow dairy consultant. In 1998 the partnership changed to his brother Jim and the two purchased a feedlot in Spring Grove, MN. The operation has now grown to 2800 acres plus custom work. The cattle feeding includes 1200 Dairy heifers for 6 dairies, 120 beef bulls at test station for 30 purebred breeders, and 130 beef cows that are used for custom embryo recipients. Ron is very active at Calvary Free Church as well as serving on various boards and committees in the cattle industry. Ron and Kimberly now have 6 kids and are buying milk by the hundred weight.

Foundation Feeders, Inc.

Ron and Jim Holty feed 1000 Holstein steers, 130 beef cows, custom feed 1200 dairy heifers and run a 120 head bull test station for 30 purebred breeders.

Costs have changed

- Corn rose from $1.36/bu in early 2000's to $8.00 now $6+
- Hay rose from $65/ton to over $200
- Machinery has doubled
- Labor has doubled

How do you deal with increased costs

Stick your head in the sand?

We decided to change

- Cost of gain $.88/lb (1994) to $1.30 (2010)
- Improved feed quality
- Protect feed investment
- Procure by-products
- Identify the realizers
- Make labor more efficient

Love your cattle but don't feed them?

Improve feed quality

- Claas chopper (Timely and processed)
- Vertical TMR (no bale grinding)

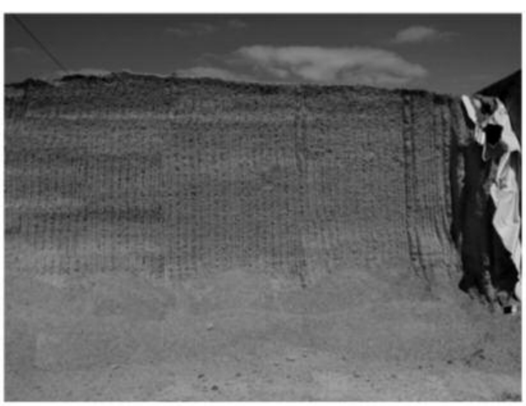
Apparently there is more money in feeding goats.

Protect Feed Investment

- Bale wrapper
- Defacer
- Plastic on bunker walls and top
- Pack silages better
- Inoculants

Wrapped bales

Alfalfa



Earlage

Corn silage

No top spoilage

Use plenty of packing power, continuous tires, double plastic on top and plastic on all side walls.

Modified distillers

30% protein 50% moisture
Worth 22 x bu price of corn

Delac from AMPI

30% DM replaces corn

SDSU Feed Cost Calculator App

Identify the realizers

Make labor more efficient

- Added lockups
- Streamlined our processing barn
- Added sand free stalls
- Custom chopping for 4 other dairies

Match intakes with their requirements

Our philosophy on dairy heifers is "spring of rib"- tease them with energy and let them eat until they are physically full.

Ask yourself, can I

- Increase what I charge?
- Improve my feed quality?
- Protect my feed investment?
- Procure by-products?
- Identify the realizers?
- Make labor more efficient?

Heifer Costs

Jud Heinrichs
Professor of Dairy Science
Penn State

Dairy heifers are the future revenue generating units on a dairy operation. However, during their pre-productive period they represent a significant cost center on every dairy farm business. For about 24 months, from birth until first calving when milk production begins, heifers are not income generating units on the farm. It has been shown that the total costs of raising dairy heifers are the second largest contributor to the annual operating expenses of dairy farms in Pennsylvania. The costs of raising dairy heifers have been shown to represent 15 to 20% of the total annual expenses of a dairy farm. However, because the annual expenses of raising heifers are included in various other expense categories such as feed, labor and vet, little information has been collected on what the actual costs of raising a replacement is on most dairy farms. Furthermore, few operations fully recognize that the management and care of their dairy heifers throughout this pre-productive period directly influences the productivity and income generating potential of these animals during their first and subsequent lactations. Optimal rates of gain as well as ages and weights at calving are well documented and allow the producer to set appropriate production goals. Daily management decisions relating to an operation's dairy heifers can compound to have great impacts on current and future farm profitability in the form of hidden expenses and lost future productivity.

Data from the Dairy Metrics benchmarking web site housed at DRMS in Raleigh, NC indicates an average age at first calving for Pennsylvania Holstein herds over 18,000 pounds of annual milk production is 25.3 months, compared to an industry benchmark of 22 to 24 months. The impact of the extra time needed to bring an animal into the milking string is significant as it requires farms to raise 5 to 15% more heifers, at identical cull rates, than those farms that hit the industry benchmarks. That same data base also indicates a tremendous range in peak milk levels, which set the stage for milk produced over the animal's lactation, achieved by dairy heifers during their first lactation, with most herds falling in a range of 63 to 82 pounds.

Despite the fact that acquiring healthy replacement heifers that calve between 22 and 24 months of age represents a major expense to dairy operations, there is limited information available to dairy producers and consultants on the factors that create a farming operation that raises profitable dairy heifers. Due to the nature of replacement heifer management, a dairy operation must invest feed, labor, and capital for a period of 22 to 24 months without receiving any realized benefits. Consequently, minimizing or optimizing heifer rearing investments while maintaining the productive integrity of the replacement heifers should be a primary objective of replacement heifer management.

Age at first calving

Age at calving and herd replacement rates are the largest factors influencing heifer costs. These factors affect the number of heifers that must be raised to maintain a profitable milking herd size as shown in Table 1.

Table 1. Heifer herd size for a 100-cow herd with a 10% heifer cull rate.

Cull Rate (%)	**Age at First Calving (months)**				
	22	**24**	**26**	**28**	**30**
26	53	58	63	67	72
30	61	66	72	78	83
34	69	76	82	88	94
38	77	84	92	99	106
42	86	93	101	109	117

When age at calving increases, so does the need for heifer housing, feed, labor, and management. This increase in input variables can be as much as 50% or more in extreme situations. An example of this magnitude of increase would be comparing a farm with a 26% herd turnover rate and 22 month calving age with another having a 38% herd turnover rate and a 30 month calving age. The first farm would need 53 heifers in the replacement herd, while the second would require 106, or twice as many heifers, just to maintain a constant 100-cow herd size. The costs to raise these extra heifers can be tremendous and make a major difference in the profit potential of each farm.

Table 2 gives a typical breakdown of heifer expenses, both ownership and operating, from birth to prefreshening. The table shows the results from a spreadsheet that calculates the costs to raise a replacement heifer. Aspects that need to be included when calculating the cost to raise a heifer are feed, labor, breeding, bedding, health, buildings, equipment, mortality, and interest.

Feed costs usually constitute 60% of the total overall expense to raise heifers. The most expensive age period in feed cost per heifer is birth to weaning. This is due to the large labor and feed costs per animal. Labor costs calculate the time required raising a heifer. Every aspect has some cost associated with it, in this instance, the cost of time. Labor costs are the second highest expense in raising a heifer, around 13% of the total cost. Table 2 below shows average costs to raise heifers in PA based on a recent study done on 45 dairy farms of various sizes in 2011. Average age at calving was 24.9 mos and average weight of pre-fresh heifers was 1264 lbs.

Table 2. Operating costs of raising replacement dairy heifers.

	Birth until Weaning	**Weaning until 6 mo**	**6 mo until 1st Bred**	**Bred until Prefresh**	**Totals**
Feed	$125	$172	$475	$546	$1318
Labor	$59	$34	$57	$53	$203
Breeding				$50	$50
Bedding	$12	$20	$33	$25	$90
Health	$6	$2	$4	$5	$17
Totals					$1808

There are some aspects of calf and heifer raising that can be more efficient than others. Many farms can benefit by reducing some cost components in their replacement program without reduction in heifer quality. The following is a listing of some areas that should be considered as potential cost saving areas for heifer raising on most farms.

1. Wean by 6 weeks of age and watch liquid feed costs.

2. Feed high quality, palatable concentrates to younger animals.

3. Analyze forages and run ration formulations for all major groups.

4. Monitor growth so that you can breed heifers soon after they reach appropriate size.

5. Monitor group size and age/weight variation within groups.

6. Use proven feed additives to improve growth and feed efficiency.

7. Keep weight gains steady at 1.8 pounds per day before nine months of age and 2.0+ pounds per day after nine months of age to reach 85% of herd mature body weight one week after calving.

Economic Implications of Stocking Density

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Stocking density

Stocking density

- Effects on cow behavior, performance
- Economic implications study

Picture Jose Santos, U of Florida

Stocking density: Basic concepts

- Overstocking improves economic returns on facility investments (Bewley et al., 2001)
- Overstocking reduces cow's ability to practice natural behaviors (Wechsler, 2007)
- Facilities and group dynamics influence response to stocking density
- **Question: "What is optimal stocking density to promote "natural" behaviors, health, and productivity?"**

Slide Peter Krawczel, U of Tennessee

Typical time budget for lactating dairy cow

- Basic behavioral needs:
  - 3 to 5 h/d eating
  - 10 to 14 h/d lying (resting)
  - 2 to 3 h/d standing/walking in alley (grooming, agonistic, estrous activity)
  - ~0.5 h/d drinking
  - 20.5 to 21.5 h/d total needed
  - 2.5 to 3.5 h "milking" = 24 h/d

Slide Peter Krawczel, U of Tennessee

Changes in productivity for heifers vs cows and at increased stocking density

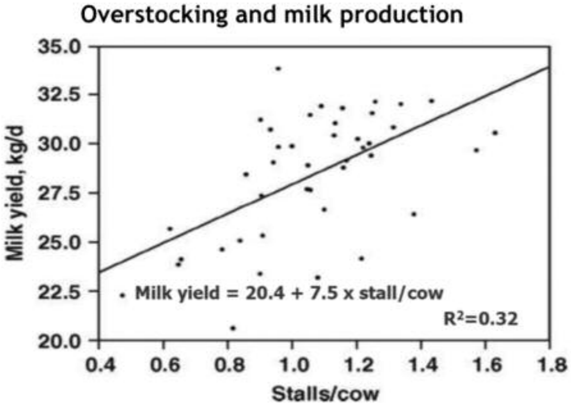
	100%	113%	131%	142%
Cows vs heifers				
Milk, lb/d	+5.9	+13.8	+21.1	+14.9
Sound vs lame				
Milk, lb/d	-9.4	+1.9	+16.7	+13.9

- **8 pairs commingled in 4 pens**
- **Milk losses reflect reductions in resting and rumination activity.**

Hill et al., 2006

Slide Peter Krawczel, U of Tennessee

Overstocking and milk production



Bach et al. 2008

Slide Peter Krawczel, U of Tennessee

Impact of stocking density on rumen function and udder health

	100%	113%	131%	142%
Milk fat, %	3.84	3.77	3.77	3.67
SCC, x 1000/ml	135	114	169	236

- Overstocked cows eat faster (25% increase), ruminate less (1 h/d less)
- Overstocked cows experience greater pathogen load in the environment; greater teat end exposure; experience immune suppression?

Hill et al., 2006

Slide Peter Krawczel, U of Tennessee

Cumulative milk yield up to 85 DIM for first-lactation heifers in a 2-row pen at 3 levels of stocking density pre-fresh and no overstocking post-fresh (unpublished data from Gary Oetzel).

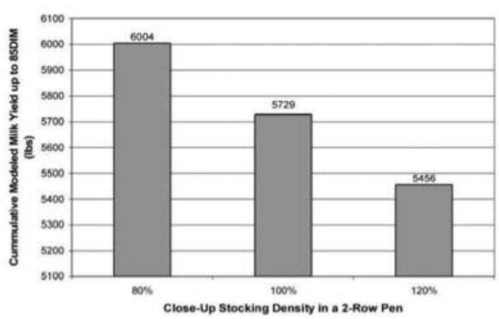


Figure Nigel Cook

Overstocking and lying behavior

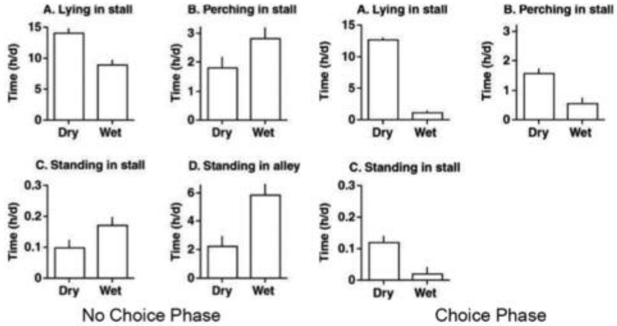
Variable	100%	109%	120%	133%	150%
Lying, h	12.9	12.1	12.0	11.5	11.2
Latency to lie, min	39	34	38	28	26
Displacements, n/5 h	0.7	0.9	1.6	2.1	1.9

- Overstocking creates illusion of good stall comfort
- May represent increased risk of environmental mastitis

Fregonsi et al., 2007

Slide Peter Krawczel, U of Tennessee

Effect of bedding quality on lying time



Fregonsi et al., 2007

Slide Peter Krawczel, U of Tennessee

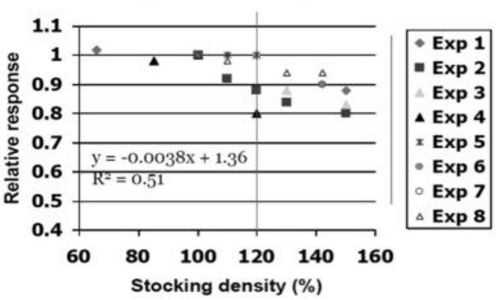
Competition at the feed bunk

- Stocking densities of 75, 100, 150, 300%
  - Headlocks and post-and-rail
- As stocking density increased:
  - Feeding time decreased curvilinear
  - Aggression increased curvilinear
  - Inactive standing increased linearly
  - Shift in feeding times
- Greater effect for post-and-rail

Huzzy et al., 2006

Slide Peter Krawczel, U of Tennessee

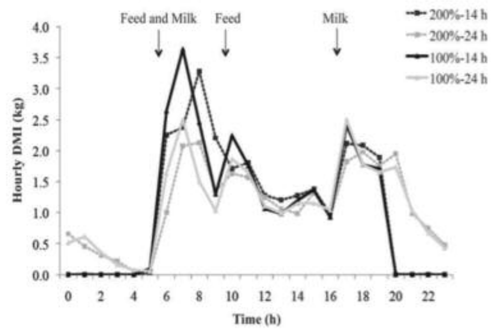
Overstocking and resting time: max = 120?



