Are Robotics Ready for Large Dairy Herds?

M.J. Brouk, Ph.D and J.P. Harner, Ph.D.
Kansas State University, Manhattan, KS
Email: mbrouk@ksu.edu

INTRODUCTION

Adoption and application of robotics in the US dairy industry is gaining strength and numbers. Industry estimates that about 2 % of the dairy cattle in the US and Canada are currently being milked via robotic milking methods. In some European countries, over 30 % of the dairy cattle are milked with robots. Currently many US dairy farms are building and planning these types of facilities. Some industry experts expect sales of robotic milking equipment to account for more than 30 % of the total milking equipment sold in the next decade. Barkema et al. (2015) estimated that the number of dairies with robotic milking parlors worldwide exceeded 25,000 in 2015. This represented a three-fold increase from estimates made 6 y earlier (De Koning, 2010). At this point, most of the sales of robotic equipment has been in herds of less than 300 cows. However, interest within the larger herds is growing rapidly. In the US, over 50 % of the dairy cattle are housed in herds larger than 1,000 head and nearly 35 % of the total herd is housed in herds with 2,000 or more cattle (USDA, 2012).

In the past 18 mo several US facilities have been constructed or existing facilities modified with robotics in herds of 500 to 1,500 cattle. Facilities outside the US located on a single farm are successfully milking over 3,000 head. Additional facilities for larger dairy farms are in the planning stage and it is very likely that the US will see a large increase in the number of larger dairy farms building new facilities and modifying existing facilities to accommodate robotic technology. The purpose of this paper is to help producers and farm advisors understand some of the key issues associated with the adoption of robotic technology.

TYPES OF ROBOTIC TECHNOLOGY

Robotic technology can be divided into 2 major categories, milking and feeding. Robotic technology for milking includes a complete system which performs all the manual operations of a conventional milking parlor. These systems are able to perform these operations without the presence of an operator. While operator assistance may be necessary for initial training of the cow and the robot, further human contact is not usually necessary for a normal milking. In most systems, the cow travels to the milking system without human aid. Most of the systems installed worldwide are individual box stalls where one robot milks an individual cow. There are also other examples where a single robot services 2 - 4 stalls. In 2010, the first automatic rotary milking system was opened in Sweden. This system featured a 24-stall rotary with 5 robots performing various functions of the milking process. This system was predicted to milk up to 90 cows per hour (Jacobs and Siegford, 2012).

More recently, robotic milking parlors have been installed with single robots at each stall and larger wheel sizes. This type of technology is very appealing to large scale producers as it would allow farms to keep their other management practices and continue to manage cows in groups. Humans would be needed to move cows to the milking parlor in these systems.

However, there are challenges to the speed of teat cleaning and attachment that result in slower wheel times than found on current conventional rotary parlors. There are also issues associated with equipment maintenance and repair that render the rest of the milking stations unavailable while these activities are performed. This is also true for the routine cleaning of the teat detection equipment. With single box stalls and multiple boxes per pen, only one milking station is closed for repair, maintenance, or cleaning while the remaining stalls continue to be available for milking. There has also been equipment designed for conventional rotary milking parlors to apply pre- and post-teat dip. This can reduce the required labor by 25-40 % depending on the size of the rotary parlor. There are also examples of teat dip applicators that can be mounted in parallel milking parlors.

Feeding application of robotics range from systems that automatically push up feed at preset times to fully automated systems that mix, deliver, and push-up feed on a schedule or when the feed bunk requires additional feed. While there are not a tremendous number of these feeding systems being utilized in the US, it is an option that could be considered. Currently the application is for herds of less than 1,000 cows, but this could change in the future.

APPLICATION OF ROBOTICS ON LARGE DAIRY FARMS

Application of robotics on large dairy farms is gaining interest in the US as a way to increase labor efficiency and to standardize the milking process. Many smaller farms have chosen automatic milking systems (**AMS**) as a way to achieve lifestyle goals (Rodenburg, 2017) as an additional benefit. Jacobs and Siegford (2012) suggested that smaller farms may find more economic benefit from the AMS than larger farms. It was also suggested that larger farms may have a greater ability to hire labor for conventional parlors and may do this at a cheaper rate. However, recent changes in the immigration practices of the US government and a robust economy have resulted in a smaller potential labor pool for US dairy farms, removing the potential advantage that existed a few years ago. While these factors may push larger farms toward robotics, there are many paradigms that must be addressed as robotics are adopted.

BREAKING THE PARADIGMS

One of the major barriers of the adoption of AMS on large dairy farms is the efficient utilization of capital. Capital investment per cow for an AMS is likely about 10-fold more than the equipment for a conventional milking parlor for a large dairy farm. This represents a significant barrier and sometimes results in a total rejection of the AMS concept without exploration. A major factor in the profitability of the AMS is the amount of milk harvested per box or robot. Currently, many farms harvest less than 5,000 lb of milk on a daily basis from each robot. There are some more intensely managed farms that are harvesting 6,000 to 7,000 lb/robot/d. Obviously, this changes the economics as an extra 1,000 lb of milk/d can add $58,000 to $68,000 to the annual gross income of each AMS. Designing facilities and management schemes to provide for excellent cow comfort and flow along with appropriate nutrition are important to allow for greater amounts of milk harvested daily per robot.

If one simply thinks of the AMS as a method to milk cows, as we do for conventional milking systems, then we are not evaluating the total value of the AMS. The AMS provides additional data that can be effectively utilized to manage the cattle. When making the comparison, keep in mind that an AMS can provide individual data daily concerning milk production, activity, concentrate intake, rumination, etc. So it is more than just a system to milk cows.

What is the value of this additional information? It depends if the information is utilized. This will require that the dairy producer and employees understand how to obtain information and react to the information received on each cow. This changes the management scheme from a group-based focus to an individual cow focus. The focus needs to be on the animals that are not performing well or those that need attention. The data can be very helpful in identifying animals that might need human intervention. Understanding the data and the logarithms that help identify the correct animals for focus is key to adding value to the information and the AMS.

Management of large dairy herds is generally based on efficient handling of large groups of dairy cattle based on parity, reproductive status, stage of lactation and/or level of milk production. Currently, almost all of the robotic milking facilities feature box type milking systems with smaller group sizes and only parity may be considered when assigning animals to groups. Some larger farms house 400 – 800 animals in a single pen to efficiently utilize large conventional milking parlors. Group size in a conventional system is often determined by the capacity of the milking parlor to milk a group of cows in 45 – 60 min. Some of the current rotary parlors can milk over 800 cows in one hour. With the current box robotic technology, each individual box can milk 60 - 80 cows/d. It is dependent on the level of milk production and the number of desired milkings per day. Multiple boxes can be installed in a single pen, but generally, the efficiency of each individual box is reduced when additional boxes are added to the pens. Current designs contain no more than 4 boxes per pen and most generally 2 - 3. Thus group sizes generally range from 60 - 240 animals depending on the number of milking units in the pen. A single stall will generally allow for 180 - 200 milkings in a 24-h period. The actual number per box is dependent on the number of animals in the pen and the desired number of daily milkings for each cow. Barn design may impact this number based on the work of Bach et al. (2009) showing that guided traffic barns may be able to milk more cows per robot than free flow traffic barns.

Handling more and smaller groups of cows is a major shift in management paradigm found on most large dairies today. In addition, performing normal practices such as breeding in all the lactating pens on the dairy, may create some questions about labor efficiency of the system. Again, one must change the management paradigm. In the AMS, cows can be sorted upon exit from the AMS to a smaller pen. The system can be set to sort animals only during certain times of the day and a text message can be sent to a telephone to notify the producer that the cow has been sorted. If the pen size is 200, the normal breeding herd would be about 35 % of the pen or 70 animals. If one only utilizes the heat detection systems based on activity, then there would be 2 - 3 average daily services per pen. If reproductive synchronization programs are utilized, cows can be sorted for injections and larger numbers of cows will be serviced on certain days. This can be managed by determining how many pens are synchronized for breeding on a certain day. Again, the paradigm of animal management must shift to accommodate the management of cattle in an AMS.

Changes in our thinking of animal flow must change as well. On a conventional dairy, animal flow is largely created by humans moving the cattle to the milking parlor 2 or 3 times/d. This has impacts on feeding behavior, heat detection, animal health detection, and many other aspects associated with the management of a large dairy. In the AMS, cows move independently to the milking system without the aid of a human. Animal flow is often interrupted by human presence in the pens of cows milked with an AMS. Thus, removal of manure, stall maintenance, and other routine management practices may disrupt the animal flow in a pen. The work day on conventional dairies is largely structured around the milking schedule. Feeding, stall maintenance, reproductive tasks, etc. all revolve around the milking schedule. Consequently, significant changes in how work is arranged on the dairy must occur. With the AMS, animals develop their own flow pattern that is not associated with the milking activity. Cows must be motivated to come to the AMS 2 - 5 times/d without human intervention. This requires additional attention and understanding of the nutrition program.

Nutrition focus and methods change significantly when adopting the AMS. Rather than feeding a total mixed ration (**TMR**) the nutritional program is split between the feed bunk, partial mixed ration (**PMR**), and the pellet or concentrates fed in the AMS. In the AMS, feed in the milking station may help with the motivation of the cow to present for milking. Animals that do not present on a regular interval become a fetch animal and require human intervention to achieve milking. Hunger may be a major motivator for the cow to move and circle between the AMS and the feed bunk. Hunger in dairy cattle is typically driven by either gut fill or metabolic factors. In early lactation, distension of the rumen is the major limiting factor to intake. Thus, the rate at which feedstuffs exit the rumen allows for additional intake of nutrients. Forages, and in particular the fiber of forages, are the slowest to ferment in the rumen. Forages also represent the greatest amount of variability in the ration. Thus, slowly fermented forages will have increased rumen retention times which could lead to reduced drive to move from the stall to the AMS or feed bunk. Owners of the AMS generally desire higher levels of milk production from their herd. Thus, attention to forage quality and the increased complexity of feeding a PMR along with concentrates in the AMS increases the attention required to properly balance the total nutritional program. It is also complicated by the fact that if cattle do not present for milking, they do not have access to a portion of the feed from the AMS. Thus commitment to training and fetching in early lactation may have an important impact on individual cow performance as well as overall herd performance.

SUMMARY

Are robotics ready for large dairy farms? Advances in the technology and equipment in the past 2 decades has resulted in very reliable equipment that can efficiently milk dairy herds. While application to this date has largely been on smaller dairies, that is about to change. Herds of over 1,000 cows can and are being milked with robotics. Several projects are in the planning phase that will handle 3,000 to 10,000 cows. One unit in another country currently milks over 3,000. In the next 10 y we will see significant interest in the further application of robotic technology on large dairy farms.

In order to be successful, dairy farm owners and managers will need to rethink the total management of the dairy. Many of our existing paradigms on personnel and cattle management will need to change to fit the new system of production. Activities that currently revolve around the milking schedule can now be accomplished at other times of the day. Additional attention will be possible for individual cattle and higher levels of productivity are possible by utilizing the vast amount of data generated by these systems. The technology is ready for application; however we will continue to develop and learn how we more efficiently utilize the technology on large scale dairy farms.

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Sponsored Topic

Top Ten Considerations for Dry Cow Cooling[1]

Geoffrey E. Dahl, Ph.D.
Department of Animal Sciences, University of Florida
Email: gdahl@ufl.edu

INTRODUCTION

While producers are quite familiar with the positive effects of cooling cows during lactation, fewer understand the impact of cooling dry cows. Yet there is increasing evidence that failure to cool cows when they are dry leads to negative effects on productivity and health in the next lactation. Perhaps more critical is the emerging data that indicates a significant impact of *in utero* heat stress on the developing heifer, which results in long term effects on that calf's productivity and health. This paper considers those topics, along with the economic and implementation considerations.

1) How does dry period cooling affect milk yield?

Cows that experience heat stress during the dry period make 8 to 10 lb less milk each day in the next lactation compared with herdmates that are cooled. There is no impact on milk composition, though component yields are increased with cooling. The effect is present on the first day of lactation and persists for at least 40 wk, though all evidence suggests it persists through the entire lactation. Mammary epithelial cell growth is depressed in heat stressed dry cows relative to cooled animals, and that is consistent with greater capacity to produce milk in the next lactation.

2) What are the metabolic effects?

Similar to lactating cows, heat stressed dry cows consume less feed compared with cooled cows. Despite the lower nutrient intake, there is no evidence that heat stressed dry cows experience any impact metabolically during heat stress. Indeed, there is no difference in basal or stimulated insulin, glucose, or free fatty acids between cooled and heat stressed dry cows. After calving there are some transient affects of dry period cooling; but they are all consistent with the observed increases in milk yield in those cows, and it is important to note that all cows are cooled during lactation, so those metabolic effects could not be due to continued heat stress.

3) Is cow health affected?

During the dry period, heat stress reduces antibody response to vaccination, and lymphocyte (i.e. white blood cell) proliferation is also lower. Thus, heat stress has direct negative impacts on the cow's ability to respond to pathogens during the dry period. Interestingly, there are carry-over effects of dry period heat stress on immune function, with those cows having lower innate immune responses in early lactation relative to their cooled herdmates, even though they are at a lower level of milk production. And cooled cows have higher circulating non-esterified fatty acid concentrations in blood, yet improved neutrophil responses. The improved

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immune status in cooled dry cows resulted in better responses to *S. uberis* challenge in early lactation.

4) What about reproductive performance?

The strongest indication that dry cow cooling does not negatively impact subsequent reproduction comes from a study that compared cows that were dry in the coolest months of the year (i.e. December to February) to those dry in the hottest months of the year (i.e. June to August). Cows dry in the coolest months produced more milk and were less likely to contract disease compared with those dry in the summer. Cows dry in the cool months had fewer services to pregnancy, as well as fewer days to pregnancy and thus fewer days open versus those dry in the hot months; all indications that despite higher milk yield, and being bred during the hottest months of the year, a dry period during the coolest months improves reproductive performance.

5) Is calf health and growth altered?

Calves born to heat stressed dams are lighter at birth, remain lighter at weaning and even through 12 mo of age, relative to calves from cooled dams. Calves that are heat stressed *in utero* are also shorter through a year of age. Passive transfer is also compromised in calves from heat stressed dams, with lower apparent efficiency of immunoglobulin (**IgG**) absorption translating to lower circulating concentrations of IgG through the first month of life. This is not due to a reduction in colostrum quality from the dam, but rather a limitation of IgG uptake. Specifically, we have evidence that gut closure is accelerated in the calves born to heat stressed dams. We have tracked calf health through the first lactation and found that more *in utero* heat stressed calves leave the herd due to sickness or illness before puberty, and thus fewer complete the first lactation.

6) Is heifer reproductive and first lactation performance affected?

Heifers born to heat stressed dams achieve puberty at the same age as those from cooled dams, but they require more services to achieve pregnancy. Most importantly, heifers born to heat stressed dams produce about 10 lb/d less milk in their first lactation compared to the heifers from cooled dams. This effect is apparent from the beginning of lactation and extends to at least 250 days in milk (**DIM**), and likely through the entire lactation. This response is not associated with differences in growth during the first lactation, as both groups of animals calved at the same bodyweight (**BW**) and had identical BW through the first lactation. Therefore the reduction in yield is not due to compensatory growth in the first lactation, so the lower yield is likely to persist into the second lactation and beyond. These fetal programming impacts are also known to be transferred to the offspring of the affected animal, so *in utero* heat stressed calves' progeny are likely to be lower productivity animals as well.

7) What are the economic impacts of heat stress for dry cows?

In a recent analysis we considered the economic losses associated with a lack of dry cow cooling across the US. Potential days during the year that a cow would experience heat stress were estimated for each state and the total number of cows in each state was used to estimate the total potential milk loss. The total potential loss from a lack of dry cow cooling is at least

$810 million annually. However, that estimate only considers milk losses, and does not include any impact on cow health or on the calf. Thus, the total negative impact is likely much greater. But prevention of the milk loss alone is enough to yield significant positive return on any cooling system improvements.

8) How do I assess heat stress?

Because temperature and humidity both influence the ability of a cow to lose heat to the environment, it is best to use the temperature-humidity index (**THI**) to assess the relative heat load on an animal. Rectal temperature (**RT**) is the gold standard to determine heat stress, and RT increases at a THI of 68, so abatement should begin before that THI is reached. In addition to RT, respiration rate (**RR**) will indicate the relative heat stress a cow is experiencing, and can be used effectively in a barn to determine if animals are heat stressed. For example, measuring RR by observation of flank movements of a group of sentinel cows within a pen should provide an indication of heat load. An average RR of 60 or greater suggests that heat stress is occurring and abatement strategies need to be employed to actively reduce the heat load on cows.

9) How are dry cows best cooled?

Methods of cooling are no different from those used on lactating cows. In a hot, humid environment such as we have in Florida, soakers, fans, and shade are effective abatement strategies for heat stress; whereas misters may be effective in more arid locations. However, shade alone will not provide adequate cooling for cows during high heat and humidity. Sand bedded stalls may also provide additional relief via conductive heat transfer to the sand. Overcrowding will exacerbate heat stress so be sure that dry cows pens are not above 100 % stocking rate.

10) Where can I get more information?

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Sponsored Topic

Surviving or Thriving? Key Profitability Drivers in the Dairy Industry

Kevin C. Dhuyvetter, Ph.D.
Elanco Animal Health, Technical Consultant
Email: kdhuyvetter@elanco.com

EXECUTIVE SUMMARY

- Similar to most agricultural sectors, the dairy industry has been consolidating, in terms of the number of producers, for many years.
- In competitive industries, such as dairy, price equals cost in the long run, on average. Thus, it is critical to continuously strive to be better than average (recognizing the average is a moving target).
- A decision rule for profit maximization (or loss minimization) is to produce where marginal revenue is greater than marginal cost.
- When comparing historical returns from different regions of the country and different sources (accounting firms, Universities, government agency) the following observations can be made:
  - Top producers (e.g., top 20 - 33 %) were considerably more profitable than the average, as measured by $/cow/y.
  - Top producers had similar year-to-year variability in returns as the average of all producers (i.e., they had higher returns, but experienced similar risk).
  - On average, top producers had larger operations.
  - On average, top producers were more productive, in terms of milk produced per cow per year.
  - On average, top producers had lower total costs ($/cow/y), but similar feed costs per cow.
  - Average herd turnover rate or herd replacement rate was not a strong indicator of profitability.
  - High profit groups received slightly higher milk price, on average; but the impact is small, indicating other factors are more important in explaining profitability differences.
- In a commodity market, being a low cost *per unit of production* (which is not the same as lowest cost per cow) is critical to business survival. This is typically accomplished by minimizing fixed costs via cows milked through facilities and milk produced per cow.
- Historically a business strategy of maximizing cows through facilities was a very effective strategy; however, as larger operations have become the norm in the industry, it will become increasingly important to also focus on high production per cow as a means to reduce costs per unit of production.

