		Section A		
Wednesday				
8:00	Welcome			
8:10		Global Perspectives of the Dairy Industry	Tim Hunt	Rabobank
8:50		Current Financial Perspectives of the Industry	Phil Plourd	Blimling and Associates, Inc.
9:30		Where Will Dairies Be Located in the Future?	Normand St. Pierre	Ohio State University
10:10	Break			
10:30		How Did You Survive? Panel	Moderated By: Steve Larson	Hoard's Dairyman
11:30		Managing Stress & Building Healthy Family Relations	Robert Fetsch	Colorado State University
12:10	Lunch			
1:40		Managing Transition Cow Issues	Todd Duffield	University of Guelph
2:20		Are You Efficiently Replacing Your Herd?	Greg Bethard	G&R Dairy Consulting
3:00	Break			
3:30		Making More Effective Use of Your Data	Steven Stewart	Valley Agricultural Software
4:10		Lameness in Dairy Cattle: A Debilitating Disease or a Disease of Debilitated Cattle?	Rodrigo Bicalho	Cornell University
4:50	Adjourn			
Thursday				
8:00		Managing Air Quality on the Dairy with the National Air Quality Site Assessment Tool (NAQSAT)	Wendy Powers	Michigan State University
8:40		Feed Center Design	Joe Harner	Kansas State University
9:20		What We Have Learned About Cross Ventilated Freestalls: A Producer Panel	Moderated By: John Smith	Kansas State University
10:20	Break			
10:50		A Re-evaluation of the Impact of Temperature Humidity Index (THI) and Black Globe Humidity Index (BGHI) on Milk Production in High Producing Dairy Cows	Robert Collier	University of Arizona
11:30		Using Genomics on the Farm	Kent Weigel	University of Wisconsin
12:10	Lunch			
1:30		Taking the Long View: Treat Them Nice As Babies and They Will Be Better Adults	Mike Van Amburgh	Cornell University
2:10		Labor Management Panel	Moderated By: William Wailes	Colorado State University
3:10	Break			
3:45	DMI Panel	McDonald's and Domino's Partnerships Results in Innovative New Dairy Products and Increased Consumption	Moderated by: Stan Erwine	Dairy Management, Inc.
5:30	Adjourn			
Friday				
8:00		Control of Energy Intake Through Lactation	Michael Allen	Michigan State University
8:40		The Nutritional Chemistry of Dry and High Moisture Corn	Pat Hoffman	University of Wisconsin
9:20		Optimizing Intake in Dry and Prefresh Cows	Thomas Overton	Cornell University
10:00		Connecting Transition Cow Physiology, Behavior, and Nutrition	Barry Bradford	Kansas State University
10:40		Managing Variability in Feed Ingredients and Feed Delivery- Panel	Moderated By: Robert James	Virginia Tech
11:40	Adjourn			

		Section B		
Wednesday				
8:00	Welcome			
8:10		Are You Efficiently Replacing Your Herd?	Greg Bethard	G&R Dairy Consulting
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3:10	Break	Please See Section A		

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Global Perspectives of the Dairy Industry

Tim Hunt
Rabobank

Notes:

Notes:

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Where Will Dairies Be Located in the Future?

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Summary

The dairy industry has shown substantial migrations over its history, and more so over the last half-century. The factors that were responsible for these migrations were primarily linked to the economics of production. This dominance of economic factors in regards to the location of dairy farms will not change in the future, but the nature of factors will likely be broadened (e.g., environmental sensitivity). Results from a large national survey indicated that many factors were important when selecting the location of a dairy. In fact, there are so many factors involved that there is probably not a single location within the United States that could be categorized as ideal. Farms looking at relocation will need to assess their strengths and weaknesses and categorize their management styles before best-matched areas can be identified. In addition, the U.S. dairy industry is becoming more dependent on foreign markets (i.e., exports). If dairy products are to be exported, U.S. dairy producers should not only be aware of the location and changes in the export markets, but should also be looking at opportunities to establish dairy production units in areas of the world that offer a competitive advantage.

What is a Dairy?

In many places around the world and in some regions of the United States a 'dairy' is a processing plant where milk is bottled or transformed into cheese, butter, milk powder, etc. In Western States, however, a 'dairy' is a farm (or ranch, or herd) where cows are milked. Considering the location of the Western Dairy Management Conference, we chose to westernize ourselves. Thus, 'dairy' shall mean 'dairy farm' in the balance of this paper.

Why Should Dairy Production Move in the Future?

The answer is simply: "it has moved in the past so why wouldn't it keep moving in the future?" We are all well aware of the dramatic changes that have occurred in regards to the location of dairy production in the U.S. over time. In 1970, the Midwest produced 51% of the U.S. milk compared to 17% for the West and Southwest regions combined. Thirty years later, the Midwest share of the national production had dropped to 35% while the West and Southwest accounted for 42%.

The location of dairy production has not changed just for the fun of it. Many factors, primarily of economic nature, were involved. Dairy (milk) is a commodity. Milk from many dairies is comingled to make mostly undifferentiated products. Milk payments are almost exclusively based on volume and simple characteristics related to yields of products (fat and protein). Commodities – all commodities – share the following characteristic: in the long-run, net returns per unit of production are small. Thus, their production is highly sensitive to cost of production. The total cost of producing milk across regions explains the migrations of the past and will explain the migrations of the future. Beware, however, that *total* costs of production is the driving factor. Total costs include direct costs, indirect costs, and hidden costs (such as unpaid family labor, opportunity cost of equity capital, and even the 'headache' cost of filing the paperwork to satisfy the government bureaucracies).

Does Change in the Location of Dairy Production Implies Relocation of Dairies?

There could be substantial realignment of regional dairy production without any dairy relocation within or across regions. But this has never happened in the past. Thus based on the principle that the past is the best predictor of the future, future changes in the location of dairy production will be associated with relocation of dairies.

So Where Will Dairies Be Relocating in the Future?

Dairies will be relocating in areas that offer them a competitive advantage. The concept of 'competitive advantage' is far broader than the simple direct costs of production. Many factors are linked to the competiveness of a production site. Some have a direct effect on the Profit and Loss statement; others are harder to quantify, but still have a definite 'utility'. In economics, the term 'utility' is a measure of relative satisfaction. It also does a marvelous job of confusing people. Its relevance to us can be illustrated as follows. Suppose that you can locate a dairy on 2 different sites. Both sites are identical in all of their characteristics (milk price, costs of production, water availability, labor, etc.) except that site A borders friendly neighbors, whereas site B borders unfriendly neighbors (say mostly PETA members). In this instance, the utility of site A would be greater than site B for most dairy people. Here, the neighborhood's friendliness reflects a hard to quantify ability to keep operating in the future.

To answer where dairies will be relocating requires the identification and valuation of the attributes associated with the desirability of a location for dairy production.

Identification and Valuation of Factors Involved in Dairy Relocation

A few years ago we conducted a large national survey of factors involved in dairy relocation. We all have our own personal opinion as to what factors are important. Our interest was in finding what the opinions were across the U.S., to rank the factors and examine regional differences. The survey consisted of a total of 906 respondents (250 agribusiness professionals and 656 dairy producers) from all regions (Central: 130, Midwest: 243, Northeast: 161, Northwest: 133, Southeast: 128, and

Southwest: 111), and various herd sizes, gender, level of education, marital status, and family status. The survey instrument consisted of 110 location factors. Respondent were asked to provide a measure of importance for each factor using a 0 to 10 scale, where 0 = not important, 5 = somewhat important, and 10=critically important. In analyzing the results, factors were grouped into 13 location decision categories using standard criteria for relocation across various industries. Eleven of the 13 categories encompassed factors that were quantitative in nature and could be classified as traditional location decision factors that were related directly to business activities. The remaining 2 categories encompassed what are known as nontraditional or qualitative decision factors (i.e., community attributes and value-based community attributes). It is important to understand that respondents were NOT asked to rank the factors. The ranking that we present is based on the average importance attributed by the respondents. Although one's opinion might differ from the average importance and the ranking of factors derived from this survey, our tenet is that 906 people cannot be completely wrong… Table 1 reports the results ranked by importance of location decision categories. What are some observations that can be made from these results?

1. Overall factors associated with *cash flow* and *capital expenditures* were (as categories) the most important, followed by *tax structure and economic incentives*, and *waste management*. *Community attributes* and *infrastructure* were deemed the least important.

2. The five most important single factors were:
    a. Availability of fresh water supply,
    b. Availability of land on which to incorporate animal waste,
    c. Average mailbox price of milk,
    d. Quality of fresh water supply, and
    e. Complexity of state and local laws governing waste handling and odor management.

3. The five least important single factors were:
    a. Number of hoof trimmers in the local area,
    b. Presence of established niche markets in the local area,
    c. Proximity of an airport with commercial, scheduled services,
    d. Proximity to cultural centers, and
    e. Proximity to recreational areas.

4. Ninety (90) out of the 110 factors were judged to be at least somewhat important (average importance > 5). Nearly one third (36 out of 110) of the factors were deemed very important to critically important (average importance > 7).

5. Likely, there is NOT a single location within the United States that meets all 36 factors deemed very important, let alone all 90 that were deemed somewhat important. Hence, there are and will be some trade-offs across the many possible areas of production.

6. Production destined to markets sensitive to costs of production (export markets, Class IV, and portions of Class III) will occur and grow in areas with a competitive advantage,

including processing and transportation costs. The total cost for producing a storable product (cheese, butter, non-fat dried milk, milk powder, etc.) will be the primary determinant (i.e., not just the cost of producing the milk). Major non-direct costs, such as the costs to meet the often capricious environmental rules, key resources allocations (e.g., water), and various bureaucratic regulations will be increasingly important. By their own nature, these are determined by government policies that are highly unpredictable. Hence, it is impossible to identify the specific locations of long-term growth of the dairy industry in the United States. Based on the current political landscape, the central region would be best at meeting the very important factors, but this could be changed by one single vote in the U.S. Congress, or one major change in the interpretation of the current laws by one of the regulating agencies.

We Are Not Alone in This World

Within the Unites States, there are well-known areas of milk surpluses and deficits (Figure 1). Contrary to what is alleged by locavores, local or even regional self-sufficiency makes absolutely no economic sense. The flawed principle of local production violates an economic law as fundamental as what gravity is to the physical sciences. The national wealth is improved by increasing inter-regional trade. It doesn't make more economic sense to artificially support milk production in Florida than to encourage pineapple production in North Dakota. Therefore, the sight of a map showing large areas of milk deficit should be no more alarming than a map showing large areas of citrus deficits. Different regions possess an economic advantage at producing select goods and services and the trading of these goods and services across regions enhances the overall wealth.

Of course, the benefits of trading extend across a nation's boundaries. The U.S. population is currently estimated at 307 million people, or about 4.4% of the world's total population. Although the U.S. is still a dominant nation with the world's largest economy, the necessity to eat extends to every human being on this planet. Although dairy products are not considered as basic, staple foods as some plant products (wheat, rice, cassava), the demand for dairy products increases substantially as soon as a population moves above near subsistence. Hence, we can expect large changes in the world supply and demand for dairy products in the future.

Milk production occurs pretty much everywhere around the world, but on largely different scales (Figure 2). Although the U.S. production of 80 million metric tons (MT) per year is significant on a world basis, is represents only 51% of the total milk production by the countries members of the European Union (EU-27), and surprisingly only 65% of the milk production in India (albeit that the latter is predominantly not commercially traded). Milk is not necessarily produced where demand occurs (i.e., where there are people). The world map shows large areas of milk surpluses and deficits (Figure 3). The important milk surplus regions consist of the EU, the US, and Oceania (New Zealand and Australia). Deficit regions are located predominantly in the world tropical belt, the area of land located between latitude 23°N and 23°S. As a whole, dairy production does not flourish in the tropical belt. China, with its population exceeding 1.3 billion people is projected to be an area of large increase in demand for dairy products. Food import, however, has never ranked very highly as a strategic policy by the Chinese government. In short, the world demand for dairy will likely increase, but in markets that are not traditional for the U.S., and that bear considerably more uncertainty than our domestic market.

Figure 4 shows an approximate world supply curve for milk. Contrary to what many people think, the cost of milk production in the U.S. is not particularly low compared to the rest of the world. But it represents a large portion of 'tradable milk', as production in most of the countries with lower costs of production is primarily of subsistence type (i.e., not traded, or very locally traded). The exceptions to this are Australia, New Zealand, and Argentina. The first two in particular export a significant proportion of their production (>50%) and will therefore likely remain first in line for exports (i.e., will basically take whatever price the world is willing to pay). In the long run, most of the milk produced in the EU is at a cost that exceeds US cost of production. Hence, as long as the US remains a significant player, the world market price for milk should be relatively near U.S. costs of production. 'Relatively' is an important word here, and does NOT imply that world prices will be exactly at US costs of production, and deviation of up to 20% can be expected. Therefore, although a national strategy based on increased dairy exports can support additional milk production, such a strategy does <u>nothing in terms of price stabilization</u> and may in fact accentuate the wild fluctuations already experienced over the last decade.

What is more important in the context of this presentation is the opportunity for US dairy producers to look at the entire world map for areas of potential expansions/relocations. The factors identified earlier in this paper apply to the world as well, but additional factors must enter the process (the political stability and 'friendliness' of a country being two obvious factors). With all due reservations (i.e., 15 pages of legal mumbo-jumbo warning you that I might not have the foggiest idea of what I am talking about), I see the following regions as potential areas to explore:

- Western Canada, if and when the country ever gives up on its obsolete and trade-distorting quota system. Don't hold your breath on this one.
- South American countries, especially Argentina, Uruguay, and Southern Brazil. But you better warn Toto that these are not Kansas… Blending in with the local culture would likely require a 'local' partner.
- Select countries of Eastern Europe, including Russia. Here again, a local partnership might be an essential step to the entry process.
- Possibly a few select countries in the South African region (including the country of South Africa). The political instability in most of these countries makes this doubtful.
- Antarctica (if one listen too much to the global warming hyper-alarmists)…

Of course, a vast potential area would open up in the tropical belt if the problems associated with high dairy productivity in this zone would ever be resolved. This would require a different way of thinking along the lines followed by Norman Borlaug with the Green Revolution.

Table 1. Importance of location decision categories, subgroups of individual factors, and individual factors across all respondents.

Location Decision Categories, Subgroups, and Factors[1]	Mean[2]	SE
Overall Mean Importance of Categories	**6.79**	**0.017**
Overall Mean Importance of Individual Factors	**6.33**	**0.039**
Cash Flow	**7.76[A]**	**0.043**
♦ **Income-related**	**8.79[a]**	**0.050**
Average mailbox prices of milk ($/cwt.)	8.79	0.050
♦ **Cost-related**	**7.51[b]**	**0.045**
Cost of hauling milk	8.26	0.058
Cost of feeds (forage, concentrates, etc.)	8.13	0.060
Average cost of utilities (electricity, gas, etc.)	7.29	0.067
Average local hourly wage (average for both farm and non-farm sectors)	6.35	0.074
Capital Expenditures	**7.74[A]**	**0.051**
Average cost of constructing new facilities	7.86	0.059
Cost of financing (cost of lending, interest, etc.)	7.83	0.068
Average price of land	7.50	0.064
Tax Structure and Economic Incentives	**7.50[B]**	**0.052**
♦ **Financing**	**7.83[a]**	**0.068**
Cost of financing (cost of lending, interest, etc.)	7.83	0.068
♦ **Tax Structure**	**7.50[b]**	**0.062**
State and local property tax rates	7.60	0.063
State and local income tax rates	7.40	0.066
♦ **Economic Incentives**	**7.15[c]**	**0.077**
Existence of economic incentives to locate in an area (tax abatements, grants, low interest loans, etc.)	7.15	0.077
Waste Management	**7.50[B]**	**0.044**
♦ **Land Availability**	**8.94[a]**	**0.052**
Availability of land on which to incorporate animal waste	8.94	0.052
♦ **Waste Management Laws and Regulations**	**8.35[b]**	**0.064**
Complexity of state and local laws governing waste handling and odor management	8.35	0.064
♦ **Water Characteristics**	**7.07[c]**	**0.088**
Proximity to perennial streams (continuously flowing)	7.18	0.093
Proximity to bodies of water (both warm-water and cold-water habitats)	6.95	0.093
♦ **Land Characteristics**	**7.00[c]**	**0.049**
Nutrient load capacity of land	7.90	0.065
Slope of the land	6.86	0.066
Percentage of clay and sand in the soil	6.01	0.069

(Continued.)

Table 1 (Continued).

Location Decision Categories, Subgroups, and Factors[1]	Mean[2]	SE
Utilities	**7.17[C]**	**0.062**
♦ **Cost**	**7.29**	**0.067**
Average cost of utilities (electricity, gas, etc.)	7.29	0.067
♦ **Availability**	**7.05**	**0.078**
Availability of specialized utility services (three-phase electricity, etc.)	7.05	0.078
Natural Resources	**7.01[D]**	**0.041**
♦ **Water Resources**	**7.34[a]**	**0.047**
Availability	9.16	0.047
Availability of adequate fresh water supplies	9.16	0.047
Quality	8.41	0.061
Quality of fresh water supplies (salinity, sulfur content, hardness, potential toxins, etc.)	8.41	0.061
Proximity to Sources	7.07	0.088
Proximity to perennial streams (continuously flowing)	7.18	0.093
Proximity to bodies of water (both warm-water and cold-water habitats)	6.95	0.093
Precipitation	6.15	0.068
Average annual precipitation	6.54	0.077
Average annual snowfall	5.76	0.087
♦ **Land Resources**	**7.26[a]**	**0.041**
Availability	8.41	0.044
Availability of land on which to incorporate animal waste	8.94	0.052
Availability of large tracts of land on which to construct and relocate	7.88	0.061
Cost	7.50	0.064
Average price of land	7.50	0.064
Characteristics	6.76	0.049
Nutrient load capacity of land	7.90	0.065
Productivity of the land	7.08	0.067
Slope of the land	6.86	0.066
Percentage of clay and sand in the soil	6.01	0.069
Percentage of organic matter in the soil	5.93	0.076
♦ **Agronomic Potential**	**6.49[b]**	**0.053**
Desirable agronomic conditions to grow forages	7.43	0.061
Productivity of the land	7.08	0.067
Slope of the land	6.86	0.066
Average number of growing degree days (GDD)	6.76	0.075
Average annual precipitation	6.54	0.077
Percentage of clay and sand in the soil	6.01	0.061
Percentage of organic matter in the soil	5.93	0.076
Uniformity of the amount of precipitation received across seasons	5.65	0.083

(Continued.)

Table 1 (Continued).

Location Decision Categories, Subgroups, and Factors[1]	Mean[2]	SE
Natural Resources (continued)		
♦ **Climate**	**6.37[b,c]**	**0.066**
Average heat/humidity index (heat stress index)	7.47	0.068
Summer high temperature	6.84	0.074
Average wind chill	6.02	0.085
Average annual snowfall	5.76	0.087
Winter low temperature	5.75	0.087
♦ **Risk of Natural Disasters**	**6.20[c]**	**0.094**
Risk of natural disasters (earthquakes, flooding, forest fires, hurricanes, tornadoes, volcanoes, etc.)	6.20	0.094
Regulatory Environment	**6.85[E]**	**0.052**
♦ **Environmental Laws**	**8.35[a]**	**0.064**
Complexity of state and local laws governing waste handling and odor management	8.35	0.064
♦ **Judicial Attitudes**	**7.90[b]**	**0.072**
Previous state and local court decisions regarding agriculture-related odor and waste management	7.90	0.072
♦ **Workers Compensation Laws**	**6.47[c]**	**0.078**
Complexity of state laws regarding workers compensation	6.47	0.078
♦ **Permitting**	**6.29[c]**	**0.061**
Average time required to obtain an environmental permit to construct facilities	6.71	0.072
Average time required to obtain a health permit to construct facilities	6.67	0.074
Use of public hearings for the permitting process	6.36	0.086
Current number of permitted operations within the state	5.42	0.091
Transportation	**6.65[F]**	**0.045**
♦ **Product Transportation**	**8.07[a]**	**0.050**
Cost of hauling milk	8.26	0.058
Proximity to milk processors and handlers (cheese plants, bottling plants, etc.)	7.87	0.060
♦ **Characteristics of the Local Road Infrastructure**	**6.55[b]**	**0.061**
Ability of local road infrastructure to support agricultural activities (support heavy machinery, etc.)	7.08	0.069
Quality of local road systems	6.72	0.069
Average daily traffic volume on state highways in the local area	5.83	0.082
♦ **Alternative Transportation**	**4.11[c]**	**0.084**
Proximity to an airport with commercial, scheduled services (Delta, US Airways, etc.)	4.11	0.084

Table 1 (Continued).