(Winkler et al., 2003; Fregonesi et al., 2007; Wierenga and Hopster, 1990; Matzke and Grant, 2002; Hill et al., 2009; Krawczel, 2008; 2009; 2010)

Slide Peter Krawczel, U of Tennessee

Stocking density alters behavior but not DMI



Collings et al., 2009

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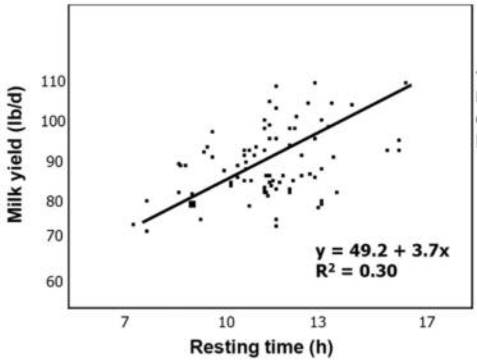
Resting time and milk yield



~3.7 lb/d more milk for each extra hour

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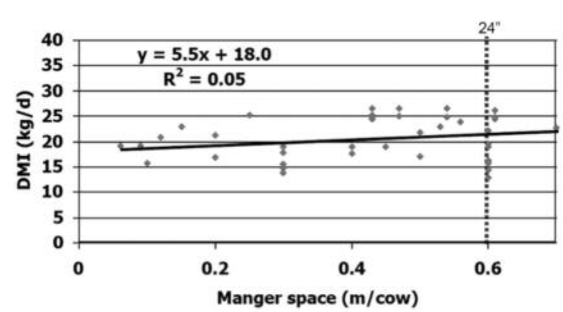
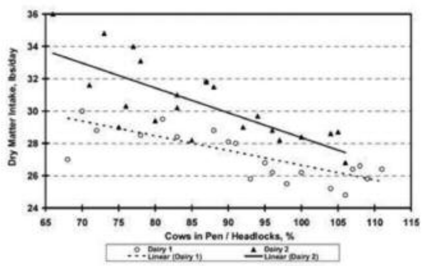
Stocking density and dry matter intake



➢Weak short-term relationship between stocking density or manger space and DMI

Slide Peter Krawczel, U of Tennessee

Group average dry matter intake of pre-fresh dry cows on 2 New Mexico dirt lot dairies and stocking density of headlocks on 24-inch centers



Ken Buelow, unpublished

Figure Nigel Cook

Name: Hailegziabher, Dechassa

Supervisors: Dr. Henk Hogeveen &

Dr. Albert De Vries

Duration: March- August 2012

Credit points: 33

Impacts of Stocking Density on Profitability & Welfare of Dairy Cows in Florida, U.S.A.

Wageningen University
Business Economics Group

UF UNIVERSITY of FLORIDA
The Foundation for The Gator Nation

Optimal stocking density

- ❑ Overstocking has negative impacts on:
  - ➢ Production performance of individual cows
  - ➢ Comfort and welfare status of the cows
- ❑ Optimum stocking density = Ideal balance between profitability and welfare of cows

---

Objectives

- To quantify impacts of stocking density on cow performance.
- What is the relationship between overstocking and profitability of the farm?
- What is the relationship between overstocking and animal welfare?

Methodology

- Literature review was used as a source of data.
  - We focused only on a stall based dairy production system.
  - The ratio of total number of cows over the available stall was used as a measure of stocking density.
  - Relationships cow performance – stocking density
  - Milk production, probability of conception

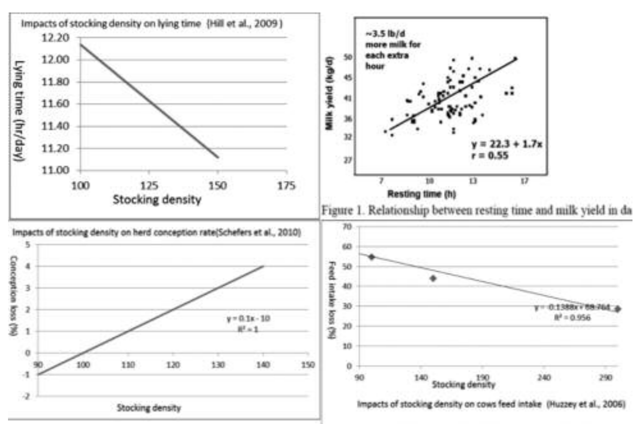


Figure 1. Relationship between resting time and milk yield in da

Herd budget calculator

- Simulates technical and economic aspects of a herd of cows (Lima et al., 2010).
- Stocking density was varied from 90% to 150%.
- Profitability expressed as profit/stall/year.

Welfare Assessment

- Lying time of cows.
- Stall Use Index (SUI)
- Feed competition and related aggression level.

Fig 1. Stocking density in figure

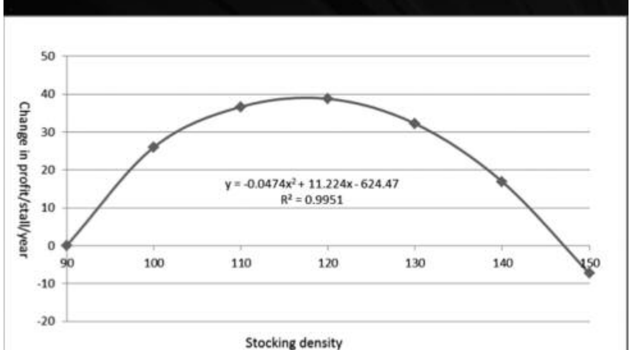


Fig 2. Impacts of variable cost on annual profit and optimal stocking density.

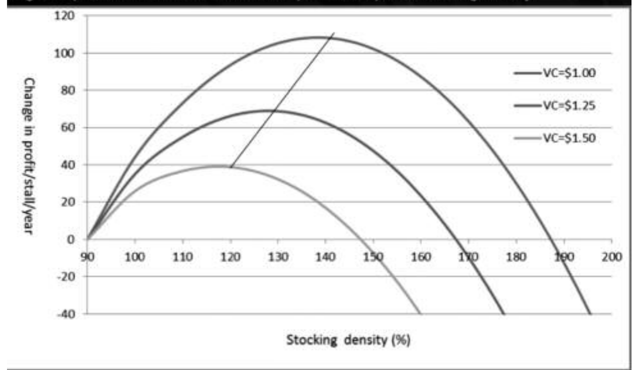


Fig 2. Impacts of fixed cost on annual profit and optimal stocking density

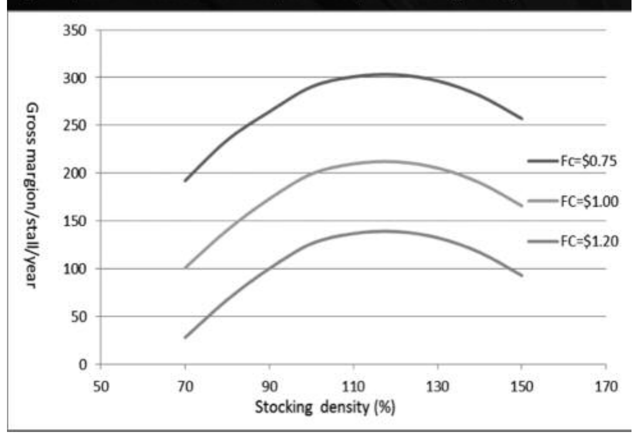


Fig4: Impacts of milk price on economics of the farm .

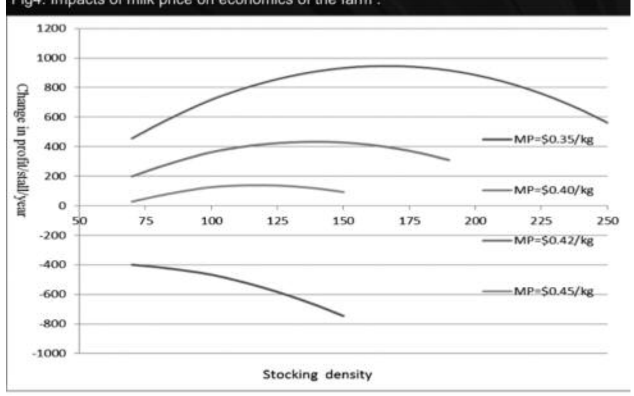


Fig 5: Interaction between lying time and annual profit

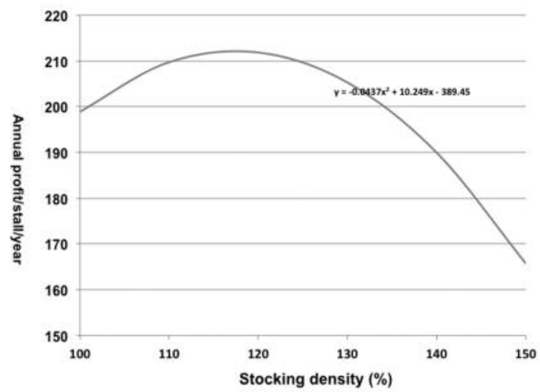


Fig 5: Interaction between lying time and annual profit

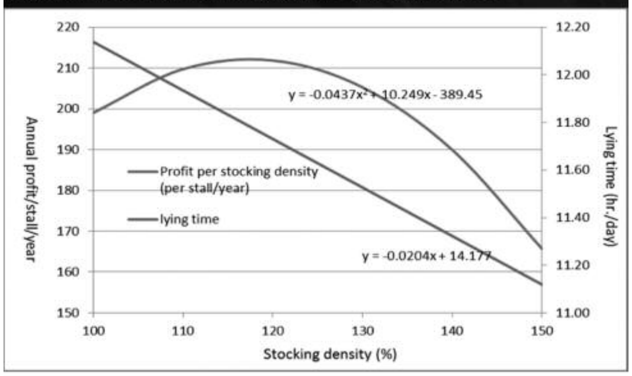
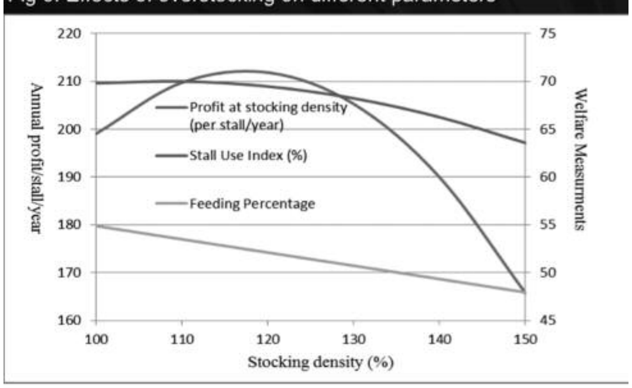


Fig 6: Effects of overstocking on different parameters



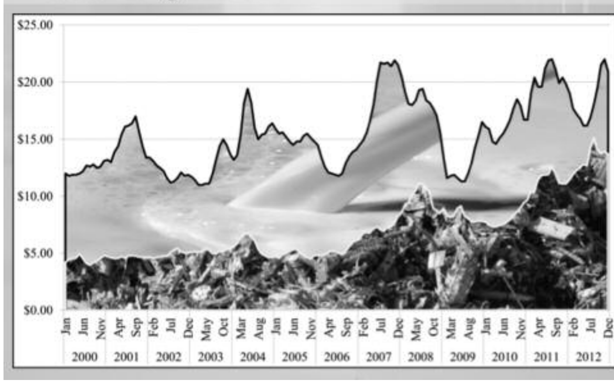
Conclusions

- At the reference line inputs cost,119% was the optimum economic stocking density.
- Lower variable input cost and higher milk price increased both the optimum stocking density and profit/stall/year.
- Fixed cost has an impact only on profitability not on optimum stocking density.
- Welfare is reduced at the economically optimum stocking density.