ECONOMIC PRINCIPLES

Most sectors of agriculture, both crops and livestock, have seen tremendous increases in price volatility in the last 10 - 15 years. Large swings in both input and output prices have resulted in corresponding large swings in year-to-year profitability. A natural concern for dairy owners and managers is to think about, and focus on, ways to manage this risk. However, predicting where prices might go in real time is challenging and managing price risk is difficult for numerous reasons (e.g., marketing tools/options available, basis risk, time frame, etc.). Thus, for many dairy owners and managers, it is more important to focus on things they have more control over. That is, making decisions based on sound economic principles and focusing on producing at the lowest cost/unit of production is important for long-term business survival. The number of dairy operations in the U.S. has been declining year-over-year for at least the last 50 years. That is, consolidation has been occurring long before the increase in price volatility, reinforcing the need to focus on much more than price risk.

The following are some economic principles/concepts that are important for managers to understand to ensure they are making sound economic business decisions.

1) Variable vs. fixed costs
2) Cash costs vs. economic costs
3) Price = cost
4) Marginal revenue vs. marginal cost

These principles are interrelated and help explain both the behavior of decision makers and trends that we observe in the industry. Following is a short explanation of each of the concepts.

Variable vs. fixed costs – Variable costs are defined as those costs that vary with additional production and fixed costs are those that are constant regardless of production. Fixed costs are directly related to the concept of economies of scale (scale). This relationship between fixed costs and economies of scale has been one of the major drivers of consolidation in the industry. We often use the term *dilution of fixed costs*, which means we can lower fixed costs *per unit of production* by increasing production. Classic examples of fixed costs are things such as facilities, management, overhead, etc. Variable costs are those costs that increase proportionately to production. For example, feed and supplies will increase as cows are added to an operation or as cows are milked more frequently. While fixed costs clearly affect the profitability of an operation, in the short run they can often be ignored when making decisions as to what is optimal (i.e., making decisions focusing on variable costs will lead to profit maximization or loss minimization).

Cash costs vs. economic costs – Managers easily can relate to cash costs, i.e., those costs that require a direct cash outlay (e.g., feed bill, vet bill, loan payment); whereas, economic costs are more difficult for many people to grasp. Put another way, cash costs are those things that show up on a cash flow statement with a lender. Cash and economic costs can be equal (and in many cases they are similar), but they can also vary considerably. Economic costs reflect the fact that all inputs (feed, supplies, labor, facilities, capital, etc.) need to be repaid or earn a competitive rate of return or else they will shift to another use in the long run. Cash and economic costs tend to differ for those things typically considered *fixed*. Economic costs incorporate the concept of *opportunity cost*, which may be different from what is actually paid (i.e., cash cost). Economic costs also incorporate the useful life of an asset as opposed to loan payments (or lack thereof), which is another reason economic costs can vary considerably from cash costs.

Price = cost – This economic principle implies that profits are equal to $0. It is important to recognize that the definition of profit here is *economic profit*, which means that all costs have been accounted for. A couple of additional qualifiers are needed regarding this statement -- profit equals zero, on average, in the long run, in a competitive industry. While many people get frustrated with this statement, i.e., "Why am I in business if I'm not making any profit?" it is important to recognize the main result of this statement – over time the below average producer will go out of business. More importantly, it points to the need to constantly strive to be better than average, recognizing this is a moving target, for long-term business survival (either that or accept below average rates of returns to some inputs – typically labor and capital).

Marginal revenue vs. marginal cost – This concept is a key rule for profit maximization and simply suggests that something should be done if the revenue from making that change (i.e., marginal revenue) is greater than the cost of making the change (i.e., marginal cost). This concept generally would assume that some costs are variable and some are fixed, but that is not a requirement. Assuming some costs are fixed, making decisions to where *the last unit of output* (marginal revenue) is equal or slightly greater than the *last unit of input* (marginal cost) ensures fixed costs are being diluted as much as possible. While the concept is fairly straightforward, identifying the marginal revenue and marginal costs associated with various decisions can become quite complex in some situations for dairy operations.

It is important when thinking about marginal cost to focus on cost per unit of production rather than cost per cow. For example, if some management intervention (e.g., reduce heat stress) is incorporated that improves production, the cost per cow likely will increase, but the cost per pound of milk produced most likely decreases. Thus, an intervention such as this would be profitable even though it increased total costs per cow. The optimal level of production will depend on how much it costs to add incremental milk and that will vary between operations and management abilities. That is, at some point adding incremental milk will not be profitable as the marginal cost will be greater than the marginal revenue. However, most dairies likely are not at this point and thus increasing milk production per cow will be profitable.

EFFICIENCY IS KEY TO PROFITABILITY

The preceding discussion about economic principles generally point to one thing – efficiency is key to profitability. Efficient use of resources is a common attribute of highly profitable operations across business sectors. When considering efficiency in the dairy business, there are three main areas to consider:

1) Efficient use of current facilities,
2) Economies of scale, and
3) Efficient use of the cows.

These concepts may increase or decrease costs per cow, but almost always decrease cost per unit of milk produced, which is the key to profitability in a commodity market.

Maximize the use of current facilities – The concept of making the most efficient use of current facilities is generally well understood and implemented across the industry. For example, dairies attempt to maximize parlor efficiency (one of the big fixed costs of a dairy) by milking the most cows possible through the parlor in a 24-hour period. However, this parlor efficiency is only realized if there are sufficient cows available on the farm to be milked. Herds that have low reproduction often see swings in cow numbers that result in inefficient use of facilities (e.g., parlor use not maximized, open stalls and/or stalls filled with low producing cows). In the last 10 years, we have seen a significant improvement in reproductive efficiencies and these improvements have helped to not only ensure that all cow slots on the dairy are full, but also that they are filled with a productive cow. As reproductive efficiencies increase, the ability to make voluntary culls (replace the least efficient cows) also increases. As top producers approach pregnancy rates > 25 %, the ability to maximize the use of current facilities is greater than most people ever thought possible.

Economies of scale – Similar to the importance of making sure that facilities are kept full at all times, the concept that larger dairies benefit dramatically from economies of scale has been behind many trends in the industry. Dairies in the Western US, particularly CA, benefitted from the benefits of milking a lot of cows on one facility. In fact, as early as 1997, the *average* cow in CA was found on a dairy with over 1000 cows, with many dairies milking over 2000 cows on a single site. At this same point in time, an *average* cow in Wisconsin would have been part of a dairy with just over 100 cows. CA and WI, the #1 and #2 dairy states in the country, are used to demonstrate a concept that helped to make the West very competitive in the dairy industry for a long time. However, in the last decade or so, this advantage for the West has essentially vanished as dairies in the Upper Midwest and Northeast have expanded and now are able to take advantage of similar economies of scale that the West has been doing for over 20 years. From 1997 to 2012, the size of the typical dairy in CA doubled (1159 to 2412 cows); however, the size of the typical dairy in WI increased almost 6X (113 to 639 cows; USDA and author calculations).

Milk production per cow – One of the key economic concepts discussed earlier was the idea that in a competitive market, price = cost. If this is true, that for the industry the price of milk is equal to the cost to produce it, on-average in the long run, then to survive in the industry one needs to be better than average. The two previous concepts highlight how efficient use of resources (e.g., cows through the parlor) and economies of scale have been used in the past to be competitive and be better than average. However, they also highlight the very important point that if you are not taking advantage of these concepts today, you are most certainly below average. With these two economic concepts becoming essentially table stakes, the final concept that can still be used to be better than average is to maximize production per cow, which will help dilute out maintenance cost on both a cow basis as well as a facilities basis over more pounds of milk.

The following section highlights multiple data sources looking at historical returns of dairy operations in different regions of the country. These data, from actual dairy operations, support the three concepts outlined above – efficient, farm size, productive – are key drivers of profitability differences between operations.

HISTORICAL DAIRY COSTS AND RETURNS

A common question often asked is "What are the primary factors that drive profitability differences across dairy operations?" One approach to gain insight into this question is to examine average historical returns from dairies (aggregated data) versus averages from a subgroup of dairies to determine what factors are related to higher or lower profitability. It is important to point out that this approach simply identifies factors that tend to be associated with higher profitability as opposed to a more rigorous approach that could identify statistically significant relationships. However, analyzing data from multiple sources and/or time periods with

Table 1. Data sources for analyses

Source	Type of Entity	Time period	Region	Subgroups
Karszes, J., W.A Knoblauch, and C. Dymond	University	1999-13	NY	Avg vs Top 20%
Nietzke & Faupel, P.C.	Accounting firm	2001-16	MI area	Avg vs Top 30%
California Department of Food and Agriculture	State agency	2006-16	CA	Herd size
Dhuyvetter[1]	University	2005-10	KS	Avg vs Top 33%
Genske, Mulder and Co., LLP	Accounting firm	2001-16	CA, ID, TX	Avg vs Top 25%

[1] Data for this analysis were from individual dairies by year and thus dairy averages reflected a multi-year average. All other data sources were annual comparisons (i.e., dairies included in the top percentile could vary from year to year).

this approach provides evidence as to how robust these results are.

Sources of data analyzed – Historical costs, returns, and limited production data were obtained from five different sources covering a range of geographies and analyses methodologies (Table 1). It can be seen that the various data sources cover a broad geographical region – i.e., Northeast, Midwest, Southern Plains, and West. The type of entity analyzing the data also varied, indicating the method of analysis is probably not consistent across data sources. Thus, while comparisons of groups within a data source are appropriate, comparing absolute values across data sources is less appropriate. The subgroups compared and the time periods vary slightly, but in all cases except one there were at least 10 years of historical data analyzed (and typically 16). The one study with less data (Dhuyvetter) used multi-year averages from individual dairies for comparison, which is preferred to year-by-year comparisons where the dairies included in the top percentile can vary. It is also important to point out that one study did not compare profitability subgroups (California Department of Food and Agriculture – CDFA). Rather than sort data based on profitability each year, these data were sorted based upon herd size. Thus, by definition, the difference in profitability between groups for CDFA is expected to be less than for the other data sources where groupings were based directly on profitability.

All herds versus top percentile groups – Table 2 reports average values of all herds versus the average of the top percentile groups for select variables. The difference in profitability ($/cow/y), remember the definition of profit varies by source, ranged from $154 to $523. The data source with the lowest difference (CDFA) is not surprising given that these data were sorted on herd size as discussed above. The key take home from this is that there are large differences between the average producers' returns and those of the top producers (keep in mind that the average group includes the top producers). The variability of returns across time (Range) is generally quite similar for all herds compared to the top percentile group indicating that while the most profitable dairies have considerably higher profit they have similar year-to-year variability in their returns. This is not surprising given that much of the year-to-year variability is due to milk and feed price changes that are generally out of the producers' control.

Across all data sources, the top percentile group averaged larger herd sizes compared to the all herds' average. It is important to point out that while this result holds on average across the time periods and for most individual years, it is not true for every year (data not shown). That is, there have been several years where the average herd size for the most profitable group is smaller than for the all herd average. This reinforces that *being big does not guarantee success* (i.e., it is more important to be *good* than to be *big*). This is particularly true when you consider that the typical dairy is getting larger and larger and therefore most dairies are already capturing the benefits of economies of scale. However, it also reinforces that economies of scale exist where there are benefits to diluting fixed costs across more cows, on average. On average, milk production (Milk/cow) was greater for the most profitable farms across all data sources. As with herd size, this result does not necessarily hold every individual year across all data sources. This result also reinforces that there are benefits to diluting fixed costs (both associated with the dairy and the individual cow) across higher production per cow. These two factors indicate that the most profitable farms use their resources more efficiently than the average dairy by milking more cows and getting more milk per cow.

The total cost on a per cow basis (cost/cow) was lower for the top percentile dairies compared to the all herds in all cases and ranged from -\$16 to -\$249. The CDFA data that were sorted on herd size, as opposed to profitability, showed a slightly higher cost/cow for the large herds compared to the small/medium herds average. This lower cost is once again indicative of spreading fixed costs over more cows, with the obvious exception of the CDFA data. Similar to total costs per cow, feed costs per cow (Feed/cow) are generally slightly lower for the most profitable dairies; however, this difference is fairly small. Thus a general conclusion might be that the most profitable dairies have lower total costs, but roughly the same feed costs as other dairies – yet those similar feed costs per cow are associated with slightly higher milk production.

Given that total costs per cow were lower for the top percentile dairies and milk production was higher, total costs per hundredweight of production (Cost/cwt) were also lower, ranging from \$0.70 to \$2.18 less/cwt. On average across the studies, the total cost/cwt of milk produced was \$1.21 lower for the top percentile dairies compared to the average for all herds. In times of extremely volatile markets, as the dairy industry has experienced in the last decade, this lower cost *per unit of production* can be an important part of risk management against lower prices. Even though feed costs per cow were similar, when that is combined with slightly higher milk production, feed costs/cwt of milk produced are lower for the top percentile dairies compared to the all herds average. This suggests that feed cost per cow is not a good indicator of profitability. Rather, feed cost per unit of production should be used.

Table 2. Summary of key indicators from various dairy data sources

Source/Group	Region	Years	$/cow/yr	Range	Herd size	Milk/cow	Cost/cow	Feed/cow	Cost/cwt	Feed/cwt	Milk price	Cull
Cornell[1]												
Avg	NY	1999-13	$510	$1,498	763	65.8	$3,221	$1,464	$13.34	$6.04	$16.74	33.8%
Top 20%	NY	1999-13	$932	$1,602	802	67.2	$2,972	$1,426	$12.04	$5.75	$16.89	32.2%
Difference			$422	$104	39	1.4	-$249	-$38	-$1.30	-$0.29	$0.15	-1.6%
N&F, P.C.[2]												
Avg	MI area	2001-16	$306	$2,018	1,380	63.9	$4,088	$1,749	$17.51	$7.48	$17.05	37.0%
Top 30%	MI area	2001-16	$637	$1,946	1,914	66.0	$3,928	$1,732	$16.31	$7.19	$17.15	37.1%
Difference			$331	-$72	534	2.1	-$160	-$17	-$1.20	-$0.29	$0.10	0.1%
CDFA[3]												
Small	CA	2006-16	$76	$1,826	359	69.4	$3,589	$2,152	$16.27	$9.75	$16.61	$279
Medium	CA	2006-16	$111	$1,902	887	71.3	$3,563	$2,132	$15.73	$9.40	$16.21	$310
Sm/Med avg	CA	2006-16	$94	$1,864	623	70.4	$3,576	$2,142	$16.00	$9.58	$16.41	$295
Large	CA	2006-16	$247	$2,175	2,218	75.1	$3,624	$2,192	$15.13	$9.14	$16.14	$327
Difference			$154	$311	1,595	4.8	$48	$50	-$0.87	-$0.43	-$0.27	$33
KSU[4]												
Avg	KS	2005-10	-$351	n/a	114	55.7	$3,964	$1,888	$19.50	$9.29	$16.29	26.0%
Top 33%	KS	2005-10	$172	n/a	133	62.4	$3,948	$1,956	$17.32	$8.58	$16.36	24.3%
Difference			$523	n/a	19	6.7	-$16	$68	-$2.18	-$0.71	$0.07	-1.7%
G, M and Co[5]												
Avg	CA	2001-16	$146	$1,501	1,822	69.6	$3,317	$1,817	$15.32	$8.36	$15.42	37.6%
Top 25%	CA	2001-16	$413	$1,577	2,661	70.3	$3,170	$1,742	$14.39	$7.89	$15.56	37.3%
Difference			$267	$76	840	0.7	-$147	-$75	-$0.94	-$0.47	$0.14	-0.3%

Table 2. Summary of key indicators from various dairy data sources (continued)

Source/Group	Region	Years	$/cow/yr	Range	Herd size	Milk/cow	Cost/cow	Feed/cow	Cost/cwt	Feed/cwt	Milk price	Cull
G, M and Co[5]												
Avg	ID	2001-16	$105	$1,553	1,898	69.6	$3,428	$1,807	$15.67	$8.22	$15.80	34.1%
Top 25%	ID	2001-16	$338	$1,970	2,172	70.8	$3,336	$1,761	$14.97	$7.88	$15.98	33.2%
Difference			$233	$417	274	1.2	-$92	-$46	-$0.70	-$0.34	$0.18	-0.9%
G, M and Co[5]												
Avg	TX	2001-16	$201	$1,877	1,928	66.0	$3,344	$1,658	$16.50	$8.13	$16.91	35.0%
Top 25%	TX	2001-16	$496	$1,824	2,371	68.1	$3,201	$1,610	$15.24	$7.63	$16.98	33.7%
Difference			$296	-$52	442	2.1	-$143	-$48	-$1.26	-$0.50	$0.07	-1.3%

[1] Karszes, et al., 2014
[2] Nietzke & Faupel, P.C., 2016
[3] California Department of Food and Agriculture, 2015
[4] Dhuyvetter, 2011
[5] Genske, Mulder and Co., LLP, 2017

Dairies in the top percentile groups averaged slightly higher milk prices, with the exception of the CDFA data, but the difference was relatively small ($0.12/cwt, excluding CDFA). Without knowing more information, it is impossible to tell what this slightly higher price is attributed to. Based on data regarding futures gains/losses (when available), it does not appear to be related to market timing/strategies (data not shown). Rather, it likely is due to volume and/or quality premiums. Regardless of what is driving the price difference, the impact is relatively small (e.g., $0.12/cwt on 70 lb/d is about $30/cow/y) compared to the total difference in profit indicating other factors are more important.

The final variable considered was a measure of herd turnover rate or annual culling. This variable is reported differently for each of the entities and thus cannot be compared across data sources. For example, the CDFA study reports an annual replacement cost ($/cow/y); whereas, all other studies report a turnover or culling rate (percent). The more profitable herds had a lower culling rate for five of the seven data sets, but two actually had a slightly higher culling rate or cost for the more profitable herds. Lower culling rates/lower herd turnover is preferred *all else equal*; however, it has been shown that a higher culling rate can be more profitable if it results in higher production (Dhuyvetter et al., 2007). In other words, without knowing why animals are leaving the herd (voluntary vs. involuntary) it is hard to determine if it is a good thing or a bad thing. Thus, these mixed results regarding the relationship between culling and profit grouping are not unexpected.

CONCLUSION

Currently many sectors in agriculture are facing tough margins due to market prices and thus it is easy and/or tempting to let these prices influence decisions that may not be optimal. As a general rule, in a commodity market being a low cost producer – *on a per unit of production basis* -- is critical for long-term business survival. Having an understanding of several key basic economic principles is important for both producers and their advisors to help them make sound economic decisions. While the need to make sound economic decisions is always important, it becomes even more critical in times of tight margins. Additionally, as operations get larger, the need to manage them more *business like* will also likely increase (i.e., base decisions more upon data and analyses and less on *gut feel*).

The profitability for dairy operations (and most all other agricultural enterprises) varies tremendously over time due to market cycles. While this variability can cause significant financial pain and hardship, it is important for producers and their advisors to focus on things they can control and manage. More importantly, profitability of dairy operations is extremely variable *across* operations indicating that management and how resources are used is important; thus, making well-informed management decisions related to production can make the difference between profit and loss and hence long-term business survival. Two factors that are consistent in explaining more profitable operations are greater herd size and production per cow – both of these are methods of spreading large fixed costs associated with running a dairy across more production (i.e., dilution of fixed costs).