Location Decision Categories, Subgroups, and Factors[1]	Mean[2]	SE
Value-based Community Attributes	**6.21[G]**	**0.053**
♦ **Public Perception**	**7.95[a]**	**0.064**
State and local public perception of animal agriculture	7.95	0.064
♦ **School System**	**7.50[b]**	**0.074**
Quality of local school system	7.50	0.074
♦ **Health Care System**	**7.49[b]**	**0.067**
Quality of local health care system	7.49	0.067
♦ **Personal**	**5.12[c]**	**0.067**
Local presence of the religious denomination of your choice	6.14	0.095
Proximity to family members (parents, siblings, etc.)	5.23	0.093
Stability of family units within the area (divorce rates, etc.)	4.58	0.095
Proximity to your current location	4.53	0.094
Labor	**6.08[G]**	**0.058**
♦ **Availability**	**6.74[a]**	**0.070**
Availability of labor for skilled positions (herdsperson, AI technician, etc.)	7.00	0.085
Availability of trained labor for unskilled positions (milkers, etc.)	6.90	0.078
Availability of untrained labor for unskilled positions	6.33	0.082
♦ **Workers Compensation**	**6.61[a]**	**0.074**
Cost of workers compensation	6.74	0.077
Complexity of state and local laws regarding workers compensation	6.47	0.078
♦ **Cost**	**6.35[b]**	**0.074**
Average local hourly wage (average for both farm and non-farm sectors)	6.35	0.074
♦ **Employee Benefits**	**6.21[b]**	**0.073**
Availability of housing for employees	6.30	0.078
Cost of housing for employees	6.11	0.077
♦ **Legal Alien Labor**	**4.92[c]**	**0.083**
Availability of state and local agencies to facilitate legal alien labor	4.94	0.091
Local presence of cultural resources to meet the needs of a diverse workforce	4.90	0.087
♦ **Training**	**4.92[c]**	**0.088**
Availability of local training for farm labor	4.92	0.088

(Continued.)

Table 1 (Continued).

Location Decision Categories, Subgroups, and Factors[1]	Mean[2]	SE
Markets	**6.07[G]**	**0.055**
♦ **Product Price**	**8.79[a]**	**0.050**
Average mailbox price of milk ($/cwt.)	8.79	0.050
♦ **Market Proximity**	**8.00[b]**	**0.062**
Proximity to large fluid milk markets (Class 1, quota milk, etc.)	8.00	0.062
♦ **Federal Milk Marketing Orders**	**5.47[c]**	**0.078**
Presence of a Federal Milk Marketing Order	5.89	0.089
Absence of a Federal Milk Marketing Order	5.09	0.100
♦ **Unique Marketing Opportunities**	**4.36[d]**	**0.086**
Opportunity to export milk (export fluid milk to Asia, Canada, Mexico, etc.)	4.60	0.099
Presence of established niche markets in the local area (organic, etc.)	4.14	0.096
Community Attributes	**5.85[H]**	**0.044**
♦ **Health Care**	**7.47[a]**	**0.065**
Proximity to a hospital with the capability to handle major traumas	7.47	0.065
♦ **Living Costs**	**7.29[b]**	**0.056**
State and local property tax rates	7.60	0.063
State and local income tax rates	7.40	0.066
Local average cost of living	6.90	0.067
♦ **Population**	**6.64[c]**	**0.062**
Local rate of increase in urban development	7.52	0.070
Local population density	6.59	0.077
Proximity to a community with a population greater than 15,000	5.80	0.089
♦ **Crime Rate**	**6.58[c]**	**0.079**
Local crime rate	6.58	0.079
♦ **Influence of Agriculture**	**6.51[c]**	**0.056**
Significant of agriculture to the local economy	7.03	0.068
Proportion of land in agricultural use	6.91	0.067
Local density of dairy farms	5.59	0.074
♦ **Housing Availability**	**6.18[d]**	**0.071**
Local availability of housing	6.18	0.071
♦ **Domestic Goods**	**6.09[d]**	**0.064**
Proximity to a grocery store	6.98	0.069
Proximity to a hardware store	6.95	0.068
Proximity to a retail store (WalMart, Kmart, etc.)	5.92	0.082
Proximity to a shopping mall	4.52	0.085
♦ **Job Opportunities**	**5.10[e]**	**0.092**
Presence of job opportunities for a spouse or significant other	5.10	0.092

Table 1 (Continued).

Location Decision Categories, Subgroups, and Factors[1]	Mean[2]	SE
Community Attributes (continued)		
♦ **Higher Education**	**4.33[f]**	**0.086**
Proximity to a college or university	4.33	0.086
♦ **Extracurricular Activities**	**4.16[f]**	**0.062**
Accessibility to civic groups and community organizations for youth and adults (4-H, Rotary Club, etc.)	5.34	0.080
Proximity to restaurants and entertainment (movies, theaters, etc.)	4.69	0.082
Proximity to cultural centers (museums, concert halls, etc.)	3.36	0.078
Proximity to recreational areas (ski resorts, boating, hiking, etc.)	3.24	0.081
Infrastructure	**5.82[H]**	**0.050**
♦ **Milk Processors and Handlers**	**7.41[a]**	**0.062**
Proximity to milk processors and handlers (cheese plants, bottling plants, etc.)	7.87	0.060
Number of milk processors and handlers (cheese plants, bottling plants, etc.) in the local area	6.95	0.076
♦ **By-product Outlets**	**7.04[b]**	**0.069**
Outlets for cull cows and bull cows	7.04	0.069
♦ **Feed Supplies**	**6.73[c]**	**0.055**
Supply of locally grown forages	7.78	0.065
Supply of by-product feeds	6.83	0.076
Supply of locally grown grains	6.19	0.081
Proximity to feed mills or feed mixing facilities	6.12	0.080
♦ **Veterinarians**	**6.62[c]**	**0.073**
Proximity to veterinarians	7.27	0.073
Number of veterinarians in the local area	5.98	0.084
♦ **Milk Equipment**	**6.59[c]**	**0.066**
Proximity to milk equipment dealers and service providers	7.09	0.066
Number of milk equipment dealers and service providers in the local area	6.10	0.078
♦ **Contractors**	**6.33[d]**	**0.074**
Proximity to building contractors that have experience in constructing dairies	6.73	0.077
Number of building contractors in the local area that have experience in constructing dairies	5.93	0.080
♦ **Extension**	**5.47[e]**	**0.086**
Quality of the state and local (county or parish) Extension program	5.47	0.086
♦ **Record Keeping Services**	**5.21[f]**	**0.097**
Availability of production record keeping services (DHI, etc.)	5.21	0.097

Table 1 (Continued).

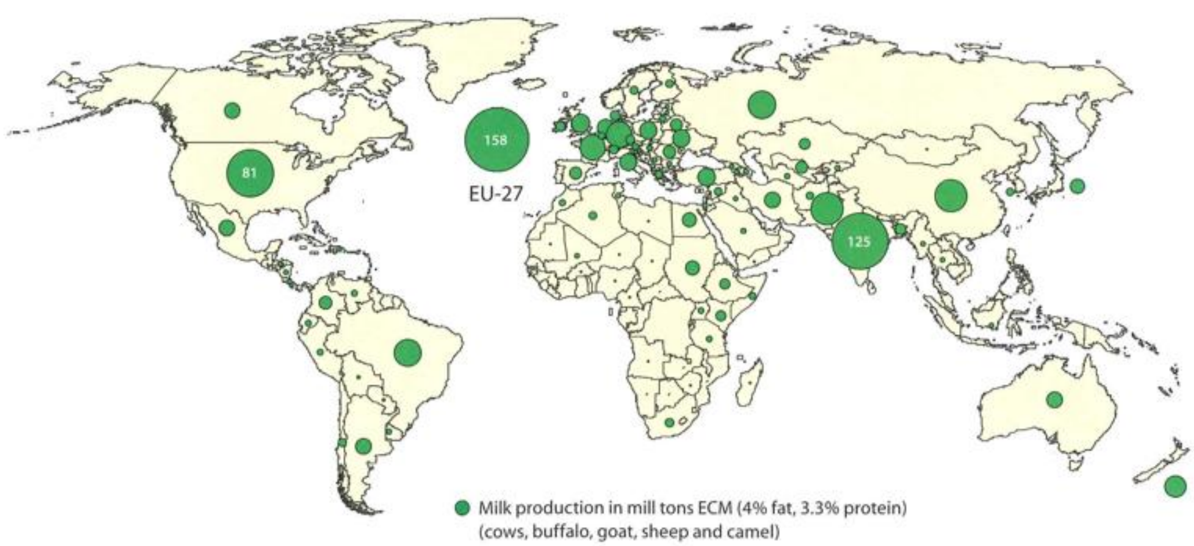
Location Decision Component and Factor	Mean	SE
Infrastructure (continued)		
♦ **Nutritional Advisers**	**4.94^{g}**	**0.080**
Proximity to nutritionists or nutritional advisers	5.42	0.084
Number of nutritionists or nutrition advisers in the local area	4.45	0.084
♦ **Heifers**	**4.70^{h}**	**0.080**
Local availability of replacement heifers	5.05	0.086
Local availability of custom heifer growers	4.34	0.088
♦ **Hoof Trimmers**	**4.68^{h}**	**0.079**
Proximity to hoof trimmers	5.05	0.081
Number of hoof trimmers in the local area	4.31	0.082
♦ **Financial Service Providers**	**4.67^{h}**	**0.077**
Proximity to lenders	4.87	0.088
Availability of financial advisers (accountants, brokers, insurance agents, etc.)	4.60	0.083
Number of lenders in the local area	4.55	0.086
♦ **State Dairy Producers Organization**	**4.50^{h}**	**0.089**
Existence of a state or local dairy producers organization	4.50	0.089

[1] Table is defined as follows: Location decision category (e.g. Cash Flow); Subgroup of location decision factors (e.g. Income-related); and Individual location decision factor (e.g. Average mailbox price of milk ($/cwt)).
[2] 0 = Not important; 5 = Somewhat important; and 10 = Critically important.
[A, B, C, D, E, F, G, H] Means of categories with different superscripts are different ($P < 0.05$).
[a,b,c,d] Means within a category with different superscripts are different ($P < 0.05$).

Figure 1. Milk surplus and deficit in the United States, 2008.[1]

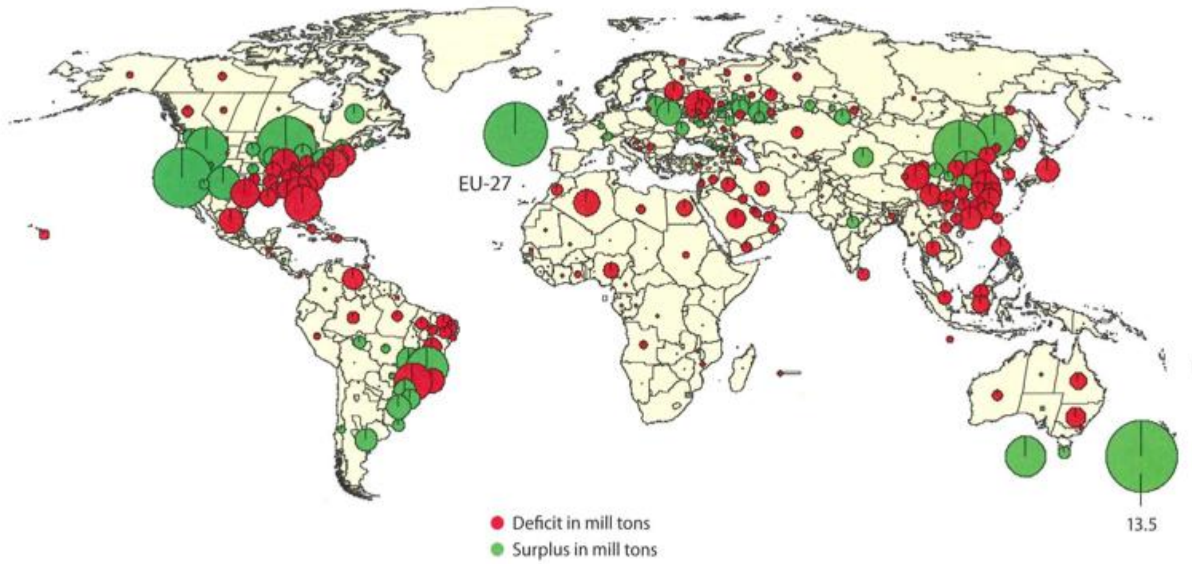
[1] Data are for 2008 in natural fat and protein content. Source: International Farm Comparison Network, Dairy Report. 2009.

Figure 2. Milk production worldwide in 2008.[1]



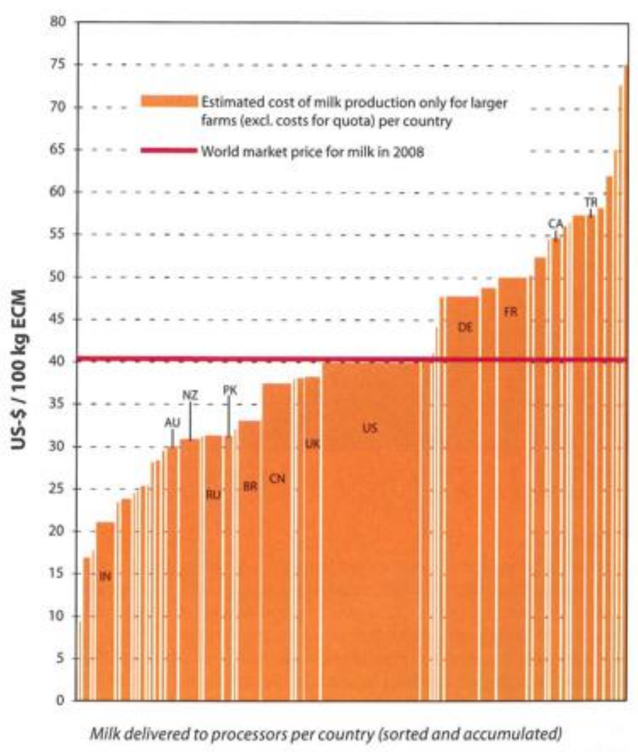
[1] Data from national statistics, FAOSTAT, and for some countries are expert estimates. Source: International Farm Comparison Network, Dairy Report. 2009.

Figure 3. Milk surplus and deficit worldwide, 2008.[1]



[1] Data from national statistics and IFCN calculations. Calculations of surplus/deficit per country (or region) based on milk production minus milk demand. Source: International Farm Comparison Network, Dairy Report. 2009.

Figure 4. World milk supply curve, 2008.[1]



[1] Based on the larger, typical dairy farms analyzed and milk delivered. Source: International Farm Comparison Network, Dairy Report. 2009.

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How Did You Survive?

Moderated By: Steve Larson
Managing Editor, Hoard's Dairyman

Notes:

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Managing Stress & Building Healthy Family Relations[1]

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Introduction

Most farm and ranch families are resilient survivors. They have learned well over the years how to bounce back from stressful times. They are optimistic. They have positive attitudes, strengths, and skills to persevere through good times and tough times. How else could their family business have survived to the fourth, fifth, and sixth generations?

Why Is Managing Stress Important in Agriculture?

Farming is one of the top 12 high stress occupations (Swisher, Elder, Lorenz, & Conger, 1998). The National Institute for Occupational Safety and Health studied 130 occupations and examined the incidence of stress-related diseases (coronary heart and artery disease, hypertension, ulcers, and nervous disorders) (Smith, Colligan, & Hurrell, 1977). They examined more than 22,000 Tennessee workers' health records, death certificates, hospital admissions, and mental health center admissions and found that farm owners were among 12 categories of workers that displayed high incidence of stress-related illnesses. When the death certificates were analyzed alone, farm owners were second only to laborers in the rate of death from stress-related diseases. People in agriculture and mining have the highest rates of disabling injuries and fatalities (National Safety Council, 1976-2009).

Among Farmers, Who Experiences More Stress*?* Among two-generation farm families in which both parents and their adult children were actively involved in operating the farm or ranch, researchers found that the younger generation experienced more stress, less perceived social support, and less occupational satisfaction than the older generation (Weigel, Weigel, & Blundall, 1987). The authors inferred that feelings of powerlessness from working on a multigenerational farm where they had little power and more financial pressure and debt load may contribute to higher stress levels among younger farmers. The most frequently occurring stressor for two-generation farm families in Iowa was living with "tight money" (Weigel & Weigel, 1987). For sons- and daughters-in-law, another frequently reported stressor was not being on one's own. For mothers and fathers, the most frequently reported stressor was taking responsibility for risks and disagreements over spending. A frequently reported stressor for daughters-in-law and mothers was "not being a part of the

[1] This is to acknowledge and express appreciation for the literature review provided by Rosie Gomez, Graduate Student, Department of Human Development & Family Studies, Colorado State University.

operation." A study of 242 senior generation farmers and 239 junior generation farmers found that: "…neither generation is happy with the communication in their two-generation farm family. Items such as handling arguments, fair criticism and family problems were ranked low by both groups" (Weigel & Weigel, 1990). In another study, daughters-in-law were reported to experience the highest level of stress within family units with a negative relationship with the parents-in-law exacerbating her stress level (Marotz-Baden & Mattheis, 1994). Stress levels were found to be higher for mixed type operations (e.g. livestock and grain) than for grain farmers (Walker & Walker, 1987). Overall, the integrated nature of working, playing, and living side by side, day after day seems to lead to stressors that may be unique among farm and ranch families.

Do Farmers and Ranchers Experience Significantly Higher Levels of Stress Than Does the General Population*?* Research with more than 22,000 Tennessee workers, as reported earlier, indicated that farming is one of the top 12 (of 130) high stress occupations (Smith et al., 1977; Swisher et al., 1998). In a study of 303 people in the United Kingdom, farmers scored significantly higher than the general population on measures of stress (Booth & Lloyd, 1999). More research is needed comparing the stress levels of farmers and ranchers with the general population.

In a comparison study of rural and urban families, researchers found that they experienced different stressors. For example, rural husbands and wives reported that financial and business strains contributed to overall pileup of stressors while urban families reported that intra-family strains contributed to a majority of their pileup (Marotz-Baden & Colvin, 1986). In the same study both rural and urban families reported using reframing the most followed by seeking spiritual support. Reframing happens when a person changes the meaning or perception of a stressor which can assist them in handling a stressor, e.g. "After dad died I knew it was up to me to step up to the plate and take the lead in where we're going with our dairy farm business." Seeking help was the next most commonly used coping strategy. Rural families used these coping strategies significantly more than urban families.

Farm and ranch families faced different hardships than urban families, many of which centered on economic, family, and personal strain (Carson, Araquistain, Ide, Quoss, & Weigel, 1994). Stressors unique to ranch and farm families that contributed to discord included ambiguous roles within the family due to illness or injury, intimate living and working conditions between immediate and extended family members, and unpredictable or uncontrollable factors such as equipment breakdown, weather, or financial markets (Carson et al.).

However, with the unique stressors also come notable strengths in farm and ranch families. In addition to external support from family members, hardiness was identified as a characteristic of many resilient farm and ranch families (Carson et al., 1994). Hardiness involves "a sense of commitment to work together to manage and solve problems, a belief that families are in control of their responses to stressful life events, and a conviction that those changes and events can be both challenging and growth-producing" (Carson et al., p. 158). Therefore, families that have high hardiness are considered to have effective coping strategies whereas families with low hardiness are considered to be more susceptible to negative effects of stressors.

Additional studies found that rural men and women tend to possess similar strengths and coping strategies that help them manage their many stressors. Gorman et al. (2007) found that rural families expressed more reasons to feel positive, despite difficult times, and they felt needed and supported by family, friends, and their communities which gave them a purpose and hope in life. This strong sense of purpose and belongingness was found to be a helpful resource in coping with significant life stressors and is particularly salient among farm and ranch communities in which family is nearby and good social structure is in place (Gorman et al.; McLarren & Challis, 2009).

All families deal with stressors and crises at some level. Families that are at increased risk for suffering from crisis have limited social support, coping strategies, family cohesion, flexibility and support, and negative appraisal of their situation. They are at higher risk for falling apart rather than adapting healthily to a crisis. Additionally, families experiencing more non-normative stressors, such as financial strain, non-normative caregiving, or ambiguous loss are at higher risk.