Dairy Programs in the 2013 Farm Bill

Dr. Marin Bozic
University of Minnesota

New face of volatility: Income-over-feed-costs margin risk



Income over Feed Costs Margin

- All-Milk ($/cwt)
  - 1.0728 x Corn ($/bu)
  - 0.0735 x Soybean meal ($/ton)
  - 0.0137 x Alfalfa hay ($/ton)
- Feed ration per cwt of milk:
  - 30 pounds of shell corn,
  - 106.4 pounds of corn silage,
  - 14.7 pounds of soybean meal
  - 27.4 lbs of alfalfa hay

Designing new dairy safety net

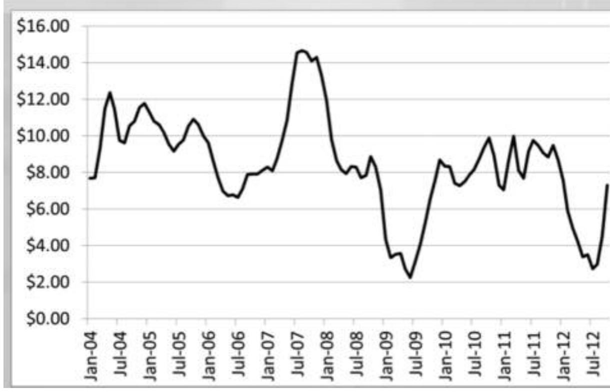
Agreement:

- Price floors should be abolished.
- Instead of milk price, focus should be on profit margins.
- Producers should not be asked to make long-term insurance commitments.

Disagreement:

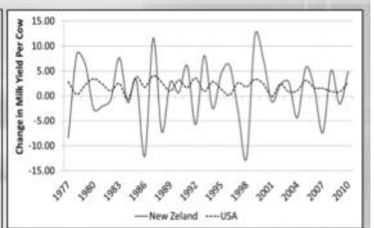
- Supply management of some form is an essential policy pillar.

Income over Feed Costs Margin: 2004-2012



Importance and Fragility of Dairy Exports

- U.S. dairy exports now consume **one day worth of milk production per week**.
- Over the last 10 years, over half of the ***growth*** in U.S. milk production was exported.
- Over the last 5 years, **over two thirds** of the growth in U.S. milk production was exported.



Milk yield per cow in NZ is highly volatile due to pasture-based production system. That means that we should anticipate large swings in U.S. milk prices in the coming decade.

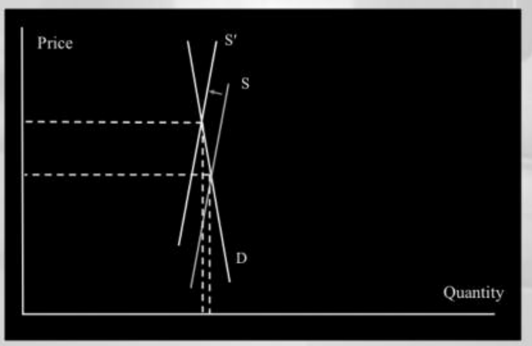
DMSP: What is the stabilization base?

- Volume of average milk marketings for the three months immediately preceding the announcement that the stabilization program is activated

OR

- Volume of monthly milk marketings for the same month in the preceding year as the month in which DMSP is declared active

Dairy Market Stabilization Program
Small changes in Q → large changes in P



DMSP: What is the 'penalty'?

- Producer is *not going to be paid for more than the greater of…*
  - *If margins were $5.00-$6.00:*
    - 98 percent of stabilization base
    - 94 percent of the marketings of milk
  - If margins were $4.00-$5.00
    - 97 percent of stabilization base
    - 93 percent of the marketings of milk
  - If margins were less than $4.00
    - 96 percent of stabilization base
    - 92 percent of the marketings of milk

Dairy Market Stabilization Program

Month	2012
January	7.57
February	5.82
March	4.96
April	4.26
May	3.41
June	3.51
July	2.74
August	2.98

Trigger:

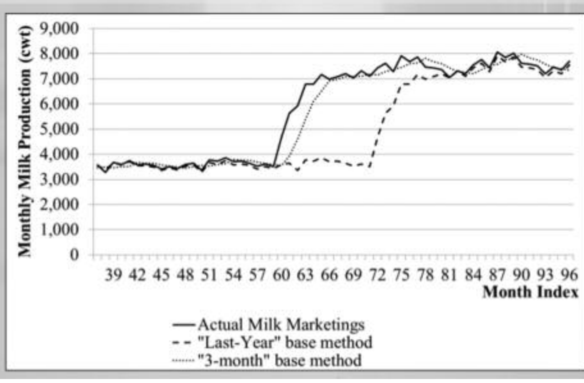
- Actual margins of $6.00 or less for *each* of the immediately preceding two months
- Actual margin of $4.00 or less for the immediately preceding month

If, effective, DMSP could indeed accelerate margin recovery

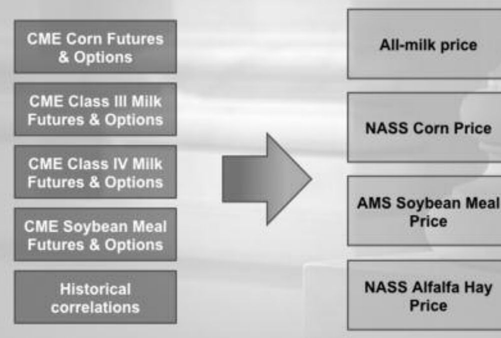
Average Annual Simulated Margin	DSA – if DSMP is Highly Effective	Goodlatte-Scott	How much more likely is scenario under G-S?
Less than $5.00	1.46%	8.86%	6.1
$5.00-$6.00	10.66%	19.96%	1.9
$6.00-$7.00	38.88%	29.68%	0.8
$7.00-$8.00	30.06%	23.98%	0.8
Over $8.00	18.94%	17.52%	0.9

Based on margins forecasted with January 15, 2013 data.
Elasticity of Demand: -0.20
Milk Volume Participation: 75%

DMSP: Stabilization base for a growing dairy



Estimating expected effects using market information



Pro and contra stabilization program

<u>Why it might be a good idea</u>:

- It *could* reduce government costs.
- It could *accelerate margin recovery* in low-margin states of the world.
- Does not present a *long-term* obstacle for milk production growth, even for farms with aggressive growth plans

<u>Why it might not be such a good idea</u>:

- Creative private contracts could reduce effectiveness.
- Interference with spatial structural changes
- *Slippery Slope* argument: What will happen in 2018 Farm Bill?

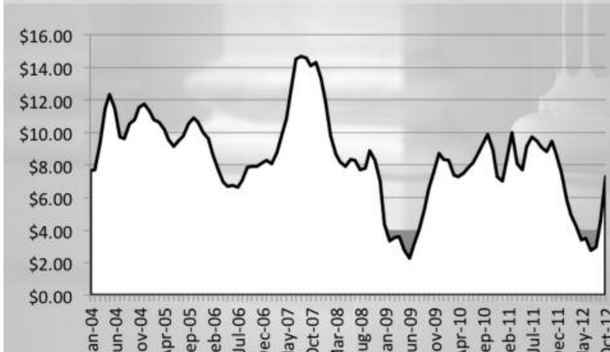
Supplemental Margin Protection - Premiums

Coverage Level	Premium Per Cwt (under 4 mil lbs)	Premium Per Cwt (over 4 mil lbs)
$4.00	$0.000	$0.000
$4.50	$0.010	$0.015
$5.00	$0.025	$0.036
$5.50	$0.040	$0.081
$6.00	$0.065	$0.155
$6.50	$0.090	$0.230
$7.00	$0.434	$0.434
$7.50	$0.590	$0.590
$8.00	$0.922	$0.922

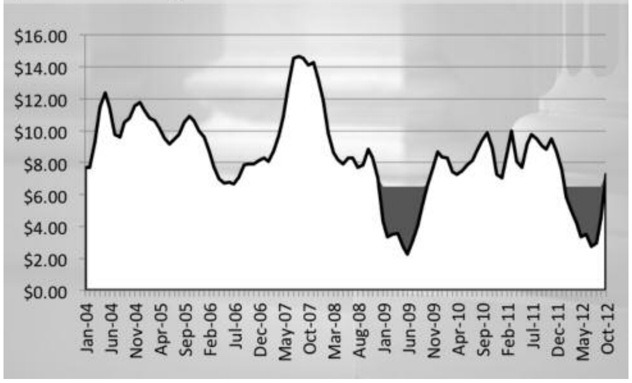
Subsidized Margin Insurance

- Official name: Dairy Producer Margin Protection Program (PDMPP)
- Two layers:
  - Basic Margin Protection – "Free" protection at $4.00 margin
  - Supplemental Margin Protection – Can buy up from $4.50 to $8.00 margin in 50 cents increments (called "Coverage Level")

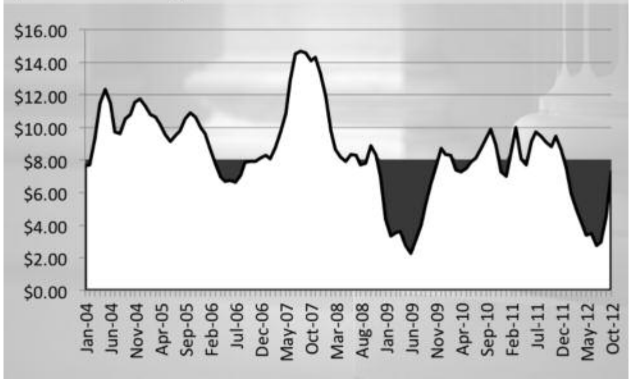
Basic Margin Protection



Supplemental Margin Protection: $6.50 Coverage Level



Supplemental Margin Protection: $8.00 Coverage Level



DPMPP: What triggers it exactly?

Consecutive Two-Month Periods	2012	Two-month Average
January	7.57	
February	5.82	6.70
March	4.94	
April	4.26	4.60
May	3.41	
June	3.51	3.44
July	2.74	
August	2.98	2.86

- Calendar year is divided into consecutive two-month periods
- Average margin must be below the purchased coverage level in order for indemnities to be due

DPMPP: What is the payment rate?

Consecutive Two-Month	Average
Jan – Feb	6.72
Mar-Apr	4.59
May-Jun	3.44
Jul-Aug	2.86
Sep-Oct	5.90

- **Basic Margin Protection**

The difference between the actual margin and $4.00, except that, if the difference is more than $4.00, the Secretary shall use $4.00

- **Example:** *Jerry subscribed for basic margin protection. For Jul-Aug, payment rate was $1.14 per cwt. If Jul-Aug margin was -$0.50, payment would have been $4.00 per cwt.*

DPMPP: What is the payment rate?

Consecutive Two-Month	Average
Jan – Feb	6.72
Mar-Apr	4.59
May-Jun	3.44
Jul-Aug	2.86
Sep-Oct	5.90

- **Supplemental Margin Protection:**

The difference between coverage level and the greater of actual margin and $4.00.

Example: *Jerry also subscribed for supplemental margin protection at $6.50 coverage level. For Jul-Aug, the payment rate on supplemental was $6.50- max($4.00, $2.86) = $2.50*

DPMPP: What is the payment base?

Basic Production History

- Used in Basic Margin Protection
- Equal to the highest annual milk marketings in any 1 of the 3 calendar years immediately preceding the calendar year in which the participating dairy signed up
- 80% of BPH is covered.

Annual Production History:

- Used in Supplemental Margin Protection
- Equal to the actual milk marketings of the participating dairy during the preceding calendar year
- 25-90% of APH can be insured (80% under G-S)

Consider the example of a Five Flags Dairy

2013 Expected production: 91,618 cwt
Happy IOFC margin: $8.00/cwt
Happy IOFC revenue: $732,944

Basic Margin Coverage: 89,821 cwt
Supplemental Coverage: 89,821 cwt

Bad memories:
2009 IOFC margin: $4.52
2012 IOFC margin: $5.31

What would $6.50 coverage level mean under different margin scenarios if we get DSA

Average Annual Simulated Margin	Probability	DMSP Price Boost	Shortfall for NON-PARTICIPATING farm*
Less than $5.00	1.46%	88,620	-311,509
$5.00-$6.00	10.66%	71,405	-214,702
$6.00-$7.00	38.88%	41,191	-134,956
$7.00-$8.00	30.06%	17,377	-50,761
Over $8.00	18.94%	5,458	69,932

What would $6.50 coverage level mean under different margin scenarios if we get DSA

Average Annual Simulated Margin	Shortfall for NON-PARTICIPATING farm	Premium for $6.50 coverage	Average Realized Indemnity	DMSP Penalty	Shortfall for PARTICIPATING farm
Less than $5.00	-311,509	-13,803	153,669	-23,881	-195,524
$5.00-$6.00	-214,702	-13,803	81,760	-14,348	-161,092
$6.00-$7.00	-134,956	-13,803	39,107	-7,807	-117,460
$7.00-$8.00	-50,761	-13,803	17,565	-4,267	-51,266
Over $8.00	69,932	-13,803	7,141	-2,195	61,074

What would $6.50 coverage level mean under different margin scenarios if we get G-S

Average Annual Simulated Margin	Probability	Shortfall for NON-PARTICIPATING	Premium for $6.50	Indemnity	Shortfall for PARTICIPATING farm
Less than $5.00	8.86%	-329,350	-14,439	151,244	-192,544
$5.00-$6.00	19.96%	-222,392	-14,439	75,181	-161,650
$6.00-$7.00	29.68%	-136,595	-14,439	33,145	-117,889
$7.00-$8.00	23.98%	-49,389	-14,439	13,083	-50,744
Over $8.00	17.52%	71,576	-14,439	5,342	62,480

Expected impacts of G-S on a 360 cow farm in 2013 (based on information on Jan 15)