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Leadership's Impact on Organizational Climate

Jorge M. Estrada, CEO
Leadership Coaching International, Inc.
Puyallup, WA
Email: jorge@leaders-coaching.com

INTRODUCTION

The changes in management of dairies include the shift in how we manage personnel in order to get the most out of their potential and passion for work. Dairies no longer have the same access to personnel applying as in years past. Changes in immigration reform are a risk to the labor pool available to dairies. Leadership and its impact on the entire employment cycle is one of the talent management aspects for managers to influence in their day-to-day operations, impacting results and the bottom line. The direct relationship of specific leadership behaviors on employee engagement raises the importance of the role of managers on employee productivity.

THE CASE FOR WHY PAY ATTENTION TO LEADER'S IMPACT

Must we make the case for why we should pay attention to the impact leaders have on their enterprise culture? For one, when leaders' behaviors negatively impact employee engagement, productivity goes down, which impacts the bottom line. The spectrum is wide for how leaders see their role in creating an organizational culture, from those who don't see that this matters, to those already doing great things to increase engagement. The reality our industry faces is that employees are just not coming around looking for jobs as much as they used to. We were spoiled for a number of years in that regard. Many owners and managers in the industry complain about the lack of applicants.

LEADERS DIRECTLY IMPACT CLIMATE AND CULTURE

It is well documented today that leaders and their styles and communication directly impact employee engagement, climate, and culture. Think about it, employees in any enterprise interact at different levels with their leaders, they are always looking to their behaviors and their words. This has been demonstrated in a Dutch study (Koene et al., 2002) where they examined the effect of different leadership styles on 2 financial measures of organizational performance and 3 measures of organizational climate in 50 supermarket stores of a large supermarket chain in the Netherlands. Their findings show a clear relationship of local leadership with the financial performance and organizational climate in the stores. The findings also show that the leadership styles have differential effects. Charismatic leadership and consideration have a substantial effect on climate and financial performance in the small stores, suggesting the relevance of personal leadership of the store manager in these small stores.

More than 60 y of research by the Hay Group shows that your leadership makes the biggest difference in team performance. Your behavior can create – or undermine – a climate of motivation, innovation, and productivity for your dairy team members. And the leadership styles you use can influence this climate by as much as 50 to 70 %.

Nothing saps performance like a bad team atmosphere. And the difference between a good and bad climate comes down to your leaders and how they behave.

It should be clear to you that at the dairy, we know our employees do better when they are motivated, involved, and clear about the job to be done. It's easier to give extra effort. But what makes a team productive?

Hay Group research shows that business performance can improve by up to 30 % when employees experience a great climate: energizing work, a positive atmosphere, and feeling part of their team's success. And a leader's behavior is the biggest factor in creating the right climate for their team. Improve your leaders' effectiveness and you'll improve business performance.
The best leaders create a climate that motivates their team. Regarding leadership styles, most leaders I come across on dairies are not self-aware or aware of the different leadership styles. Hay Group research shows that the world's top leaders draw on a repertoire of 6 different leadership styles; they change their approach according to the situation, the challenge, and the person they're dealing with at any given time. Most of the time, leaders are drawing on 1 or 2 leadership styles they have become used to using, and are probably very comfortable with, it is a habit.

STRATEGIC VERSUS OPERATIONAL FOCUS

Most dairies across the industry maintain an operational focus on human resources (**HR**). It is understandable, cows have to get milked, fed, bred, and managed. People help us complete those tasks. People have to get paid and their schedules managed. This traps most dairy managers and owners into the daily grind and operational focus, not leaving any time for thinking more strategically; i.e. taking on the big perspective for helping them solve some of their current talent management challenges. Take organizational development and training for example. What percentage of dairies take an operational approach to problems, like a mastitis problem? Do they chose training employees on the milking procedure and cleanliness, or even what is mastitis and how it is caused, versus a more strategic approach of asking a larger question on what development does the workforce need for the next fiscal year (which does likely involve training, but involves much more). As leaders take a more strategic focus for themselves, they can step back and work on the larger issues facing the dairy. One focus area is to be clear on what the main strategy is for people. You have strategies (or objectives) around levels of production, milk quality, and reproduction. Now you need to add a strategy or objective around people; whatever your focus will be for the year or next couple of years.

THE LEADER'S ROLE IN EMPLOYEE ENGAGEMENT AND PRODUCTIVITY

The era of trying to use techniques or gimmicks here and there to improve employee motivation is gone. Also, the era of pretending that my own leadership as a dairy leader doesn't impact climate, is also gone. Any business trying to make a dent in talent management must work on making their leaders self aware. Gostick and Elton (2009) have found in some studies that close to 50 % of an employee's engagement is driven by the quality of the relationship with their supervisor. They found, thru their research across different industries globally, how 5 fundamental behaviors of leaders impact engagement directly. When expressed by employees, these behaviors include:

a. My leader establishes trust with me: one of the key drivers in developing long lasting relationships.
b. My leader communicates with me constantly: another key driver in developing long lasting relationships, but also the role of continuous feedback (about 50% of the total communication needed from their leader)
c. My leader works with me to establish SMART goals. We work to fine tune goals for our work.
d. My leader holds me accountable: this accountability is held both ways, supporting communication and trust.
e. My leader recognizes my work: he/she sees me, tells me specifically what I am doing to support results.

Many organizations have focused their leaders on developing these qualities and have changed the percent engagement in their organizations, increasing productivity, and impacting the bottom line positively.

LEADERS AND THEIR IMMEDIATE TEAM OF MANAGERS/SUPERVISORS

In large part, the effectiveness of leaders on a dairy hinges on their effectiveness of managing their immediate team of managers or supervisors, and then in turn those managers managing their supervisors and supervisors managing their teams. Part of the operational focus that top leaders have many times, keeps them in the woods, going to the front lines even when they have middle managers/supervisors in place. In fact, the one team they need to work with most of the time is their direct team of managers and/or supervisors. Top leaders need to focus time and effort with that team, which is likely to be 5 to 8 people tops.

TRUST AS THE LUBRICANT TO MAKING THINGS HAPPEN

Warren Bennis, one of the most impactful leadership Gurus of the last decades put it perfectly, "trust is the lubrication that makes it possible for organizations to work." We saw above how developing trust in your organization can have a direct impact on the organizational climate, and on engagement. This is such a soft skill that many times dairies don't pay sufficient attention to developing it. Think about what trust makes possible. Trust allows you to be able to delegate work to your managers/supervisors. Trust allows you to have conversations that matter, that focus on feedback, be able to say what needs to be said. Trust allows you to let go of control and let others do what they need to do. You then can focus on the strategic, more important aspects of the current and future needs of the dairy. And when everyone around your dairy sees you modeling and practicing trust, they in turn trust back, thru the thick and thin of dairying these days. And this trust creates followership.

THE ROLE OF THE LEADER IN SUPPORTING THE ON-BOARDING PROCESS

Leaders of a dairy, more than anyone else, should have intricate involvement in the entire employee experience including talent acquisition and retention. From speaking to many out there about the company, to being constantly recruiting, instead of only when recruitment is urgent. Leaders need to have the skills of recruitment, selecting via experiential interviews, and getting involved in talking to new employees during orientation. Forming strong relationships during the on-boarding process with key people so that feedback can be provided all the time is imperative, particularly for those reporting directly to you. The entire employee experience, from applying to jobs on the dairy, thru the first 90 d of employment, should be directly supported by the top leaders. This impacts engagement of employees, early in their entire work life at your dairy.

THE LEADER'S ROLE IN MEASURING – METRICS

Successful dairies achieve their results in part because they are able to measure the impact of the work on results. Metrics for the talent management or HR part of your business has become a must. It is not enough anymore to just continue to hire, try to retain, and fire people. Your role as a leader must also include measuring aspects of HR, not just production measures. Some of the metrics dairies can measure are:

1. **Time to hire (avg time per hire).** This is a key metric for recruitment for a dairy. This metric shows the efficiency of the recruitment process and provides insight into the difficulty of filling a certain job position at the dairy.
2. **Cost per hire (total cost of hiring/the number of new hires).** Similar to the time to hire, the 'cost per hire' metric shows how much it costs the dairy to hire new employees. This also serves as an indicator of the efficiency of the recruitment process.
3. **Early turnover (% of recruits leaving in the first year, first 6 mo., first 3 mo., first month).** This is probably the most important metric to determine hiring success in a dairy. Early turnover is also very expensive. This metric can indicate whether there is a mis-match between the person and the dairy or between the person and his/her position. What is it that we are doing on dairies that results in the highest early turnover being experienced in the parlor? It usually takes weeks to months before employees have fully learned the ropes and reach their optimum productivity level. The cost of this turnover is important to assess for a dairy.
4. **Time till promotion (avg time in months until internal promotion).** This straightforward metric is useful in explaining why your high potentials and high performers leave the dairy.
5. **Revenue per employee (revenue/total number of employees).** This metric shows the efficiency of the dairy as a whole. The 'revenue per employee' metric is an indicator of the quality of hired employees. I have also seen on dairies a metric around pounds of milk shipped/employee, for milking employees. Similar metrics can be used in feeding, breeding, etc.
6. **Performance and potential (the 9-box grid).** The 9-box grid is a tool helpful in measuring and mapping both an individual's performance and potential in 3 levels. This model shows which employees are underperformers, valued specialists, emerging potentials, or top talents on a dairy. This metric is great for differentiating between, for example, wanted and unwanted turnover. A dairy's top leadership should consider using this tool to map talent once a year.
7. **Engagement rating.** An engaged workforce is a productive workforce on a dairy, or on any business for

that matter. Leaders must know how specific behaviors of theirs impact engagement, as mentioned above. Engagement might be the most important *soft* HR outcome. People who like their job and who are proud of their company are generally more engaged, even if the work environment is stressful and pressure is high. Engaged employees perform better and are more likely to perceive stress as an exciting challenge, not as a burden. Additionally, team engagement is an important metric for a team manager's success. There are several tools available out there to measure engagement (Galvez, 2018).

8. **Cost of HR per employee (e.g. $ 600).** This metric shows the cost efficiency of HR expressed in dollars.
9. **Ratio of HR professionals to employees (e.g. 1:60).** Another measure that shows HR's cost efficiency. A dairy with fully developed analytical capabilities should be able to have a smaller number of HR professionals do more.
10. **Ratio of HR business partners per employee (e.g. 1:80).** A similar metric to the previous one. Again, a set of highly developed analytic capabilities will enable HR to measure and predict the impact of HR policies. This will enable HR to be more efficient and reduce the number of business partners.
11. **Turnover (number of leavers/total population in the organization)**. This metric shows how many workers leave the dairy in a given year. When combined with, for instance, a performance metric, the *turnover* metric can track the difference in attrition in high and low performers. Preferably you would like to see low performers leave the dairy and high performers stay. This metric also provides HR business partners with a great amount of information about the departments and functions in which employees feel at home, and where in the organization they do not want to work. Additionally, attrition could be a key metric in measuring a manager's success.
12. **Absenteeism (absence %).** Like turnover, absenteeism is also a strong indicator of dissatisfaction and a predictor of turnover on a dairy. This metric can give information to prevent this kind of leave, as long-term absence can be very costly. Again, differences between individual managers and departments are very interesting indicators of (potential) problems and bottlenecks.

As you can see there are a lot of different examples of HR metrics. While some metrics are easier to implement than others, all of them provide insights into the workforce and HR. Combining these insights will prove vital for making substantiated decisions with proven impact.

CONCLUSIONS

Leaders on dairies must know the impact they create in their organizational climate and culture.

- Beginning with working on being more self-aware of their own leadership styles and learning about other styles,

- Continuously working on specific behaviors that drive engagement, and then
- Moving to actually measuring the impact of self on culture.

Leaders can and should work on evolving their behaviors so that they can create the best impact on productivity and results.

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New Trends in Transition Cow Management: Separating Facts from Fiction

Ric R. Grummer, Ph.D.
Professor Emeritus
University of Wisconsin-Madison
Email: rgrummer@wisc.edu

INTRODUCTION

Management of transition cows (generally regarded as cows between 3 wk prior to calving and 3 wk postcalving) continues to be intensely studied. A review of the literature for the past 2 y indicates the following areas being actively researched:

- Factors affecting immune function and oxidative stress,
- Interrelationships between environment and animal behavior or welfare,
- The effects of subclinical hypocalcemia on animal performance and effects of oral calcium supplements on blood calcium,
- Nutritional effects on gene expression in a variety of tissues,
- Benefits of cooling dry cows,
- Implications of reducing dry period length,
- The effects of hyperketonemia on animal performance, and
- Electronic monitoring (e.g., rumination time) for predicting animal health and well-being.

The quantity of research is overwhelming and beyond the scope of this presentation as well as beyond my area of expertise. Therefore, for this presentation I will discuss some of the recent trends in managing energy status of transition cows that are fast becoming dogma and provide some cautionary notes for you to think about. Hence the title includes the wordage *fact or fiction*.

CONTROLLING DRY PERIOD ENERGY STATUS

Numerous studies have indicated that there is no need to *steam up* cows being fed a totally mixed ration, i.e., feed a separate pre-fresh diet for the final few weeks before calving that has increased grain content (Grummer, 2008). If that is the case, then a dairy producer should be able to feed a diet with a consistent energy density for the entire dry period. Doing so would save money as feed costs would be lower and there would be less labor required for mixing diets if only 1 dry cow diet (rather than 2) needed to be mixed.

Many studies (e.g., Janovick and Drakley, 2010; Silva-del-Rio et al., 2010; Mann et al., 2015; Zenobi et al., 2018) have compared the feeding of a controlled energy diet (**CED**; also known as the Goldilocks diet) versus overfeeding for the dry period. The concept behind the CED is to formulate a diet, that when consumed *ad libitum*, would meet but not exceed the cow's energy requirement. These diets are high in fiber, low in nonstructural carbohydrate, and contain considerable amounts of low quality forage, often wheat or oat straw. Most of the studies have compared feeding the CED to one that provides 40 to 50 % more than the cow's requirement. That may seem high, but often in experiments treatments are exaggerated to increase the likelihood of seeing treatment differences. However, historically, dairy producers commonly have over fed energy to dry cows because of forages being higher quality than necessary.

In theory, cows fed above their maintenance energy requirement during the entire dry period become similar to human type II diabetics; they become more insulin resistant. Since insulin suppresses fat mobilization, a more insulin resistant cow will have higher rates of fat mobilization. Consequently, the cow becomes more susceptible to fatty liver, ketosis, and other health problems. When conducting research to evaluate CED, there have been 2 ways to achieve the controlled energy intake treatment. In a few studies, the approach has been to limit feed a diet relatively rich in energy that would normally lead to body weight gain if consumed *ad libitum*. While feasible with cows fed in stanchion barns, it is not practical for cows housed in groups. Most studies have included low energy feeds, such as straw, so that energy requirements are met when cows consume the diet *ad libitum*.

The effects of overfeeding cows on blood nonesterified fatty acids (**NEFA**, an indicator of fat mobilization), beta-hydroxybutyrate (**BHBA**, a ketone body), and liver fat are very consistent across trials (Dann et al., 2005, 2006; Douglas et al., 2006; Grum et al., 1996; Janovick and Drackley, 2010; Janovick et al., 2011; Richards, 2011; Mann et al., 2015; Zenobi et

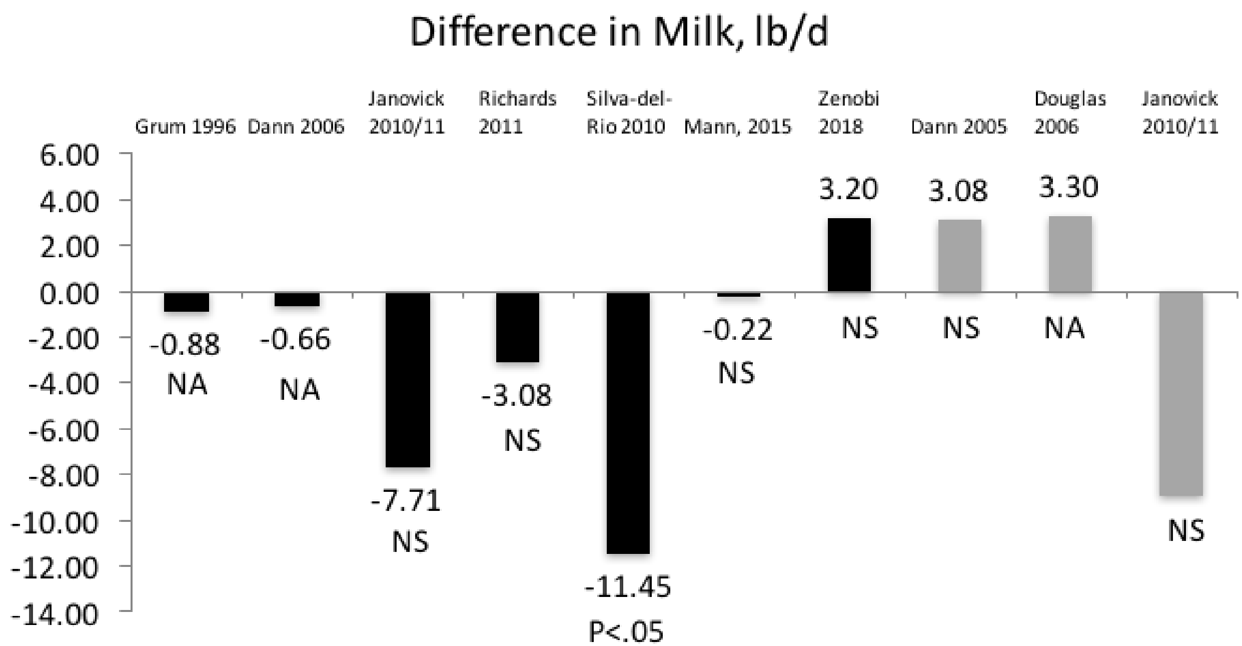

Figure 1. Differences in milk yield between dry cows fed a controlled energy diet (80 - 100 % of energy requirements) vs. a diet that provides in excess of requirements (typically 140 – 150 % of requirements). Black bars represent trials in which energy intake was controlled by feeding a high fiber (straw) diet; grey bars represent trials in which energy intake was controlled by limiting feed intake (cows receiving the high energy treatment and controlled energy treatment were the same diet but fed at different amounts. NA = there were other treatments in the experiment and the statistical analysis did not allow a direct contrast between these 2 treatments), NS = a statistical contrast between controlled energy and excess energy intake was available, but differences between treatment were not significant.

al., 2018); consequently, there is no controversy on these effects and, therefore, they will not be discussed here. Higher NEFA, BHBA and liver fat in cows that are overfed energy are consistent with the hypothesis that these cows are diabetic-like. Typically, there may be a transient increase in feed intake postcalving when feeding CED compared to higher energy diets, but it is only for a few days and may be related to CED treated cows relishing a diet that finally has more grain! One other benefit of feeding CED may be lower incidence of displaced abomasum (Cordoso, 2013). Unquestionably, these trials indicate that cows fed a CED have an improved *metabolic profile* and consequently there has been wide spread adoption of this feeding practice.

However, what I consider to be controversial is the milk production response of cows that are fed CED. Figures 1, 2, and 3 contain a summary of milk yield, fat %, and fat- or energy-corrected milk yield. Some of the trials have observed reductions in milk yield, although this has not been a consistent response. Much more consistent is the reduction in milk fat percentage and fat- or energy-corrected milk yield.