The purpose of this paper is to assist dairy farm families in understanding the effective coping strategies and resources that families can use to bounce back from crises rather than disintegrate to a point that is no longer manageable. Learning and understanding some of these tested methods for dealing with stressor pile-up is important in achieving healthy family functioning.

To understand the process how families move from a state of stress or strain through a crisis to re-balance afterwards, it is critical to identify what determines whether a family will end up in trouble or will end up with increased skills at handling crises and at re-establishing their family equilibrium, balance, or homeostasis (Lavee, McCubbin, & Patterson, 1985).

4 Steps to Building Healthy Family Relations Through Stressful Times

Managing stress and building family relations is essential for the survival of dairy farms. Research studies have shown that survivors of major stressors do four things differently with their stressful times than do non-survivors. They manage their stressor *pileup*. They utilize existing and new internal and external *resources.* They reframe their meanings or *perceptions* of their stressful times from negative to more positive meanings. Finally, they *adapt* to the crisis and rebalance their family after the crisis. Let's explore each of these in more detail.

1. Pileup. Pileup refers to the pile-up of stressors and strains that a family experiences when dealing with a crisis. Dairy, farm, and ranch families, like all families, experience normal stressors, stressors unique to their occupations, and nonnormative stressors.

Livestock are a major cause of injury. Male principal operators who worked with animals more than 15.75 hours per week were found to have twice the risk of sustaining injury (Park et al., 2001). Dairy farmers' rate of injury was 2.5 times higher than for non-dairy farmers in Iowa (Nordstrom et al., 1995). Injuries that resulted from animals tended to be more serious than for other farming accidents. For farmers or ranchers with a physical disability, secondary injury was more likely to occur in a livestock-related accident (Allen, Field, & Frick, 1995).

Several research studies have identified major stressors of dairy farmers in New Zealand and of farmers in New Zealand, England, Wales, and Iowa. In a study of close to 1,000 New Zealand dairy farmers, the major stressors included time pressures, machinery failures, weather, and government policies (Alpass et al., 2004). A study of 1,015 individuals from 669 New Zealand farms reported that their leading stressors were "increased work load at peak times," "dealing with workers' compensation," "bad weather," and "complying with health and safety legislation" (Firth, Williams, Herbison, & McGee, 2006). In a study of 500 farmers in England and Wales, the major stressors were government regulations, paperwork, financial difficulties, and health related problems (Simkin, Hawton, Fagg, & Malmberg, 1998). Other studies identified the top stressors as economic factors, work overload, relationship issues (Simkin, Hawton, Yip, & Yam, 2003), coping with new legislation, excessive paperwork, and media criticism (Booth & Lloyd, 1999). A study of 1,343 Iowa farm residents identified their top ten stressors to include death of a spouse, death of a child, disabling injury of a family member, disabling injury to oneself, foreclosure on a mortgage or loan, divorce, machinery breakdown during harvest, loss of crop to weather, loss of crop to pests or disease, and severe weather conditions (Freeman, Schwab, & Jiang, 2008). One of the most stressful intergenerational farming/ranching issues is the transfer of the family ranch/farm from one generation to the next and the need to keep it stable and operating in order to sustain profitability (Anderson & Rosenblatt, 1985; Fraser et al., 2005; Russell, Griffin, Flinchbaugh, Martin, & Atilano, 1985; Zimmerman & Fetsch, 1994).

The more pileup of stressors and the more previous life stressors that a family faces, the more at-risk they are for high stress and strain (Lavee et al., 1985). Not surprisingly, higher stress levels often result in lowered satisfaction with family life style, personal well-being, and an increase in probability of health, emotional, and relational difficulties (Lavee et al.). They are more at risk for accidents that could lead to injury or fatality (National Safety Council, 1976-2009). Additionally, they are at risk of experiencing relationship problems including family, marital, and parenting difficulties, psychological distress for children and adolescents, increased risk of domestic violence, alcohol, and other drug abuse, and increased levels of depression and suicide.

For many families a significant increase in additional stressors often results in an adjustment in roles, boundaries, and rules within the family system which often causes additional stress. Families can experience these strains over short or chronic periods depending on the severity of the stress they experience. Often families deal with more than one stressor at a time (Xu, 2007). Marotoz-Baden and Colvin (1986) reported that three types of stressors contribute to pile-up. First is the initial stress that leads a family into a state of crisis. Second are the normal life changes that the family experiences such as the birth of a child or death of an elderly person and the non-normative life changes such as an unexpected drop in milk prices or sudden, unexpected increase in feed, fertilizer, or diesel costs. Third are those stressors associated with a family dealing with the hardship or crisis situation.

2. Resources. In response to a pileup of stressors and strains, families use resources to help them deal with the demands and needs of the situation. Particularly helpful in stressful times are family resources such as personal resources like self-esteem, knowledge or skills, emotional health, personality characteristics, and financial well-being. Family researchers have found that family members with high self-esteem and self-efficacy are able to cope more effectively with stress than those with lower self-esteem (Xu, 2007). Self-efficacy is a person's assessment of their abilities to perform specific tasks in relation to their own goals and standards rather than in comparison with others' capabilities (Retrieved December 27, 2010 from http://en.wikipedia.org/wiki/Self-efficacy). Family resources also include social support and family system resources. Social support refers to external resources such as friends, institutions, or outside networks that the family can draw upon during tough times (Lavee et al., 1985). Social support serves as a buffer and reduces strain. Families who were involved in their communities and who networked with friends were found to be better adjusted to major disruptions like relocating in the army (Lavee et al.). Family system resources include internal characteristics such as family cohesion, adaptability, and open communication. Open communication, sense of mastery over events, and mutual support among family members are helpful family resources for families in a hardship or crisis situation (Xu). The more cohesive, flexible, and communicative a family is especially with supportive messages, the better able to adjust to severe crises the family will be. The more they use both internal and external resources and the more they work together to solve problems, the more successful they will be.

3. Perception. Perception or family meaning refers to the meaning that the family attributes to the entire crisis situation, including the initial stressor, additional pile-up stressors, and family resources. A family's perception can pertain to their internal environment, such as their perceived interpersonal and familial strengths, as well as their external environment, including both positive and negative experiences pertaining to the family's ability to adapt (Lavee et al., 1985). Research suggests that families who reinterpret initial negative to more positive meanings of their overall crisis situation are more likely to be in control of their stressors, to find possible solutions to crisis situations, and to adapt well eventually to the crisis (Xu, 2007). This ultimately helps the family to re-establish a state of equilibrium, balance, or homeostasis following the crisis.

Despite a commitment and bond one may feel to their community, there still is a social stigma, especially for men, in asking for help if it pertains to a private issue or a matter that brings up shame. This stigma and shame that a person may feel when dealing with a particular stress or crisis is often a barrier for a family trying to adapt well to a stressor, and it ultimately puts them at further risk for harm and additional stressor pile-up (Gorman et al., 2007). It is important to note that social stigmas and shame serve as a barrier for families to manage tough times well because sadly, suicide rates are high among farmers as compared to the general population (McLarren & Challis, 2009). Dairymen who survive figure out how to make a call to a professional and see it as a good way to solve a problem.

4. Family Adaptation. Family adaptation is how a family adapts to the crisis and develops skills to re-balance the family to the crisis. Ultimately, experiencing a very high dosage of family strain and stress can lead a dairy farm family into a state of crisis. However, the better they manage their pileup of stressors, the better they use their resources, and the better they reinterpret the meaning of their stressful event, the healthier they will be in the future. The ultimate goal is to adapt well to and to function more effectively following crisis. Families that are able to make positive meaning of their stressors and use effective coping strategies as well as internal and external resources are more likely to adapt well eventually (Xu, 2007).

Despite the high risk for mental health issues such as depression and suicidal ideation that often results from very stressful financial times, social isolation or loneliness, and limited access to mental health services, farm and ranch families can manage the pileup, use resources, and reframe their perceptions of their tough times to manage stressors well and ultimately work to maximize profits. Whether farm and ranch families are dealing with similar or different stressors than other families, by accessing the resources available to them including personal characteristics and hardiness as well as social supports, and by viewing stressor events as challenges or opportunities for growth instead of as threats or crises, dairy, farm, and ranch families can make good decisions to manage stressor pile up, cope effectively with tough financial times, increase business profitability, and bounce back resiliently from stressful times.

How Do Resilient Families Build Healthy Family Relations?

Healthy, resilient dairy farm families use many of the following strategies.

- Be aware of family strengths, skills, and weaknesses.
- Focus on family strengths.
- Use open (rather than closed) communication with family members with two and three generations.
- Encourage open communication about needs, wants, feelings, desires, dreams, etc. (See “Ranching and Farming with Family Members” below.)
- Reduce blame and accept responsibilities.
- Use democratic or consensus decision making (rather than autocratic decision making). (See “Making Decisions and Coping Well with Drought.”)
- Plan early for normal family changes like a child turning 2 or 13, a parent needing in-home care.
- Practice reinterpreting initial negative meanings to more positive meanings of a crisis situation.
- Hold effective family meetings to solve problems. (See “Manage Anger through Family Meetings.”)
- Adapt family roles.
- Adjust to financial hardships.
- Spot signs of high stress, anger, depression, and suicidal thinking. (If a family member or friend is suicidal, call 1-800-SUICIDE/800-784-2433 for local resources.)
- Call on professional help when needed. (Check the yellow pages of your telephone book under “counselors” for family consultants, marriage and family therapists, mental health

professionals, priests/ministers, financial mediators, e.g. Colorado Agricultural Mediation Program 303-477-0054.)

- Encourage spirituality and use support systems like faith-based communities.
- Use problem-solving skills. (See "Dealing with Couples' Anger.")
- Resolve feelings of grief and loss.
- Maintain a balance that meets the needs of all family members.
- Practice a variety of healthy stress management skills, like exercise, relaxation, problem solving, and assertiveness. (See "Farming and Ranching: Health Hazard or Opportunity?")
- Use the two handouts in the Appendix below.
- Take good care of yourself and each other.

Resources

For more trustworthy information on this and on related topics, call Colorado State University Extension (970-491-6281) or Google http://www.ext.colostate.edu/pubs/consumer/.

- Managing Stress During Tough Times (no. 10.255)
- Making Decisions and Coping Well with Drought (no. 10.256)
- Farming and Ranching: Health Hazard or Opportunity? (no. 10.201)
- Ranching and Farming with Family Members (no. 10.217)
- Transitions and Changes: Who Copes Well? (no. 10.215)
- Transitions and Changes: Practical Strategies (no. 10.214)
- Preventing Youth and Adult Suicide (no. 10.213)
- Dealing with Our Anger (no. 10.236)
- Dealing with Others' Anger (no. 10.237)
- Dealing with Couples' Anger (no. 10.238)
- Manage Anger through Family Meetings (no. 10.249)

For additional trustworthy information, contact the University of Wyoming web site, http://agecon.uwyo.edu/riskmgt/humanrisk/HUMANFamily.htm.

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APPENDIX

Farm and Ranch Family Stress and Depression: A Checklist and Guide for Making Referrals

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SIGNS OF FARM AND RANCH STRESS

The last few years have been difficult for farm and ranch families. Many are experiencing financial and emotional stress as a result. There are several signs or symptoms when a farm family may be in need of help. These are signs that can be observed by friends, extended family members, neighbors, milk haulers, veterinarians, clergy persons, school personnel or health and human service workers. These signs include:

- **Change in routines**. The rancher or ranch family stops attending church, drops out of 4-H, FFA, Homemakers or other groups, or no longer stops in at the local coffee shop or feed mill.
- **Increase in illness**. Farmers or farm family members may experience more upper respiratory illnesses (colds, flu) or other chronic conditions (aches, pains, persistent cough).
- **Appearance of farmstead declines**. The farm family no longer takes pride in the way farm buildings and grounds appear, or no longer has the time to do maintenance work.
- **Care of livestock declines.** Cattle may not be cared for in the usual way; they may lose condition, appear gaunt or show signs of neglect or physical abuse.
- **Increase in farm or ranch accidents.** The risk of farm accidents increases due to fatigue or loss of ability to concentrate; children may be at risk if there isn't adequate childcare.
- **Children show signs of stress.** Farm and ranch children may act out, decline in academic performance or be increasingly absent from school; they may also show signs of physical abuse or neglect.

SIGNS OF CHRONIC, PROLONGED STRESS

When farm and ranch families are stressed out for long periods of time – chronic, prolonged stress – they may experience a number of signs and symptoms. Watch for the following effects in farm families you see on a day-to-day basis:

Physical	**Emotional**	**Behavioral**
☐ Headaches	☐ Sadness	☐ Irritability
☐ Ulcers	☐ Depression	☐ Backbiting
☐ Backaches	☐ Bitterness	☐ Acting Out
☐ Eating Irregularities	☐ Anger	☐ Withdrawal
☐ Sleep Disturbances	☐ Anxiety	☐ Passive-Aggressiveness
☐ Frequent Sickness	☐ Loss of Spirit	☐ Alcoholism
☐ Exhaustion	☐ Loss of Humor	☐ Violence

Cognitive	**Self-Esteem**
☐ Memory Loss	☐ "I'm a failure."
☐ Lack of Concentration	☐ "I blew it."
☐ Inability to Make Decisions	☐ "Why can't I…?"

SIGNS OF DEPRESSION OR SUICIDAL INTENT

The greater the number of signs or symptoms a ranch or farm family is experiencing, the greater your concern should be. In addition, if family members are exhibiting the following signs of depression or suicidal intent, it is important that you connect them with professional help as soon as possible. All cries for help should be taken seriously.

Signs of Depression

- **Appearance**: Sad face, slow movements, unkempt look.
- **Unhappy feelings**: Feeling sad, hopeless, discouraged, and listless.
- **Negative thoughts**: "I'm a failure;" "I'm no good," "No one cares."
- **Reduced activity and pleasure in usual activities**: "Doing anything is just too much of an effort."
- **People problems**: "I don't want anyone to see me," "I feel so lonely."
- **Physical problems**: Sleeping problems, decreased sexual interest, headaches.
- **Guilt and low self esteem**: "It's all my fault," "I should be punished."

Signs of Suicidal Intent

- **Anxiety or depression**: Severe, intense feelings of anxiety or depression.
- **Withdrawal or isolation**: Withdrawn, alone, lack of friends and supports.
- **Helpless and hopeless**: Sense of complete powerlessness, a hopeless feeling.
- **Alcohol abuse:** There is often a link between alcoholism and suicide.
- **Previous suicidal attempts**: May have been previous attempts of low to high lethality.
- **Suicidal plan**: Frequent or constant thoughts with a specific plan in mind.
- **Cries for help**: Making a will, giving possessions away, making statements such as "I'm calling it quits," or "Maybe my family would be better off without me."

HOW TO REFER A PERSON FOR HELP

1. Be aware of the agencies and resources available in your community – what services they offer and what their limitations are.
2. Listen for signs and symptoms that the person or family needs help which you can't provide, i.e., financial, legal or personal counseling.
3. Assess what agency or community resources would be most appropriate to address the person's (or family's) problems.
4. Discuss the referral with the person or family (It sounds/looks like you are feeling ____. I think ____ could help you deal with your situation.")
5. Explore the individual's or family's willingness to initiate contact with the community resource ("How do you feel about seeking help from this person/agency?").
6. Where the person or family is unwilling to take the initiative or where there is some danger if action is not taken, you should take the initiative:
    a. Call the agency and ask to speak to the intake worker (if there is one).
    b. Identify yourself and your relationship with the person or family.
    c. State what you think the person's or family's needs are (needs immediate protection from suicidal acts, needs an appointment for counseling, needs financial or legal advice).
    d. Provide the agency with background information (name, address and phone; age and gender; nature of current problem or crisis; any past history you're aware of; further information as called for).
    e. Ask the agency what follow-up action they will take:
    *When will they act on the referral?
    *Who will be the person for you to contact later if necessary?
    *What will be the cost of the service (flat fee/sliding scale)?
    *Do you need to do anything else to complete the referral?
7. Make sure the person or family and the referral agency connect and get together. Make one or more follow-up contacts with the agency if called for by the situation.

PREDICAMENT-PROBLEM CONTINUUM*

1. Please list your eight to ten major stressors you are currently experiencing or anticipate experiencing within the next month. A stressor is a life event of sufficient magnitude to bring about change in an individual or family.

Stressor	Rank	%
____	_____	_____
____	_____	_____
____	_____	_____
____	_____	_____
____	_____	_____
____	_____	_____
____	_____	_____
____	_____	_____
____	_____	_____

2. Would you select the top four you would like to do something about in the next 30 days and rank order them?

3. Many of us sometimes find ourselves getting stressed out and worried about things outside our control. In the third column beside your stressors and their rank orderings, please indicate the percentage of control you have over each of your ten stressors—from 0% control to 100% control....

4. Do you already know the difference between a predicament and a problem? A predicament is something over which we have no control. A problem is something over which we have control.

5. Would you please create your own personal "Predicament Problem Continuum"? On the continuum below, please write each of your top four stressors at the point on the continuum representing your level of control over it .... For example, if the weather is a stressor on your short list and if you have no control over it, then write it toward the left end near 0% control. If lying awake worrying is a stressor, since the amount of time you spend worrying is largely within your control, write worrying toward the right end of the continuum near 100% control. Most parents have 80-90% control over their two-year-old and less as she or he grows up to be 10, 15, and 18 years old.

Predicament-Problem Continuum

PREDICAMENT PROBLEM

0% Control 100% Control

____

6. How do you handle the predicaments in your life? ... If your number one stressor that you wanted to do something about in the next 30 days is a predicament over which you have no control, e.g. mother's dying of cancer, would you start today to practice letting it go? Sometimes when we think about it, we discover that we have precious little control over how a spouse acts and even less over what a neighbor thinks or does. Practice letting go of any stressors you experience that are predicaments. How? By accepting them. Some people find it helpful to remember Reinold Niebuhr's prayer: "Lord, grant me the serenity to accept the things I cannot change (predicaments), the courage to change the things I can (problems), and the wisdom to know the difference." When we accept the predicaments in our lives, we free up energy to solve the problems within our control.

7. From the list of stressors in item #1 above, write down the top stressor problem (over which you have 50-100% control) that you'd like to do something about in the next 30 days. _________________
____

8. What meaning/belief do you currently hold about that stressor problem? One person's belief was, "This crisis is terrible; I can't cope." Another's was, "Boy, I've got a challenge on my hands; I wonder what I can learn from it." ____
____

9. Brainstorm two or three more positive ways you could reframe or reinterpret your stressor problem.
____
____

10. What personal inner strengths/resources could you use to increase your control over your responses to this stressor problem (e.g. your sense of determination, your experience with previous crises)?
____
____
____

11. What family resources could you use to increase your control over your responses to this stressor problem (e.g. your spouse's flexibility, family's flexibility, family's sense of humor)?
____
____
____

12. What community resources could you use to increase your control over your responses to this stressor problem (e.g. couple's group to share similar problems and solutions, baby-sitting co-op among friends, marriage and family therapist)?
____
____
____

13. Now would you mark on your calendar to review in a month how well you are responding to the top stressor problem identified in item #7 above? Would you also write on your calendar the steps you will take to reframe that problem in more positive ways and to use those resources that would be most beneficial to you? Thank you! You and your family will be glad you did!

____

*By Robert J. Fetsch, Ph.D., Extension Specialist, Human Development & Family Studies. (Predicament-Problem Continuum (Rev. 12.2810). Fetsch, R. J. (1992). The predicament-problem continuum: Dealing with stressors outside our control. *Journal of Counseling and Development, 71*(2), 192-193.

Notes:

Managing Transition Cow Issues

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Abstract

A smooth transition from the late dry period through early lactation has profound impacts on the success of both the lactation and conception. Most problems that herds experience during transition manifest as metabolic disease issues, or stem from them. High incidence rates of retained placenta, metritis, ketosis and displaced abomasums can be obvious reasons for poor herd performance. However, often metabolic problems are still the root of suboptimal performance but go unnoticed on many dairies. Monitoring transition cow health through routine ketone testing or with precalving serum tests can be a valuable tool for tracking herd metabolic status and helping to uncover reasons for transition cow problems. Metabolic problems on most herds usually have multiple component causes that will frequently relate to cow, feed, and environment problems. These causes may include many factors such as pen density or feed access issues, stressful grouping strategies, frequent group changes, feed issues or body condition problems. Effective monitoring programs can not only help identify problems but can be used to track the success of management changes.