Coverage Level	Fees & Premium	Expected Indemnity	DMSP Penalty*	DMSP Price Boost*	Net Revenue
$4.00	1,196	3,181	-	-	1,985
$4.50	2,114	5,641	-	-	3,527
$5.00	3,271	9,708	-	-	6,438
$5.50	5,504	16,224	-	-	10,720
$6.00	8,814	26,604	-	-	17,790
$6.50	14,439	42,317	-	-	27,878
$7.00	20,906	62,853	-	-	41,947
$7.50	52,281	86,805	-	-	34,524
$8.00	72,649	113,359	-	-	40,710

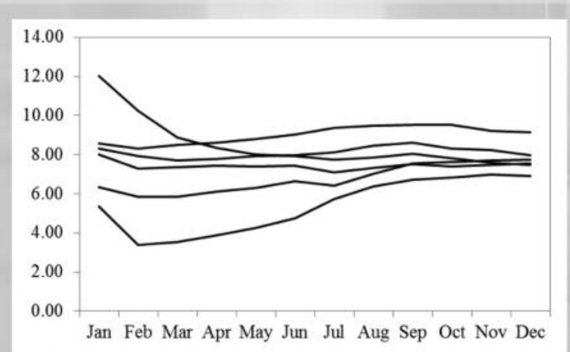
Expected impacts of DSA on a 360 cow farm in 2013 (based on information on Jan 15)

Coverage Level	Fees & Premium	Expected Indemnity	DMSP Penalty*	DMSP Price Boost*	Net Revenue
$4.00	250	959	-6,612	31,178	-5,903
$4.50	1,283	2,260	-6,612	31,178	-5,634
$5.00	2,764	4,785	-6,612	31,178	-4,591
$5.50	5,322	9,552	-6,612	31,178	-2,382
$6.00	9,540	18,260	-6,612	31,178	2,108
$6.50	13,803	32,797	-6,612	31,178	12,382
$7.00	35,334	52,873	-6,612	31,178	10,927
$7.50	47,945	77,081	-6,612	31,178	22,524
$8.00	74,784	104,676	-6,612	31,178	23,280

Supplemental Margin Protection – Premiums for Production over 4 million lbs

Coverage Level	Senate 2013	House 2013	Dairy Freedom Act
$4.00	$0.00	$0.00	$0.03
$4.50	$0.02	$0.02	$0.05
$5.00	$0.04	$0.04	$0.07
$5.50	$0.10	$0.08	$0.11
$6.00	$0.15	$0.16	$0.19
$6.50	$0.29	$0.23	$0.29
$7.00	$0.62	$0.43	$0.38
$7.50	$0.83	$0.59	$0.83
$8.00	$1.06	$0.92	$1.06

Six beginning-of-year margin scenarios



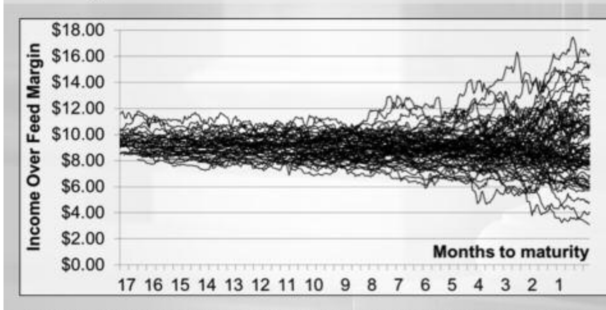
Déjà vu all over again?

1970-1980s: Support prices at 80-85% of parity.

2013: "Sweet spot" at $7.00/cwt?
That is 84% of the average IOFC over 2000-2012 period.

2018: Liquidity of dairy futures markets?
Milk oversupply?
Rate of consolidation?

Solution: Sign-up in March with Coverage Period starting in October



In March, before Prospective Plantings report is published, very little is known about new crop corn and soybeans prices. 6-months gap should suffice to substantially reduce incentive to "game the system".

Premiums are fixed for the next five years, but conditions may vary…

Figure 2: Low Risk of Flood

Figure 3: Water is at Your Knees!

Would you charge the same price to insure against a flood… **when the house is located in a flood plain***?*

Source: Newton, J. NWDEPA 2013

Dairy Policy Timeline (hopefully)

June 2013: Senate and House pass their versions of 2013 Farm Bill

July-August 2013: Differences reconciled in Senate-House Conference Committee

September 2013: Both chambers pass 2013 Farm bill.

2014: Dairies will have one-year to sign up for new programs.

Dairy Markets and Policy Farm Bill Task Force are…

John Newton, Cameron Thraen
The Ohio State University

Mark Stephenson, Brian W. Gould
University of Wisconsin-Madison

Christopher Wolf
Michigan State University

Marin Bozic
University of Minnesota

Dairy Programs in the 2013 Farm Bill

prepared for 4-state Dairy Nutrition & Management Conference

Thursday, June 13, 2013
Dubuque, IA

Dr. Marin Bozic
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University of Minnesota-Twin Cities

University of Minnesota
Driven to Discover

Identifying Sick and Poor Growing Calves

Amy Stanton
University of Wisconsin Extension

Identifying sick and poor growing calves

Amy Stanton – Four State Planning Meeting 2013

Sickness Behaviour

- Fever
- Depression
- Decrease in hunger
- Decrease in thirst
- Decreased exploratory behavior
- Decreased socialization

Sickness and Motivation

- Sickness behavior is not a reflex
- Can be suspended if required
- For example:
  - To care for young
  - To save your own life
  - To procreate

Sickness behaviour-Cattle

Cattle considered 'stoic'

- Obvious expression of illness in prey animals detrimental
- Increases need for species specific indicators of sickness behavior

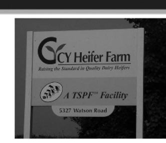
Hypotheses

1. Selected behaviours would be associated with lower ADG

2. Responses to behavioral measures will be different in calves with active diarrhea relative to healthy controls

Materials & Methods

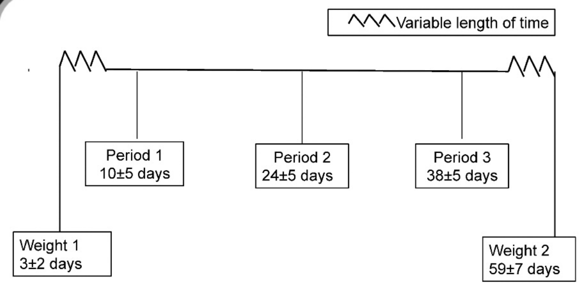
744 Holstein heifers
CY Heifer Farm
3 ± 2 days of age at arrival
Injected with 1.0 mL tulathromycin or placebo at arrival
Housed in individual pens



Feeding

- Calves fed milk replacer by bucket
  - (26/18, Grober Nutrition)
- 2.1 quarts twice a day 0-5 weeks (5 am & 5pm)
- 2.1 quarts once a day week 6
- *Ad libitum* water and calf starter (23% protein/5% fat)

Timeline



Behavioral Measures

1. Lethargy Score
2. Human Approach Test
3. Postures

Behavioral Measures

Lethargy Score

0 : Already standing or stands with no encouragement

1: 1 vocal encouragement

2: Open gate + 2 vocal encouragement

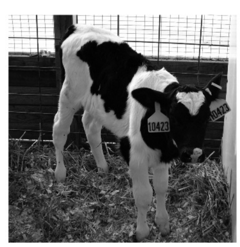
3+: Enter pen + 3 vocal encouragements

Behavioral Measures

Human Approach Test

- Stationary observer
- 30 Seconds
- Yes or No

Postures



Statistical Analysis Hypothesis 1

- Linear mixed models
- Each behaviour score at each time point tested for association with ADG in Nursery
- Age at scoring
- Weight at arrival
- Antimicrobial treatment
- Random effect enrolment group and source farm

Encouragement to Rise

Period 3 (*P*=0.006)

Encouragement Score	ADG (lb/day)
0	1.37 ± 0.04[a]
1	1.39 ± 0.04[a,b]
2	1.30 ± 0.04[b,c]
3+	1.26 ± 0.04[c]

Human Approach Test

At period 3, calves that did not approach had an ADG 0.15 ± 0.04 lb lower than those that did approach(*P*=0.0002)

Postures

Calves statue standing had ADG 0.24 ± 0.07 lb lower than normal postures.

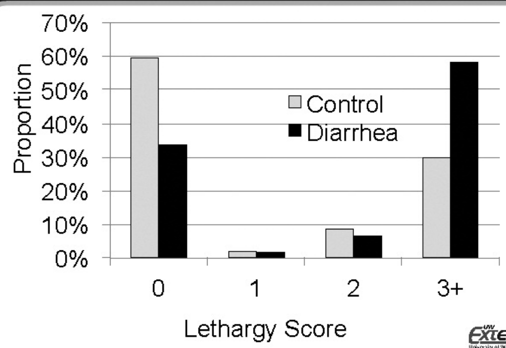
Hypothesis 2

Which behaviours were associated with calves with clinical diarrhea?

Results

Human Approach Test (*P*=0.007)
- **70% (33/47) of healthy calves**
- **46% (105/229) of diarrhea calves**

Results



Discussion

- **Failure to approach** a stationary person associated with lower ADG and active disease
- **More encouragement to rise** associated with lower ADG and diarrhea
- **Statue standing** associated with lower ADG

Thank you

- **Co-authors: David Kelton, Suzanne Millman, Ken Leslie, Stephen LeBlanc, Tina Widowski**
- **CY Heifer Farm: Manager, Staff and calves**
- **Discussions with Janet Higginson, Cindy Todd, and Mark Carson**

Serotonin (5-HT) and Its Potential Role in the Transition Period of Dairy Cattle

Jimena Laporta, Spencer A. E. Moore and Laura L. Hernandez
University of Wisconsin-Madison
Department of Dairy Science

Summary
The rising demand for calcium during the transition from pregnancy to lactation places extreme pressures on calcium homeostatic mechanisms. The inability of the animal to maintain adequate circulating calcium concentrations can cause subclinical or clinical hypocalcemia (milk fever) in several mammalian species, particularly the dairy cow. Cows that succumb to periparturient hypocalcemia have decreased feed intake and milk production, and have a higher risk of developing additional transition related disorders, therefore negatively impacting their productive and reproductive performance. Several feeding strategies during the dry period have been developed, such as feeding low calcium diets and manipulating the dietary cation-anion difference, in order to prevent milk fever. Different oral and intravenous calcium supplementations strategies have been applied to treat hypocalcemic cows, however, they are not implemented until the animal is noticeably ill. Bone resorption is the primary contributor of calcium in the milk during lactation. Mammary secretion of parathyroid hormone related protein (PTHrP) is responsible for mobilizing of maternal bone calcium at the onset of lactation. Additionally, serotonin (5-HT) has been identified as a homeostatic regulator of lactation and bone turnover. Our research in rodents has shown that 5-HT is responsible for the induction of PTHrP in the mammary gland, and therefore results in stimulation of calcium mobilization from bone. In addition, we have shown that 5-HT serum concentrations on day 1 of lactation is positively correlated with PTHrP and ionized calcium concentration, and negatively correlated with milk fever incidence and severity of ketosis in multiparous Holstein cows. A greater understanding and characterization of this physiological 5-HT/ PTHrP axis could be a promising therapeutic target to explore for the prevention of subclinical and clinical hypocalcemia in dairy cows. This promising novel strategy could help alleviate the complications associated with present preventive treatment strategies for hypocalcemia in transition cows.

Calcium homeostasis and Hypocalcemia
The transition period, 3 weeks pre-calving through 3 weeks post-calving, is an extremely critical time period in the life of a dairy cow. At this time, the animals are highly susceptible to a variety of disorders that negatively impact their health, and hence their overall production (Erb et al., 1984). Of particular concern during this time is the inability of the animal to maintain adequate blood calcium concentrations due to increased demand for calcium by the mammary gland at the onset of lactation. Normally, blood calcium is tightly regulated and maintained within a narrow range (2.0–2.5 mmol/L). On the day of parturition a dairy cow will produce 10 liters or more of colostrum containing at least 23 g of calcium (Goff, 2008) and the loss of calcium into milk can exceed 50 g per day during early lactation (DeGaris and Lean, 2009). This sudden shift of calcium requirements to the mammary gland to support adequate milk synthesis challenges the cow's ability to maintain blood calcium concentrations within an adequate range, drastically altering the mineral metabolism of the animal. This drastic decrease in circulating calcium concentrations can lead to the development of periparturient hypocalcemia (milk fever), a complex metabolic disorder that typically occurs shortly after parturition.

Periparturient hypocalcemia is one of the most common metabolic diseases of dairy cattle (Oetzel, 1988). Due to inadequate blood calcium concentrations at the onset of lactation, animals experience a range of clinical symptoms, depending on the extent of the decreased calcium levels (Adams et al., 1996). Clinical hypocalcemia is defined as a total blood calcium concentration of less than 1.4 mmol/L, and subclinical hypocalcemia defined as total blood calcium concentration of 1.4 to 2.0 mmol/L (DeGaris and Lean, 2009). Approximately 25% of primiparous and 50% of mulitparous cows will succumb to subclinical hypocalcemia and between 5 to 10% of animals will develop clinical hypocalcemia (Goff 2008; Reinhardt et al., 2011).