The reduction in milk fat percent, and potentially milk yield, makes biological sense. If cows fed CED precalving are mobilizing less body fat postcalving, compared to those overfed energy during the dry period, then there is less NEFA available

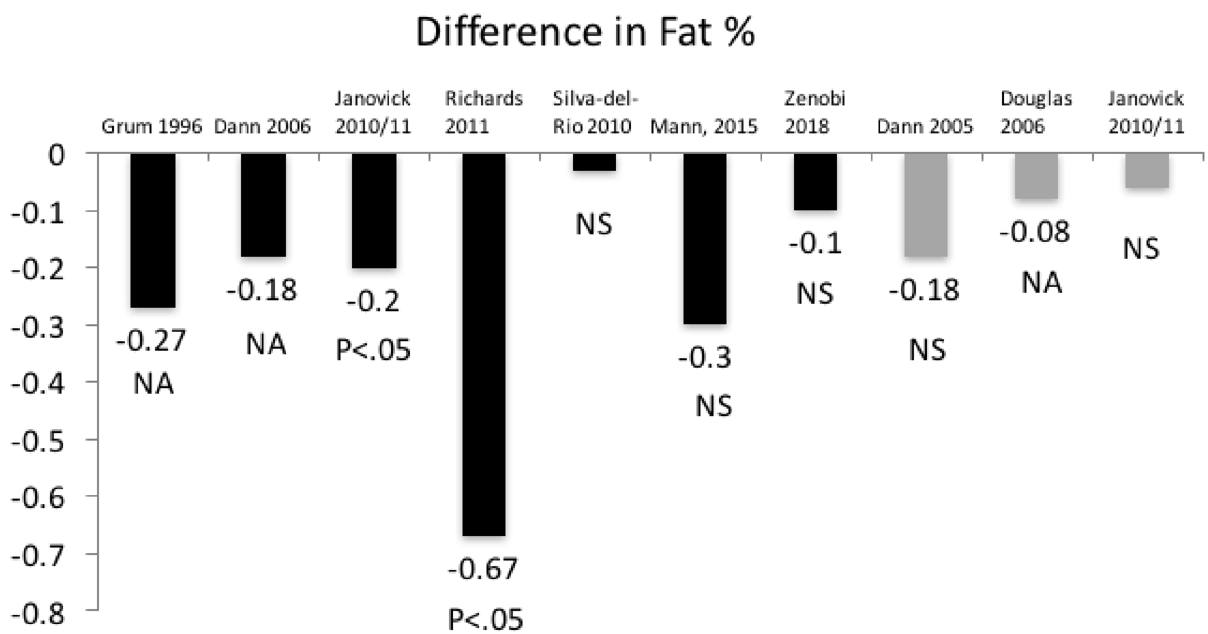

Figure 2. Differences in milk fat percentage units between dry cows fed a controlled energy diet (80 - 100 % of energy requirements) vs. a diet that provides in excess of requirements (typically 140 - 150 % of requirements). Black bars represent trials in which energy intake was controlled by feeding a high fiber (straw) diet; grey bars represent trials in which energy intake was controlled by limiting feed intake (cows receiving the high energy treatment and controlled energy treatment were the same diet but fed at different amounts). NA = there were other treatments in the experiment and the statistical analysis did not allow a direct contrast between these 2 treatments, NS = a statistical contrast between controlled energy and excess energy intake was available, but differences between treatment were not significant.

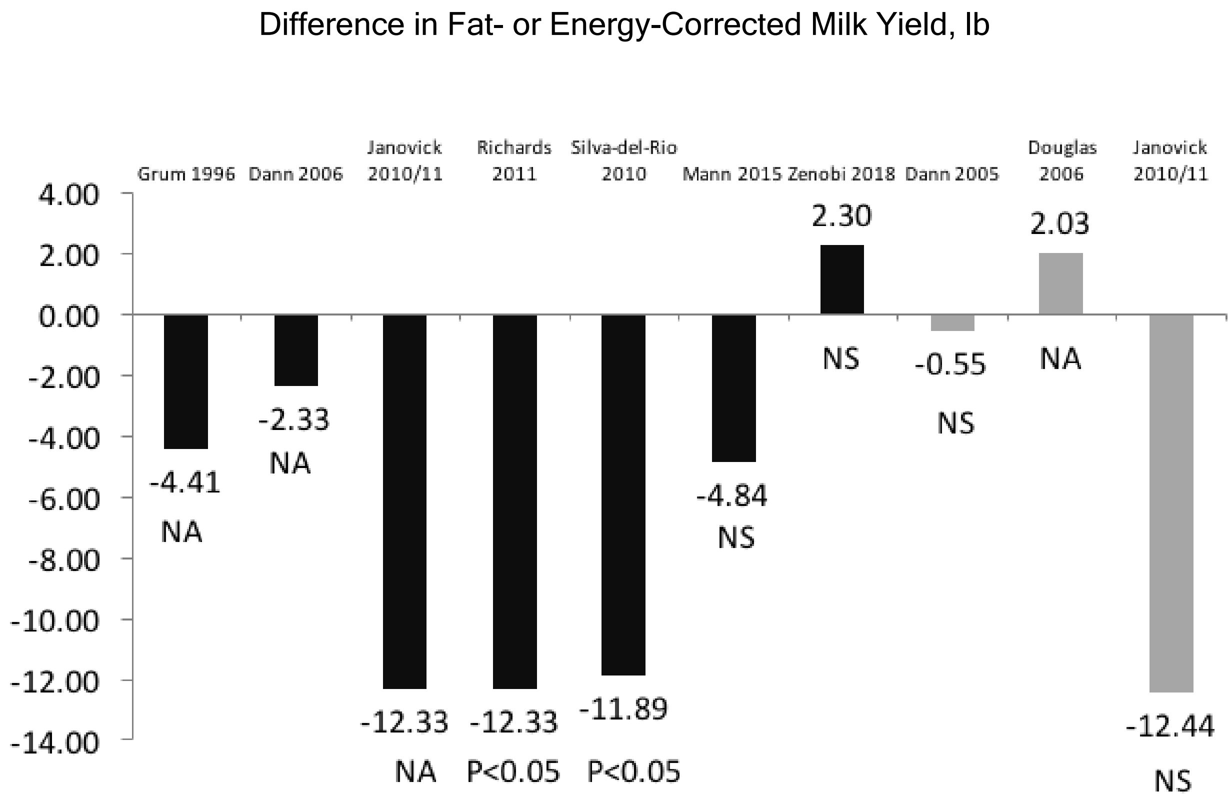

Figure 3. Differences in fat- or energy-corrected milk yield between dry cows fed a controlled energy diet (80 – 100 % of energy requirements) vs. a diet that provides in excess of requirements (typically 150 % of requirements). Black bars represent trials in which energy intake was controlled by feeding a high fiber (straw) diet; grey bars represent trials in which energy intake was controlled by limiting feed intake (cows receiving the high energy treatment and controlled energy treatment were the same diet but fed at different amounts). NA = there were other treatments in the experiment and the statistical analysis did not allow a direct contrast between these two treatments, NS = a statistical contrast between controlled energy and excess energy intake was available, but differences between treatment were not significant.

to the mammary gland for an energy source or for a precursor for milk fat synthesis. Unfortunately, most of the trials have implemented a very high level of energy intake for the overfed cows (140-150 % of requirement). Further research is needed to determine the optimal energy density for producers that elect to feed diets with a consistent energy density throughout the dry period. In other words, is there a dry cow diet energy density that provides some protection against excessive fat mobilization while not sacrificing energy output by the mammary gland? In the meantime, caution should be exercised when employing CED. I would recommend feeding slightly above energy requirements, perhaps target .65 - 67 Mcal/lb of dry matter (**DM**). I would also avoid feeding more than 25 – 30 % straw. Lastly, feeding a CED should not preclude the inclusion of a close-up transition diet. Even though this may not be needed from an energy density perspective, there are numerous diet supplements that can be incorporated into a close-up diet to assist the cow through the transition period (e.g., monensin, choline, yeast, anionic salts).

MAXIMIZING DRY MATTER AND ENERGY INTAKE IMMEDIATELY POSTPARTUM

Surprisingly, there is very little research to identify optimal starch or fiber feeding in cows during the first 3 wk postpartum. Most early lactation research in this area has commenced when cows are beyond 3 wk postpartum. Consequently, there are many questions on this topic, but few answers. For example,

- Should cows be fed straw or other low quality forage right after calving?
- Does this help acclimate them to higher starch diets (avoid acidosis) or help maintain a rumen mat and reduce the incidence of displaced abomasum?
- Does it promote greater feed intake?
- Or, can fresh cows be fed the same diet formulated for the highest producing cows?

From a management standpoint, it begs the question: "Do I need to mix a separate diet for cows during the first few weeks postpartum?" All these questions have intensified since Dr. Mike Allen proposed the *hepatic oxidation theory*, also known as **HOT** (Allen et al., 2009). His theory states that if too much fermentable carbohydrate (e.g. starch) is fed immediately after calving, feed intake will be depressed. The hypothesized mechanism of action is through propionate production in the rumen. If too much propionate is delivered to the liver, end products of hepatic propionate oxidation signal to the brain to decrease feed intake. There is excellent evidence in support of the theory that has come through a model employing propionate infusion into the rumen of dairy cows. Some have refuted this theory in the belief that very little propionate gets oxidized by the liver during the first few weeks after calving due to the tremendous demand for hepatic conversion of propionate to glucose (McCarthy et al., 2013). Applied feeding trials testing the theory with transition dairy cows are limited.

From the limited amount of research available, it appears that early lactation cows often respond with more milk production when energy density of the diet is increased by increasing non-fiber carbohydrate (**NFC**) and decreasing neutral detergent fiber (**NDF**) (Anderson et al., 2003; Rabelo et al., 2003, 2005). In general, other strategies to increase energy availability to the early postpartum cow (e.g. increase starch content, increase starch fermentability, increase NDF digestibility, supplement monensin) have not had negative effects on intake or lactation performance and in some cases have had positive effects (Dann et al., 1999; Adin et al., 2009; Rockwell and Allen, 2016; McCarthy et al., 2015).

There are some feeding trials supporting the HOT. Nelson et al. (2011) lowered starch content for the first 21 d postcalving (while maintaining NE_l/lb DM) and improved feed intake and milk yield. They fed controlled (low starch) energy diets pre-fresh, while higher starch levels were fed pre-fresh in other trials (Rabelo et al., 2003, 2005; McCarthy et al., 2015). Perhaps acclimation to high starch diets needs to occur immediately post-fresh if dietary starch content is extremely low in pre-fresh diets? After an initial trial showed no effects of starch fermentability on dry matter intake (**DMI**) (Rockwell and Allen, 2016), a second trial was conducted to determine if starch fermentability may be more crucial at higher dietary starch levels (Albornoz and Allen, 2016). Indeed, feeding high moisture corn decreased DMI compared to dry corn (lower fermentability of starch) and the effect was more dramatic when diets contained 28 % starch as compared to 22 % starch.

Clearly, more research is needed to determine factors that influence optimum starch content in fresh cow diets. Based on the limited data available, fresh cows should be able to be fed diets containing 25 – 26 % starch without incurring any problems. Higher starch diets may be tolerated by fresh cows and could be explored to promote greater energy intake. However, doing so should be done judiciously with careful observation for signs of subclinical acidosis or effects of HOT. This can probably best be monitored by closely following fresh pen feed intakes. Additionally, all the research trials cited above employed a totally mixed ration. Conclusions from these studies may not apply when feeding management deviates from that, e.g., feeding concentrates separate from forage, grazing systems, etc.

NEFA AND BHBA TESTING TO MONITOR ENERGY STATUS

When body fat is mobilized during the transition period, NEFA enters into the blood stream and approximately 25 – 30 % of the NEFA are taken up by the liver. If the capacity to oxidize NEFA or export NEFA from the liver as a constituent of lipoprotein triglyceride is exceeded, partial oxidation to ketone bodies may occur. One of those is BHBA. Consequently, blood NEFA and BHBA are used to monitor energy status of transition dairy cows. Indeed, there is considerable research describing the negative effects that excessive blood NEFA or BHBA may have on cellular, tissue, and whole animal function (Grummer, 2016). On farm, blood BHBA is most commonly measured because it is very easy to do so in a quantitative fashion using hand held meters. Over the past several years, BHBA testing has become common place on commercial dairies. Several excellent large epidemiological studies have been conducted to determine *cut-off* blood concentrations, that when exceeded, signal potential losses in subsequent milk yield, poorer health, and decreases in reproductive efficiency (for a review see Overton et al., 2017). Rather consistently, these studies report BHBA values above 1.2 - 1.4 mmol/L are detrimental to the cow and hence should be classified as hyperketonemic. Protocols usually recommend sampling 12 - 15 cows between 4 and 14 d postpartum and if 10 – 15 % of cows test above 1.2 or 1.4 mmol/L, an *alarm level* has been reached. On many farms, all fresh cows are tested and treated (propylene glycol drench is most common) if BHBA concentrations exceeds the cut point.

As the popularity of BHBA testing has increased, I regularly receive questions that go something like this: “I am testing BHBA and my herd is above the alarm level, but my cows are milking like crazy. What should I do?” As with most blood tests, we tend to oversimplify and make black and white interpretation of the results. Unfortunately, this can be problematic. Consider the results of a multi-state university study (Harrison et al., 1990) in which herds were subdivided so that for several decades, cows and subsequent offspring were bred with semen from bulls with superior genetic merit or semen from bulls with average genetic merit. For the first 75 d postpartum, cows with superior genetic merit produced 11.6 lb/d more milk than cows with average genetic merit and yield differences started immediately after calving. However, during the first 3 - 5 wk postpartum, genetically superior cows did not consume more feed. Consequently, they were in a more severe negative energy balance (**NEB**) and had higher blood NEFA and BHBA. A recent study (n = 570) from the University of Wisconsin-Madison (Rathbun et al., 2017) indicated that cows testing above 1.2 mmol BHBA/L produced 6-10 lb more milk per day for the first 30 d postpartum. The hyperketonemic cows were treated with 300 ml propylene glycol/d for 3 d, but clearly there was insufficient energy from propylene glycol to account for the increase in milk yield. A recent study from the Netherlands (Vanholder et al., 2015) surveyed 23 herds (1,149 cows) and found that first test day milk was 7.3 lb/d higher for cows testing between 1.2 to 2.9 mmol BHBA/L than those testing less than 1.2 mmol/L. How can one reconcile results from large epidemiological studies suggesting milk production is reduced when BHBA exceeds 1.2 mmol/L with studies cited above in which high BHBA was associated with higher milk yield? Realize that the inference from the epidemiological studies is to a very large population of cows and the *cut-off* value of 1.2 or 1.4 mmol/L is really a *one size fits all* recommendation. However, there is herd-to-herd variation and cows in high producing herds will likely test higher for BHBA and may need a different cut point. This needs to be researched.

For the record, I am not against BHBA testing! However, interpretation of results may be complicated and must be done with caution. BHBA testing allows producers to monitor relative changes in energy balance and can be helpful for early detection and troubleshooting of energy-related problems within the herd. That said, I tell producers whose herds are above the alarm level, are achieving high levels of milk production, and are not having problematic issues related to NEB: R-E-L-A-X!

MANAGING FAT STORES

Body fat stores are a valuable resource. During early lactation, energy from one point of body condition loss is approximately equivalent to energy in 550 lb of diet DM and can support approximately 1300 lb of fat-corrected milk production. As previously mentioned, there are potential drawbacks when fat mobilization becomes excessive, e.g., fatty liver, ketosis, impaired immune system, and reduced reproductive efficiency. On the flip side, NEFA (and BHBA) are an extremely important source of energy and are precursors for milk fat synthesis during the time of NEB. Hence a balance must be struck between supporting lactation and avoiding health and reproductive problems.

Historically, managing fat mobilization has been restricted to strategies that reduce fatty acid mobilization (e.g, niacin, CED). As previously discussed, this approach may potentially reduce fat test and milk yield, especially fat or energy-corrected milk yield. Dr. John Newbold (2005) stated it very well: "Nutritional restriction to adipose tissue mobilisation might be necessary, but there is a philosophical problem. We have selected cows that have increased reliance on mobilised body reserves as a source of nutrients for milk production. The farmer has paid the geneticist for this - are we now going to ask him to pay the nutritionist to work in the opposite direction? We have our priorities wrong. We should explore what can be done to help the liver deal with mobilised fatty acids before considering whether we need to try to reduce the amount of fatty acid supplied to the liver." Choline is the only compound that has been shown to help the liver *deal* with mobilized fatty acids (Goselink et al., 2013; Chandler and White, 2017). Choline helps the liver export fatty acids as a constituent of lipoprotein triglyceride. Once exported from the liver, the fatty acids can become available to the mammary gland to support milk synthesis. Dietary choline is degraded, so if supplemented, it must be encapsulated to protect it from ruminal degradation. A meta-analysis of trials in which choline has been supplemented to transition cows beginning prior to calving shows that it supports lactation (+ 4.9 lb milk/d; Grummer, 2012) and the benefits of feeding choline during the 6-wk transition period carry over for the entire lactation (Zenobi et al., 2017). If compounds such as niacin are fed to suppress fat mobilization, I generally recommend that use occurs prepartum and ceases when lactation begins.

FINAL COMMENTS

Sometimes good concepts catch on and become dogma. This presentation was not intended to discourage you from implementing CED during the dry period, reducing fermentable starch feeding in post-fresh diets, or testing for BHBA. The purpose was to point out that often times management recommendations and guidelines become overly simplistic and are presented as *one size fits all*. That is rarely the case! In reality, novel management concepts and resulting recommendations are seldom completely fact or completely fiction.

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Drinking Water Considerations on Dry Lot Dairies

J.P. Harner[1], J.G. Martin[2], M.J. Brouk[1], D. Greene[3], J.M. Zulovich[4] and D.V. Armstrong[5]
[1]Kansas State University, [2]JGM Dairy Design, [3]Barton, Kiefer & Associates,
[4]University of Missouri and [5]University of Arizona
Email: jharner@ksu.edu

INTRODUCTION

Dairy cows require large amounts of water daily. Sources of water for the dairy cow include:

1) Drinking or free water,
2) Water (moisture) in feed, and
3) Metabolic water.

An average of 83 % (range: 7 to 97 %) of total water consumed by cattle is from drinking water. Metabolic water is insignificant compared with water ingested freely or contained within feeds. Some major factors affecting water intake by dairy cattle are: dry matter intake (**DMI**), milk production, dry matter (**DM**) content of the diet, temperature and environment, and sodium (**Na**) intake (NRC, 2001).

A small limitation in water intake may decrease DMI by 1 to 2.2 lb/d, which may limit peak milk production by 2 to 5 lb/d. Lactating dairy cows require total water intakes of 4.4 to 5 lb of water/1 lb of milk produced. The total daily water intake comes from both drinking and moisture (water) in the consumed ration. Cows have peak water intake during the hours when feed intake is greatest.