Introduction

Unraveling the cause of transition cow problems is a complex task. The “cause” will always be multifactorial, meaning that there will be multiple components that have ultimately contributed to the eventual problem. Since this is the case, often investigations will stop once one issue has been identified. A solution or remedy directed at this one particular issue may fail to alleviate the big problem. The investigation will then continue until the next issue is identified. This process is frustrating and lacks a systematic approach. Recognizing the multifactorial nature of disease and using a systematic approach to problem solving can help with making a more efficient diagnosis and often remedy the transition cow problem much faster.

Most problems that herds experience during transition manifest as metabolic disease issues. High incidence rates of retained placenta, metritis, ketosis and displaced abomasums can be obvious reasons for poor herd performance. However, suboptimal performance may be caused by subclinical metabolic disease and go unnoticed on many dairies. Monitoring transition cow health through routine ketone testing or with precalving serum tests can be a valuable tool for tracking herd metabolic status and helping to uncover reasons for transition cow problems. Metabolic problems on most herds usually have multiple component causes. These causes may include many factors such as pen density or feed access issues, stressful grouping strategies, frequent group changes, feed issues or body condition problems. Effective monitoring programs can not only help identify problems but can be used to track the success of management changes.

Circulating concentrations of non-esterified fatty acid (NEFA) and β-hydroxybutyrate (BHBA) measure the success of adaptation to negative energy balance. NEFA reflects the magnitude of mobilization of fat from storage. BHBA indicates the completeness of oxidization ("burning") of fat in the liver. Ketone bodies (BHBA, acetone and acetoacetate) are intermediate metabolites of oxidation of fatty acids; as the supply of NEFA to the liver exceeds the ability of liver to completely oxidize the fatty acids to supply energy, the amount of ketone body production increases. Ketone bodies can be used by muscle as an alternative fuel source to glucose, sparing glucose for milk production (Herdt, 2000a). However, ketone production does not result in as much net energy release as does complete oxidation of fatty acids. Additionally, increasing concentrations of ketones are thought to suppress feed intake.

Glucose is the primary metabolic fuel, and is absolutely required for vital organ function, fetal growth, and milk production. In dairy cows, the massive energy demand to support milk production is partly met through gluconeogenesis. Glucose concentrations are under tight homeostatic control. Therefore, although glucose has a central role in metabolism, it is a poor analyte for monitoring or investigating herd problems (Herdt, 2000b). Aspartate aminotransferase is an enzyme that becomes elevated with cell damage and may be elevated in cows with fatty liver disease. Although there have been associations between AST and subsequent occurrence of displaced abomasums (Geishauser et al, 1997), the test lacks both sensitivity and specificity. For energy balance NEFA and BHBA are the best two measures.

Calcium demand is tremendous immediately postpartum and monitoring serum calcium in cows less than a week following calving may have some utility but before or beyond this time period, it makes no sense to measure calcium. Recently, low serum calcium concentrations (subclinical hypocalcemia) have been linked with increased risk of early lactation culling (Duffield et al, 2005).

Haptoglobin is an acute phase protein that becomes elevated under situations of inflammation. However, this inflammation indicator is non-specific and could reflect for example dystocia, mastitis, metritis or displaced abomasum. However, despite its non-specific nature haptoglobin may have utility for monitoring transition cows. **Currently the strongest data exists for the use of NEFA and BHBA testing in transition dairy cows.**

Impact of Transition Cow Metabolic Parameters on Performance

Key associations of NEFA and BHBA with health and performance in transition dairy cows are:

- High NEFA in the 2 weeks before calving is associated with
  - 2 to 4 times increased risk of LDA
    (Cameron et al, 1998; LeBlanc et al, 2005; Opsina et al, 2010)
  - 1.8 times increased risk of retained placenta (RP) (LeBlanc et al 2004)
  - 2 times increased of culling before 60 days in milk (DIM) and 1.5 times increased risk of culling over the whole lactation (Duffield et al, 2005)
  - Reduced milk yield (Carson, 2008; Opsina et al, 2010)

- Subclinical ketosis (BHBA > 1200 – 1400 μmol/L) in early lactation is associated with
  - 3 to 8 times increased risk of LDA (Duffield, 1997; Geishauser et al, 2000b; LeBlanc et al 2005)

- Decreased probability of pregnancy at first AI (Walsh et al, 2008)
- Decreased milk production (Duffield, 2009)
- Increased duration and severity of mastitis (Suriyasathaporn, 2000)

Key Monitoring Parameters for Transition Cows

NEFA

This test should only be used precalving on samples obtained within 1 week of parturition. The data for NEFA is frequently right skewed and thus averages can be very misleading. One suggested threshold is 0.5 units/L. Cows within 1 week of calving with serum NEFA above this threshold were at a 3.5 times greater risk of subsequently developing a displaced abomasums (Leblanc et al, 2005). Whole herd interpretation is best made by calculating a proportion of cows above a threshold value, however, there is limited data on an appropriate goal for this parameter. In a muti-herd 1060 cow study near Guelph, 30% of cows were above 0.5 U/L during the last week prior to calving (Leblanc et al, 2005).

One study evaluated 136 transition cows and 24 had BHBA concentrations ≥ 1400 μmol/L of serum in the first week post-calving (17.6%). There was a significant association between NEFA concentration in the week prior to calving and BHBA concentration in the first week post-calving. A nearly 5-fold increased risk of SCK was noted when the NEFA concentrations in the week before calving were greater than 0.7 mmol/L (OR=4.8, P=0.04) (Osborne, 2003).

BHBA

In contrast to NEFA, serum BHBA should only be used postcalving. The first two weeks are the primary risk period for subclinical ketosis, defined by a serum concentration of 1400 umol/L BHBA or greater (Duffield, 2009). A reasonable goal is to have less than 2 cows per 10 with BHBA above 1400 umol/L in the first 2 weeks post-calving.

Sample Handling

Both NEFA and BHBA can be measured with either plasma or serum. Both analytes are subject to interference with hemoglobin in the sample, thus, hemolysis will artificially elevate measurements and should be avoided. Both NEFA and BHBA are subject to changes relative to time of feeding. Samples meant to compare performance on the same farm should be obtained at approximately the same time of day. The most severe swing in values in our experience appears to be with NEFA with highest values obtained just before first feeding. Therefore. it is best to sample herds at some point after the first feeding of the day. NEFA concentrations could be slightly falsely elevated if serum were not separated within 12-24 h of blood collection, or if samples were not kept chilled (Stokol and Nydam, 2004). Serum can be kept frozen for at least 1 month without affecting NEFA results. Samples should be collected from the tail vein (not the milk vein) and ideally chilled, separated within a few hours, and then frozen or shipped chilled for receipt at the laboratory within 1 to 2 days. However, delay of up to 24 hours for separation, and kept at room temperature for 1 day or refrigerated for < 3 days does not substantially affect results (Stokol and Nydam, 2004).

Cowside Tests

Milk Ketone Tests

Most milk ketone tests measure acetone and acetoacetate through a reaction with nitroprusside which causes a colour change from white to pink or purple. These tests in general are poorly sensitive in milk (<40%) but highly specific (>90%) (Duffield, 1997; Geishauser et al, 1998). One exception is a milk ketone test that measures BHBA. It is marketed in Europe as "Ketolac BHB", in Japan as "Sanketopaper", and in Canada as "Keto-Test". This test has a much higher sensitivity in milk (>70%) and reasonably good specificity (>70%, up to 90%) (Oetzel, 2004). This is a semi-quantitative test that allows choosing a lower threshold for screening to increase sensitivity, and a higher threshold for diagnosis to increase specificity.

Urine Ketone Tests

The urine ketone tablet tests are based on the same nitroprusside reaction as the milk powder ketone tests. These tablet tests are highly sensitive (approaching 100%) but are poorly specific. Thus, they are great tests for ruling out subclinical ketosis with a negative test result. However, their use overestimates a subclinical ketosis problem because of a high probability of false positive reactions (see table 1). The use of Ketostix in urine allowing for only a 5 to 10 second interpretation window is highly accurate with performance as good or better than the Keto-Test in milk (Carrier et al, 2005).

Blood Ketone Tests

The Precision Xtra glucometer has been tested several times for accuracy for measurement of blood BHBA. It is highly accurate compared to laboratory values for detecting subclinical ketosis. This test is the best performing cowside test available.

Selection and Interpretation of Cowside Tests

There are two possible actions resulting from screening a group of fresh cows with a ketone test. One action might be to treat all positive animals with the goal to prevent subsequent development of clinical disease. In this case, a high predictive value of a positive test is desired so that normal animals are not unnecessarily treated. The second action might be to compare the percent of positive reactors to a goal for determining the effectiveness of either the transition ration or some prophylactic measure in reducing the incidence of subclinical ketosis. In this situation, the apparent prevalence is the parameter that actually would be used. The use of the urine Acetest tablet would substantially overestimate the prevalence of subclinical ketosis, while the Ketocheck™ test would grossly underestimate the prevalence. Despite a consideration of the inherent sensitivity and specificity of these two tests, their utility for group level decision making is questionable. However, both the Keto-Test and the Ketostix are useful tests for group level monitoring and for individual animal identification, while the Precision Xtra would be considered the best performing test of the three. The decision on which of these tests to select should be based on the convenience of taking either milk, urine, or blood, and also the cost of the test itself.

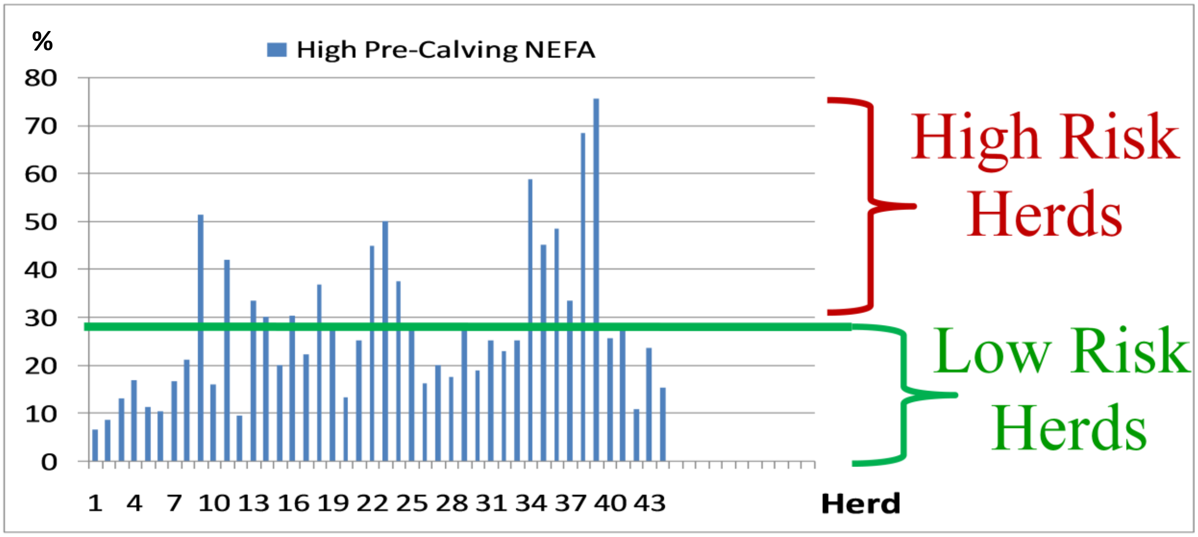
Herd Level Goals

Each herd that monitors these parameters (ketones or NEFA) should set their own goals with their advisors. A prevalence of 10% high ketones might be a problem for some herds, while on other herds this could be considered excellent performance, depending on the herd history. However, as a starting point Table 1 illustrates some suggested goals based on median values of herd performance from a multi-region North American transition cow study. Figure 1 illustrates the range in herd performance for high precalving (- 1 week from calving) NEFA values (≥ 0.5 mmol/L).

Figure 1. Suggested herd goals based on Median herd prevalence of high NEFA or ketones in a Multi-Region North American transition cow study.

Parameter	Time Relative to Calving	Cutpoint	Median Herd Prevalence	HERD GOAL
NEFA	- 1 Week Pre	0.5 mmol/L	25%	< 3/12
	+1 Week Post	1.0 mmol/L	20%	< 2/12
BHBA	+1 Week Post	1400 umol/L	15%	< 2/12

Figure 1. Prevalence of high precalving NEFA (≥ 0.5 mmol/L) across 44 herds in a multi-region North American transition cow study.



Other Tests

Herd Disease Records

Herd records are important tools for monitoring the incidence of periparturient disease. However, it is highly critical that standardized disease definitions are in place to allow comparison from year to year and from farm to farm. Producers should set goals for the minimizing the incidence of metabolic disease. Herd consultants should periodically review herd performance relative to these goals. In addition, intervention levels should also be considered. Several diseases are associated with increasing age and this must be taken into account when assessing herd performance. For example, in monitoring and comparing herd incidence of milk fever and clinical ketosis, it is important to stratify this parameter by parity. A high proportion of first lactation animals will likely give a herd a much lower incidence of milk fever and clinical ketosis, since risk increases with age.

Dry Matter Intake

Clearly cows that are mobilizing excess NEFA precalving will have suboptimal dry matter intake. Serum BHBA concentration in the first week post-calving was significantly associated with the average DMI in the week prior to calving (Osborne, 2003). There was a significant increase in the risk of subclinical ketosis (BHBA ≥ 1400 μmol/L of blood serum) if the DMI was below 12 kg/d (*OR*=5.7, *P*=0.05) in the three weeks prior to calving. If the DMI in the week prior to calving was below 11 kg/d, there was a greater risk of an animal developing subclinical ketosis in the first or second week post-calving (*OR*=2.9, *P*=0.05) (Osborne, 2003). Thus, measuring and monitoring the dry matter intake in the close-up group every week has utility. However, beware of group demographics relative to time of expected calving and parity, which can influence these parameters dramatically. Fresh cow intakes may be less useful because we are primarily interested in the intakes of cows within the first three weeks postcalving. Larger farms are more likely to have more useful opportunities for measuring dry matter intake because of the ability to group cows into parity and smaller days in milk windows.

DHI Test Day Data

Since milk fat and milk protein percentages are altered in sublinical ketosis, these parameters have been investigated for their utility in defining subclinical ketosis. Among all protein and fat parameters, a protein to fat ratio of ≤ 0.75 was the best test for diagnosing subclinical ketosis, at the cow level, in a Canadian study (Duffield et al, 1997). However, the protein to fat ratio was not a good test overall, having a sensitivity of 58% and a specificity of 69%. A big problem with both this and protein to fat ratio is the frequency of sampling. Subclinical ketosis is prevalent in the first few weeks postpartum. However, DHI testing frequency is typically every 30 to 40 days. Thus the intereval of sampling is too infrequent to hold great utility. However, the incorporation of milk ketone testing into in-line sampling methodology that could be done daily, holds tremendous promise.

Identifying High Risk Herds

Herd incidence of certain diseases may be useful to decide whether a herd has a problem with subclinical ketosis. Using data from a 25 herd study conducted in Guelph in 1995/1996, the median cumulative herd incidence of subclinical ketosis was 41% in the first two months postcalving, which crudely broke down into a threshold of 20% in week 1 and week 2 postcalving. Summary data for each herd from each cows first DHI test postcalving was used to assess the protein to fat ratio as a test at the herd level for classifying a herd as a high or low incidence herd for subclinical ketosis. If more than 40% of cows in the herd at 1st DHI test had a protein to fat ratio of less than or equal to 0.75, those herds were likely to be problem herds. This test had a sensitivity of 69%, and a specificity of 83%. Although more work needs to be done on herd level indicators of subclinical ketosis, herd level protein to fat ratios appear to be better indicators of herd level issues than individual cow protein to fat ratios are of identifying cows with subclinical ketosis problems.

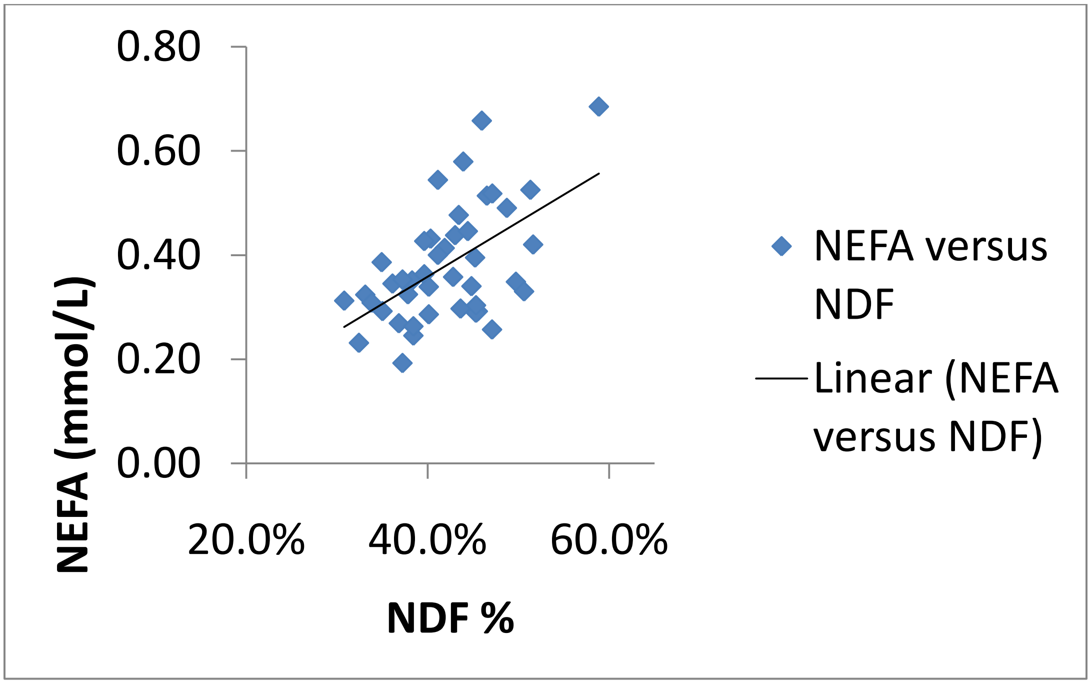
Additional analysis indicates that the herd incidence of displaced abomasum is positively associated with the probability of a herd having a high incidence (>20% in the first 2 weeks of lactation) of subclinical ketosis. In addition, if herds had greater than 10% of transition cows with a BCS ≥ 4.0 at 3 wks precalving, that herd was extremely likely to have a problem with subclinical ketosis.

Key Strategies for Prevention

Management Guidelines

Since metabolic disease problems occur in early lactation, recommendations for prevention have focused on the nutritional management of the dry and transition cow. The goals of the transition diet (specifically designed to prevent energy-related metabolic disease) are to maximize dry matter intake and to provide adequate energy density (Oetzel, 1998). Avoidance of ketogenic feedstuffs and the reduction of overconditioning cows in late lactation and the early dry period have also been suggested as aids in prophylaxis. Maximizing dry matter intake and maintenance of a consistent intake through the last three weeks prior to calving is likely the hallmark of a successful transition cow program. High fibre diets have been effective in reducing excess energy in dry diets and for maintaining rumen fill. However, NDF still limits intake; so excessively high NDF diets can reduce or limit dry matter intake. Figure 2 displays the relationship between diet NDF% in the close-up diet and herd mean precalving NEFA values (-1 week from calving) that was observed in a multi-region North American transition cow study. The relationship had an R^2 value of 0.30.

Figure 2. Relationship between NDF% in the Close-up diet and Herd mean precalving NEFA (taken 1 week precalving) for 44 herds in a multi-region North American transition cow study.



Osborne (2003) indicated that a dry matter intake (DMI) of less than 12 kg per cow per day in the last 3 weeks prior to calving substantially increased the subsequent risk of subclinical ketosis postcalving (Odds Ratio 5.7, $p < 0.05$). Achieving group DMI targets above an average of 12 kg per cow per day should be a goal for the close-up group. More important than ration formulation and ration ingredients, close attention should be paid to cow comfort and environmental issues. These factors include but are not limited to adequate pen space or stall space per cow, adequate feed bunk space, sufficient and comfortable bedding, adequate water supply and minimization of heat stress. The frequency of group changes and additions to groups around transition is a huge stressor that should be limited as much as possible. Recent research has identified several social stressors as being associated with suboptimal herd performance. These include mixing of primiparous and multiparous cows precalving, and the use of individual calving pens.