Older cows have greater risk of developing hypocalcemia associated with a decrease in their capacity to mobilize calcium from the bone. In fact, the risk for milk fever increases by 9% per lactation (Lean et al., 2006). Unfortunately, the early symptoms (stage I) of milk fever often go undetected because they are short-lived. Identification of cows with subclinical hypocalcemia is not practical because the cows do not display evident clinical signs (Oetzel and Miller, 2012). Not until the animal begins to exhibit decreases in body temperature, incoordination when walking, and muscle trembling (stage II) do the signs of milk fever become increasingly noticeable to the producer (Adams et al., 1996).

Incidences of subclinical and clinical hypocalcemia are long known to result in a variety of other disorders in dairy cattle during the transition period (Goff, 2008; Reinhardt et al., 2011). Particularly, cows with subclinical hypocalcemia have a higher risk of developing fever, metritis, retained fetal membranes, displaced abomasum, dystocia, ketosis, and to develop infectious diseases (Oetzel, 1988, Kimura et al., 2006; Goff, 2008). Furthermore cows with subclinical hypocalcemia also exhibit reduced feed intake and pregnancy rates, as well as longer intervals to pregnancy compared with normocalcemic cows (Martinez et al., 2012). The prevalence of milk fever and subclinical hypocalcemia is more common in older cows, which are less efficient in mobilizing calcium, and in Jersey cattle, likely due to their higher milk production per unit body weight, as well as increased calcium content of milk (Oetzel, 1988). On average, treatment of each incidence of clinical and subclinical hypocalcemia costs approximately $300 and $125, respectively (Guard, 1996). This estimate includes the direct cost of treating the animal, along with production losses, which are estimated to be approximately 14%.

Milk fever prevention strategies

Current practices for the prevention of periparturient hypocalcemia focus primarily on dietary manipulations during the end of the dry period. The two major feeding strategies utilized are the manipulation of the dietary anion-cation difference (DCAD) and the feeding of low calcium diets (LCD). The main focus of the DCAD strategy is to increase the number of absorbable dietary anions and decrease the number of absorbable dietary cations in the diet through feeding of anionic salts (Goff, 2008). This strategy has shown to be effective for preventing milk fever (Charbonneau et al. 2006; Beede et al. 1992) but it presents two important issues. First, being that anionic salts are very expensive, increasing feed costs of animals during this time period, and second they are highly unpalatable leading to reductions in dry matter intake predisposing animals to other common metabolic disorders that occur during the transition period (Bethard and Smith, 1998). Feeding LCD has been shown to induce calcium mobilization from the bone and increase calcium absorption from the small intestine to ensure these processes are stimulated at parturition (Bethard and Smith, 1998). Daily calcium needs are approximately 40 g calcium/day. Ideally a diet of 8 - 10 g of calcium/day has the best effect on the prevention of milk fever (Horst et al., 1997), but diets with this little calcium are difficult to achieve, mainly because alfalfa, which is the primary forage of choice in diets, is high in calcium.

Several other methods have been attempted to prevent periparturient hypocalcemia including administration of vitamin D3 or metabolites and oral calcium administration, however none of these treatments have been entirely effective in preventing milk fever and have shown to be highly dependent on the timing of administration in relation to calving (Martín-Tereso and Verstegen, 2011). A better understanding of the physiological pathways involved in regulation of calcium homeostasis in the periparturient cow is needed to allow development of management practices to prevent the incidence of clinical and subclinical hypocalcemia would alleviate the dietary issues associated with current practices, and potentially reduce costs for dairy producers.

Bone and parathyroid hormone related protein

Several redundant pathways exist to protect the lactating mother against hypocalcemia. Intestinal calcitrol increases calcium absorption from the diet and renal mechanisms decrease calcium elimination. However, since 99 % of calcium body reserves are in the bone, the main homeostatic mechanism in the lactating dam is bone calcium mobilization. Therefore, bone resorption is the primary contributor of calcium in the milk of mammals (Kovacs, 2011). Calcium mobilization from bone during lactation is stimulated by mammary secretion of parathyroid hormone-related protein (PTHrP) (Kovacks, 2011; Wysolmerski, 2012), which is present in human, rat, goat, and bovine milk and in the serum of the lactating mother. Rat mammary PTHrP transcript (mRNA) and protein concentrations are induced by suckling and rise over the first few days postpartum

(Rakopoulos et al., 1992). Initially, PTHrP was discovered as a factor responsible for the clinical syndrome humoral hypercalcemia of malignancy, a common metabolic complication that occurs in metastatic epithelial cancers that are osteolytic in nature (Fiaschi-Taesch and Stewart, 2003; Stewart, 2005). Other than in instances of malignancy, PTHrP is only detectable in the systemic circulation during lactation (Wysolmerksi, 2010). Mammary secretion of PTHrP has been described as the molecule responsible for mobilizing of maternal calcium from bone that occurs at the onset of lactation in mammals (VanHouten, 2004; Wysolmerski, 2010).

The skeletal system consists of two cell types, osteoblasts (OB), which are responsible for bone formation and osteoclasts (OC), which are responsible for bone resorption. Communication between these cells is crucial for calcium mobilization. Specifically, PTHrP signals to decrease OB cell proliferation, and up-regulate genes responsible for OC differentiation. In OB, PTHrP increases gene expression of receptor-activated nuclear factor kappa-B ligand (RANKL), matrix metalloproteinase 13 (MMP13), macrophage-colony stimulating factor (M-CSF), interleukin-6 (IL-6), and monocyte chemotactic protein-1 (MCP1), which are known factors that activate OC differentiation (Matsuso and Irie, 2008; Datta and Abou-Samra, 2009). These factors produced by OB cells are then responsible for the induction of numerous genes including: metalloproteinase (MMP9), receptor-activated nuclear factor kappa-B (RANK), cathepsin K, and tartrate-resistant alkaline phosphatase (TRAP) in OC (Datta and Abou-Samra, 2009). These genes are then responsible for the physical degradation of the bone. In rodent models, it has been demonstrated that mammary-specific depletion of PTHrP results in decreased bone turnover markers (VanHouten et al., 2003).

Serotonin

Serotonin (5-hydroxytryptamine, 5-HT) is well known to act as a neurotransmitter mediating a wide range of central nervous system functions (ie, mood, behavior, sleep, and thermoregulation) (Berger, 2009). In addition, 5-HT is synthesized and secreted in different tissues throughout the body (Roth et al., 1998; Berger, 2009). Serotonin is synthesized from the amino acid L-tryptophan into 5-hydroxy-L-tryptophan (5-HTP) by the rate-limiting enzyme tryptophan hydroxylase-1 (TPH1), which is found in non-neuronal tissues, whereas TPH2 is found in neuronal tissues exclusively. These two different rate-limiting enzymes in 5-HT synthesis define two distinct serotonergic systems, one in the brain and the other in the peripheral tissues. 5-hydroxy-L-tryptophan is then converted to 5-HT by aromatic amino acid decarboxylase. Serotonin exerts its actions physiologically by signaling through approximately 15 different receptors throughout the body (Hannon et al., 2008).

5-HT is a known homeostatic regulator of the mammary gland. Several studies have demonstrated its role in milk protein gene expression, as well as the disassembly of tight junctions that occurs during the involution process (Matsuda et al., 2004; Stull et al., 2007; Hernandez et al., 2008; Pai and Horseman, 2008). In addition to 5-HT functions in the mammary gland several studies have shown that 5-HT regulates bone mass, is involved in the induction of bone-regulating factors, maintenance of bone density, and initiation of bone remodeling (Bliziotes et al., 2001; Yadav et al., 2008; Modder et al., 2010; Wysolmerski, 2010; Ducy, 2010; Hernandez et al., 2012). Osteoclasts within the bone express the 5-HT reuptake transporter and various 5-HT receptor subtypes (Bliziotes et al., 2001; Collet et al., 2008). It has been shown that 5-HT deficiency rodents reduce mammary and circulating PTHrP concentrations (Hernandez et al., 2012). Conversely, 5-HT treatment of lactogen-treated mammary epithelial cells induced PTHrP expression (Hernandez et al., 2012).

Manipulation of serotonergic axis as a plausible treatment for hypocalcemia

The long-term goal of our research is to identify molecular mechanisms that protect the lactating mother from hypocalcemia (subclinical and clinical), particularly in dairy species that are prone to hypocalcemia during lactation. We recently demonstrate the plausibility of supplementing a 5-HT precursor during the transition period using a less-expensive animal model to investigate serotonergic regulation of calcium recruitment in lactating mothers (Laporta et al., 2013a) in order to draw conclusions in which we can pursue this work in dairy cattle. Additionally, we also showed novel correlations in dairy cows that encourage us to perform further experiments using the cow as a model.

Evidence in Rodents. Our group recently demonstrated that 5-HT is intimately involved in mammary gland PTHrP induction and bone turn-over for calcium mobilization during lactation in rodents (Laporta et al., 2013a). In short, transition rats were fed either a control growth diet (CON) or a diet supplemented with the 5-HT precursor, 5-HTP (0.2% of total growth diet) from day 13 of pregnancy through day 9 of lactation. Blood and milk samples (days 1 and 9 of lactation) were collected. On day 9 of lactation rats were euthanized and mammary gland and bone tissue was harvested. Diets supplemented with 5-HTP increased maternal circulating concentrations and mammary gland production of 5-HT and PTHrP **(Figure 1 A-D)**, and increased maternal circulating serum calcium (d1) and milk calcium concentrations (d9) compared to control rats, only fed growth diet **(Figure 1 E,F).**

Different transporters exist within the mammary epithelium to transport calcium into milk, which is the major calcium rich fluid. The mammary gland has adapted a powerful transport system to ensure calcium enters the milk effectively (i.e. NCX1, sodium-calcium exchanger-1; SERCA2, sarco(endo)plasmic reticulum calcium ATPase-2; SPCA1, secretory pathway calcium ATPase-1; SPCA2, secretory pathway calcium ATPase-2; PMCA2, plasma membrane calciumATPase-2). Interestingly, supplementation of 5-HTP resulted in increased mammary gland mRNA expression of all the maternal calcium transporters mentioned above **(Figure 2A).** These various pumps are critical to maintaining adequate calcium concentrations in the milk, as well as adequate calcium levels inside the mammary epithelial to take part in other biochemical processes.

We demonstrated that dams fed a diet enriched in 5-HTP had greater 5-HT and PTHrP circulating concentrations on d9 of lactation, also had enhanced femoral bone resorption and therefore increased calcium mobilization, indicated by increased osteoclast number and diameter as well as mRNA expression of the classical markers of bone resorption previously described above **(Figure 2B-F).** The OC quantification in femurs collected from dams on day 9 of lactation was performed by counting TRAP-positive multinucleated cells, and their resorptive activity was determined indirectly from their cell size. Giant multinucleated regions undergoing resorption, greater in size and number, were evident in the dams consuming the 5-HTP enriched diet. This indicates that the calcium was primarily coming from bone resorption.

In addition to 5-HT being involved in calcium metabolism, we also showed that 5-HT is involved in glucose and energy homeostasis (Laporta et al., 2013b), as previously suggested by other authors (Moore et al., 2005; Watanabe et al., 2011). We showed (Laporta et al., 2013b) that increasing 5-HT production during the transition from pregnancy to lactation increases mRNA expression of enzymes involved in glucose metabolism in the liver, and mRNA abundance and distribution of glucose transporters within the mammary gland (**Figure 3A, B**). Finally, phosphorylated AMP-activated protein kinase (pAMPK), a known regulator of intracellular energy status, was elevated in mammary glands of 5-HTP fed dams (**Figure 3C, D**). Upon activation, AMPK is responsible for decreasing activity or expression of catalytic proteins, which conserves ATP by switching off biosynthetic pathways (McFadden and Corl, 2009; Hardie et al., 2010). Additionally, AMPK also regulates metabolic energy balance at the whole body level and regulates uptake and metabolism of glucose and fatty acids (Hardie et al., 2010). Interestingly, AMPK promotes glucose uptake into cells that express GLUT-1 (McFadden and Corl, 2009). These data highlight the potential use of 5-HT in the treatment of ketosis, another major metabolic disorder in transition dairy cows.
To date, our group is performing studies using genetically modified mouse models to delineate the molecular signaling mechanism(s) through which 5-HT induces PTHrP-mediated mobilization of calcium from bone during lactation. Additionally, we are investigating the role of supplementing 5-HTP during the transition period in dairy cattle as a potential role for regulating bone resorption.

Evidence in Dairy Cattle. To our knowledge no studies have evaluated the relationship between circulating 5-HT concentrations on day 1 of lactation with other circulating variables and transition related disorders in commercial dairy herds. Therefore, we set out to determine if circulating 5-HT concentrations on day 1 post-partum were correlated with circulating ionized calcium, PTHrP, and glucose concentrations, as well as to assess the relationship between circulating 5-HT and the incidence of milk fever (postpartum d 1 / onset of lactation) and incidence and severity of ketosis (during the first 10 d post-partum) in multiparous Holstein cows. Serum 5-HT on day 1 of lactation was positively correlated with ionized calcium concentrations ($r = 0.51$, $P = 0.0008$) as well as with plasma PTHrP concentrations ($r = 0.37$, $P = 0.034$) on the same day (Figure 4A,B), and was negatively correlated milk fever incidence (r = - 0.33, P = 0.039) as well as with cow's most severe ketosis grade during the first 10 days post-partum (r = - 0.69, P = 0.0007, Figure 4C,D). These data suggest that 5-HT plays a role in regulating calcium and glucose homeostasis during the transition period in cattle, which we previously demonstrated in rodents (Laporta et al., 2013 a,b). According to these results, it is plausible that increasing circulating levels of 5-HT could have a positive impact on milk fever incidence at the onset of lactation and ketosis severity in dairy cows.