RELATIONSHIP BETWEEN WATER AND FEED

Kume et al. (2010) studied the impact of feed water intake and free water intake (**FWI**). The average total water requirement was 26.0 gal/d (**gpd**)/cow with approximately 5.5 gal (20 %) obtained from the feed source and the balance from drinking water. The ratio of FWI to milk was 2.6 and ratio of FWI to DMI was 3.74.

Appuhamy et al. (2016) reviewed multiple research studies involving FWI of dairy cows. They reported average water consumption of all of the studies was 19.9 ± 6.4 gpd/cow. The range of the full data set was from 2.9 to 32.3 gpd. The average ratio of FWI to DMI was 4.1 and average ratio of FWI to milk production was 2.67. Dry cow water consumption was reported as 9.3 gpd/cow with a ratio of FWI to DMI of 3.1.

Dry matter content of the diet has been shown to affect the FWI. Holter and Urban (1992) showed a decrease of ration DM from 50 to 30 % decreased FWI by 8.75 gpd. Ration DM percent can have a negative impact when considering total water intake. When ration DM percent increases, FWI per cow increases; but total water intake decreases. Murphy (1992) suggests this happens because of the need to excrete more nitrogen (**N**) and potassium (**K**) in urine when feeding wet diets. Holter and Urban (1992) concluded that this is only relevant to cows on high protein pasture or succulent silage.

Dewhurst et al. (1998) performed an experiment to examine the effects of silage characteristics on water intakes. In this study, 16 silages were used with DM ranging from 15.9 to 28.0 %. Free water intake per cow ranged from 5.3 to 23.8 gpd, total water intakes from 12.8 to 32.8 gpd, and milk production from 36 to 85 lb/d. They found that FWI increased with increasing silage DM concentration. It also confirmed other reports suggesting that FWI replaces silage water at a rate less than 1:1.

Winchester and Morris (1956) found water intake per unit of DMI remained constant from 10 to 40 °F. From 10 to 40 °F, cows consumed about 0.16 gal (1.36 lb) of water/lb of DMI. At the peak of 90 °F cows consumed 0.38 gal (3.18 lb) of water/lb of DMI. These water to feed ratios may be different with today's genetics in the dairy industry.

Murphy et al. (1983), Holter and Urban (1992), Little and Shaw (1978), Stockdale and King (1983), Castle and Thomas (1975), and Dahlborn et al. (1998) have published formulas for predicting water consumption. The Murphy et al. (1983) formula is as follows:

$$FWI = 15.99 + 1.58 \times DMI + 0.90 \times MY + 0.05 \times SI + 1.20 \times Temp_{min}$$

Where:

FWI is free water intake in kg/d,
DMI is dry matter intake (kg/d),
MY is milk yield (kg/d),
SI is sodium intake (g/d) and
$Temp_{min}$ is minimum temperature (°C).

The 2001 NRC recommendations used the formula developed by Murphy et al. (1983) to estimate FWI. The Murphy et al. (1983) formula shows that drinking water changes 1.58 kg for every 1 kg change in DMI, 0.90 kg for every 1 kg in milk yield, 0.05 kg for each 1 g change in Na intake, and 1.20 kg for every 1 °C change. This shows that DMI, minimum temperature, and milk yield have more influence than Na intake on drinking water intake. Potts (2012) developed a meta-analysis using data from 50 individual studies recording water intake by dairy cattle. Ration water intake (**RWI**) was calculated from the DMI and DM percent reported. Table 3 reports the actual FWI from the data set and what the prediction equations estimate for FWI using the meta-analysis data points. Using the 116 data points, the ratio of FWI to milk yield averaged 2.82. Figure 1 shows the relationship between daily milk production and FWI based on the 2.82 ratio. Daily water requirements are proportional to increased milk production.

Table 1. Comparison of four prediction equations of free water intake (FWI) to prediction equations of actual water intakes and milk efficiency from all data points (116) from scientific papers where dry mater intake, ration water intake, and milk yield were reported.

Data Source	Estimated Free Water Intake (gal/cow/day)	Predicted Milk Efficiency (lb water/lb milk)
Actual	21.4	2.82
Little and Shaw (1978)	20.1	2.64
Stockdale and King (1983)	10.2	1.35
Potts et al. (2012)	21.4	2.82
Castle and Thomas (1975)	22.6	2.92
Dahlborn et al. (1998)	18.7	2.46

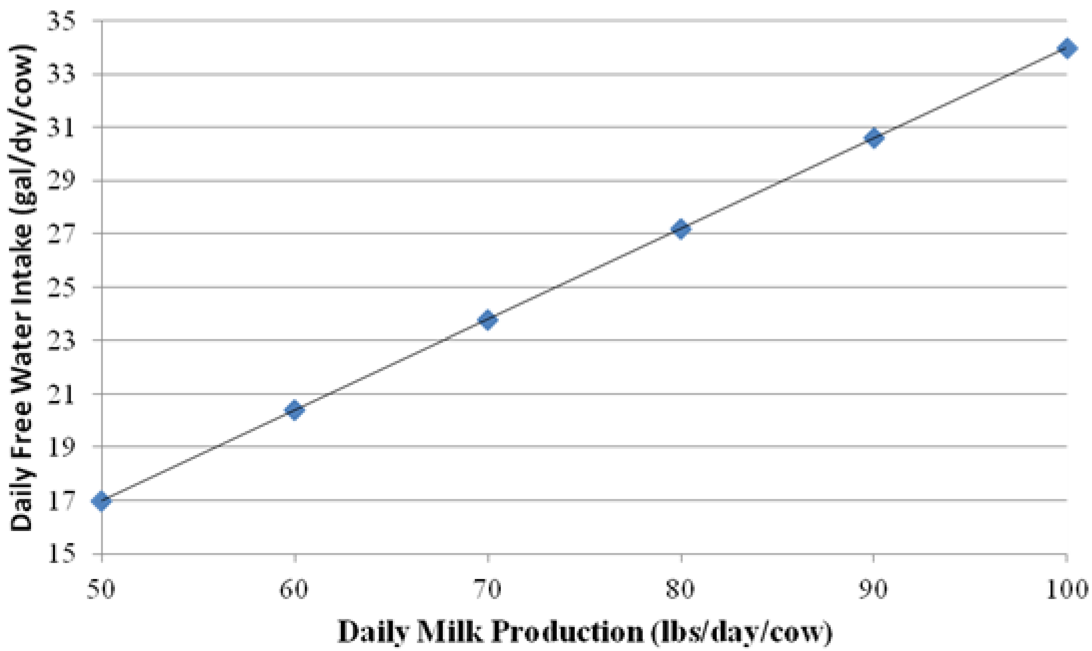

Figure 1. Relationship between daily milk production and free water intake assuming a water intake to milk ratio of 2.82 based on scientific data (Potts, 2012).

DRINKING WATER REQUIREMENTS OF DAIRY COWS

Total water consumption of lactating milk cows is between 30 and 50 gpd/cow. Brugger and Dorsey (2008) compiled total dairy farm water usage from January 1, 2005 to December 31, 2006. This study was conducted on a 1,000 cow dairy farm in northwest Ohio where the average high temperature was 60 ˚F and the average low temperature was 39 ˚F. Over the 2 y period the total farm water usage averaged 29.6 gpd/cow. The total water usage included the milk center and drinking water usage but there was minimum cow cooling. Free water intake by the dairy cows was lowest during the month of December 2005 at 11.6 gpd/cow and the highest was in July 2005 at 33.8 gpd/cow. The cows alone consumed an average of 23.3 gpd/cow of FWI over the entire study period. No information on milk yield, DMI, or ration moisture content was provided.

Zuagg (1989) summarized the daily water usage on 5 dairies in Arizona. Early lactating cows drank between 29 and 35 gpd/cow, while late lactating cows drank 25 to 28 gpd/cow. This was a function of milk production and feed intake. Water consumption was less than 20 gpd/cow during the dry period on all of the farms.

Impact of Water Restriction

Severe water restriction can have a profound impact on productivity and feeding behavior of cattle. Steiger Burgos et al. (2001) evaluated the impact of 50 and 75 % restriction in water intake for 8 d. The 50 % water restriction resulted in a 21.3 % decrease in 24-h feed intake, a 57.4 % reduction in size of first meal, and a 41 % increase in number of meals/24 h. The 75 % reduction in water intake resulted in an 11.3 % decrease in 24-h feed intake, a

53 % reduction in the size of the first meal every day, and a 31 % increase in the number of meals/24 h. A reduction in size of the first meal each day of greater than 50 % accounted for most of the suppression in feed intake.

Andersson et al. (1984) looked at the effect of water flow rates in water cups on the consumption of water by tied up dairy cows. Using flow rates of 0.5, 1.8, and 3 gal/min they reported that Swedish Red and White breed cows drank 2.5 and 3.3 gpd more water with the increased flow rates. The time spent drinking by each group of cows also decreased from 37 min/d on the low flow rate to 7 min/d on the high flow rate. The cows also spent more times per day drinking with low flow rates (40 times/d) than the high flow rate (30 times/d). No data was provided on the impact of flow rate on water wastage. While the cows spent more time drinking, the flow rates did not affect milk production or DMI. However, at the high flow rates there was a tendency for increased milk production. These results indicate that cows will adapt to slower flow rates by changing their drinking behavior (Andersson et al., 1984).

Andersson and Lindgren (1987) studied the consumption of water by cows by restricting access to water during feeding. The treatments were a control where cows had free access to drinking water, no drinking water for 1 h after feedings, and no drinking water for 2 h after feeding. They reported that cows prefer to have water available during feeding. However, cows will consume 60 to 80 % of total water consumption within a few hours after feeding. There were no differences in water intakes between treatments once water was made available. However, the cows with free access to drinking water drank within 15 min after eating (Andersson and Lindgren, 1987).

Dairy Cow Drinking Behaviors

Data collected during the study comparing the impact of dietary fiber (Dado and Allen, 1995) indicates a cow will drink about 1.5 gal of water/trip to a watering trough at a rate of 1.27 gpm. They also found a cow will spend about 12 to 16 min/d drinking water. Their measured FWI were lower than most studies. However, using this data, a cow makes about 18 trips/d if she drinks 28 gpd and consumes 1.5 gal/visit. Assuming a 12-ft watering trough and 6 cows present, the minimum water flow rate would be 8 gpm. A single cow will spend approximately 25 min/d at watering troughs. Even though cows spend only about 2.5 % of their time at the water trough, adequate water space recommendations per cow are to provide 2 ft of tank perimeter or 1 watering space/15 to 20 cows (MWPS, 1997).

Cardot et al. (2008) evaluated water intake on dairy cows housed in freestall housing. Milk production was 58.3 lb ± 13.0 lb/cow/d and FWI was 22.1 ± 4.5 gpd/cow. Cows went to the water troughs an average of 7.3 ± 2.8 times/d. During each visit average water consumption was 3.4 ±1.3 gal/cow/drinking bout. Almost 75 % of the water was consumed between 6:00 and 19:00 and 75 % of the cows visited a water trough within 2 h after the evening milking (2X/d milking). Cardot et al. (2008) estimated 25 % of the daily water consumption occurred within 2 h of milking or feeding. In this study the average FWI to DMI ratio was 4.0. The FWI to milk ratio was 3.15. The 22.1 gpd FWI reported by Cardot et al. (2008) was similar to 22.17 gpd of FWI reported by Meyer et al. (2004) and

21.7 gpd reported by Melin et al. (2005). Drinking bouts per day ranged from 5.2 (Jago et al., 2005) to 9.4 (Huzzey et al., 2005) and average water intake was very similar. Cardot et al. (2008) also reported between 6:00 and 19:00 that 20 and 55 % of the cows hourly visited a water trough. During the 20:00 to 5:00 time period less than 10 % of the dairy cows visited a water trough. This study also examined the effect of overstocking and found that FWI/cow/d did not vary as stocking density per water bowl was increased from 11 to 40 %, but volume of water drank per visit increased while drinking bouts (visit to a water bowl) decreased. The study demonstrated overstocking a pen changes the drinking behavior of dairy cows.

Gavojdian et al. (2010) evaluated the seasonal effect on drinking behavior of dairy cows. The average number of drinking bouts was 8.15 during the winter, but 16.10 during the summer. The actual time spent drinking was 0.82 min in the winter and 0.84 min in the summer. During the winter 85.9 % of the water was consumed between the hours of 7:00 and 21:00, however during the summer only 65.5 % was consumed during that same time period. Water consumption was equally distributed during the three 8-h time periods during the summer months. Gavojdian et al. (2010) found cows visited a water trough within 63.4 ± 7.89 min following milking during the 7:00 to 14:00 period. During the 14:00 to 21:00 time period, cows visited a water trough within 33.4 ± 7.99 min. In the winter time, the time between milking and first drink of water almost doubled as compared to the summer months. They found during the summer months cows consumed water within 6.5 min after finishing ration consumption.

IMPACT OF WATER TROUGH DESIGN

Filho et al. (2004) found grazing dairy cows prefer larger water troughs. They found dairy cows prefer water troughs that are 24 in high compared to 12 in. Water consumption, drinking time, and number of sips all increased with the higher water trough. Drinking time was 27.26 ± 6.22 sec and consumption was 2.45 ± 0.60 gal/visit from the higher water trough.

Brouk et al. (2001) studied the difference in water consumption based on the location of the water trough in a freestall building during summer months. More water was consumed at the center cross alleys than end cross alleys (Table 2). McFarland et al. (1998) reported similar results in an earlier study. Brouk et al. (2001) found cows consumed about 8 % of their daily water needs at watering troughs located near the parlor exit. In addition, daily refilling water troughs after tipping was equal to 10 to 15 % of the daily drinking water requirements. They reported average water disappearance per cow in the housing area ranged from 34.5 to 36.5 gpd/cow in the 4-row freestall pens. They estimated 85 % of the water disappearance was due to drinking and 15 % from tipping / cleaning water troughs daily. The ratio of water disappearance per pound of milk production ranged from 3.6 to 5.4 lb of water/lb of milk, while average milk production per pen ranged from 56 to 98 lb/cow/d. Water consumption ranged from 24.2 to 28.1 gpd/cow in the 2-row freestall, excluding water drank at the parlor exit. The water to milk ratio ranged from 2.6 to 3.5. These values do not include the water drank at the milk parlor exit. Approximately 9 % of the drinking water requirements were met from the 2 additional water troughs located along the back alley of the freestall barn. On a third dairy, water consumption ranged from 28.8 to 30.3 gpd/cow with milk production ranging from 64.3 to 85.6 lb/cow/d. The water to milk ratio ranged from 2.9 to 3.8, while the water to feed ratio averaged 4.2 on this dairy. Water usage tended to decrease as milk production increased. The FWI to milk ratio generally ranged from 3 to 4 lb of water/lb of milk.

WATER TROUGH DESIGN CONSIDERATIONS FOR DRY LOT DAIRIES

Typically, the water trough recommendation is based on 2 to 3 in/cow. This recommendation is based on dairy cows in freestall housing systems, where water troughs are 100 to 140 ft apart. In a freestall housing system a cow is generally within 60 to 80 ft of a water trough. Data shows cows will drink at the nearest water troughs. Dry lot facilities often have 2 or 3 water troughs distributed along the length of the feedline with spacing 200 to 300 ft apart. Occasionally owners opt to place the water troughs at the back of the pen or midway along the fence line increasing the walking time between the feed line and water trough. It is important to have adequate space for all of the cows to be able to reach water in a timely manner following milking and feeding. One research study showed during summer months cows were drinking water within 6.5 min of leaving the feed line. Research shows at least 75 % of the cows will obtain a drink within 2 h following one of these events. Additionally, cows locked in headlocks for extended periods will quickly seek water upon release, particularly during hot weather. While the normal recommendation is 2 to 3 in of water space/cow, owners may want to consider 3 to 4 in of water space for water troughs not shaded (i.e., outside a building). If adequate water space is available upon exiting the milk center, then 3 in/cow should be adequate in a pen. If water is only available in the pen, then 4 in of water trough/cow should be considered. Cows may tend to surge more to a water trough in open lots due to the summer heat, particularly in late afternoon when temperatures drop. As a general guideline, there should be a water trough within 250 - 300 ft of all feed spaces. Water space should be provided for 10 to 12.5 % of the feeding spaces or assuming 150 cows/300 ft of feed space (24 in/feed space or head lock) or a minimum of 15 to 20 cows should be able to

Table 2. Percentage of drinking water utilization at different locations within pens from a dairy where there were 2 water troughs in each cross-over alley (Brouk et al., 2001).

Location of Water Trough	Location in Cross-over	Percentage of Total Utilization	Percentage of Location within Cross-over	Percentage of Total Water Utilization by Cross-over
Pen exit cross-over	Feedlane	12.0	62.2	19.3
	Stall	7.3	37.8	
Cross-over between exit and middle	Feedlane	16.1	62.2	25.9
	Stall	9.8	37.8	
Middle cross-over	Feedlane	15.9	58.2	27.3
	Stall	11.4	41.8	
Cross-over between middle and end of pen	Feedlane	10.9	62.3	17.5
	Stall	6.6	37.7	
Pen end cross-over	Feedlane	5.5	55.0	10.0

drink at once. This recommendation is based on 5 min/cow/drinking event (includes time standing or blocking water trough and drinking time) and assumes all cows will drink within a 40 - 60 min period following milking and/or feeding. Using 3 in of watering space/feed space, it is recommended having 40 ft of trough/150 feeding spaces in the pen and then appropriate watering space along the return lane from the parlor. It is important to remember, the water trough design is not based on average; but on the 2 h period immediately following the afternoon milking when at least 75 % or more of the cows will obtain a drink of water upon exiting the parlor. If we assume 15 min return time from parlor to the pen and 45 min for feeding. Basically, the design has to be based on 75 % of the cows being able to drink within a 60 min period.

Some producers opt to use round or wider tanks to allow cows to drink anywhere around the perimeter of the water trough. Rectangular water troughs where cows drink from both sides should be at least 3 ft wide. Cows should be able to drink without interference from a cow on the opposite side of the water trough. A 10 - 12 ft concrete apron around all sides of a water trough accessible by cows is necessary to provide firm footing. Concrete aprons, if possible, should be sloped towards the feed apron to prevent water/mud holes within the pen.

IMPACT OF WALKING SPEED

Research has shown that cow's walking speed in alleys is 2.5 to 5 ft/sec (**fps**). Chapinal et al. (2009) estimated walking speed of cows with different gait scores. Regardless of hoof health, cows walking speed was 4.9 ± 0.20 fps. Walker et al. (2010) reported walking speeds of 1.7 to 4.5 fps in a study on ground reaction forces. Flower et al. (2006) also evaluated gait speed for cows with and without sole ulcers before and after milking. All cows after milking had a longer stride 4 vs 4.4 ft and walked faster 2.8 vs 3.2 fps. They reported cows without sole ulcers had before and after milking walking speeds of 3.5 vs 2.9 fps. Anon (2018) suggested average herd walking speed was 2.5 fps, but dependent upon many design factors. Telezhenko and Bergsten (2005) reported walking speeds varied from 3.2 to 3.7 fps and stride length ranged from 4.4 to 5.2 ft, depending on floor surface (concrete, rubber, sand, etc.).