Role of Feed Additives

In addition to good nutrition, certain feed additives have been found beneficial in improving transition cow health. Propylene glycol has been used successfully for the prevention of subclinical ketosis (Emery et al, 1964; Sauer et al, 1973). Several studies have been conducted with varying doses and durations of treatment. Generally, propylene glycol is more effective when drenched because the bolus effect provides a stronger insulin response. A dose in the range of 300 to 500 ml (or 10 to 16 oz) is sufficient when started on the day of calving and administered for 3 days.

A series of meta-analysis of monensin studies in lactating dairy cattle has demonstrated that monensin through the transition period reduces BHBA, NEFA, acetoacetate; and increases glucose. These improvements in metabolic parameters result in a reduced risk of displaced abomasum, clinical ketosis, and mastitis. In addition, cows administered monensin through transition produce significantly more milk.

Rumen protected choline has been shown to influence liver glycogen and triglyceride (Pipenbrink and Overton, 2003), but not in all studies (Zahra, 2004). A topdress of 56 g per day of rumen protected choline during the transition period did not affect BHBA, NEFA, liver glycogen or liver triglyceride. However, milk production was significantly increased in choline treated cows and this effect was more pronounced in cows that were over-conditioned.

Several studies have demonstrated an improvement in dry matter intake through transition with the feeding of yeast products. However, impacts on metabolic parameters and clinical health outcomes have not been investigated to date.

Conclusions

Excessively high circulating NEFA and BHBA in transition dairy cattle are associated with increased risk of clinical diseases, lost milk production, reduced reproductive performance and increased culling risk. Estimates indicate that subclinical ketosis costs at least $78 US (Geishauser et al, 2001). This is likely a gross underestimate, since the estimate did not include impacts on culling or potential impacts on immune function. Based on return over feed cost estimates in dairy herds in Ontario, subclinical ketosis was estimated to cost $547 CDN per cow per lactation (McLaren et al, 2006). However, regardless of the accuracy of these estimates, when metabolic disease is considered at the herd level, it is considerably more costly than most clinical diseases, since subclinical disease is far more frequent. Cow-level risk factors are parity, body condition score and season of calving. Herd variation for this disease problem is wide and herd level risk factors are poorly described. However, herd level risk factors most likely involve combinations of management, feed quality and nutritional programs, cow comfort, environment, and other variables that influence dry matter intake. Routine monitoring programs for subclinical ketosis is beneficial on many dairies.

Notes:

Are you Efficiently Replacing Your Herd?

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Introduction

The top three costs of producing milk on most dairies in the US are Feed Costs, Replacement Costs, and Labor Costs. Normally expressed on a hundredweight basis, these three key areas are greatly impacted by management and herd performance. To efficiently produce milk, herds must excel in these critical areas. Accounting systems need to be designed to place costs into appropriate expense categories so these three key areas can be accurately assessed. Table 1 displays regional averages for Feed, Replacement, and Labor costs from 2006 to June 2010. Collectively these top three costs account for 65-72% of total costs.

Conceptually, Replacement Cost is the Cost of Maintaining Herd Size and Structure. Although dairy accountants have various methods to determine Replacement Costs, all methods are basically similar in concept. The formula [(value of cows sold - cost of replacement) / cwt milk sold] is the basis for determining Replacement Costs. The value of cows sold is impacted by the kind of cows that are sold (fat, late lactation culls that sell well or beat-up fresh cows that are thin and sell poorly), and the number that are actually sold (deads and condemned are generally not sold). The cost of replacement is impacted by the cost of purchased heifers, or the money invested in home-raised replacement (not including value at birth). Cull rate and quantity of milk shipped impact the calculation as well. A "trade in value" can be estimated as (cost of replacement – average value of cull). Currently, with low springer prices and moderate beef prices, trade-in values are quite low in many areas.

Replacement Cost is intended to represent the cost of maintaining herd size and structure. Often cull rate or herd turnover is used to measure herd health and replacement success. When fully considering the concept and implications of Replacement Cost, it becomes obvious that cull rate or any measure of herd turnover is a poor proxy for herd health or cost of maintaining herd size. The best measuring stick of successful herd replacement is Replacement Cost/cwt, and a reasonable goal in most areas of the country is <$1.50/cwt.

Replacement Cost is not a unique concept to the dairy industry. Definitions in unrelated industries include “The price that will have to be paid to replace an existing asset with a similar asset” (Investopedia.com) and “The actual cost to replace an item or structure at its pre-loss condition” (Wikipedia.com). The concept is routinely applied in the accounting and insurance industries. For a manufacturing business, it can be thought of as the cost of keeping productive assets needed to produce the desired volume of product.

Since it is normally expressed on a hundredweight basis, Replacement Cost is size and production neutral. It can be compared for herds milking 100 cows or 10,000 cows, or for herds milking 50 pounds per day or 100 pounds per day. In the simplest of terms for a 1000 cow herd, Replacement Cost is the cost of keeping 1000 cows in the herd day after day.

Replacement Costs in US Dairy Industry

Figures 1-5 summarize average Feed, Replacement, and Labor costs per hundredweight from 2006 to June 2010 for Genske, Mulder, and Company, LLP, clients. It is obvious that 2008 and 2009 were historically high for feed costs in the US Dairy Industry. Replacement Costs tended to be lower with mature industries (Washington, Arizona, and California). The Midwest and Texas summaries include many recently constructed dairies, many of which had no replacement enterprise after startup. Not surprisingly, they had the highest Replacement Cost. Labor costs have been less variable but are regionally trending in different directions.

Many believe that Replacement Costs are closely correlated with milk production and/or cull rate. Figures 4 and 5 represent scatter plots to illustrate these relationships. The 30 data points in both scatter plots correspond to average values for each of the 5 years (2006-2010) in each of the 6 regions (AZ, CA, ID, Midwest, WA, TX). Note that each data point does not represent a single herd, but rather the region average for a year. Accordingly, these scatter plots are biased by region and time, and are presented to characterize industry averages and not to make strong conclusions. Considering the bias and limitations of the observations in Figures 4 and 5, the scatter plots illustrate several general points. First, it is difficult to make any strong statements from the scatter plots. The strongest statement is that there are no clear patterns. Second, there are many factors that impact Replacement Costs, and looking at one factor only is misleading. The numbers are real accounting numbers across regions and time, which makes it difficult to clearly see patterns with so many variables.

In Figure 4, with the exception of a few outliers, there does not appear to be a strong correlation between turnover and Replacement Costs. Some herds had low Replacement Costs with higher culling rates; some had low Replacement Costs with lower culling rates. It is worthy to note that the average Replacement Cost for the 21 data points with cull rate <35% was $1.73; for the 9 data points with cull rate >35%, average Replacement Cost was $1.94. This graph suggests that high replacements costs are unlikely at low cull rates, but low Replacement Costs are possible at any cull rate.

In Figure 5, strong relationships are lacking for reasons similar to Figure 4. It is noteworthy that data points above 70 lbs of milk averaged $1.56 Replacement Cost; data points below 70 lbs averaged $1.86. This graph suggests that high Replacement Costs are unlikely at high production levels, but low Replacement Costs are possible at all production levels.

Based on the industry data presented from 2006 to 2010, what are realistic goals for Replacement Costs? Generally speaking, Replacement Costs should be dropping as heifer prices slide. As noted in the GAAP Method section, there is lag in the GAAP method for calculating Replacement Costs, so the impact of the current heifer market will not be immediately evident on financial statements. In past years, the best dairies have constantly achieved Replacement Costs less than $1.50/cwt (Table 2). Considering the current heifer market, top herds will probably be below $1.25/cwt in the near future.

GAAP (Generally Accepted Accounting Principles) Method for Determining Replacement Cost

Generally Accepted Accounting Principles are rules that all accountants in the United States are required to follow when preparing accrual based financial statements. For dairy purposes, when a cow is put into productive use the cost is depreciated over the animals useful life, which is usually 5 to 7 years. It is referred to as depreciation of dairy cows expense. Once the cow is removed from the herd (sold or died), the remaining cost that has not been depreciated is removed and compared to the cull cow proceeds. This is either a gain or loss from sale of cows. Generally, dairy cows are removed using the FIFO method (First in First Out). In layman's terms this means the oldest cows on the depreciation schedule are removed first.

Figure 6 is a simple example of tracking depreciation and calculating Replacement Costs using the GAAP method. Using an example herd with simple metrics, there is a depreciation schedule for cows and a Replacement Cost calculation. Assume the dairy was started in 2007 and has a 33% historical cull rate. In 2010 the dairy sold 128,772 cwts and received $90,350 in cull cow proceeds. In the example, heifer prices reflect historic trends: $2250/head in 2007, $2200/head in 2008, $1600/head in 2009, and $1300/head in 2010. Note that since cull rate is 33% only 3 years of cows are on the depreciation schedule at the end of each year

Using 2007 as an example year to explain the calculations in Figure 6:

- 200 heifers were purchased at $2250 for a total of $450,000.
- The current depreciation on those heifers in 2010 is $32,143; the depreciation in 2007-2009 totaled $160,174.
- The remaining basis at the end of 2010 is $257,763 (450,000 - $160,714 - $32,143).

The GAAP Replacement Cost in Figure 6 is $2.11per cwt. This is comprised of depreciation ($0.82) and Loss on Sale of Cows ($1.30) as follows:

- The Depreciation is simply the sum of all 2010 depreciation. Cows purchased in 2007, 2008, 2009, and 2010 had depreciation in 2010 that totaled $105,000 or $0.82/cwt.
- The remaining basis at the end of 2010 ($257,763) is offset by cull cow proceeds ($90,500), for a $166,793 or $1.30/cwt Loss on Sale of Cows.

Note that the more expensive cows purchased in 2007 were removed in 2010, which resulted in a high herd Replacement Cost ($2.11/cwt) for 2010. When cattle prices are stable the GAAP method accurately reports herd Replacement Cost. When cattle prices are fluctuating, as we have seen in the past 5 years, the GAAP method will eschew herd Replacement Cost. The cash method may be more useful when prices are fluctuating, as it more closely reflects markets and management in the year measured.

Cash Method for Determining Replacement Costs

Many herds in the US do not have a dairy accountant, or choose to ignore GAAP methods and avoid determining Replacement Costs. For these herds, a cash method can be used to estimate Replacement Cost/cwt. As discussed previously, the Cash Method may be more useful at times than the GAAP method, particularly when heifer prices are fluctuating. The Cash Method formula is very simple:

$$\frac{\text{(Cost of Raising or Purchasing Replacements) - (cull cow income)}}{\text{Cwts of milk produced}}$$

Cost of Raising or Purchasing Replacements

- Includes all costs incurred for getting an animal to the day of calving.
- For home raised heifers, this includes all costs from birth until day of calving, and includes feed, labor, vaccines, health treatments, equipment costs, etc. To answer the question "should an expense be included in Replacement Costs", consider if this cost would go away if the heifers were off site. If the answer is yes, then it should be part of Replacement Cost.
- For purchased heifers, it includes all costs involved with purchasing the animal, including hauling and commissions. It also includes the costs incurred from the time of purchase until calving, such as feed, labor and health costs. So if an animal is purchased 30 days before calving, the cost of the animal plus 30 days of expenses are included.
- For purchased adult cows, all costs associated with purchasing the animal are included.

Cull Cow Income

- Includes the revenue received from selling cull cows and cull heifers.
- Includes the revenue received from selling heifers for dairy purposes.
- In a situation where all heifers are purchased, the value of heifer calves sold can be included in the value of cows sold.

Cwts Milk Produced

- The quantity of milk sold for the time-frame under consideration

Factors Impacting Replacement Costs

There are several factors that directly impact the calculation of Replacement Costs, including death loss, milk production per cow, cull rate, average cull value, and heifer costs. The graph in Figure 7 summarizes the impacts of each factor on Replacement Costs, using the Cash Method. The graph was calculated by taking a "best case" scenario (80 lbs milk/cow, 30% cull rate, 2% death loss, $500 cull value, $1200 replacement animal cost) that results in a very low Replacement Cost ($0.89/cwt), and changing each factor 10 increments to determine independent impacts on Replacement Cost. The increment and range of data for each item are listed in the graph legend. For example Death Loss was 2% in the Best Case scenario, and was increased by 10 increments of +1%, for a range of 2% to 12%.

Summarizing Figure 7:

- The linear change in Replacement Cost for each independent incremental change was as follows:
    - **Death Loss**: For each 1% increase in death loss from 2-12%, Replacement Costs increased by 2.2 cents per cwt. So increasing death loss from 5% to 10% (5 increments) without changing other factors would increase Replacement Costs 11 cents per cwt in this scenario.
    - **Cull Rate**: For each 2% increase in cull rate from 30-50%, Replacement Costs increased by 6.3 cents per cwt. So increasing cull rate from 30% to 40% (5 increments) without changing other factors would increase Replacement Costs 31.5 cents per cwt in this scenario.
    - **$/cull**: For each $25 drop in cull value from $500 to $250, Replacement Costs increased by 3.1 cents per cwt. So decreasing cull value from $500 to $375 (5 increments) without changing other factors would increase Replacement Costs 15.5 cents per cwt in this scenario.
    - **Heifer Cost**: For each $50 increase in heifer cost from $1200 to $1700, Replacement Costs increased by 6.7 cents per cwt. So increasing heifer cost from $1200 to $1450 (5 increments) without changing other factors would increase Replacement Costs 33.5 cents per cwt in this scenario.
- The only non-linear change was for Milk per Cow:
    - **Milk/cow:** Over the range of incremental change in Figure 1 (80 to 60 lbs), Replacement Costs increased by 2.3 cents per cwt when milk per cow dropped from 80 to 78 lbs, and 3.8 cents per cwt when milk per cow dropped from 62 to 60 lbs. The average change in Replacement Cost, across the range of 60 to 80 lbs milk per cow, was 3.3 cents per cwt for each 2 lb change in milk per cow.
- Within the range of the factors, cull rate and heifer cost had the largest impact on Replacement Cost. This assumes that no other factors change.

- Changes in milk production per cow impacted Replacement Costs more so at lower production levels within the range of factors, although the differences were small.

Heifer costs are a major driver of Replacement Costs. Using the marginal heifer costs from Figure 7, $2000 springers would increase Replacement Costs $0.67/cwt compared to $1500 springers (assuming similar performance). Many herds in 2007 and 2008 that had to purchase expensive springers were in the unfortunate position of buying $2000+ heifers. Those with home raised heifers had less than $1500 invested in the heifer at freshening, giving these herds a significant advantage in Replacement Cost. The current heifer market is an oddity in that purchased springers are similar in value to home-raised heifers. In most years, there is a significant advantage to dairies providing their own heifers.

For dairies that supply their own heifers, reducing the costs of rearing will directly reduce Replacement Costs. Feed is the largest expense, and most herds closely monitor feed costs. A hidden feed cost is delayed age at first calving. Herds with low rearing costs get heifers pregnant quickly and into the herd quickly, resulting in a tight distribution of calving ages.

Comparing Herd Scenarios Using Cash Method

Table 3 illustrates Replacement Costs for four 1000 cow herds with varying cull rates, death loss, and production levels. Using the Cash Method formula, Replacement Cost for Herd A is: [($1200*350) - ($500*300)] / 217,000 = $1.24/cwt. For Herd B the calculation is: [($1700*350) - ($175*250)] / 217,000 = $2.42/cwt.

Often in the dairy industry milk production and cull rate are viewed as primary determinants of operational efficiency (low cost per cwt). If this were true, Herd A and Herd B would have similar Replacement Costs, yet they are more than a dollar per hundredweight different. The four herds in Table 3 dispel some of the myths related to Replacement Costs.

Description of Each Herd

- **Herd A** had average production, average cull rate, low death loss, and high quality cull cows. All replacements were internal. Herd A represents a typical management model.
- **Herd B** had average production, average cull rate, high death loss, and poor quality cull cows. This herd had to purchase some replacements to stay full due to insufficient heifer numbers, which inflated heifer costs. Herd B represents a herd with health problems and poor financial results despite reasonable production and cull rate.
- **Herd C** had low production, low cull rate, low death loss, and high quality cull cows. All replacements were internal, and at a lower cost. Herd C represents a "low input cost" management model.
- **Herd D** had high production, high cull rate, low death loss, and high quality cows. All replacements were internal. Herd D represents a "high input" management model, with a

high replacement stream where healthy lower-producing cows are replaced by younger more productive cows.

Myths Dispelled from Table 3.

- *Myth #1: High Cull rate means high Replacement Costs.* This is often true but not always. Herd D is a high producing herd that has excellent herd health. Death loss is relatively low and the cull cows are valuable. The dairy ships a lot of milk, which dilutes the Replacement Costs over more hundredweights.
- *Myth #2. Low production is not a viable business model.* A low production, low input model can be very successful, provided Feed, Labor, and Replacement Costs are low. Lower producing herds can achieve low Replacement Costs by having low death loss, low cull rate, and high quality culls. Herd C is an example of this.
- *Myth #3. A dairy only sells milk.* Dairies also sell a lot of beef. The quality of cows being sold greatly impacts cull cow income and Replacement Costs. Selling fat, late lactation cows is very different from selling skinny fresh cows or thin lame cows. The high death loss and low value of culls is killing Herd B.
- *Myth #4. Lowering cull rates will always lower Replacement Costs.* Depending on market conditions, simply lowering cull rate may not improve Replacement Costs. Keeping low producing cows and holding on to cows too long to where their cull value is lessened will typically not improve Replacement Costs.
- *Myth #5. Herd health is tied to cull rate.* Low Replacement Costs result from a healthy herd where management makes good economic decisions on cows, regardless of cull rate. Herd D is a high producing herd with a high cull rate but reasonable Replacement Costs. Unhealthy herds like Herd B have higher death loss, poorer quality culls, and higher Replacement Costs despite reasonable cull rates.

Startup Dairies

Replacement Costs are easy to track and understand in a steady-state situation where the herd is mature and not growing. Startup or growing dairies have different circumstances regarding Replacement Costs. Table 4 outlines two start-up scenarios where the initial population is either heifers or cows (replacements are heifers in both cases):

Startup Where Springing Heifers Are Purchased. Typically these herds have low culling rates, but with a high portion of the culls being dead or condemned, and culls having a lower value. An example of a heifer startup is portrayed in Table 4 (Startup-Heifers). In this example the herd started with 1000 heifers, and had a low cull rate with moderate production. All replacements were from purchased heifers. There were more deads, and the value of sold cows was lower. Heifers needed to replace sold animals were all purchased. This scenario resulted in a $1.59 Replacement Cost per cwt.

Startup Where Mature Cows From Another Dairy Are Purchased. In the scenario portrayed in Table 4 (Startup-Cows), mature cows were purchased to start the dairy and heifers were purchased to replace cows. Compared to the heifer startup, milk was higher, cull rate was higher, death loss was lower, and cull values were higher. This scenario resulted in a $2.54 Replacement Cost per cwt.

The decision to start with heifers or cows is complex, and the scenario described in Table 4 only evaluates Replacement Cost. Starting with heifers typically requires more investment than starting with cows, but typically is less expensive to replace in the first 2-3 years.

Conclusions

Replacement Costs are typically the 2nd or 3rd highest cost of producing milk on dairies in the US. Herd health and cost of raising or buying heifers are key drivers. Purchasing heifers when the springer market is high escalates Replacement Costs. The difference in Replacement Costs from the poorest herds to the most efficient herds exceeds $1.00/cwt. Lowering Replacement Costs is critical to lowering total cost per hundredweight and a significant opportunity for many dairies.

References

Genske, Mulder, & Company, LLP. 2010. Accounting summaries containing averages for all clients in AZ, CA, ID, Midwest, TX, and WA from 2006 through June 2010. Personal Communication.

Table 1. Five-year average costs from accounting summaries (average from 2006 to June 2010)[1].

	Feed cost/cwt	Replacement cost/cwt	Labor cost/cwt	Feed+Labor +Replacement	% of total costs
Arizona	$ 8.22	$ 1.68	$ 1.38	11.28	70%
California	$ 7.85	$ 1.55	$ 1.22	10.63	72%
Idaho	$ 7.83	$ 1.64	$ 1.28	10.75	70%
Midwest	$ 7.23	$ 2.27	$ 1.59	11.09	65%
Texas	$ 7.52	$ 2.04	$ 1.46	11.01	67%
Washington	$ 7.27	$ 1.56	$ 1.38	10.21	68%

[1] From Genske, Mulder, & Company, LLP.

Table 2. Replacement Cost for top 25% for total cost of production[1].