Determining circulating and milk concentration of 5-HT, PTHrP and calcium in Holstein and Jersey cattle throughout their pregnancy / lactation cycle
The evidence in the rodent studies and our initial investigation in dairy cattle substantiates the potential that the serotonergic pathway could be instrumental in the management of hypocalcaemia in dairy cattle. We believe that the use of supplemental 5-HTP during the late pregnancy / early lactation period in dairy cattle could potentially be a management tool for improving calcium mobilization from bone and, thereby, preventing subclinical and clinical hypocalcaemia events during lactation. There is currently a limited understanding of the role of 5-HT and PTHrP during the early pregnancy / lactation cycle of dairy cattle. In order to effectively evaluate and design experimentation of 5-HTP supplementation during the late pregnancy / early lactation period, we must first delineate the 5-HT / PTHrP axis in dairy cattle to discern what is occurring naturally in these animals.

The study we are currently conducting employs 25 Jersey and 25 Holstein multiparous cows to elucidate the contribution of mammary synthesized 5-HT to regulation of calcium mobilization during the transition period. The comparison of Holsteins and Jerseys should prove interesting, as the Jersey breed has been shown to be more susceptible to hypocalcaemia due to its greater milk calcium concentration and calcium demand per unit of body weight compared to their Holstein counterparts (Oetzel, 1988). The study looks at these 50 animals over 5 days pre-parturition through an entire 305-day lactation cycle. Blood and milk samples are collected on d -5 through d+10, d+30, d +60, d+90, d+150, and d+300 relative to parturition. All samples will be evaluated for circulating concentrations of 5-HT, PTHrP, glucose, ionized calcium, C-telopeptide (CTx) fragments of collagen type I and BHBA, as well as levels of 5-HT and calcium in milk.

This study will provide us with the knowledge of how the 5-HT / PTHrP axis fluctuates throughout the transition period and the entirety of a 305-day lactation cycle. In addition, herd records will be collected and the relationship between the parameters measured and disease incidence during early lactation will be analyzed. We expect that Jersey cows will have lower levels of 5-HT, PTHrP, as well as C-telopeptide (CTx) fragments of collagen type I, due to decreased bone turnover. This experiment will provide us a snapshot of not only how the 5-HT / PTHrP axis fluctuates over the course of lactation, but it will provide us with the knowledge of the best ways to manipulate the system to prevent metabolic disorders during the transition period.

As we look to gain a greater understanding of the serotonergic pathway, in future experiments we will be using molecular biology and cell culture to determine which 5-HT receptor is responsible for the induction of PTHrP production. Finally, we aim to characterize the possibility of using 5-HTP to manipulate calcium and glucose homeostasis during the

References

Adams, R., V. Ishler, and D. Moore. 1996. Trouble-shooting milk fever and downer cow problems.
DAS 96-27. IVE1f. PENpages 2890216: 1-7.
Beede, D. K., C. A. Risco, G. A. Donovan, C. Wang, L. F. Archbald, and W. K. Sanchez. 1992. Nutritional management of the late pregnant dry cow with particular reference to dietary cation-anion difference and calcium supplementation. The Bovine Proceedings 24:51-55.
Berger, M., J. A. Gray, and B. L. Roth. 2009. The expanded biology of serotonin. Annu Rev Med 60:355–66.
Bethard, G., and J. F. Smith. 1998. Controlling milk fever and hypocalcemia in dairy cattle: use of
dietary cation-antion difference (DCAD) in formulating dry cow rations. NMSU Ag. Expt. Stat. Tech. Report 31, Las Cruces, NM.
Bliziotes, M. M., A. J. Eshleman, X. W. Zhang, and K. M. Wiren. 2001. Neurotransmitter action in osteoblasts: expression of a functional system for serotonin receptor activation and reuptake. Bone 29:477–86.
Charbonneau, E., D. Pellerin, and G. R. Oetzel. 2006. Impact of lowering dietary cation-anion difference in nonlactating dairy cows: A meta-analysis. J. Dairy Sci. 89:537-548.
Collet, C., C. Schiltz , V. Geoffroy, L. Maroteaux, J. M. Launay, and M. C de Vernejoul. 2008. The serotonin 5-HT2B receptor controls bone mass via osteoblast recruitment and proliferation. FASEB J 22:418–27.

Datta, N. S., and A. B. Abou-Samra. 2009. PTH and PTHrP signaling in osteoblasts. Cell Signal 21:1245–54.

DeGaris, P. J., and I. J. Lean. 2009. Milk fever in dairy cows: A review of pathophysiology and control principles. Vet J 176:58–69.
Ducy, P., and G. Karsenty. 2010. The two faces of serotonin in bone biology. J Cell Biol 191:7–13.
Erb, H. N., R. D. Smith, P. A. Oltenacu, C. L. Guard, R. B. Hillman, P. A. Powers, M. C. Smith, and M. E. White. 1985. Path Model of reproductive disorders and performance, milk fever, mastitis, milk yield, and culling in Holstein cows. J. Dairy Sci. 68:3337-3349.
Fiaschi-Taesch, N. M., and A. F. Stewart. 2003. Minireview: parathyroid hormone-related protein as an intracrine factor—trafficking mechanisms and functional consequences. Endocrinology. 144:407-11.
Guard, C. L. 1996. Fresh cow problems are costly; culling hurts the most. Hoard's Dairyman 141:8.
Goff, J. P. 2008. The monitoring, prevention, and treatment of milk fever and subclinical hypocalcemia in dairy cows. Vet J 176:50–57.
Hannon, J., and D. Hoyer. 2008. Molecular biology of 5-HT receptors. Behav Brain Res 195:198–213.
Hardie, D. G., F. A. Ross, and S. A. Hawley. 2012. AMPK: a nutrient and energy sensor that maintains energy homeostasis. Nat Rev Mol Cel Biol 13: 251–62.
Hernandez, L. L., B. E. Grayson, E. Yadav, R. J. Seeley, and N. D. Horseman. 2012. High fat diet alters lactation outcomes: possible involvement of inflammatory and serotonergic pathways. PLoS One 7:32598.
Hernandez, L. L., C. M. Stiening, J. B. Wheelock, L. H Baumgard, A. M. Parkhurst, and R. J. Collier. 2008. Evaluation of serotonin as a feedback inhibitor of lactation in the bovine. J Dairy Sci 91:1834–44.
Horst, R. L., J. P. Goff, T. A. Reinhardet, and D. R. Buxton. 1997. Strategies for preventing milk fever in dairy cattle. J. Dairy Sci. 77:1936-1951
Kimura, K., T. A. Reinhardt, and J. P. Goff. 2006. Parturition and hypocalcemia blunts calcium signals in immune cells of dairy cattle. J. Dairy Sci. 89:2588-2595.
Kovacs, C. S. 2011. Calcium and bone metabolism disorders during pregnancy and lactation. Endocrinol Metab Clin North Am 40: 795–826.
Laporta, J., T. L. Peters, S. R. Weaver, K. E. Merriman, and L. L. Hernandez. 2013a. Feeding 5-hydroxy-L-tryptophan during the transition from pregnancy to lactation increases calcium mobilization from bone in rats. Domest. Anim. Endocrinol. S0739-7240.
Laporta, J., T. L. Peters, K. E. Merriman, C. M. Vezina, and L. L. Hernandez. 2013b. Serotonin (5-HT) affects expression of liver metabolic enzymes and mammary gland glucose transporters during the transition from pregnancy to lactation. PLoS One. 8:e57847.
Lean, I. J., P. J. DeGaris, D. M. McNeil, and E. Block. 2006. Hypocalcemia in dairy cows: meta-analysis and dietary cation anion difference theory revisited. J. Dairy Sci. 89:669-684.
Martín-Tereso, J., M. W. A. Verstegen. 2011. A novel model to 374 explain dietary factors affecting hypocalcemia in dairy cattle. Nutr Res Rev 24: 228-243.
Martinez, N., C. A. Risco, F. S. Lima, R. S. Bisinotto, L. F. Greco, E. S. Ribeiro, F. Maunsell, K. Galvão, and J. E. Santos. 2012. Evaluation of peripartal calcium status, energetic profile, and neutrophil function in dairy cows at low or high risk of developing uterine disease. J Dairy Sci. 95:7158-72.
Matsuda, M., T. Imaoka, A. J. Vomachka, G. A. Gudelsky, Z. Hou, M. Mistry, J. P. Bailey, K. M. Nieport, D. J. Walther, M. Bader, and N. D. Horseman. 2004. Serotonin regulates mammary gland development via an autocrineparacrine loop. Dev Cell 6: 193–203.
Matsuo, K., and N. Irie. 2008. Osteoclast-osteoblast communication. Arch Biochem Biophys. 473:201-9.
McFadden, J. W., and B. A. Corl. 2009. Activation of AMP-activated protein kinase (AMPK) inhibits fatty acid synthesis in bovine mammary epithelial cells. Biochem Biophys Res Commun 390: 388–393.
Modder, U. I., S. J. Achenbach, S. Amin, B. L. Riggs, L. J. Melton, and S. Khosla. 2010. Relation of serum serotonin levels to bone density and structural parameters in women. J Bone Miner Res 25:415–22.
Moore, M. C., K. Kimura, H. Shibata, T. Honjoh, M. Saito, C. A. Everett, M. S. Smith, and A. D. Cherrington. 2005. Portal 5-hydroxytryptophan infusion enhances glucose disposal in conscious dogs. Am J Physiol Endocrinol Metab 289: E225–31.
Oetzel, G. R., and B. E. Miller. 2012. Effect of oral calcium bolus supplementation on early-lactation
health and milk yield in commercial dairy herds. J. Dairy Sci. 95:7051–7065.
Oetzel, G. R., J. D. Olson, C. R. Curtis, and M. J. Fettman. 1988. Ammonium chloride and ammonium sulfate for prevention of parturient paresis in dairy cows. J. Dairy Sci. 71:3302–3309.
Pai, V. P., and N. D. Horseman. 2008. Biphasic regulation of mammary epithelial resistance by serotonin through activation of multiple pathways. J Biol Chem 283:30901–10.
Rakopoulos, M., S. J. Vargas, M. T. Gillespie, P. W. Ho, H. Diefenbach-Jagger, D. D. Leaver, V. Grill, J. M. Moseley, J. A. Danks, T. J. Martin. 1992. Production of parathyroid hormone-related protein by the rat mammary gland in pregnancy and lactation. Am J Physiol 263:E1077–85.
Reinhardt, T. A., J. D. Lippolis, B. J. McCluskey, J. P. Goff, r. l. Horst. 2011. Prevalence of subclinical hypocalcemia in dairy herds. Vet J 188, 122–124.
Roth, B. L., D. L. Willins, K. Kristiansen, W. K Kroeze. 1998. 5-Hydroxytryptamine2-family receptors (5-hydroxytryptamine2A, 5-hydroxytryptamine2B, 5-hydroxytryptamine2C): where structure meets function. Pharmacol Ther 79: 231-57.
Stewart, A. F. 2005. Clinical practice. Hypercalcemia associated with cancer. N Engl J Med 352:373-9.
Stull, M. A., V. Pai, A. J. Vomachka, A. M. Marshall, G. A. Jacob, and N. D. Horseman. 2007. Mammary gland homeostasis employs serotonergic regulation of epithelial tight junctions. Proc Natl Acad Sci U S A 104:16708–18.
VanHouten, J., P. Dann, G. McGeoch, E. M. Brown, K. Krapcho, M. Neville, and J. J. Wysolmerski. 2004. The calcium-sensing receptor regulates mammary gland parathyroid hormone–related protein production and calcium transport. J Clin Invest 113:598-608.

VanHouten, J. N., P. Dann, A. F. Stewart, C. J. Watson, M. Pollak, A. C. Karaplis, and J. J. Wysolmerski. 2003. Mammary-specific deletion of parathyroid hormone–related protein preserves bone mass during lactation. J Clin Invest 112:1429–36.
Watanabe, H., M. T. Rose, and H. Aso. 2011. Role of peripheral serotonin in glucose and lipid metabolism. Curr Opin Lipido l22: 186–191.
Wysolmerski, J. J. 2012. Parathyroid hormone-related protein: an update. J Clin Endocrinol Metab 97:2947–56.
Wysolmerski, J. J. 2010. Interactions between breast, bone, and brain regulate mineral and skeletal metabolism during lactation. Ann N Y Acad Sci 1192:161–9.