Cow walking speed should be considered when calculating the time between the feed line and water trough. The 300 ft maximum distance recommendation between feed line and water trough suggests cows should be able to reach a water trough in 2 min or less based on a walking speed of 3 fps. In freestall housing systems the time interval is less than ½ min, but there are impedances to cow movement in the alleys. Cows seek water within 6.5 min after feeding during the summer months. However, there are other natural activities such as:

- Backing away from the feed line,
- Approaching a water trough occupied by other cows, or
- Distractions

that must be factored into any time allowance.

WATER AVAILABILITY EXITING THE MILKING PARLOR

Brouk et al. (2001) found cows will consume 8 - 10 % of their daily water intake if water is available at the end of exit lanes. A reasonable goal is for all of the cows exiting the milking platform within a 5 min time period to be able to drink simultaneously. For parallel or herringbone style parlors, the rule of thumb to determine water trough length is number of milking units per one side of parlor x 2 ft. For example, the exiting water trough from a double 40 parlor should be at least 80 ft (40 units x 2 ft/unit) long. Table 3 shows the minimum recommended water trough length for the exit of a parallel or herringbone parlor. Table 4 shows the minimum recommended water trough length for rotary parlors based on stall entry time. Regardless of parlor type or sorting technologies, cows should be able to obtain a drink of water within 5 min of exiting the milking unit or stall. Water troughs located along the outside walls of parallel parlors provide access to water immediately; however, cows tend to bunch and may interfere with the next group being released. Another option is to locate parlor exit water troughs along the transfer lane back from the parlor. This also allows cows to pass through foot baths and sorting technologies before drinking. Water troughs should be located within 300 ft of the milk platform. Dairies not able to install water troughs within 300 ft of the milking platform should consider adding an extra water trough near the pen entrance. Often the first water trough is 200 to 300 ft from the pen entrance/exit gate to the milk parlor.

Table 3. Recommendations on water trough length for parallel or herringbone parlors

Parallel or Herringbone Parlor	Minimum Length of Water Trough
Double 20	40 ft
Double 30	60 ft
Double 40	80 ft
Double 50	100 ft

The 300 ft distance should enable cows to drink within 5 min of exiting the milking platform, assuming normal walking speeds and some distractions. Assuming cows drink 1.5 gal/milking prior to returning to their pen, the refill rate of the water trough should be designed based on 0.5 gpm/cow drinking space. If the water trough is designed for 50 cows, the water system should be able to supply 25 gpm (50 cows x 0.5 gpm/cow). If the water demand is not met, the subsequent groups coming to drink may not have adequate water available.

Table 4. Recommendations on water trough length for rotary parlors

Rotary Parlor Stall Entry Time	Equivalent Parallel Parlor	Minimum Length of Water Trough
8 sec	D40	80 ft
7 sec	D44	88 ft
6 sec	D50	100 ft
5 sec	D60	120 ft

WATER AVAILABILITY WHILE MILKING

Water access during milking has been minimally documented; therefore it is uncertain whether the cost of installing water access in the parlor is economically viable given the complexities of implementation and unknown returns. Some dairies with parallel parlors provide water at the milking units, but the water troughs have to be cleaned frequently. Cows may still want to congregate around a water trough after leaving the parlor anyway. With rotary parlors, challenges that must be addressed include: meeting water demands, flushing or cleaning the water trough, and water splash on to electronic components. Currently water troughs are not available to be attached to the inside of the rotary, making water availability during the approximate 6 min rotation time an issue. However, water cups (similar to those used in a tie stall facility) might be an option. In addition, the parlor manufacturer must be contacted to determine if the rotary parlor can handle the extra weight, which is estimated to be 1,200 to 2,000 lb for a 100-stall rotary parlor.

SUMMARY

Research on water consumption in dry lot dairies is not readily available, but ratios of FWI to milk or DMI are consistent. Therefore, dairies should be able to estimate daily free water consumption based on DMI or milk yield. As a starting point, water intakes can be estimated by 0.4 gal/lb of milk (ratio of 3.3 water intake to milk yield) or 0.5 gal/lb of DMI (ratio of 4.2 water intake to DMI). This is average water consumption and some studies suggest cows will drink 25 to 50 % more water during the summer months as compared to winter months. Since water consumption data is not available on dry lot dairies, which tend to be located in hotter/drier regions, the estimates above should be considered as minimum water consumption design recommendations.

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Evaluation of Heat Stress Abatement on Texas Dairy Farms

B.W. Jones, Ph.D.*† and E.R. Jordan, Ph.D.‡
*Tarleton State University, †Texas A&M AgriLife Research,
and ‡Texas A&M AgriLife Extension
Email: BWJONES@tarleton.edu

INTRODUCTION

Heat stress is a major challenge important to the global dairy industry (Polsky and von Keyserlingk, 2017). In the US dairy industry alone, heat stress results in economic losses estimated at $900 million (St-Pierre et al., 2003). Heat stress is defined as the entirety of external forces (temperature, wind speed, etc.) acting on an animal that elicits an increase in body temperature (Dikmen and Hansen, 2009). Temperature humidity index (**THI**) considers ambient temperature and humidity to estimate the cooling requirements needed by cattle to improve the efficiency of management practices to dissipate heat. Cooling standards should start at a THI of 68 (Collier et al., 2011).

Heat stress can cause increased morbidity and mortality, negatively impact milk production (Renaudeau et al., 2012), and impair reproductive performance (Polsky and von Keyserlingk, 2017). De Rensis and Scaramuzzi (2003) reported the decrease in conception rates during warmer months to be between 20 and 30 %. West (2003) highlighted different studies that reported decreases in milk production upward of 0.32 kg (0.70 lb)/unit increase of THI.

Cooling options can occur based on the philosophies of convection, conduction, radiation, and evaporation (Polsky and von Keyserlingk, 2017). Fans help with convection cooling, sprinklers help with evaporative cooling, shade helps reduce solar radiation exposure, and stall base temperature can help with conduction cooling (Polsky and von Keyserlingk, 2017). Two disadvantages exist when employing evaporative cooling: large amounts of fresh water are used in cooling and large amounts of waste water must be properly managed (Polsky and von Keyserlingk, 2017). Modifying dairy cattle housing environments helps to reduce the adverse effects associated with heat stress (Beede and Collier, 1986). The objective of this study was to evaluate heat abatement systems on 3 different dairy farms in the High Plains region.

MATERIALS AND METHODS

Study farms

This study was conducted on 3 farms in the Texas panhandle 1 wk/mo from June 2017 to September 2017. Farm A utilized a cross ventilated barn for lactating cows with a freestall barn and dry lot for close-up and far off dry cows, respectively. Farm B utilized dry lot pens for both lactating and close-up dry cows, swamp coolers in the parlor, and holding pen cooling with soakers and fans. Farm C utilized dry lot pens for lactating cows with shades.

Vaginal temperature measurement

Vaginal temperature was recorded every 10 min using Thermochron iButtons (Embedded data systems, Lawrenceburg, KY). The Thermochron iButtons were placed into intravaginal devices (CIDRs, Zoetis) that lacked the progesterone either from being blank or being used twice

Table 1. Pens on each farm that housed a HOBO U23 Pro v2 External Temperature/Relative Humidity Data Logger - U23-001 (Onset, Bourne, MA)

Farm Letter	Pen Description
A	Inlet lactating cow pen Middle lactating cow pen Exhaust lactating cow pen Far-off dry cow dry lot pen Close-up dry cow freestall pen
B	Dry lot lactating cow pen
C	Dry lot lactating cow pen

previously to remove progesterone. The intravaginal devices were inserted into 10 cows/pen location on Monday morning and removed Friday morning of each study week.

Cattle demographics

Cow demographics information was obtained from Dairy Comp 305 (Valley Ag Software, Tulare, CA). Only pregnant, multiparous cattle were enrolled in the study. Milk yield for lactating cattle enrolled in the study was equal to or greater than whole farm average milk yield to ensure high yielding cattle were enrolled in the study.

Statistical analysis

All data analysis was performed in SAS (Version 9.4, SAS Institute, Inc. Cary, NC). Data points were removed if relative humidity equaled 0, vaginal temperatures were < 36° C, or vaginal temperature were > 42° C. The MEANS procedure of SAS was used to evaluate the means, minimums, and maximums of temperature, relative humidity, and THI for each pen. The inlet pen in the cross ventilated barn for farm A did not have any data recorded as the data logger was lost. The MIXED procedure of SAS was used to evaluate the fixed effects of pen, milk yield, and their 2-way interaction on vaginal temperature. Stepwise backward elimination was used to remove non-significant interactions ($P \geq 0.05$). Main effects were kept in the model regardless of significance. The MIXED procedure of SAS was also used to evaluate the fixed effects of pen, milk yield, and their 2-way interaction on vaginal temperature when outside THI was > 68. Stepwise backward elimination was used to remove non-significant interactions ($P \geq 0.05$). Main effects were kept in the model regardless of significance.

Table 2. Temperature, relative humidity, and temperature humidity index means (± SD)[1] for each pen on farm

Temperature mean ± SD	Relative humidity mean ± SD	Temperature humidity index mean ± SD	Pen	Farm
-	-	-	Inlet	A
71.80 ± 3.64	85.84 ± 6.44	70.71 ± 3.08	Middle	
73.17 ± 3.81	84.72 ± 5.87	71.88 ± 3.18	Exhaust	
76.38 ± 9.48	59.72 ± 19.46	71.59 ± 5.41	Far-off dry cow dry lot pen	
76.51 ± 9.08	60.73 ± 19.28	71.86 ± 5.42	Close-up dry cow Freestall pen	
76.50 ± 10.65	60.71 ± 20.69	71.63 ± 6.54	Dry lot	B
77.97 ± 9.82	60.29 ± 21.13	72.96 ± 5.92	Dry lot	C

[1]Ambient temperature and relative humidity was measured with a HOBO U23 Pro v2 External Temperature/Relative Humidity Data Logger - U23-001 (Onset, Bourne, MA) every 10 min. Temperature humidity index was computed using the following formula (NOAA and Administration 1976): THI = temperature (°F) - [0.55 – (0.55 × relative humidity/100)] × [temperature (°F) – 58.8].

Table 3. Temperature, relative humidity, and temperature humidity index[1] minimums and maximums for each pen on farm

Temperature minimum, ºF	Temperature Maximum, ºF	Relative humidity minimum	Relative humidity maximum	Temperature humidity index minimum	Temperature humidity index maximum	Pen	Farm
-	-	-	-	-	-	Inlet	A
64.20	80.80	58.30	97.36	63.89	76.30	Middle	
65.75	82.09	56.93	95.68	65.27	77.83	Exhaust	
55.26	98.23	26.98	99.61	55.58	82.73	Far-off dry cow dry lot pen	
56.83	95.95	26.94	97.66	56.56	81.81	Close-up dry cow Freestall pen	
53.03	99.96	26.69	100.00	53.42	84.10	Dry lot	B
55.17	99.96	26.95	100.00	55.55	83.81	Dry lot	C

[1]Ambient temperature and relative humidity was measured with a HOBO U23 Pro v2 External Temperature/Relative Humidity Data Logger - U23-001 (Onset, Bourne, MA) every 10 min. Temperature humidity index was computed using the following formula (NOAA and Administration 1976): THI = temperature (ºF) - [0.55 – (0.55 × relative humidity/100)] × [temperature (ºF) – 58.8].

RESULTS

Description of each farm and pen that cattle were housed in is depicted in Table 1. Means, minimum, and maximums for temperature, relative humidity and THI are depicted in table 2 and 3. Vaginal temperature least square means (± SE) for lactating and dry cows in each pen are displayed in Table 4 and 5, respectively. Lactating cows housed in the dry lot on Farm C had the greatest vaginal temperatures when compared to cows housed in different pens on Farm A and B. Within the cross ventilated barn, cattle housed in the pen near the exhaust had the greatest vaginal temperatures compared to the inlet and middle pens. Cows housed in a dry lot pen on farm B had the least vaginal temperatures compared to both Farm A and C. Cows housed on farm B were subject to cooling in the holding pen and parlor; where Farm C did not utilize cooling in the holding pen. The cows on farm B were milked at 6:30 a.m., 3:00 p.m. and 11:00 p.m.; thus this holding pen and parlor cooling may have been strategically timed to mitigate the effects of heat stress.

Table 4. Least squares means (± SE)[1] of vaginal temperatures[2] for each pen of lactating cattle

Vaginal Temperature, °C	Pen	Farm
39.03 ± 0.02[c]	Inlet	A
39.10 ± 0.03[bc]	Middle	
39.12 ± 0.03[b]	Exhaust	
38.97 ± 0.02[d]	Dry lot	B
39.33 ± 0.02[a]	Dry lot	C

[1]Least squares means (± SD) were evaluated using the MIXED procedure of SAS® (Version 9.3 SAS Institute, Inc., Cary, NC)
[2]Vaginal temperatures were measured every 10 min via Thermochron iButtons (Embedded data systems, Lawrenceburg, KY) placed into intravaginal devices, like CIDR's but lacking the progesterone either from being blank or being used twice previously to remove progesterone
[a,b,c,d] Pairs with different superscript letters ([a,b,c]) are significantly different ($P \leq 0.05$)

Table 5. Least squares means (± SE)[1] of vaginal temperatures[2] for each pen of dry cattle

Vaginal Temperature, °C	Pen	Farm
39.15 ± 0.02[b]	Far-off dry cow dry lot pen	A
39.41 ± 0.02[a]	Close-up dry cow Freestall pen	
39.16 ± 0.02[b]	Dry lot	B

[1]Least squares means (± SD) were evaluated using the MIXED procedure of SAS® (Version 9.3 SAS Institute, Inc., Cary, NC)
2Vaginal temperatures were measured every 10 min via Thermochron iButtons (Embedded data systems, Lawrenceburg, KY) placed into intravaginal devices, like CIDR's but lacking the progesterone either from being blank or being used twice previously to remove progesterone
[a,b] Pairs with different superscript letters ([a,b]) are significantly different ($P \leq 0.05$)

CONCLUSIONS

In conclusion, differences were observed in cattle housed in different housing options. Mean vaginal temperatures were greatest in a drylot pen with limited cooling. Cows housed in a dry lot pen may experience more heat stress due to less heat abatement strategies. However, when drylot cows received strategic cooling, vaginal temperatures were lowest. Additional investigations using cows matched for milk production need to be conducted to determine if this is a reflection of the increased heat increment associated with the higher milk production of cows in the cross-ventilated barn.

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Managing Reproduction of Lactating Dairy Cows with Limited Use of Timed AI Programs

Luís G. D. Mendonça, D.V.M., M.S. and Alexandre L. A. Scanavez, D.V.M.
Department of Animal Sciences and Industry
Kansas State University, Manhattan, KS
Email: mendonca@k-state.edu

INTRODUCTION

Reproductive efficiency of dairy herds is impacted by pregnancy per AI (**P/AI**) and AI submission rate. Because milk yield is negatively correlated with estrus expression in dairy cows, timed AI (**TAI**) protocols were developed to synchronize ovulation in order to submit cows to AI in a timely manner and partly eliminate the need of detecting estrus on dairy farms. In the past decades, researchers have refined and perfected these TAI programs, which has helped producers increase reproductive efficiency, and consequently, profitability. Even though it is well-accepted that the use of TAI protocols maximizes overall efficiency in dairy herds, recent increases in public concerns related to food production may force the dairy industry to further justify current reproductive management practices. Because TAI programs require a set of treatments to synchronize the estrous cycle, research evaluating the impact of reducing the use of synchronization protocols on dairy farms is needed. Reproductive efficiency influences cost of production on dairy farms; therefore, it is of utmost importance for the dairy industry to estimate potential ramifications associated with the possible demand for reduced use of reproductive synchronization protocols.

Apart from the convenience of synchronizing the day and time of AI, synchronization protocols enable insemination of all eligible cows promptly. Hence, TAI programs eliminate the issue of reduced expression of estrus that may be caused by several intrinsic and extrinsic factors, such as anovular condition, flooring not conducive to estrus expression, and high milk production. Nonetheless, estrus detection continues to be a common part of reproductive programs for some herds because estrus detection aids (e.g., tail paint, pressure-sensitive devices, and activity monitoring systems) have been shown to be effective tools to identify cows in estrus. Indeed, these tools may be used to overcome the issue of reduced estrus expression in dairy cows.

In a hypothetical scenario in which a farm would have to reduce the use of synchronization protocols, increasing the number of inseminations based on estrus detection would be required. Although a series of research projects compared reproductive efficiency of programs that rely mostly on TAI vs. programs focusing on AI based on estrus detection, these experiments were not tailored to test the impact of reducing number of treatments before AI. Instead, researchers aimed to compare 2 management strategies. Summarizing findings from these experiments, however, is valuable to comprehend possible consequences of having to minimize the number of treatments in reproductive programs.

REDUCING THE USE OF TIMED AI PROGRAMS FOR FIRST SERVICE

Reproductive programs that do not rely predominantly on TAI for first service use prostaglandin treatment(s) to induce estrus expression. On the other hand, programs that aim to submit a large proportion of cows to TAI use a combination of GnRH and prostaglandin to synchronize the estrous cycle, and ultimately, timing of ovulation. As a result, programs relying on TAI protocols require several treatments before AI. Both strategies have proven to be effective methods to maximize reproductive efficiency; however, studies comparing economic outcomes of these strategies are limited. In order to evaluate which reproductive management strategy results in greater reproductive efficiency and profitability, several aspects must be considered, such as P/AI and days in milk (**DIM**) at first service, calving interval, and proportion of cows initiating a subsequent lactation.

Researchers have reported inconsistent results for P/AI for both strategies. Chebel and Santos (2010) and Dolecheck et al. (2016) reported no difference in P/AI between both strategies. In contrast, Stevenson et al. (2014) and Fricke et al. (2014) showed that first-service P/AI is greater for cows submitted to TAI compared with cows inseminated based on estrus. A recent meta-analysis, a method used to compile findings from several studies, demonstrated that submitting 100 % of cows to a TAI program for first service results in greater P/AI compared with a program that incorporates estrus detection (Borchardt et al., 2016). Although DIM at first service is an important aspect to consider when comparing both strategies, this indicator will be highly influenced by the design of the reproductive program. Programs that rely mostly on TAI can submit cows to first service in a desirable range of DIM. Conversely, reproductive programs that rely mostly on estrus detection may have extended DIM at first service because of cows in anovular condition, poor response to prostaglandin treatment(s), or inefficient estrus detection. Using prostaglandin to induce luteolysis and estrus expression is effective only in cows with a corpus luteum (**CL**) present. Cows in an anovular condition or not bearing a CL do not respond to prostaglandin treatment, resulting in delayed time to first AI, and consequently, impacting reproductive performance. Although programs that use 100 % TAI for first service may present greater P/AI and tighter timeframe for first service, compliance issues in protocols that require several treatments may prevent successful outcomes.