	2006	2007	2008	2009	2010
CA	$1.26	$1.49	$1.49	$1.45	$1.39
ID	$1.32	$1.69	$1.48	$1.62	$1.87
TX	$1.43	$1.83	$1.64	$1.64	$1.71
WA	$1.10	$1.31	$1.48	$2.32	$1.29

[1] From Genske, Mulder, & Company, LLP.

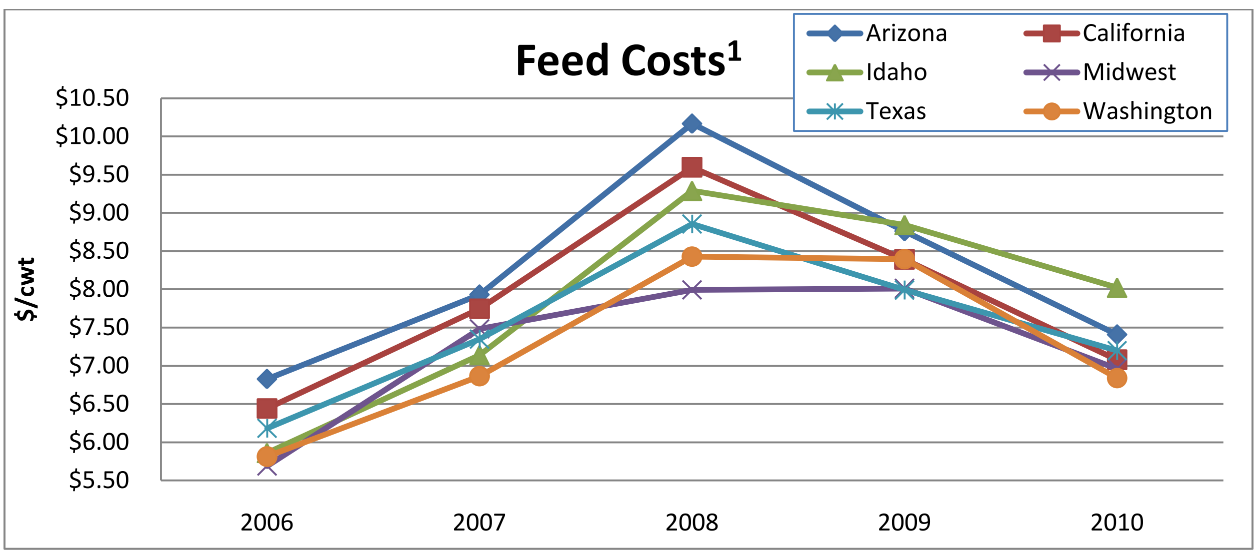
Table 3. Replacement Costs calculated using the cash method for four different herds.

	Herd A	Herd B	Herd C	Herd D
Herd Size	1000	1000	1000	1000
Milking Cows	850	850	850	850
Milk lbs/cow/day	70	70	60	85
Cwts/year	217,000	217,000	186,000	263,000
Cull rate	35%	35%	25%	45%
Death loss	5%	10%	5%	5%
$/cull	$500	$275	$500	$500
Culls/yr to sell	300	250	200	400
Replacements, $/head	$1200	$1700	$1100	$1200
# replacements	350	350	250	450
Replacement Cost/cwt	$1.24	$2.42	$0.94	$1.29

Table 4. Replacement Costs portrayed for startup dairies where the initial population is heifers (Startup – Heifers) or mature cows (Startup-Cows).

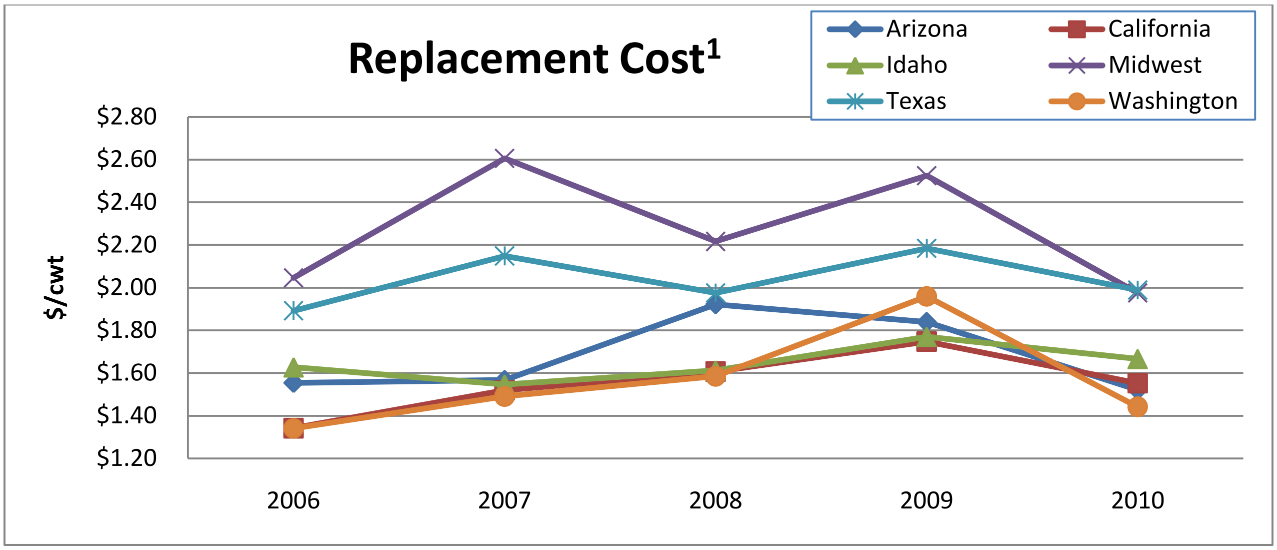
	Startup- Heifers	Startup- Cows
Herd Size	1000	1000
Milking Cows	850	850
Milk lbs/cow/day	65	70
Cwts/year	201,000	217,000
Cull rate	20%	40%
Death and condemned loss	10%	8%
$/cull	$200	$400
Culls/yr to sell	100	320
Replacements, $/head	$1700	$1700
# replacements	200	400
Replacement Cost/cwt	$1.59	$2.54

Figure 1. Feed Costs per cwt by region from 2006 to June 2010[1].



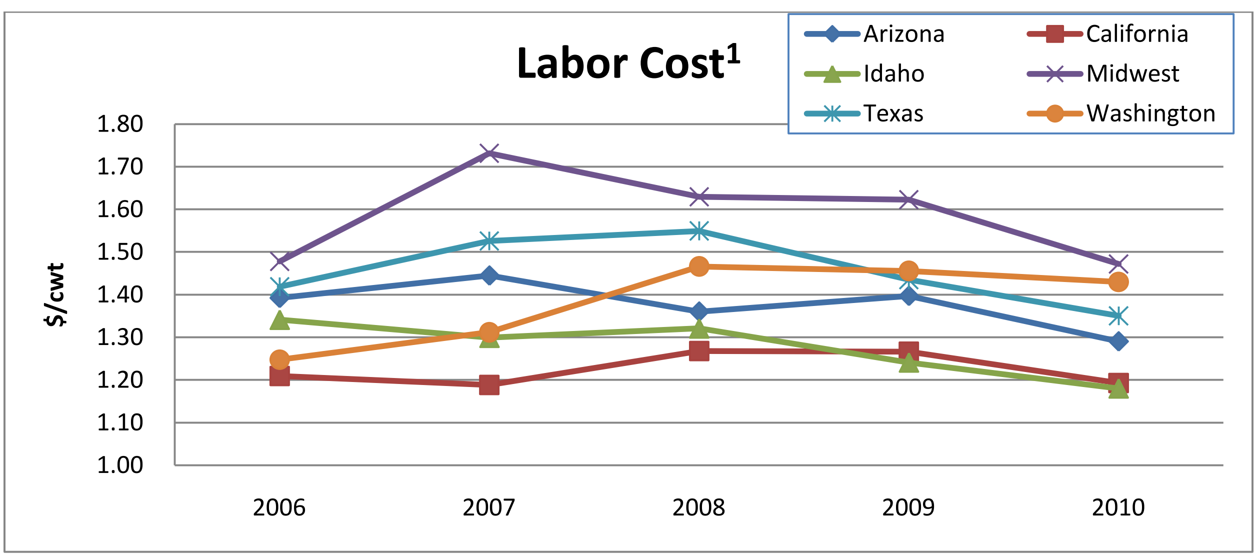
[1] From Genske, Mulder, & Company, LLP.

Figure 2. Replacement Costs per cwt by region from 2006 to June 2010[1].



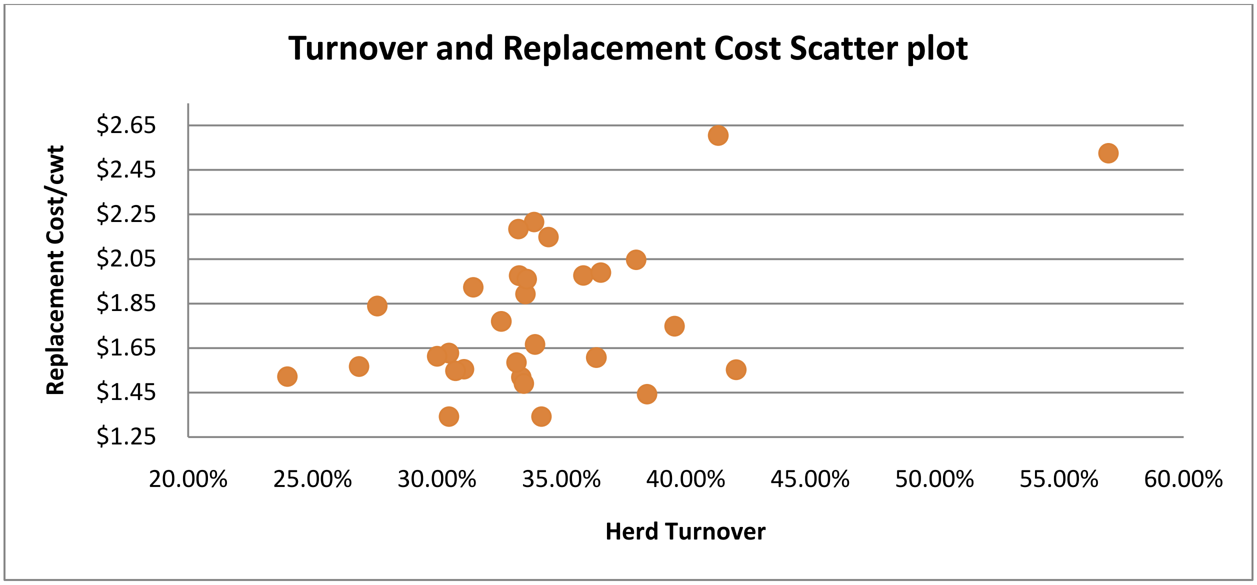
[1] From Genske, Mulder, & Company, LLP.

Figure 3. Labor Costs per cwt by region from 2006 to June 2010[1].



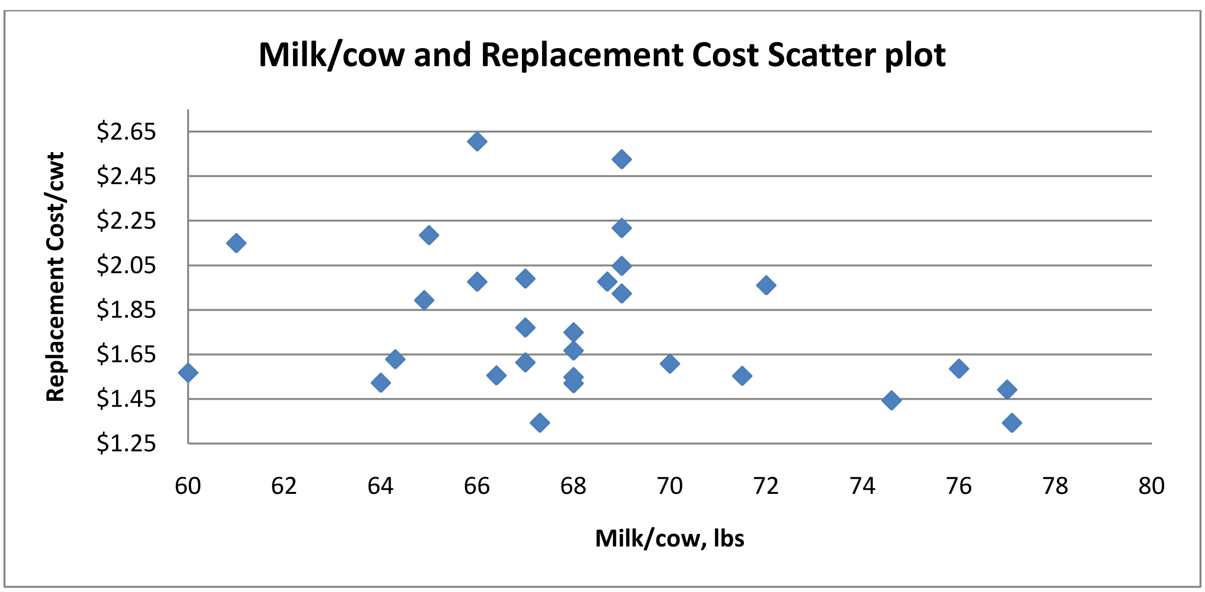
[1] From Genske, Mulder, & Company, LLP.

Figure 4. Herd Turnover and Replacement Costs scatter plot, using data from 2006 to June 2010[1].



[1] From Genske, Mulder, & Company, LLP.

Figure 5. Milk production and Replacement Costs scatter plot, using data from 2006 to June 2010[1].



[1] From Genske, Mulder, & Company, LLP.

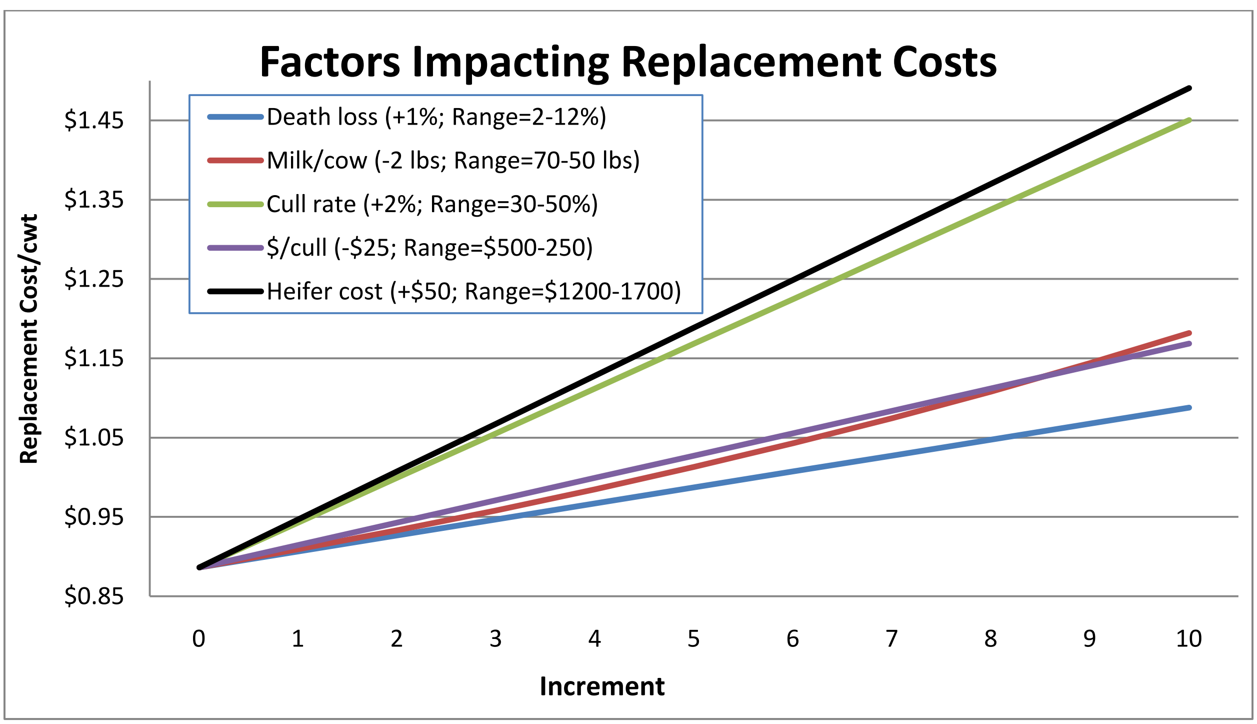
Figure 6. Example of GAAP accounting method for determining Replacement Costs.

Year Purchased	# Head	Cost	Prior Depreciation	Current Depreciation	Remaining Basis
2007	200	450,000	(160,714)	(32,143)	257,143
Sold 2010	(200)	(450,000)	160,714	32,143	(257,143)
2008	200	440,000	(94,286)	(31,429)	314,285
2009	200	320,000	(22,857)	(22,857)	274,286
2010	200	260,000	-	(18,571)	241,429
Totals	600	1,020,000	(117,143)	(105,000)	830,000

2010 Herd Replacement cost:

		Amount	Per Cwt
	Depreciation - dairy cows	105,000	0.82
***	Loss on sale of cows	166,793	1.30
	Total Herd Replacement Cost	271,793	2.11
	Remaining basis from 2007	257,143	
	Cull cow proceeds	(90,350)	
***	Loss on sale of cows	166,793	

Figure 7. Factors impacting Replacement Costs: incremental changes of death loss, milk/cow, cull rate, $/cull, and heifer cost. Increment and range for each item is noted in legend.



Notes:

Making More Effective Use of Your Data

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Introduction

Modern dairies require excellent performance in a variety of different management areas. Quite often the performance in one area influences or is affected by performance in another management area.

Some example areas for management focus include feeds and feeding; diet formulation; reproduction; transition, maternity and fresh cows; parlor performance; mastitis control; culling and replacements; genomic selection; and manure disposal. Regardless of the specific management area, performance depends on competent, conscientious personnel implementing sound programs consistently in each management area.

In general, successful management:

- Is based on sound principles involving biology, economics and management
- Is designed to facilitate implementation by avoiding unnecessary complication
- Has very consistent implementation by well-trained personnel
- Incorporates new ideas and technology quickly, but only after critical scrutiny
- Focuses on monitoring processes as well as ultimate outcomes

The proper use of accurate and timely data is critical in guiding and monitoring these personnel in their respective roles to achieve high levels of performance in any program. This paper will discuss some general principles involved in the use of data to improve management. The reader is referred to a list of publications by the authors and others that more fully address analytical approaches for specific management areas.

General Concepts

The primary reason to collect data is the improvement of management. Successful managers share certain characteristics when collecting and using data.

1. *Have a clearly stated reason (question) that determines the data to be collected (i.e., they do not collect data solely for the sake of collecting data).*

A commonly repeated mantra over the last 30 years has been that "dairymen need to spend more time collecting data/using records". While the presence of sufficiently complete and accurate data is important, possessing data alone is not sufficient. Data must be properly placed in a well designed framework and utilized in pursuit of a specific inquiry. Additionally, analysis without decisions or actions servers little purpose.

2. Recognize data may come from a variety of sources, not just computers.

- Computerized and paper records (examples)
    - Individual cow reproduction and diseases
    - Feed mixing and delivery
    - Parlor performance
    - Bulk tank shipment
- Discussions with their managers and supervisors plus other third parties
- Direct observations

There is a tendency to dismiss any data that did not come from computers as unimportant or non-objective. While it is true that a manager likely will not succeed if all decisions are based on unfounded feelings, data sources such as visual observations and input from supervisors and labor are extremely valuable and should not be viewed as completely subjective.

Computers are tremendous tools, but they cannot replace humans capable of logical thought and prudent judgment.

3. Understand the differing data and reporting needs of various audiences.

- Personnel actually performing the tasks
- Personnel in direct supervisory roles
- Middle and upper level managers
- Owners
- Third parties (e.g., veterinarians, consultants, drug companies, and universities)
- Bankers

One-size seldom fits all. For example, the person giving prostaglandin injections today needs a different report than the banker needs for his end of year evaluation of overall reproductive performance. While the needs of all levels have merit, the needs of the personnel performing tasks must be foremost.

4. Place focus on the current daily work-processes rather than solely ultimate outcomes.

Performing the proper tasks at the correct times for the correct targets (animals, pens, feedings, etc.) each day is the surest path to success. Timely data should be captured and used to ensure consistent performance.