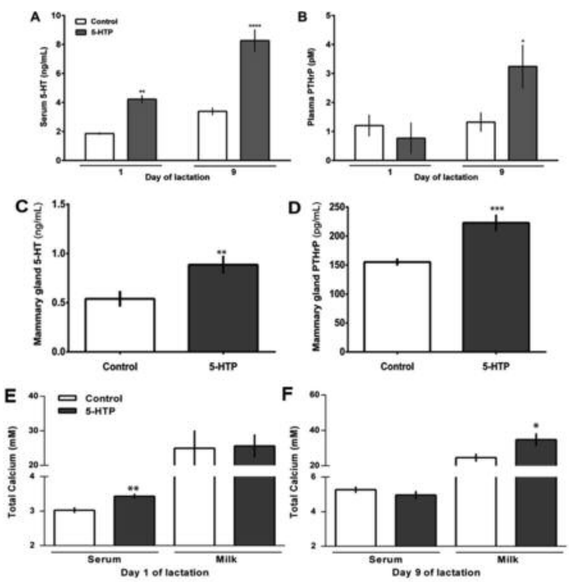


Figure 1. Serum 5-HT and plasma PTHrP concentrations on day 1 and day 9 of lactation (A,B), mammary gland 5-HT and PTHrP protein concentration on day 9 lactation (C,D) and calcium concentrations on day 1 (E) and day 9 of lactation (F) in serum and milk of Sprague-Dawley rats fed control diet (n = 15) and diet enriched with 5-HTP (0.2%; n = 15). Data are represented as mean ± SEM. *P < 0.05, **P < 0.01, ***P < 0.001, ****P < 0.0001. 5-HT, serotonin; PTHrP, parathyroid hormone related-protein; TPH1, tryptophan hydroxylase-1.

Yadav, V. K., Je- H Ryu, N. Suda, K. F. Tanaka, J. A. Gingrich, G. Schutz, F. H. Glorieux, C. Y. Chiang, J. D. Zajac, K. L. Insogna, J. J. Mann, R. Hen, P. Ducy, and G. 2008. Karsenty. Lrp5 controls bone formation by inhibiting serotonin synthesis in the duodenum. Cell 135:825–37.

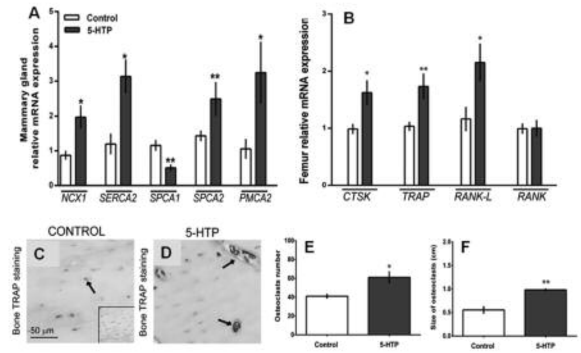


Figure 2. Supplemental 5-HTP influences maternal mammary gland calcium transport and bone resorption on day 9 of lactation. Maternal mRNA expression of mammary gland calcium transporters (A) and bone mRNA expression of markers of femur bone resorption (B), tartrate-resistant acid phosphatase staining of bone femurs (day 9 of lactation) as a histochemical marker for skeletal resorbing osteoclasts (black arrows) in control rats (n = 15) and rats fed 5-HTP (0.2%; n = 15). Inset contains a negative control. Osteoclast number (E) and size (F) per treatment. Data are represented as mean ± SEM. *P < 0.05, **P < 0.01.

OC, osteoclast; 5-HTP, 5-hydroxytryptophan; NCX1, sodium-calcium exchanger-1; SERCA2, sarco(endo)plasmic reticulum calcium ATPase-2; SPCA1, secretory pathway calcium ATPase-1; SPCA2, secretory pathway calcium ATPase-2; PMCA2, plasma membrane calciumATPase-2; tartrate-resistant acid phosphatase, TRAP; cathepsin K, CTSK; receptor activator of nuclear factor Kb, RANK, RANK ligand, RANK-L.

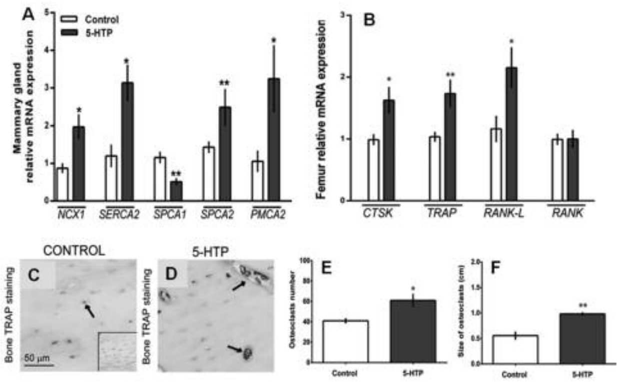


Figure 3. Liver mRNA expression of gluconeogenic enzymes pyruvate carboxylase (PC), phosphoenolpyruvate carboxykinase-1 (PCK1) and pyruvate dehydrogenase kinase, isozyme 4 (PDK4)(A), mammary gland mRNA expression of glucose transporters 1 and 8 (GLUT-1 and GLUT-8) (B), western blot analysis of mammary glands for phosphorylated AMP-activated protein kinase (pAMPK), total AMPK and b-actin (n = 8 per group; (C)) from in control rats (n = 15) and rats fed 5-HTP (0.2%; n = 15) collected on day 9 of lactation. *P < 0.05, **P < 0.01.

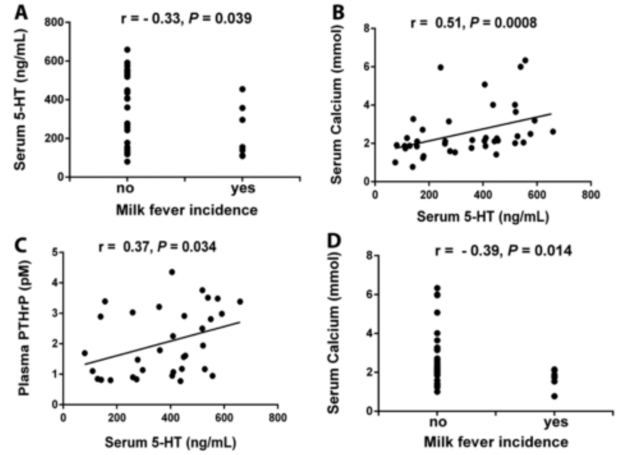


Figure 4. Spearman correlations between serum circulating serotonin (5-HT) concentrations on d 1 of lactation with: (A) milk fever incidence (on d 1 of lactation), (B) serum ionized calcium (on d 1 of lactation), and (C) plasma parathyroid hormone related-protein (PTHrP, on d 1 of lactation) in Holstein cattle (n=42). Correlation between serum calcium and milk fever incidence on d 1 of lactation is shown in (D). Milk fever incidence (yes / no) was determined subjectively (i.e. subnormal body temperature, cold extremities, dry nose, ataxia and recumbence).

Choline: A Limiting Nutrient for Transition Dairy Cows

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Choline has been shown to be a required nutrient for many animals including rats, mice, dogs, pigs, guinea pigs, chickens, and trout. Choline is often referred to as a vitamin, however, it doesn't fit any of the classical definitions for a vitamin. It is not a co-factor in enzymatic reactions, it can be synthesized endogenously, and it is required in larger amounts than vitamins. The ability to synthesize choline endogenously does not mean it is a dispensable or non-essential nutrient. Deficiency symptoms include suppressed growth rates, renal dysfunction, and development of fatty liver. Choline is crucial for normal function of all cells. The most common form of choline in biological systems is phosphatidylcholine (PC), a phospholipid that is a component of all cell membranes and lipoproteins that function to transport lipids through the circulatory system. Choline is a source of methyl groups, therefore, it can spare methionine and have interactions with other nutrients involved in one-carbon metabolism (e.g. folate). Choline is also a component of acetylcholine, an important neurotransmitter.

The NRC (2001) wrote: "The establishment of a choline requirement, either for the lactating dairy cow, or a transition cow in the late dry period and in early lactation, will require more extensive feeding experiments than available at the time of this publication." It has now been 12 years since publication of the last NRC and at this time there has not been an announcement for the formation of a new committee to author the next NRC. That means it will probably be at least 2016 until publication of the 8th revised edition. Since publication of the last NRC, numerous studies have been conducted to examine the effects of feeding ruminally protected choline to dairy cows, particularly as they transition from the dry period to early lactation. In light of new research and because a revised NRC is not on the immediate horizon, it seems appropriate to initiate discussion on whether choline should be considered a required nutrient in dairy diets.

TRANSITION COW AND CHOLINE BIOLOGY

Several studies have shown 50 to 60% of transition cows experience moderate to severe fatty liver (Bobe et al., 2004). These studies have been conducted in numerous countries across different genetic lines of cattle and varying management systems and the data do not represent problem cows or herds . The consistency amongst these studies suggests that development of fatty liver is a "normal" part of the cow's biology. Because fatty liver is a classic deficiency symptom for choline, it is reasonable to question if transition cows are typically deficient in choline.

At calving there are hormonal changes that trigger an intense period of lipid mobilization from adipose tissue and as a result, blood nonesterified fatty acid (NEFA) concentrations typically increase 5- to 10-fold (Grummer, 1993). NEFA remain elevated, although to a lesser extent, during early lactation when cows experience negative energy balance. Blood flow to the liver doubles as a cow transitions from the dry period to lactation (Reynolds et al., 2003). NEFA concentration and blood flow are the two biggest factors affecting how much NEFA is taken up by the liver. As a result, daily fatty acid uptake by the liver increases 13-fold at calving, from approximately 100 to 1300 g/day (Reynolds et al., 2003). Not all of the fatty acids taken up by the liver will be stored and contribute to fatty liver. However, Drackely (2001) estimated that during peak blood NEFA concentration, approximately 600 g might be deposited in 24 hours which would correspond to an increase in liver fat of 6-7% by weight. As a reference, fat above 5% in the liver (wet basis) is considered by the veterinary community to be moderate to severe fatty liver. It is important to understand that this dramatic increase in NEFA uptake by the liver is part of the normal biology of transition cows and is not restricted to fat cows, poorly fed cows, or cows housed in suboptimal environments.

The most desirable fate of fatty acids entering the liver would be complete oxidation to provide energy to the liver or reesterification and export as triglyceride from the liver as part of a very low density lipoprotein (VLDL). Hepatic oxidation increases approximately 20% during the transition period (Drackley et al., 2001). This increase does not represent a strategic move by the cow's liver to cope with the sudden surge of NEFA uptake at calving. It occurs because the liver becomes metabolically more active. Unfortunately, the increase in oxidation is not sufficient to cope with the increased load of fatty acid being presented to the liver. Research conducted 25 years ago at the University of Wisconsin (Kleppe et al., 1988) and Michigan State University (Pullen et al., 1990) revealed that ruminants have a low capacity to export triglyceride from the liver as very low density lipoprotein (VLDL) as compared to nonruminants. This and the inability to markedly increase fatty acid oxidation is why transition dairy cattle develop fatty liver when experiencing elevated blood NEFA.

It is now apparent that choline deficiency is a limiting factor for VLDL triglyceride export from the liver. It has been shown in many species, using a wide variety of experimental approaches, that rate of VLDL export is highly related to the rate of hepatic PC synthesis (Cole et al., 2011). Models include monograstrics fed choline deficient diets, isolated hepatocytes cultured in choline and methionine deficient media, and knock out mice for genes involved in PC synthesis (Cole et al., 2011). Interestingly, there is no evidence that synthesis of any other phospholipid is required for hepatic VLDL assembly and secretion. In addition to direct PC synthesis from dietary choline, there is endogenous hepatic synthesis of PC via methylation of phosphotidylethanolamine (PE). Sharma and Erdman (1988) demonstrated dietary choline is extensively degraded in the rumen of dairy cows and very little is available to the small intestine for absorption. Choline flow to the duodenum increased less than 2 g/day, even when free choline intake was increased to more than 300 g/d. Therefore, ruminants are more highly dependent than nonruminants on endogenous synthesis of PC from PE. Is endogenous synthesis of PC from PE sufficient during the transition period or do cows require choline supplementation? The high proportion of transition cows developing moderate to severe fatty liver during the transition period suggests that endogenous synthesis is not sufficient in many cows.

EVIDENCE FOR A CHOLINE DEFICIENCY IN TRANSITION DAIRY COWS

The first piece of evidence that transition cows are deficient in choline is the development of fatty liver during the periparturient period (Grummer, 1993; Bobe et al., 2004). More compelling evidence is the alleviation of fatty liver when supplying cows with choline that is protected from ruminal degradation (Cooke et al., 2007; Zom et al., 2011). Dutch researchers (Goselink et al., 2012) recently demonstrated greater gene expression for microsomal triglyceride transfer protein (MTTP) in liver of transition cows supplemented with rumen-protected choline (RPC). MTTP is an important protein required for hepatic VLDL synthesis. This provided solid evidence that choline limitation is a causative factor for inadequate fat export out of the liver.