Ultimately, reproductive performance during the entire lactation should be considered when comparing both strategies. Chebel and Santos (2010) and Dolecheck et al. (2016) demonstrated no difference in the interval from calving to pregnancy between these strategies. Regarding economic outcomes, Galvão et al. (2013) compared profitability of reproductive programs using 100 % TAI, 100 % estrus detection, or a combination of TAI for first service and estrus detection incorporated at subsequent breedings. The most profitable program consisted of submitting cows for a TAI protocol for first service (95 % compliance of treatments) followed by subsequent services based on estrus detection (60 % estrus detection rate with 95 % accuracy) and TAI. Unfortunately, Galvão et al. (2013) did not evaluate a scenario in which a certain proportion of cows were inseminated in TAI for first service in programs focusing on inseminating cows based on estrus detection after the end of the voluntary waiting period (**VWP**). Nevertheless, it is expected that programs that focus on accurate and efficient estrus detection for first AI in addition to incorporating TAI should result in profitable and efficient reproductive programs.

An experiment being conducted by our research group will determine the impact of reducing the use of reproductive treatments before first AI. In this experiment, multiparous cows (n = 1,955) from 3 dairies located in the High Plains region underwent 1 of 2 programs: Presynch-Ovsynch56, or Presynch-Ovsynch70. Programs are outlined in Figure 1. Both programs focused on inseminating cows based on estrus after the end of the VWP (53 DIM). Cows submitted to Presynch-Ovsynch56 were treated with prostaglandin within 6 d after the end of the VWP. Cows submitted to Presynch-Ovsynch70 were treated with prostaglandin between 14 to 20 d after the end of the VWP. Although both reproductive programs consisted of strategies with minimal use of TAI protocols, the Presynch-Ovsynch70 protocol represents a scenario with minimum treatments before AI. Number of treatments per AI for both strategies are represented in Table 1. In addition, Table 1 depicts the estimated number of treatments per AI of reproductive programs that rely on TAI protocols for first service. Even though initiation of treatments were delayed for cows submitted to Presynch-Ovsynch70, 55 % of cows were inseminated before the first prostaglandin treatment, which suggests that farms with efficient estrus detection do not have to rely extensively on reproductive treatments. Furthermore, P/AI did not differ between Presynch-Ovsynch56 and Presynch-Ovsynch70. Considering that we exclusively enrolled multiparous cows, both programs resulted in acceptable pregnancy outcomes at 36 d after AI (38.6 %). Average number of treatments per pregnancy were 4.3 and 2.3 for Presynch-Ovsynch56 and Presynch-Ovsynch70, respectively. Number of treatments per pregnancy in programs with 100 % TAI for first service was estimated to be between 12.5 to 15.0 (Table 1). This demonstrates that in a scenario in which producers would have to reduce the number of reproductive treatments in lactating cows, limiting the percentage of cows submitted to a TAI protocol would be a reasonable approach. It is important to note that our research focused on multiparous cows. We purposely used only

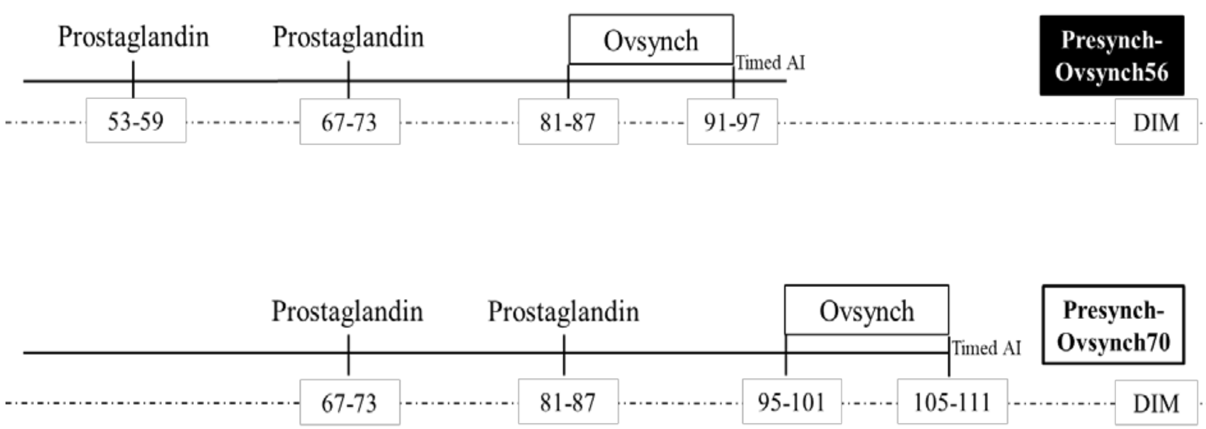

Figure 1. Outline of reproductive programs that evaluated the impact of reducing reproductive treatments of multiparous lactating cows. Programs consisted of treating cows with prostaglandin 14 d apart before initiating an Ovsynch protocol 14 d after the last prostaglandin treatment. Days in milk at initiation of treatments was the only difference between programs. Presynch-Ovsynch56 was started between 53 to 59 DIM and Presynch-Ovsynch70 was initiated between 67 to 73 DIM. Cows were deemed eligible to be inseminated after the end of the voluntary waiting period, which was 53 DIM. Estrus detection was performed once daily based on tail paint removal. Cows in estrus were inseminated and did not receive any further treatment related to first service.

Table 1. Estimated number of treatments before first service for multiparous cows submitted to reproductive programs focusing on timed AI (**TAI**) or AI based on estrus detection (**ED**)

	Reproductive programs[1]				
Item	Double-Ovsynch 100 % TAI	Presynch-Ovsynch36 100 % TAI	Presynch-Ovsynch36 ED + TAI	Presynch-Ovsynch56 ED + TAI	Presynch-Ovsynch70 ED + TAI
Average number of treatments per AI	6.0	5.0	2.9	1.5	0.8
Average number of treatments per pregnancy[2]	15.0	12.5	8.4	4.3	2.3
Cows receiving first treatment, %	100	100	100	88	45
Cows receiving second treatment, %	100	100	100	34	17
Cows receiving first GnRH of Ovsynch, %	100	100	30	10	7
Cows inseminated on TAI, %	100	100	28	8	5

[1] Presynch-Ovsynch consists of two prostaglandin treatments administered 14 d apart followed by an Ovsynch protocol initiated 14 d later. Days 36, 56, and 70 represent DIM at initiation of the program. In programs with ED, voluntary waiting period was assumed to be approximately 50 DIM.
[2] Estimated pregnancy per AI for cows submitted to 100 % TAI and ED + TAI programs were 40 % and 35 %, respectively.

multiparous cows in the study because this group of animals has poor reproductive efficiency compared with primiparous cows. Thus, our intent was to evaluate the impact of reducing treatments in cows that are less likely to become pregnant, and usually, represent a large proportion of cows in the herd (> 50 % of the lactating herd).

Median days to first AI and conception were greater ($P \leq 0.04$) for Presynch-Ovsynch70 compared with Presynch-Ovsynch56 (69 vs. 62 d and 108 vs. 102 d, respectively). Although median days to conception differed ($P = 0.04$) by 6 d between programs, the proportion of cows starting the subsequent lactation did not ($P = 0.75$) differ. The slight difference observed in days open between programs may not impact overall economic return. Our research group is currently collaborating with Dr. Victor Cabrera from the University of Wisconsin to evaluate the impact on profitability by reducing the number of reproductive treatments for first service. Despite the critical importance of determining economic impact of reducing number of reproductive treatments, it may become imperative to take into account labor required to implement reproductive programs in the future. Several factors (e.g., location of the farm, facilities, labor costs, etc.) may dictate the feasibility of implementing a specific program. Availability of workforce and compliance of treatments may be a limiting factor to rely on programs that require several treatments to create pregnancies.

REDUCING THE USE OF TIMED AI FOR COWS DIAGNOSED NOT PREGNANT

Resynchronization strategies that focus on reducing the use of TAI programs should rely on protocols that involve treating cows with prostaglandin upon non-pregnancy diagnosis, besides having an efficient and accurate estrus detection program. Because treatment with GnRH reduces estrus expression of lactating dairy cows (Mendonça et al., 2012), GnRH-based protocols are not the preferred option for resynchronization strategies if the goal is to minimize the use of TAI in a reproductive program.

Approximately 60 to 80 % of cows will be inseminated based on estrus detection after prostaglandin treatment upon non-pregnancy diagnosis (Bruno et al., 2013; Chebel et al., 2013; Rocha et al., 2014). Although a large proportion of cows is expected to respond to prostaglandin treatment, submitting a group of cows to TAI is inevitable to reduce reinsemination interval. In order to optimize resynchronization strategies when utilizing prostaglandin treatments, researchers have evaluated pregnancy outcomes of protocols based on ovarian structures present at non-pregnancy diagnosis. Even though it seems logical that cows not bearing a CL should not be treated with prostaglandin, submitting these cows to GnRH-based protocols (e.g., Ovsynch) may not be the best approach if the goal is to minimize the number of cows submitted to TAI. In a field trial conducted by our research group, we observed that cows not bearing a CL at non-pregnancy diagnosis and treated with prostaglandin have a similar reinsemination pattern compared with cows with a CL present (Figure 2). Absence of a CL at non-pregnancy diagnosis does not necessarily indicate that these cows are in an anovular condition. It is likely that a proportion of cows not bearing a CL might recently have undergone luteolysis. In fact, submitting cows in proestrus, the stage of the estrous cycle before estrus, to a GnRH-based protocol suppresses estrus expression and increases the likelihood of these cows being inseminated with TAI. In addition, accuracy of technicians in detecting the presence of a CL via ultrasound examination ranges from 57 to 70 % (Bicalho et al., 2008). Hence, determining specific reproductive protocols based on CL presence may result in a greater percentage of cows being inseminated with TAI if cows are submitted to a GnRH-based protocol.

In a scenario in which the goal is to minimize use of TAI programs, blanket treatment with prostaglandin at non-pregnancy diagnosis is one option. In situations when ovaries are being examined by ultrasonography, target treatment may be performed. In this case, cows bearing a CL may be treated with prostaglandin, and cows without a CL present may receive no treatment. Notwithstanding, further research is needed to evaluate the latter strategy. Cows not inseminated in estrus within 7 to 12 d after non-pregnancy diagnosis should be enrolled in a TAI protocol to ensure appropriate reproductive efficiency.

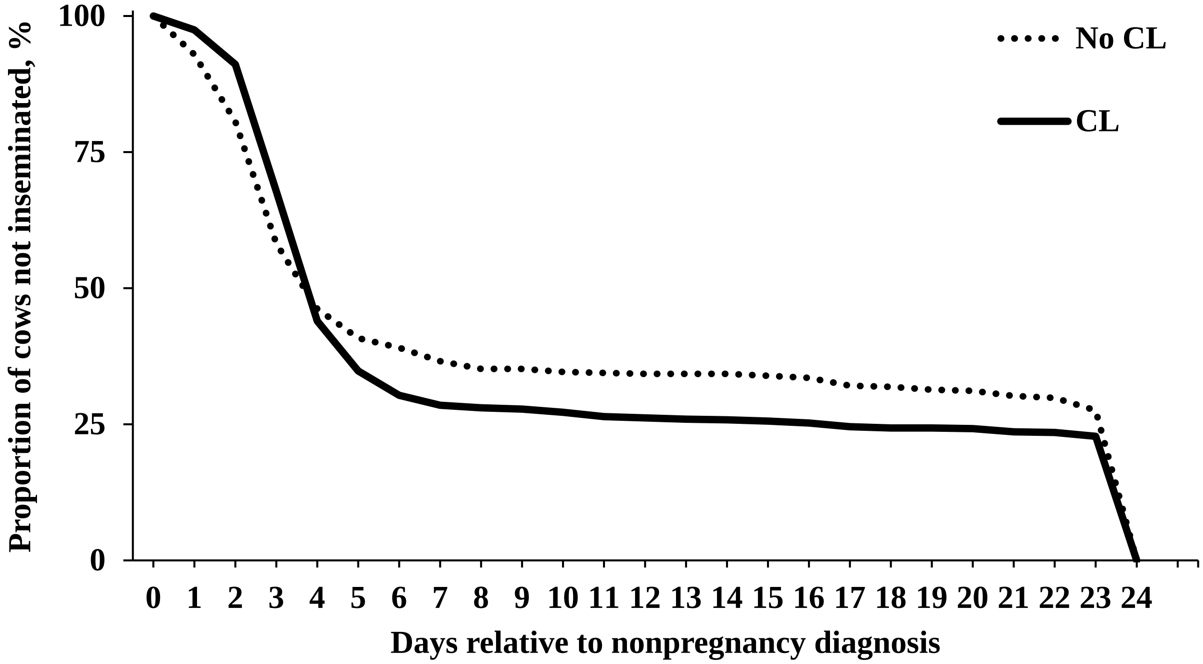

Figure 2. Survival curve for days to reinsemination according to ovarian structure from 1,479 cows from three dairies located in the High Plains region. Ovaries were scanned immediately after non-pregnancy diagnosis by transrectal ultrasonography by one experienced technician. Accuracy of corpus luteum (CL) detection was 80%, which was determined by comparing technician diagnoses with concentration of plasma progesterone from samples collected from a subgroup of cows (n = 210). Estrus detection was conducted after treating cows with prostaglandin at non-pregnancy diagnosis. Cows not inseminated based on estrus were submitted to a TAI protocol on d 7. Timed AI protocol consisted of the following treatments: GnRH on d 7, 14 and 24, and prostaglandin on d 21 (GGPG protocol). Mean days to reinsemination did not (P = 0.20) differ between cows with or without CL present (cows with CL = 9.0 ± 0.3 d and cows without CL = 10.2 ± 0.4 d). Fifty percent of cows were inseminated in the first 4 d after prostaglandin treatment.

CONCLUSIONS

It is likely that dairy farms with efficient and accurate estrus detection programs can achieve reproductive success in a scenario with limited use of synchronization protocols. Further research is needed to understand how facilities may impact reproductive efficiency of programs with reduced reproductive treatments. In fact, field trials evaluating profitability are the ultimate and critical step in determining whether reducing treatments will increase cost of production, which would demand further compensation for producers in such a setting. It is important to acknowledge that TAI protocols are comprised of treatments that are labeled for dairy cattle. These treatments are approved by the Food and Drug Administration (**FDA**) and present no risks to human health and safety.

Lastly, banning the use of reproductive treatments is cost-prohibitive. Timed AI protocols and synchronization programs are important management tools for dairy farmers to produce milk as the world population continues to grow. In addition, adoption of these tools positively impact cows' well-being by guaranteeing optimal reproductive performance. Cows with poor reproductive performance are more likely to become over-conditioned because of extended lactation, negatively impacting cow health and longevity.

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Sponsored Topic

Optimizing Personnel Management with Emphasis on Dairy Cattle Welfare

Gustavo M. Schuenemann, D.V.M., Ph.D.
Veterinarian and Dairy Extension Specialist
Department of Veterinary Preventive Medicine
The Ohio State University
Email: schuenemann.5@osu.edu

INTRODUCTION

It is common to observe great variation in dairy personnel performance and turnover within and between dairy herds. Farm owners and managers determine whether or not to hold training programs for their employees for a variety of reasons. They often struggle to balance investing the time and resources that go into training with employee turnover.

Recently, we assessed the types of training requested by stakeholders for their dairy personnel and the actual problems reported by workers. A total of 1,100 individual written requests for dairy personnel training were assessed to determine the perceived needs for training by stakeholders (farm owners, managers, veterinarians, or consultants). According to stakeholders, the top 5 requests for personnel training were as follow:

1. Milking routine and mastitis control
2. Nutrition management (TMR and feed bunk)
3. Health screening for cows and calves (including proper animal handling techniques)
4. Replacement heifers (e.g., calving, colostrum)
5. Health and management protocols

These training sessions consisted of a 1-h lecture followed by 1–2 h of demonstration and supervised hands-on practice designed to improve both knowledge and skills. At the beginning of each training session, dairy personnel answered the question, “What problem needs to be addressed to improve your work?” We received written responses from 2,900 individual workers representing 450 dairy herds distributed in 11 US states and assessed them to determine the actual needs by personnel responsible to execute the daily tasks. The top 5 areas to improve work performance, according to personnel, were as follow:

1. Lack of communication with co-workers or managers
2. Lack of written protocols and resources for the tasks
3. Lack of facility maintenance
4. Properly organize and schedule tasks
5. Schedule regular meetings to communicate and discuss tasks or issues

Figure 1. What problems need to be addressed to improve your work? A word frequency representation of 2,900 responses provided by workers. The font size for each word (word cloud) represents the frequency of words from source text (the larger the font, the higher the frequency).

Developing knowledge and skills are essential for implementing protocols and standard operating procedures (**SOP**) to improve the overall performance and welfare of animals. To perform at his or her best for any given task, employees must have the appropriate attitude. Attitude is the way a person views something or tends to behave towards it. It is important to note that dairy workers have the ability to learn new concepts and improve their skills over time. These are important traits for management because both knowledge and skills are key for worker performance.

We also found that fully trained workers *know what to do* and *how to do it*; however, workers with poor attitude (e.g., due to conflicts with co-workers or managers, lack of communication) have low work performance regardless of their level of knowledge and skills. Therefore, while a training program is an essential management tool for modern dairy operations, the trainer must take into account the underlying problems negatively affecting work performance. For instance, a training program designed to improve the dairy's milking routine will likely not fix poor nutrition management, lack of proper facilities/equipment or maintenance needed to optimize the transition cows' immune system.

We looked at the management practices of the top 10 % of these dairy operations (cows housed in free-stall barns, dry-lots or combination of both) in terms of consistent reproductive performance (≥ 26 % 21 pregnancy rate (**PR**), longevity of the herd (mean of ≥ 3.2 lactations), and milk quality (mean bulk tank with < 200,000 SCC/mL).

They share a *system-in-place* with the following characteristics:

1. ***Committed and well organized herd managers***: These herd managers are characterized by their problem-solving and communication skills with a trusted relationship with their workers and advisors. These individuals have excellent organizational skills, manage their time effectively and always make sure workers have the tools and resources to execute their tasks. Usually, these managers actively seek and accept feedback, either positive or negative, and look for ways to improve their operation. They tend to devote a large portion of their daily work hours to mentoring and supervising workers using a list of *talking points* (e.g., potential conflicts or signs of distress among workers, consistency of daily TMR delivery, timing of colostrum administration, milking schedules, monitoring body condition of animals). They are always making sure their workers are properly compensated for their work, including a fair distribution of bonuses. Also, they value formal continuing education programs outside their working environment and interaction with professionals and colleagues (example feedback "*the opportunity for outside professional development and interaction allows me to re-energize and overcome the wear-off associated with my daily routine*"). A well trained manager who focuses on managing the working environment will likely improve workers' attitudes. This in turn improves teamwork (compliance with protocols) and often overcomes many other farm limitations, such as facilities.

2. ***Management program designed for transition cow needs***: Although the word *program* was not always used during our farm visits, they did have a *plan of action* detailing what tasks needed to be completed (who, when, and what resources should be used). In practice, the program was characterized by having a defined grouping (with weekly cow move) and feeding strategies for transition cows and calves that take into account their facilities. The overall program connected the following management areas:
   - Defined strategy to prevent hypocalcemia in prepartum animals,
   - Defined heifer replacement program and
   - Defined strategy to manage energy balance and prevent ketosis in early lactation.

   These areas were connected using health and management protocols that most humans can follow within the calendar week (greater than 90 % agreement between what was stated on protocols versus what people were able to do at the farm).