Some examples would include:

- Reproduction: Did all eligible animals receive their scheduled prostaglandin injection today?
- Feeding: Did the proper amounts of the correct feeds get mixed and delivered?
- Parlor: Did the most recent milking start and end at the scheduled times?
- Mastitis: Are treatment protocols being followed as defined in the plan?

Additionally, rewards for implementation need to be based on data that is under the control of the personnel. For example, basing parlor employee bonuses solely on monthly bulk tank somatic cell count may not be a fair method of rewards, especially if there are issues with overall cow cleanliness and bedding maintenance.

5. *Place great emphasis on capturing required data.*

- In a timely manner
- Accurately
- Efficiently (automated whenever possible)

However, without a clearly articulated question or reason, the data collection process either eventually fails or unnecessarily consumes time and resources if it becomes an end unto itself.

6. *Use data and reports in a proper manner for motivation.*

- Primarily for motivation and improvement of personnel implementing tasks
- Minimally for punishment

Even if punishment results in short term improvement, using punishment alone is seldom effective over the long run.

7. *Recognize the difference between the level of proof needed to begin a management investigation or change and the required level of proof for scientific certainty or actual field research trials.*

Many traditional performance measures were adapted from scientific trials. In science the primary focus is minimization of mistakenly stating sometime is true when in fact it is not. A very high level of proof is expected prior to assuming truth. The level is typically (but somewhat arbitrarily) set at 95% + certainty. While evidence is still extremely important, in many cases management must make decisions at levels of evidence less than those required for stating scientific proof.

8. *Recognize improper interpretation of records can lead to two types of mistakes.*

- Inappropriate action (acts of commission)
    - Taking an action when no action was needed

    - Taking action with negative results when a positive action existed
    - Taking action with positive results when a more positive action existed
- Inappropriate inaction (acts of omission)
    - Taking no action when an action would have had a positive effect
    - Taking no action, leading to a more negative effect

In many cases the concern is on avoiding inappropriate action but inappropriate inaction may be more common and more costly.

9. Carefully select monitoring tools (metrics) that possess certain characteristics.

- When a positive individual outcome occurs, the overall metric indicate improvement.
- When a change occurs, the metric should reflect the change as soon as possible.
- The metric should be useful to evaluate different groups and different interventions.

10. Do not confuse precision with accuracy.

Suppose a cow actually produced 25.2 pounds of milk at a milking. Stating the cow gave:

- 20.53 pounds would be precise but not accurate.
- In the mid-20s would be accurate but not very precise.
- About 25 pounds would be accurate and precise (enough)

11. Do not have increased trust due solely to the complexity of the underlying mathematics.

This mistake may actually be more common with increasing education. Do not place greater faith in a calculation just because it is complicated or unfamiliar.

12. Recognize the possible existence of systematic errors in common calculations.

Summary statistics such as averages can be skewed due to:

- Presence of a wide distribution or outlier values (“Variation”)
- Damping due to excessive historical data (“Momentum”)
- Delays between the action and the determination of the outcome (“Lag”)
- Inappropriate inclusion or exclusion of animals (“Bias”)

13. Are careful when using benchmarking against other herds and do not use it as the primary means of judging their own performance.

Benchmarking has been heavily promoted in recent years, but has multiple concerns:

- Many of the selected parameters are susceptible to misleading
- Summary statistic errors outlined above abound in benchmarking
- Seldom do the parameters shed much specific illumination on specific followup actions

Conclusion

Today's dairies are extremely dependent on the availability and the proper use of data. However, merely collecting or possessing data is not sufficient. Data must be utilized in manners that assist in both improved implementation of daily tasks as well as monitoring of ultimate outcomes.

The presentation will outline in more detail process and outcome monitors in several different management areas.

Related Resources for Additional Reading

Stewart, S., Fetrow, J., Eicker, S.. Analysis of current performance on commercial dairies. The Compendium on continuing education for the practicing veterinarian. Aug 1994; v. 16(8) p. 1099-1103.

Stewart, S., Fetrow, J., Eicker, S.. Field use of DHIA somatic cell counts with scatter graphs. The Compendium on continuing education for the practicing veterinarian. Nov 1995; v. 17(11) p. 1429-1439.

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Notes:

Lameness in Dairy Cattle: A Debilitating Disease or a Disease of Debilitated Cattle?

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Relevance of Lameness to the Dairy Industry

A growing concern of the dairy industry is to increase dairy cattle wellbeing in anticipation of a demand from the general public of welfare-certified dairy products. Lameness is one of the most important welfare issues of high producing dairy cows in North America (Vermunt, 2007). It is a debilitating condition that challenges sustainability of production systems used in North America because of the pain and subsequent animal welfare consequences (Vermunt, 2007) and also the significant economic losses (Warnick et al., 2001). A study conducted in England concluded that lameness was the second most costly disease in the dairy industry following only mastitis (Kossaibati and Esslemont, 1997).

Lameness results in earlier culling of animals as well as lower carcass weight, conformation class, and fat cover class and hence a lower carcass economic value (Booth et al., 2004; Bicalho et al., 2007c; Fjeldaas et al., 2007). It has also been reported that prevention or early identification and treatment of the problem can improve the value of the carcass and reduce culling rates (Fjeldaas et al., 2007). Several studies have also shown that lameness has a negative effect on the fertility of dairy cows (Sprecher et al., 1997; Hernandez et al., 2001; Garbarino et al., 2004). More recently, it has been reported that cows detected with clinical lameness in the first 70 days in milk (**DIM**) were 25% less likely to become pregnant compared to non-lame cows (Bicalho et al., 2007c). The prevention of lameness is the most important step to reduce its welfare implications for cows and associated economic losses to the dairy farmers (Mill and Ward, 1994). Hence it is important to create a system that accurately predicts the occurrence of lameness, thus allowing farmers to target high risk animals with preventive strategies.

Importance of Lameness to the Wellbeing of Dairy Cows

Lameness is a crucial welfare issue in modern dairy production (Espejo and Endres, 2007; Vermunt, 2007). Lame cows suffer discomfort and pain of long duration (Green et al., 2002). Additionally, the observation of lameness has been classified as the most representative animal-based indicator of welfare in dairy cattle (Whay et al., 2003). There is an increasing societal concern about the moral and ethical treatment of food animals (Fulwider et al., 2008). Lameness is of welfare concern due to its debilitating effects and high prevalence in herds throughout the world (Cook, 2003; Bicalho et al., 2007c). Furthermore, dairy cattle mortality is a major cause of economic losses and is an important animal welfare issue (Thomsen and Houe, 2006). A large retrospective cohort study with over 900 dairy farms reported that dairy operations with high prevalence of lameness (≥ 16 %) had 2.9 higher odds of on farm dairy cow mortality compared to dairy farms with low lameness incidence (McConnel et al., 2008); dairy cows that died on the farm because of lameness were usually euthanized by a farm employee or veterinarian. Lameness is perhaps the biggest challenge for dairy farmer to overcome as society becomes more concerned with the origin of their food and the welfare of farm animals.

Polls and surveys conducted within the United States show general agreement that there is public support for the protection of farm livestock and poultry (Swanson, 2008). The animal welfare assurance and audit programs developed by the private sector are an attempt to assure consumers that best practice measures and independent oversight result in a reasonable quality of life for food-producing animals. It is a possibility that milk processing plants will start to market and commercialize milk from welfare-certified herds in an attempt to anticipate the demand from welfare-oriented consumers. In fact, the commercialization of bST (bovine somatotropin) free milk is a reality; consumers perceive that welfare of the animals from bST-free herds is better than otherwise. As it happened to bST-free milk, the motivation for marketing welfare-certified milk will come from the concern of the general public (consumers) regarding the wellbeing of dairy cows. Some attempts to voluntarily achieve welfare certification are already in place; The New York State Cattle Health Assurance Program (NYSCHAP) is an example of such a program. The NYSCHAP welfare certification requires that at least 85% of each animal management group must have a locomotion score of two (using a five-point-scale visual locomotion score system). This benchmark would be at the very least a hard to achieve goal for most dairy farms given the reported prevalence of lameness throughout the United States (Cook, 2003; Espejo et al., 2006; Bicalho et al., 2007c).

Dairy farmers in North America are not regulated in regards to the welfare of their animals and production standards except in extreme cases of neglect and abuse. In contrast, regulation of food animal production has become part of mainstream life for European Union livestock and poultry producers (Swanson, 2008). The freedom that European producers once had to produce animals as they saw fit gradually vanished by public command. To enable the dairy industry in the United States to effectively anticipate and respond to societal concerns about ethical treatment of animals, there is a great need to identify opportunities to prevent the incidence of lameness in dairy cattle.

The Pathogenesis of Non-Infectious Causes of Lameness

Despite the undeniable relevance of lameness resulting from non-infectious diseases, very little is known about its pathophysiology. Although severe cases of laminitis (inflammation of the laminar tissue of the digit) caused by abnormally high intake of readily available carbohydrates have been described in the literature (Bazeley and Pinsent, 1984), the link between subclinical laminitis and claw lesions has been recently challenged (Logue et al., 2004). To make matters worse, research knowledge on the pathogenesis of equine laminitis was uncritically generalized to the field of bovine lameness without taking into account the profound anatomical and physiological differences between the two species. Thus far, there is limited evidence that claw horn lesions in cattle are caused by subclinical laminitis (Logue et al., 2004; Thoefner et al., 2004; Lischer et al., 2002). Lately, the hypothesis that claw lesions are a consequence of contusions within the claw horn capsule has been suggested (Tarlton et al., 2002; Raber et al., 2004). Raber et al. (2004) reported that it is widely accepted by workers in the Northern Hemisphere that most bovine claw lesions (and thus lameness) originate from contused tissue within the claw horn capsule. While it has been reported that sole ulcers and white line lesions are caused by subclinical laminitis (Thoefner et al., 2004), there are others who clearly state that the evidence to support this is limited (Logue et al., 2004). The suspensory apparatus in cattle is less well developed than in the horse and the digital cushion must support a considerably higher proportion of the body weight (Raber et al., 2004). The digital cushion is a complex structure composed mostly of adipose tissue located underneath the distal phalanx; it plays an important function of dampening compression of the corium tissue beneath the cushion. The biomechanical importance of the digital cushion in alleviating compression under the tuberculum flexorum of the distal phalanx is well known (Raber et al., 2006; Raber et al., 2004; Logue et al., 2004).

Research Summary

Research currently in progress, or recently completed by key personal, has focused on the impact of lameness on production parameters, validation of lameness detection systems, pathophysiology of sole-ulcers and white-line-diseases, and evaluation of lameness prevention strategies. Our recent research has allowed us to explore a new pathogenesis theory for claw horn disruption lesions (**CHDL**) and consequently envision novel preventive strategies. Historically, lameness researchers and experts believed that CHDL were caused by sub-clinical rumen acidosis and that the poor body condition observed in affected cows was a consequence of lameness and not a cause of lameness. We currently demonstrated that cows with low BCS have significantly thinner digital cushions and therefore a lower capacity to protect the corium tissue from compression by the third phalanx. Details about our recently completed significant activities and its link to our proposed project are described below.

Impact of Lameness on Reproduction, Survivability, and Milk Production of Dairy Cows (Bicalho et al., 2007b; Bicalho et al., 2008):

Previously, we estimated the detrimental effects of lameness on calving-to-conception interval and hazard of dying or being culled in lactating Holstein cows. Data were collected from 5 dairy farms located in upstate NY from November 2004 to June 2006. The study design was a prospective observational cohort study. Cows were assigned a visual locomotion score (VLS) using a 5-point scale ranging from 1 = normal, 2 = presence of a slightly asymmetric gait, 3 = the cow clearly favored 1 or more limbs (moderately lame), 4 = severely lame, to 5 = extremely lame (non-weight bearing lame). In total 1,799 cows were enrolled. In 2 alternative categorizations, cows were considered lame if at least 1 VLS was ≥ 3 during the first 70 DIM and secondly, if at least 1 VLS was ≥ 4 for the same period. Lameness (VLS ≥ 3) was detected at

Figure 1: *The effect of lameness on reproduction (Bicalho et al., 2007)*

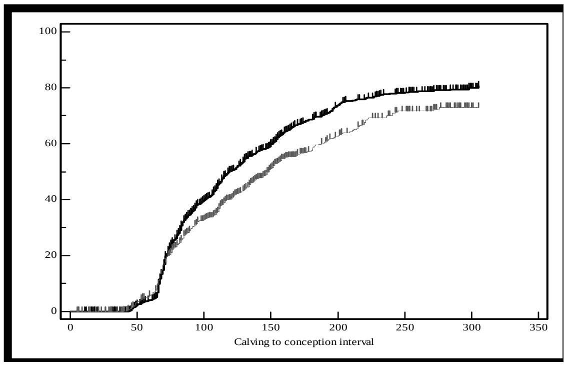
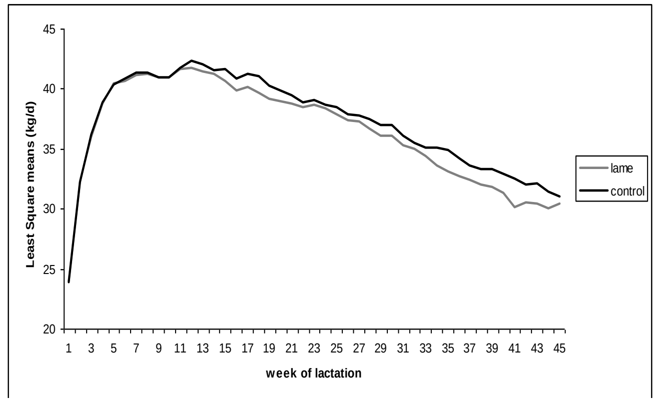


Figure 2: *The effect of lameness on milk production (Bicalho et al., 2008)*



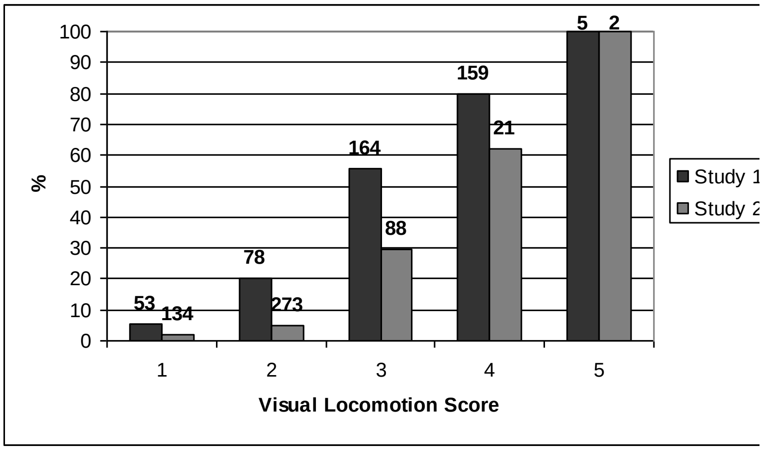
least once in 26.5%, 54.2%, 33.9%, 51.8%, and 39.3% of all cows in farms 1 to 5, respectively. The hazard ratio of being detected pregnant was 0.85 for lame cows (VLS ≥ 3) versus non-lame cows; hence, lame cows were at a 15% decreased risk of pregnancy than non-lame cows. When lameness was redefined as VLS ≥ 4, the hazard ratio having been detected pregnant was 0.76 for lame cows versus cows with VLS < 4 (Figure 1). Lameness increased the hazard ratio of culling/death, 1.45 and 1.74 for VLS ≥ 3 and VLS ≥ 4, respectively, versus cows with VLS < 3 and VLS < 4, respectively. The detrimental effects were amplified when considering only severely lame and non-weight-bearing cows.

Recently, we have shown that high milk production in the beginning of the lactation is an important risk factor for CHDL; lame cows produced an excess of 3 kg/d more milk during the first three weeks of lactation compared to non-lame cows. However, when using an ANOVA that included the average milk production for the first 3 weeks of lactation as an independent variable, it was revealed that lameness incidence was associated with a milk production loss of up to 424 kg\cow per 305-day lactation (Figure 2). In summary, lameness significantly decreased the hazard of pregnancy, increased the hazard of culling/death, and was associated with significant milk loss.

The Accuracy of Visual Locomotion Score (Bicalho et al., 2007a)

Visual locomotion scoring of cows is normally used in lameness research as a method to identify lameness. To define the accuracy of such system and also to define the best cut-off for lameness classification, we designed and conducted a large field trial on two commercial dairy farms. Of the cows diagnosed with foot lesions, 33% were detected with sole ulcer, 26% with white line disease, 14% with white line abscess, and 27 % with other diseases. A strong increasing trend in the proportion of cows with painful lesions was detected as VLS increased. The proportion of cows with painful lesions were 6% (n = 53), 20% (n = 78), 55% (n = 164), 80% (n = 159), and 100% (n = 5) for VLS 1 to 5, respectively (Figure 3). A receiver operating characteristic curve analysis was performed and the optimal sensitivity specificity relationship was determined when a cutoff point of VLS ≥ 3 was used to detect PL. When the cut-off of VLS ≥ 3 was used a sensitivity of 67% and a specificity of 86% was achieved for the identification of painful foot lesions. This study validated the use of VLS to diagnose painful foot lesions.

Figure 3: *The association of visual locomotion scores and incidence of painful foot lesions. (Bicalho et al., 2007)*



Association of Digital Cushion Thickness with Lameness and Body Condition Scores (Bicalho et al. 2009)

Sole ulcers and white line abscesses are ubiquitous diseases with a chronic nature that have the highest associated economic losses amongst all foot lesions. Their underlying causes are still not fully understood. The digital cushion is a complex structure composed mostly of adipose tissue located underneath the distal phalanx and plays an important function of dampening compression of the corium tissue beneath the cushion. The biomechanical importance of the digital cushion in alleviating compression under the tuberculum flexorum of the distal phalanx is well known (Raber et al., 2006; Raber et al., 2004; Logue et al., 2004).

We recently conducted an observational cross-sectional study to investigate the association between claw horn lesions and the thickness of the digital cushion. The thickness of the digital cushion was evaluated by ultrasonographic examination of the sole at the typical ulcer site (Figure 4). A total of 501 lactating Holstein dairy cows were enrolled in the study. The prevalence of sole ulcers was 4.2% and 27.8% (P-value <0.001) for parity 1 and parity greater than one, respectively. The prevalence of white line disease was 1.0 and 6.5% for parity 1 and parity greater than one, respectively. The prevalence of lameness (visual locomotion score ≥ 3) was 19.8% and 48.2% (P-value < 0.001) for parity 1 and greater than 1, respectively. The prevalence of sole ulcers and white line diseases

Figure 4: *Sagital section of the bovine digit illustrating the site of ultrasonography. (Bicalho et al., 2009).*

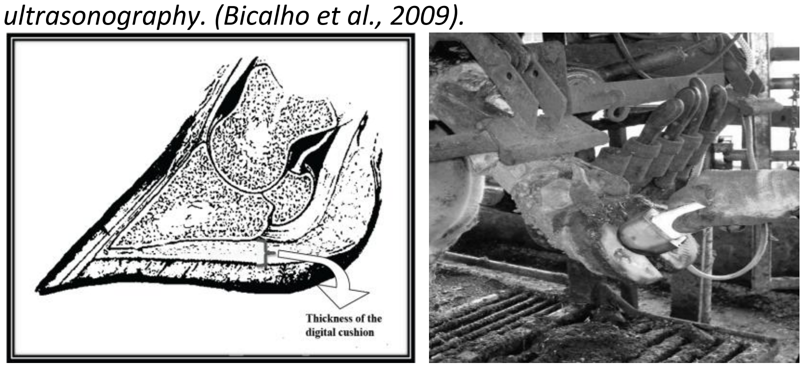
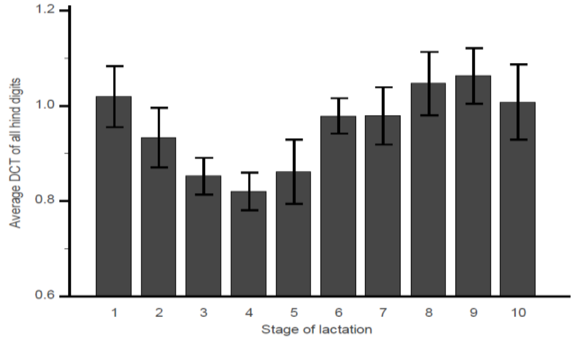


Figure 5: *Adjusted mean digital cushion thickness (MDCT) of all four hind digits by stage of lactation.(Bicalho et al., 2009)*

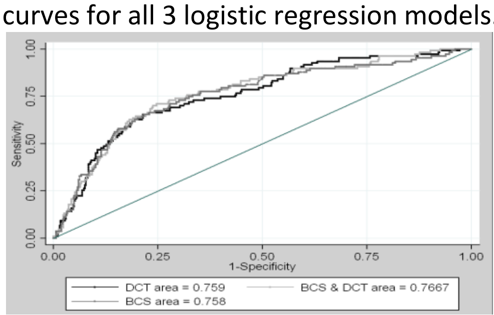


was significantly associated with thickness of the digital cushion; cows in the upper quartile of digital cushion thickness had an adjusted prevalence of lameness that was 15 percentage points lower than the lower quartile (24.4% versus 8.6% prevalence). Body condition scores were positively associated with digital cushion thickness. The mean gray value of the sonographic image of the digital cushion had a negative linear association with digital cushion thickness ($R^2 = 0.14$) indicating that the composition of the digital cushion may change with its thickness. Furthermore, digital cushion thickness decreased steadily from the first month of lactation and reached a nadir 120 days after parturition (Figure 5). These results give support to the concept that sole ulcers and white line abscesses are related to contusions within the claw horn capsule and such contusions are a consequence of the lower capacity of the digital cushion to dampen the pressure exerted by the third phalanx on the soft tissue beneath.