The reduction in liver fat content when feeding transition cows RPC is accompanied by improved health and production. Lima et al. (2011) observed reduced incidences of clinical ketosis, mastitis, and morbidity when feeding RPC from 25 days prepartum to 80 days postpartum. It has been known for years that elevated fat in the liver is associated with poor reproductive performance (Bobe et al., 2004). First service conception rate was increased by feeding RPC in one study (Oelrichs et al., 2004) but not another (Lima et al., 2011). We (Grummer and Crump, unpublished) recently completed a meta-analysis for 13 studies that fed RPC to transition cows. Feed stability or evidence of bioavailability of choline source was not a criterion for study selection. Studies were not screened for "soundness" of research. Treatment means and sample size (standard error of the mean) had to be available for the analysis. Ten of the thirteen trials were published in peer-reviewed journals. For studies to be included in this analysis, RPC had to be fed prior to calving. Time when RPC supplementation was started varied between 28 to 7 days prior to expected calving. RPC supplementation was terminated anywhere from the day of calving (one study) to 120 days in milk. Response variables included DMI, milk yield, energy corrected milk yield, fat %, protein %, and fat and protein yield. Insufficient data was available for analysis of liver fat or energy-related blood parameters. Analysis revealed a significant increase of 4.9 lb milk/day and 1.6 lb of dry matter intake/day (Table 2; Figure 1). Milk fat and protein yield percentage were not significantly affected by treatment but yields were (Table 2). These studies were conducted in several countries under a variety of management conditions and they did not target problem herds or cows. This implies that benefits to supplementing protected choline can be realized by a wide variety of herds. Alleviating a choline deficiency not only reduces liver fat but also improves parameters that are economically important to dairy producers.

CAN PROTECTED METHIONINE SUBSTITUTE FOR PROTECTED CHOLINE?

Protected methionine has often been suggested as a possible alternative to protected choline for supplementation to transition dairy cows. Methionine and choline both serve as methyl donors. Methionine methyl groups can be used for endogenous synthesis of PC from PE. Therefore, there is a conceptual basis for methionine substitution for choline. Additionally, as an amino acid, methionine is needed for the synthesis of apolipoproteins.

Five feeding trials have been conducted to examine the effects of feeding methionine analogs or protected methionine on liver fat content. Feeding 13 g/d of 2-hydroxy-4-(methylthio)-butanoic acid (HMB; also referred to methionine-hyrdoxy-analog or MHA) did not reduce triglyceride accumulation in the liver of feed restricted dry cows (Bertics et al., 1997). Feeding 0, .13, .20% of dry matter as HMB from 21 days prepartum to 84 days postpartum did not affect liver triglyceride at 1 day postpartum and resulted in a tendency ($P < 0.15$) for a quadratic increase in liver triglyceride at 21 day postpartum (Piepenbrink et al., 2004). They also observed a quadratic effect of HMB for increased fat-corrected milk yield providing further indication that the cows were responsive to treatment. The amount of HMB absorbed from the gastro-intestinal tract and converted to methionine by the liver has not been well established.

Cows fed 0 or 10.5 g methionine/day as Smartamine from 14 days precalving to 105 days postcalving had similar liver total lipid postcalving (Socha, 1994). Liver triglyceride was not measured. Milk protein percentage was increased by treatment indicating that supplementation delivered more methionine to the blood stream. Feeding 9 g Mepron/day precalving and 18 g Mepron/day postcalving increased liver triglyceride ($P=0.02$) but the means from 4 liver biopsies taken over 16 weeks were small and the increase was small (Preynat et al., 2010). Milk protein percentage was increased by feeding Mepron which indicated an improved methionine status. Feeding MetaSmart (.18% of DM) or Smartamine (.07% of DM) from 21 days prepartum until 20 days postpartum did not affect total lipid and triglyceride concentrations in the liver (Osorio et al., 2001a). The researchers indicated that the slope of liver total lipid between day 7 and 21 postpartum was different ($P < .04$) for cows fed MetaSmart and Smartamine implying that methionine prevented increased lipid accumulation during that time. The justification for this method of analyzing the data was not obvious because the researchers did not indicate that there was a significant time of sampling x treatment interaction. Dry matter intake, milk yield, and fat percentage were increased by methionine supplementation indicating that methionine status was improved (Osorio et al., 2011b). Further examination of the data must wait until a full length report becomes available in a peer-reviewed publication. Considering the five studies conducted to date, there is insufficient evidence to suggest that feeding methionine analogs or protected methionine can replace protected choline for the prevention of fatty liver.

CONCLUSIONS

The time between NRC publications is increasing and when (or if) the next publication will occur is not known. Consequently, discussions outlined in this article become important for providing nutritionists with updates regarding nutrient requirements. Since the last NRC (2001) publication, a significant body of evidence has accumulated to support choline being a required but limiting nutrient in transition cow diets. An analogous situation occurred when the last NRC (2001) committee included a supplemental vitamin E recommendation to improve mammary health and reproduction. The recommendation was made despite the lack of titration trials, knowing the amount of vitamin E in the basal diet would seldom be known, and realizing there could be numerous interactions with other antioxidants. Similarly, our knowledge of availability of choline from rumen-protected sources is incomplete as is our knowledge of interactions between choline and other nutrients involved with one-carbon metabolism. Nevertheless, there is overwhelming evidence that feeding transition dairy cows 15 g choline/day in a form that is protected from ruminal degradation will alleviate choline's classic deficiency symptom and lead to improvements in health and performance.

REFERENCES

Ardalan, M., M. Dehghan-banadaky, K. Rezayazdi, and N. Ghavi Hossein-Zadeh. 2011. The effect of rumen-protected methionine and choline on plasma metabolites of Holstein dairy cows. J. Agric. Sci. doi:10.1017/S0021859610001292.

Bertics, S. J., and R. R. Grummer. 1999. Effects of fat and methionine hydroxy analog on prevention and alleviation of fatty liver induced by feed restriction. J. Dairy Sci. 82:2731-2736.

Bobe, G., J. W. Young, and D. C. Beitz. 2004. Invited review: Pathology, etiology, prevention, and treatment of fatty liver in dairy cows. J. Dairy Sci. 87:3105-3124.

Cole, L. K., J. E. Vance, and D. E. Vance. 2011. Phosphatidylcholine biosynthesis and lipoprotein metabolism. Biochim. Biophys. Acta. 1821:754-761.

Cooke, R. F., N. Silva Del Rio, D. Z. Caraviello, S. J. Bertics, M. H. Ramos, and R. R. Grummer. 2007. Supplemental choline for prevention and alleviation of fatty liver in dairy cattle. J. Dairy Sci. 90: 2413-2418.

Drackley, J. K., T. R. Overton, and G. N. Douglas. Adaptations of glucose and long-chain fatty acid metabolism in the liver of dairy cows during the periparturient period. J. Dairy Sci. 84(E. Suppl.):E100-112.

Elek, P., J. R. Newbold, T. Gaal, L. Wagner, and F. Husveth. 2008. Effects of rumen-protected choline supplementation on milk production and choline supply of periparturient dairy cows. Anim. 2:1595-1601.

Goselink, R., J. van Baal., A. Widaja, R. Dekker, R. Zom., M. J. de Veth, and A. van Vuuren. 2012. Regulation of hepatic triacylglycerol level in dairy cattle by rumen-protected choline supplementation during the transition period. J. Dairy Sci. 95:submitted.

Grummer, R. R. 1993. Etiology of lipid related metabolic disorders in periparturient dairy cattle. J. Dairy Sci. 76:3882-3896.

Hartwell, J. R., M. J. Cecava, and S. S. Donkin. 2000. Impact of dietary rumen undegradable protein and rumen-protected choline on intake, peripartum liver triacylglyceride, plasma metabolites and milk production in transition dairy cows. J. Dairy Sci. 83:2907-2917.

Janovick Guretzky, N. A., D. B. Carlson, J. E. Garret, and J. K Drackley. 2006. Lipid metabolite profiles and milk production for Holstein and Jersey cows fed rumen-protected choline during the periparturient period. J. Dairy Sci. 89:188-200.

Kleppe, B. B., A. J. Aiello, R. R. Grummer, and L. E. Armentano. 1988. Triglyceride accumulation and very low density lipoprotein secretion by rat and goat hepatocytes in vitro. J. Dairy Sci. 71:1813-1822.

Lima, F. S., M. F. Sa Filho, L. F. Greco, F. Susca, V. M. Magalhaes, and J. E. P. Santos. 2007. Effects of feeding rumen-protected choline on metabolism and lactation. J. Dairy Sci. 90(Suppl. 1):174

Lima, F.S., M.F. Sa Filho, L. F. Creco, and J. E. P. Santos. 2011. Effects of feeding rumen-protected choline on incidence of diseases and reproduction in dairy cows. Vet. J. (in press/available on line).

National Research Council. 2001. Nutrient Requirements of Dairy Cattle, Seventh Revised Ed. Washington, D. C.: National Academy Press.

Osorio, J. S., P. Ji, J. K. Drackley, and J. Loor. 2011. Effects of supplemental Smartamine or MetaSmart in moderate-energy close-up diets on peripartal liver tissue composition and blood metabolites. J. Dairy Sci. 94(Suppl. 1):766.

Sharma, B. K., and R. A. Erdman. 1988. Effect of high amounts of dietary choline supplementation on duodenal flow and production responses of dairy cows. J. Dairy Sci. 71:2670-

Sheer, W. A., M. C. Lucy, M. Kerley, and J. N. Spain. 2002. Effects of feeding soybeans and rumen protected choline during late gestation and early lactation on performance of dairy cows. J. Dairy Sci. 85(Suppl. 1):276.

Oelrichs, W. A., M. C. Lucy, M. S. Kerley, and J. N. Spain. 2004. Feeding soybeans and rumen-protected choline to dairy cows during the periparturient period and early lactation. 2. Effects on reproduction. J. Dairy Sci. 87(Suppl. 1):344.

Piepenbrink, M. S., and T. R. Overton. 2003. Liver metabolism and production of cows fed increasing amounts of rumen-protected choline during the periparturient period. J. Dairy Sci. 86:1722-1733.

Pinotti, L., A. Baldi, I. Politis, R. Rebucci, L. Sangalli, and V. Dell'Orto. 2003. Rumen-protected choline administration to transition dairy cows: effects on milk production and vitamin E status. J. Vet. Med. A 50:18-21.

Pullen, D. L., J. S. Liesman, and R. S. Emery. 1990. A species comparison of liver slice synthesis and secretion of tyriacylglycerol from nonesterified fatty acids in media. J. Anim. Sci. 68:1395-1399.

Reynolds, C. K., P. C. Aikman, B. Lupoli, D. J. Humphries, and D. E. Beaver. 2003. Splanchnic metabolism of dairy cows during the transition from late gestation through early lactation. J. Dairy Sci. 86:1201-1217.

Sales, J., P. Homolka, and V. Koukolova. 2010. Effect of dietary choline on milk production of dairy cows: A meta-analysis. J. Dairy Sci. 93:3746-3754.

St-Pierre, N. R. 2001. Integrating quantitative findings from multiple studies using mixed model methodology. J. Dairy Sci. 84:741-755.

Xu, G., J. Ye, J. Liu, and Y. Yu. 2006. Effect of rumen-protected choline addition on milk performance and blood metabolic parameters in transition dairy cows. Asian-Aust. J. Anim. Sci. 19:390-395.

Zahra, L. C., T. F. Duffiled, K. E. Leslie, T. R. Overton, D. Putnam, and S. J. LeBlanc. 2006. Effects of rumen-protected choline and monensin on milk production and metabolism of periparturient cows. J. Dairy Sci. 89:4808-4818.

Zom, R. L. G, J. van Baal, R. M. A. Goselink, J. A. Bakker, M. J. de Veth, and A. M. van Vuuren. 2011. Effect of rumen-protected choline on performance, blood metabolites, and hepatic triacylglycerols of periparturient dairy cattle. J. Dairy Sci. 94:4016-4027.

Table 1. Studies used in the Meta-Analysis.

Study	Choline Dose, g/d	Product	Duration	Exp.Units	Parity
Hartwell et al., 2000	0,6,12	Capshure	-21 to 120	24	M
Zom et al., 2011	15	ReaShure	-21 to 42	19	M
Lima et al., 2007[1]	15	ReaShure	-25 to 80	4 (pen)	M, P
Lima et al., 2007[1]	15	ReaShure	-22 to 0	5 (pen)	P
Oelrichs et al., 2002[1]	15	ReaShure	-28 to 100	32	M, P
Zahra et al., 2006	14	ReaShure	-25 to28	91	M, P
Piepenbrink et al., 2003	11,15, 19	ReaShure	-21 to 63	12	M
Janovick et al., 2006	15	ReaShure	-21 to 21	21	M
Elek et al., 2008	25/50 Pre/Post	Norcol-25	-25 to 60	16	M, P
Ardalan et al.	14	Col 24	-28 to 70	20	M, P
Pinotte et al.	20	Overcholine 45%	-14 to 30	13	M
Xu et al. #1	7.5	Not reported	-7 to 21	7	M
Xu et al. #2	11,22,33	Not reported	-15 to 15	9	M, P

[1]Studies have not been published in a peer-reviewed journal. Standard errors were not reported in abstracts but were obtained from the authors.

Table 2. A Meta-analysis of 13 studies examining the effects of feeding RPC to transition cows on dry matter intake and milk.

	Control	RPC	SEd	P =
DMI, lb/d	39.98	41.60	.46	.0042
Milk, lb/d	70.88	77.75	.75	<.0001
ECM, lb/d	76.87	82.78	1.33	.0038
Fat yield, lb/d	2.788	3.042	.086	.021
Protein yield, lb/d	2.300	2.467	.053	.010

Figure 1. Individual study results from a meta-analysis of 13 transition cow trials that examined the effects of feeding rumen-protected choline (Grummer and Crump, unpublished).