3. ***Record-keeping designed to monitor processes***: They have implemented a simple, but meaningful record-keeping system with emphasis on monitoring processes. The record-keeping system integrated the following areas:
   - Nutrition management (e.g., bunk space per animal, daily availability of feed within reach of animals, forage quality, weekly urine pH when feeding on an anionic diet),
   - Cow comfort (e.g., stocking density, grooming of bedding),
   - Metabolic balance at the onset of lactation (e.g., energy and calcium),

- Survival/health events (e.g., stillbirth, metritis, ketosis, culling within the first 60 DIM), and
- Development of replacement heifers with key biological outcomes of lactating cows (e.g., milk yield and components, reproduction).

The farm team regularly meets on-farm with input from advisors (nutritionist and veterinarian) to discuss the data, review protocols and use benchmarks for decision making. They are aware of short term variations (e.g., due to environment) and usually do not overreact with sudden management changes.

4. ***Training program integrated and consistent with established protocols***: The training program follows the established protocols, is available for all farm employees, and is delivered by in-house or third party trainers. Meetings with employees are scheduled at least every 2 mo to discuss meaningful items such as current protocols and making appropriate changes or management adjustments. The owner(s) or herd managers regularly attend these training sessions to remain engaged and generate meaningful discussions (collecting and providing feedback as well as answering questions or concerns). Knowing that the employer provides proper training and development, the overwhelming majority of farm workers feel valued and considered that their work was important. Often I hear *doubts* or *hesitations*" from owners to invest in a proper training program because workers will eventually leave the operation. Although personnel turnover is an inevitable part of the dairy business, perhaps the real question is: "What would happen if an employee decides to stay without proper training?" An example of unclear recommendations written on protocols is, "wait 2 h and assist cows experiencing difficult births" or "if there is no calving progress call for help". In this particular example, the calving protocol must provide clear reference landmarks for time zero and signs of the normal progression of calving; otherwise, most calving personnel would not be able to properly follow the above recommendations. Training should be a critical component of managing modern dairy operations because of its implications on the overall performance and welfare of animals.

The dairy business is the art of controlling variation and managing risk. The best or most successful dairy farms have achieved *consistent management* over time by integrating the 4 points listed above. Every dairy operation is an integrated system and management decisions made in 1 area of the farm will impact other areas. The entire transition cow management relies on a number of preventive management practices to achieve optimal lactating dairy cow performance and thus, profitability and welfare of the herd. Disease prevention at the herd level requires a constant effort and effective coordination of the whole system (animals, environment, facilities/equipments, feed/water, and personnel). Substantial knowledge exists to prevent many diseases or conditions; however, it must be translated into on-farm applications or practices to have a meaningful effect at the herd level. With the scrutiny of antimicrobial use and welfare practices in food animals, dairies are always under the watchful eye of consumers, legislators, and activists. It is important to have well trained employees who follow the established protocols.

CONCLUSIONS

Investing in the best genetics, nutrition, veterinary care, cow comfort, and equipment are all important for the dairy community, but will fall short without developing the *human element*. How to remain competitive? This is the big question. As a starting point, consider reviewing the consistency of your transition cow program (making sure animals receive a balanced diet) taking into account the facilities (e.g., grouping animals, comfort), resources for tasks, and personnel needed to properly implement the health and management protocols within the calendar week. Perhaps this conversation or exchange of ideas may lead to developing the *know how* of a more economically sustainable management system with best animal welfare practices for years to come. Have this discussion with your veterinarian and nutritionist. These little details make the difference at the end of the day.

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Normand St-Pierre
Perdue AgriBusiness

Rating and Ranking Feedstuffs by Economic Value

What are feeds used for?

- Animals do not <u>require</u> feeds!
- Feeds are *packages* of nutrients.
- The value of a feed is the sum of the values of the <u>nutrients</u> that it contains.

What are the nutrients of economic value?

It depends…

- On the buyer…
- On the class of animals
- On the objective
  - Tactical vs. Strategic

Our Approach…

- Moderately sophisticated buyer
- Lactating dairy cows
- Strategic

- Also assumes that feeds are free of unacceptable properties/compounds
  - Molds
  - Weeds

What nutrients?

- Set 1:
  - NE_L
  - RDP
  - dRUP
  - eNDF
  - neNDF

→

- Set 2:
  - NE_L
  - MP
  - eNDF
  - neNDF

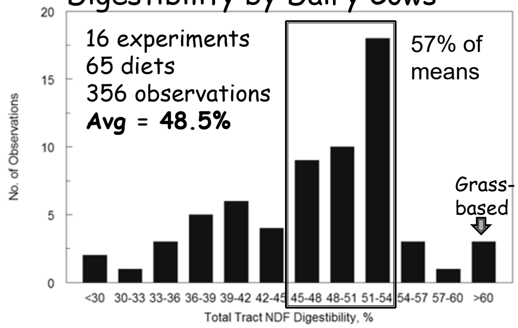
What is TDN?

Why not use ivNDFd?

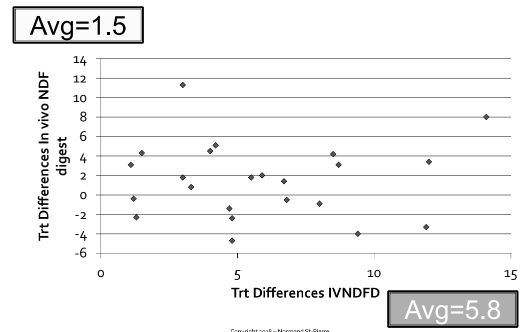
Sum of:

dProtein	High, well estimated by ADICP
dNDF	VARIABLE Surface ratio of lignin to NDF
dFat (x 2.25)	High, 100% for fatty acids
dNFC	High, 98% at maintenance

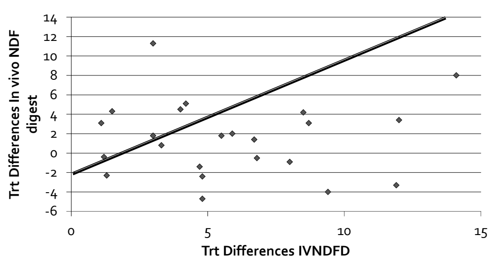
Total Tract In Vivo NDF Digestibility by Dairy Cows



Trt Differences: IVNDF of ingredient vs TMR In vivo



Trt Differences: IVNDF of ingredient vs TMR In vivo



ivNDFd

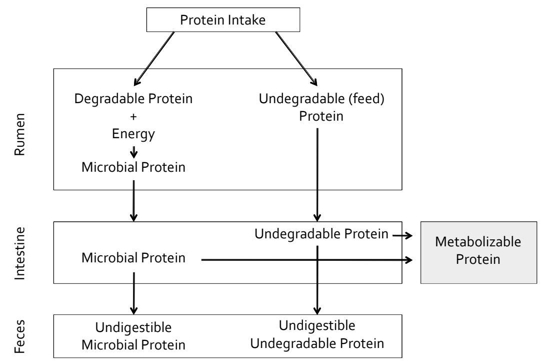
- Overestimates differences.
- Magnitude of the difference in ivNDFd is NOT related to the magnitude of the difference in <u>true</u> (in vivo) NDF digestibility.
- BUT, the ranking within experiment was often OK
  - ivNDFd might have potential, but NOT as a direct replacement.

What is NE_L

- A linear transformation of TDN
- But NOT with a zero intercept
  - 5% TDN = 0.00 Mcal/kg NE_L
- TDN <u>overestimates</u> the energy of forages relative to concentrates.

What is MP?

- Metabolizable protein



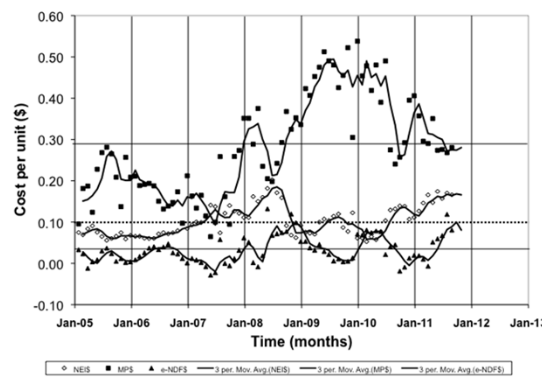
Aufmerksamkeit!

- Forages are all relatively low in undegradable protein.
- Degradable protein has NO value unless there is sufficient ruminal energy to grow microbes.
- *CRUDE PROTEIN* (by itself) is not a ***Meaningful*** measure of economic value!

Market prices of nutrients

- Use all feeds sold in a given market
  - NOT just corn and soybean meal
- Use their nutritional composition
- Solve simultaneously (hedonic pricing)

- Sesame™ software
  - Free at: https://dairy.osu.edu/node/23
- Progressive Dairyman



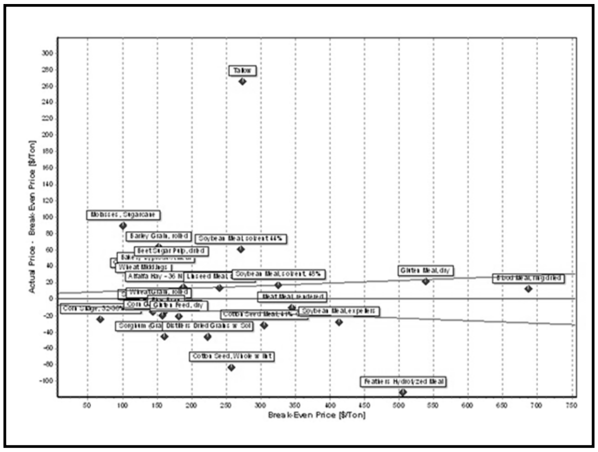
January 2012 to December 2014

Nutrients	Average	S.D.	Min	Max
NE_L (¢/Mcal)	15.2	2.1	11.1	17.4
MP (¢/lb)	31.1	4.8	26.8	40.6
eNDF (¢/lb)	4.7	4.0	0.0	11.9
neNDF (¢/lb)	-8.5	2.8	-12.4	-5.1

2012-2014 vs Jan. 2018

Nutrients	Average
NE_L (¢/Mcal)	15.2
MP (¢/lb)	31.1
eNDF (¢/lb)	4.7
neNDF (¢/lb)	-8.5

Nutrients	Average
NE_L (¢/Mcal)	3.8
MP (¢/lb)	52.4
eNDF (¢/lb)	11.1
neNDF (¢/lb)	- 1.9



Calibration set								
Name	Actual [/T]	Predicted [/T]	Lower limit	Upper limit	Corrected	75.0% CI	75.0% CI	Weight
Alfalfa Hay - 36 NDF 22 CP 1	203.000	187.854	162.433	213.276	221.627	196.205	247.048	1.000
Bakery Byproduct Meal	185.000	147.064	132.095	162.034	-	-	-	1.000
Barley Grain, rolled	216.000	152.007	139.750	164.265	-	-	-	0.500
Beet Sugar Pulp, dried	215.000	169.263	156.310	182.217	-	-	-	1.000
Blood Meal, ring dried	700.000	687.051	658.315	715.788	-	-	-	1.000
Corn Grain, ground, dry	138.000	157.304	143.366	171.241	-	-	-	1.000
Corn Silage, 32-38% DM	43.500	68.013	59.030	76.996	68.013	59.030	76.996	1.000
Cotton Seed Hulls	157.000	124.863	90.387	159.338	-	-	-	0.500
Cotton Seed Meal, 41% CP	273.000	304.472	293.455	315.490	-	-	-	1.000
Cotton Seed, Whole w lint	174.000	257.359	217.132	297.587	-	-	-	0.250
Distillers Dried Grains w Sol	177.000	222.882	207.709	238.055	-	-	-	1.000
Feathers Hydrolyzed Meal	392.000	505.711	486.930	524.492	-	-	-	0.125
Fish Menhaden Meal, mech.	1495.000	519.004	499.882	538.126	-	-	-	0.003
Gluten Feed, dry	160.000	180.817	170.169	191.464	-	-	-	1.000
Gluten Meal, dry	560.000	538.373	519.045	557.700	-	-	-	1.000
Hominy	129.000	144.323	132.896	155.751	-	-	-	1.000
Linseed Meal, solvent	254.000	239.599	227.688	251.511	-	-	-	1.000
Meat Meal, rendered	335.000	345.444	330.342	360.546	-	-	-	1.000
Molasses, Sugarcane	190.000	100.009	87.179	112.839	-	-	-	0.250
Rice Bran	148.000	162.166	148.813	175.520	-	-	-	1.000
Sorghum (Grain), Grain, rolle	115.000	160.202	148.291	172.113	-	-	-	1.000
Soybean Hulls	122.000	129.014	105.021	153.007	-	-	-	1.000
Soybean Meal, expellers	385.000	413.309	400.021	426.597	-	-	-	1.000
Soybean Meal, solvent 44%	332.000	270.773	260.371	281.176	-	-	-	0.500
Soybean Meal, solvent, 48%	342.000	325.131	313.551	336.712	-	-	-	1.000
Tallow	540.000	273.641	222.902	324.379	-	-	-	0.025
Wheat Grain, rolled	147.000	151.727	138.336	165.118	-	-	-	1.000
Wheat Middlings	156.000	130.097	115.066	145.127	-	-	-	1.000

Appraisal set						
Name	Actual [/T]	Predicted [/T]	Pred.-Act.	75.0% CI	75.0% CI	Corrected
Alfalfa Hay - 32 NDF 24 CP 1	0.000	187.352	187.352	164.346	210.359	238.011
Alfalfa Hay - 40 NDF 20 CP 1	0.000	183.209	183.209	155.697	210.721	200.095
Alfalfa Hay - 44 NDF 18 CP 1	0.000	181.075	181.075	151.078	211.071	181.075
Alfalfa Hay - 48 NDF 16 CP 1	0.000	178.035	178.035	145.454	210.616	161.149

Alfalfa - Entries

Nutrients	Units	Low	Reference	High
Dry matter	%	88	88	88
Crude protein	%	16	20	24
NDICP	%	2.5	2.5	2.5
ADICP	%	1.5	1.5	1.5
Ether Extracts	%	2.0	2.0	2.0
NDF	%	44	40	36
ADF	%	34	30	26
Lignin	%	8.8	7.0	5.4
Ash	%	10	10	10
RUP	% CP	25	25	25
RUPd	% RUP	70	70	70
NDFe	% NDF	92	92	92

Alfalfa – Calculated Values

Nutrients	Units	Low	Reference	High
TDN from NFC	%	29.9	29.9	29.9
TDN from NDF	%	15.8	15.4	14.8
TDN from CP	%	14.3	18.3	22.3
TDN from EE	%	2.3	2.3	2.3
TDN at 3X	%	50.7	54.0	57.1
NE_L at 3X	Mcal/cwt	51.5	57.6	63.5
MP at 3X	%	7.02	7.99	8.95

$ Value – Reference Alfalfa - 2018

	Comp.	DM %	Mcal or Lbs/ton	Unit Prices ¢/unit	Value $/ton
NE_L (Mcal)	57.6	88	1014.2	3.8	38.54
MP (%)	7.99	88	140.7	52.4	73.73
eNDF (%)	36.8	88	647.7	11.1	71.89
neNDF %)	3.2	88	56.3	- 1.9	- 1.07
TOTAL					**183.09**

57.6 x 88 x 0.2 = 1014.2

1014.2 x 3.8 ÷ 100 = 38.54

$ Value – Reference Alfalfa – 2012-2014

	Comp.	DM %	Mcal or Lbs/ton	Unit Prices ¢/unit	Value $/ton
NE_L (Mcal)	57.6	88	1014.2	15.2	154.15
MP (%)	7.99	88	140.7	31.1	43.76
eNDF (%)	36.8	88	647.7	4.7	30.44
neNDF %)	3.2	88	56.3	-8.5	-4.79
TOTAL					223.56

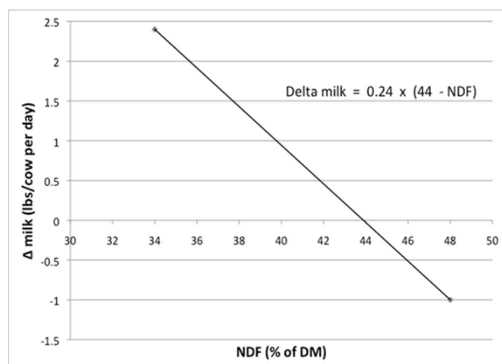
$ Value – Reference Alfalfa – 2012-2014 vs 2018

	Value $/ton
NE_L (Mcal)	154.15
MP (%)	43.76
eNDF (%)	30.44
neNDF %)	-4.79
TOTAL	**223.56**

	Value $/ton
NE_L (Mcal)	38.54
MP (%)	73.73
eNDF (%)	71.89
neNDF %)	- 1.07
TOTAL	**183.09**

Not quite done…

- Two TMRs with same nutrient concentrations
  - TMR A – High quality alfalfa
  - TMR B – Low quality alfalfa
- Cow fed TMR A produce a bit more milk because the forage is "less filling".



Quality adjustments
$/ton of hay per 1% deviation from reference[1]

Forage	+/- $1/cwt	$10/cwt	Milk Price $15/cwt	$20/cwt
Alfalfa	0.24	2.40	3.60	4.80
Grass	0.26	2.64	3.96	5.28

[1] References are:
Alfalfa: 44% NDF
Grass: 53% NDF

Examples

- Alfalfa at 39% NDF, milk at $20/cwt
- 44 - 39 = 5 units of deviation
- 5 units x $4.80/unit = + $24/ton

- Alfalfa at 35% NDF, milk at $18/cwt
- 44 - 35 = 9 units of deviation
- $18/cwt x $0.24/unit = $4.32/unit dev.
- 9 units x $4.32/unit = + $38.88/ton

Correction factor

- Depends on % NDF
  - Less than 44% (alfalfa) → ↑ value of forage
  - More than 44% (alfalfa) → ↓ value of forage

- Depends on milk price
  - Milk price high → Large adjustment
  - Milk price low → Small adjustment

Marginal change in value

Entries	Alfalfa SD units	Grass SD units	Change in value ($/ton) Alfalfa	Grass
Dry matter	1.4	1.1	3.83	2.41
Crude protein	2.6	3.1	5.52	5.81
NDICP	0.9	1.3	1.15	1.48
ADICP	0.4	0.5	-2.11	-2.57
Ether extracts	0.5	0.7	2.36	3.31
NDF	6.3	6.2	-31.09	-31.59
Lignin	0.9	1.1	-4.00	-5.91
Ash	1.2	1.5	-4.41	-5.50
RUP	3.0	3.0	2.30	1.28
RUPd	5.0	5.0	1.37	1.00
NDFe	1.0	1.0	0.93	1.40

Summary

- Economic value of a feeds are driven by their nutritional contents.
- Economically important nutrients are:
  - NE_L, RDP, RUP, eNDF, neNDF
  - NE, MP, eNDF, neNDF
- Values of nutrients vary a LOT across time and location.

Summary

- Forage values must be corrected for quality effect on milk production
  - Correction is dependent on NDF and milk price

Summary

- Economically important chemical assays:
  - Dry matter
  - Crude protein
  - Neutral detergent fiber ←
  - Lignin
  - Ash