Predicting the Probability of Lameness in the Subsequent Lactation Using a Logistic Regression Model with Predicting Variables Collected at Dry-Off:

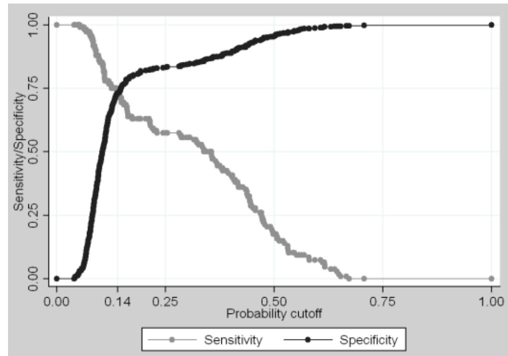
The objective of this study was to select the most economical statistical model that could accurately predict the incidence of lameness in the subsequent lactation by using information available at the dry-off hoof trimming. Our hypothesis was that digital cushion thickness, body condition score, age, and the presence of CHDL at dry-off are associated with the incidence of foot lesion (sole ulcers and white-line-disease) in the subsequent lactation. Data were collected from a dairy farm located near Ithaca NY from September 11th of 2008 until January 15th of 2009. A prospective cohort study design was used. The data were collected at dry-off by the research team and throughout the subsequent lactation by trained farm employees. The following data were collected at dry-off: body condition score which ranged from one to five with a quarter point system as described by Edmonson (1989), cow height measurement which was assessed as the distance in centimeters from the floor to the dorsal aspect of the caudal sacral joint, and visual locomotion score as described by Bicalho (2007). Additionally, all cows were hoof trimmed by one of the research team members and digital cushion thickness and digital lesions were recorded as described by Bicalho (2009). After the onset of lactation, cows were monitored on a daily basis for visual signs of lameness (presence of a limp) by trained farm employees. Cows that were limping were taken to the hoof trimming table for therapeutic hoof-trimming. Therapy was applied according with the diagnosed foot disorder and following a

Figure 6: Receiver operating characteristic curves for all 3 logistic regression models.



protocol designed by the Cornell Ambulatory and Production Medicine Clinic; data were recorded and entered into Dairy Comp 305. To predict the incidence of CHDL in the subsequent lactation logistic regression models were fitted to the data using Stata (StataCorp LP, Texas, USA). After variable selection steps the following variables were significant (*P*-value ≤ 0.10); digital cushion thickness (**DCT**), BCS, CHDL at dry-off, and age in days (**AGED**).

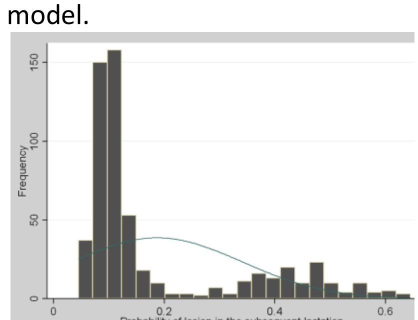
Figure 7: Sensitivity and specificity analysis for the third logistic regression model which included the variables BCS, AGED, and lesion at dry-off as independent variables.



To select the most parsimonious logistic regression model with good predictability of CHDL in the subsequent lactation three different models were evaluated. All three logistic regression models predicted the incidence of CHDL in subsequent lactation with good accuracy; the area under the ROC curves were 0.76, 0.76, and 0.77 for the first, second and third logistic regression models, respectively (Figure 6). There was no significant difference between the areas under the ROC curves for the three models. When the recommended probability cut-offs were used to dichotomize cows into high risk and low risk for lameness in the sub-sequent lactation an overall accuracy of 0.74, 0.76, and 0.76 was estimated for models 1, 2, and 3 respectively.

To illustrate the dynamics of the sensitivity and specificity as the probability cut-off is gradually incremented from 0 until 1, a graphical analysis was performed for the third logistic regression model (Figure 7). The intersection of the sensitivity and specificity lines indicates the recommended cut-off probability for defining lameness. Further analysis and predictions were completed for the third logistic regression model. Predicted probabilities calculated with the probability equation described in Table 4 had a bimodal distribution, likely because of the effect of the binomial independent variable CHDL at dry-off (Figure 8). Older cows with low BCS at dry-off and a CHDL detected at dry-off hoof trimming had the highest probability of CHDL incidence in the subsequent lactation (predicted probability = 0.65, 95% C.I. 0.49 – 0.78, Table 4). Whereas the lowest predicted probability of lameness was for a young cow with high BCS and without CHDL at dry-off (predicted probability = 0.03, 95% C.I. 0.01 – 0.08, Table 4). In conclusion, we were able to predict lameness in the subsequent lactation with an overall accuracy of 0.76 using a the simple logistic regression equation described below:

Figure 8: Frequency distribution plot of the predicted probabilities from the third logistic regression model.



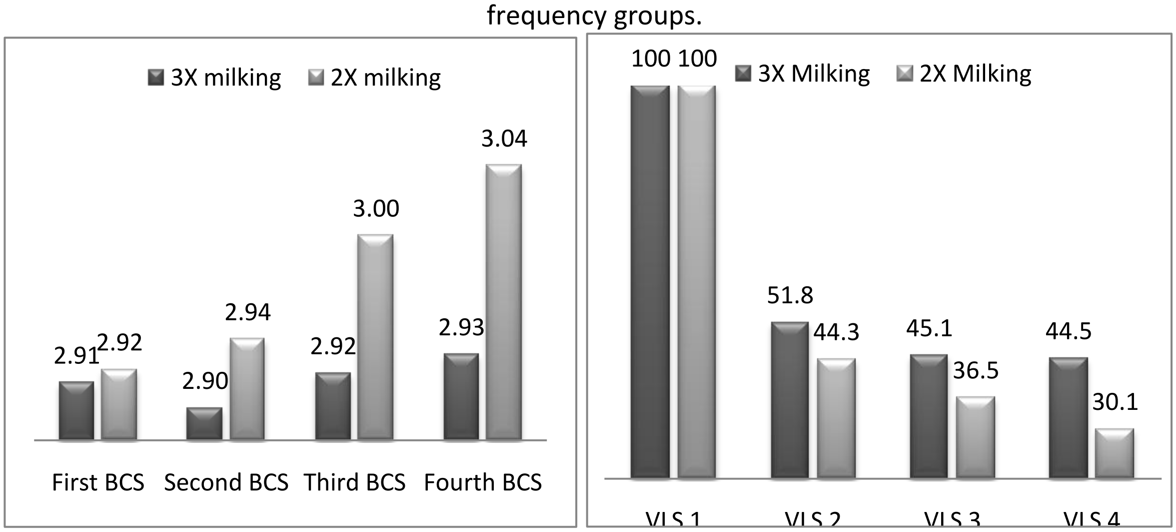
$$P(lesion) = \frac{e^{-1.05 - 0.57*BCS + 0.0005*AGED + 1.64*Lesiondry}}{1 + e^{-1.05 - 0.57*BCS + 0.0005*AGED + 1.64*Lesiondry}}$$

Demonstration that a Lower Milking Frequency (Twice Daily Versus Thrice Daily) Decreased the Prevalence of Lameness, and Improved Body Condition Score of Lame Cows:

We recently conducted a pilot study using a randomized clinical trial design to determine the effect of milking lame cows (VLS>2) twice daily versus thrice daily on milk production, culling, body condition score, and prevalence of lameness. The study was conducted on a large commercial dairy farm (3,000 milking cows) near Ithaca NY from January 1st until May 20th of 2009. Our hypothesis was that lame cows would benefit from a lower frequency milking schedule because they would spend less time standing on their feet, and consequently intra-claw corium concussions caused by the third phalanx would be decreased. Visual locomotion score and BCS of the entire milking herd were performed by two trained veterinarians. A total of 700 clinically lame cows were randomly assigned to one of two treatments: twice daily milking group and thrice daily milking group. Enrolled cows were VLS and BCS scored monthly for a total of 4 months. Additionally, daily milk production and culling information was recorded.

A mixed general linear model was used to assess the effect of milking frequency of lame cows on milk production. Lame cows that were milked twice daily produced a total of 3.5 lb/day more milk compared to the lame cows that were milked thrice daily. It is possible that the lower milking frequency allowed lame cows to spend time resting and eating which resulted in better

Figure 9: Lame cows that were milked twice daily recovered from lameness and poor BCS better then lame cows that were milked thrice daily. The left graph illustrates median BCS by milking frequency groups and the graph on the right illustrates the % of lame animals (VLS > 2) by milking frequency groups.



milk production. Additionally, lame cows in the 2X milking group significantly improve BCS and had a lameness prevalence that was 14.4 percentage points lower than the controls by the end of the study period (Figure 9).

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Notes:

Managing Air Quality on the Dairy with the National Air Quality Site Assessment Tool (NAQSAT)

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Overview

The National Air Quality Site Assessment Tool (NAQSAT) was developed for livestock and poultry to assist them in determining the areas on their operations where opportunities exist to make changes resulting in reduced air emissions. (http://naqsat.tamu.edu). The tool is intended for voluntary and educational use and can be more valuable when conducted in cooperation with agency personnel or private consultants. The tool can be used for swine, dairy, beef, broilers chickens, laying hens and turkeys and has been designed in cooperation with more than 20 university professionals and fifteen partnering agencies to be applicable across the diversity of enterprises in the nation.

The National Air Quality Site Assessment Tool (NAQSAT) is available free of charge and used online. The program will not download onto the user's computer. Each NAQSAT session is assigned its own unique URL, which may be bookmarked and saved by the user. All NAQSAT sessions are maintained on the host computer and may be accessed by the user over the next 30 days for updates and additional comparisons. The on-line tool addresses eight management areas that relate to air emissions: animals and housing, feed and water, collection and transfer of manure, manure storage, land application, mortalities, on-farm records and public perception. NAQSAT is based on the most accurate, credible data currently available regarding mitigation strategies for air emissions of ammonia, methane, volatile organic compounds (VOCs), hydrogen sulfide, particulates, and odor. When the science-based data was lacking, theories were based on the best professional judgment by leading air quality scientists. This allowed for both quantitative and qualitative based information to be used in developing the feedback portion of the tool.

Air Emissions of Interest

The NAQSAT allows input and provides "Effectiveness Results" for the following constituents of potential concern.

Odor. Odors from livestock farms can be made up of hundreds of compounds (odorants). How these odorants interact with one another contributes to the specific character of an odor. Odorous compounds tend to be carried on dust particles, and, therefore, strategies to reduce odors from animal agriculture often include strategies to reduce dust.

Particulate Matter (PM*).* Particulate matter, or dust, varies in size on the basis of source and formation. The primary concerns related to airborne particles are haze/visibility and health effects. Dust emitted from farms is highly complex in size, physical properties and composition. For regulatory purposes, airborne particulates are commonly classified into PM10 (≤10 µm in aerodynamic diameter) and PM2.5 (≤2.5 µm in aerodynamic diameter). Coarse particles (2.5 to10 µm in diameter) tend to be deposited in the upper airways of the respiratory tract; fine particles (PM2.5) can reach and be deposited in the smallest airways (alveoli) in the lungs. Farms can contribute coarse particles directly through animal activity, feed preparation, animal housing ventilation units and vehicular traffic. They can also contribute fine particles as the result of a secondary formation process (gas-to-particle conversion; see section on ammonia).

Ammonia. Ammonia is a colorless, pungent, nitrogenous gas. It volatilizes from a solid or liquid material when the ammonium ion is present and other physical conditions exist. Ammonia gas can react in the atmosphere with gaseous acidic species to form fine particulates (ammonium [NH_4^+] aerosols), which are a health concern. Atmospheric NH_3 can be deposited during rain events and lead to soil acidification and increased concentrations of nitrogen in surface waters, potentially contributing to eutrophication.

Hydrogen Sulfide. Hydrogen sulfide is a colorless, pungent gas best known for its characteristic rotten-egg odor. At high concentrations, hydrogen sulfide can be toxic (silo gas), and even at low concentrations it is a respiratory irritant. Although hydrogen sulfide is not transported great distances, at the farm it can mix with other compounds to contribute to odor.

Methane. Methane is a greenhouse gas. It is a natural product of decomposition of organic materials in the absence of oxygen (anaerobic). Sources of methane include landfills, anaerobic manure storages and the rumens of dairy and beef animals (enteric emissions). Methane can be collected and used as an energy source (biogas for compressed gas fuel or electrical generation through a genset engine).

Volatile Organic Compounds (VOCs). VOCs are a large group of organic chemicals that include an atom of carbon (excluding carbon monoxide, carbon dioxide, carbonic acid, metallic carbides or carbonates, and ammonium carbonate) and that participate in atmospheric photochemical reactions. Some of these reactions may lead to increased concentration of tropospheric ozone (a criteria pollutant) at ground level, thereby contributing to levels exceeding the National Ambient Air Quality Standard. VOCs can be odorous or contribute to farm odor.

Using NAQSAT

To use NAQSAT, a user first selects one of the six animal species listed on the right-hand side of the home page. On the next screen, listed on the left side, are the eight management categories that contribute to farm air emissions and are considered in the NAQSAT effectiveness report: Animals and housing, feed and water, collection and transfer, manure storage, land application, mortalities, on-farm roads and public perception. The user enters information into each category. The program is set up to include or remove questions from view on the basis of user input. Answers to some questions will generate additional questions to be answered.

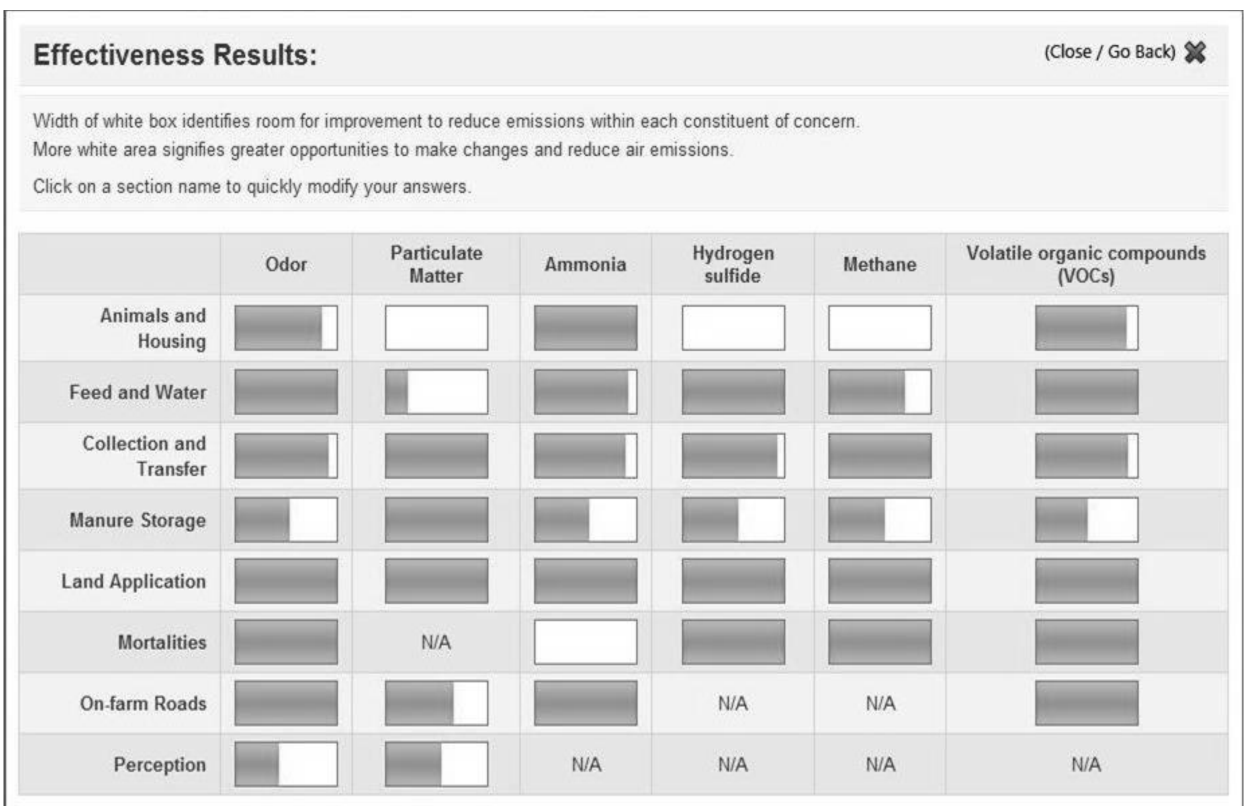
Pop-up pictures assist the user in determining the relative rating to select when questions require a visual evaluation of the existing practices. Pictures are used when a visual appraisal of current practices is most appropriate. Placing the cursor over the picture will generate a text description of the management practice.

A user can complete all eight sections or just those sections that are of specific interest to them.

User results are presented in the form of a bar graph for each of the management areas that estimate the degree to which current management has incorporated practices to manage air emission given the current understanding of how production practices impact emissions and the opportunity for additional changes to mitigate air emissions. The tool works with the current facilities and structures on a farm and provides information based on the facilities and structures present.

Example Output and Results Interpretation

Example output is shown below. The effectiveness of current practices for each management category and each emission of concern is reflected by the percentage of green in the boxes under each emission. The larger the green area in each box, the more effective current management practices are and the fewer the opportunities to reduce emissions of that constituent in that management category. If all boxes are completely green, it does not mean there are no emissions. Fully green boxes simply indicate that the current management practices for the existing structural facilities provide few or no opportunities to reduce the emissions of that constituent in that management category.



Depending on the availability of funds or willingness to change management practices, the producer can use the tool to simulate changes made and the impact on air emissions. The provided example output suggests that improvements might be made in housing management practices that result in reduced particulate matter emissions. One thing that is important to recognize is that such changes might increase expected ammonia emissions, thereby reducing the amount of green in that box. NAQSAT was designed to allow users to save their original inputs and effectiveness results and then run scenarios comparing the results of implementing proposed changes in management practices with the current conditions.

Summary

The NAQSAT assessment tool evaluates management practices and control technologies that are in place or under consideration relative to the potential for managing emissions from the given facility and associated infrastructure. The tool is unique in that multiple gaseous emissions, including odor, particulates, hydrogen sulfide, ammonia, methane, and VOCs will be considered during a single assessment. The tool does not provide emissions data; rather it is designed to provide producers with opportunities to make on-farm changes to reduce air emissions. The tool provides the opportunity to run scenarios with proposed changes to determine the impact a new practice would have on emissions. Trade-offs may exist within a production system such that all emissions cannot effectively be minimized. NAQSAT does not provide emissions data and/or regulatory guidance. The tool provides a free, voluntary, non-threatening, on-line, user-friendly format. When used in concert with consultants, NRCS personnel and published emission mitigation resources, livestock producers will identify areas of concern within their operation and alternative management practices that reduce air emissions from all aspects of their farm.

Benefits of Using NAQSAT for Producers

- Voluntarily assess current management practices using a tool tailored to your farm.
- Make a side-by-side comparison of how different practices or technologies impact emissions.
- See how changing one practice to reduce emission of one gas or pollutant changes other emissions.
- Print your reports to document progress over time.
- Access a list of technical experts involved in tool development.
- Link to other technical resources.

Benefits of Using NAQSAT for Technical or Agency Staff

- Identify mitigation options and cross reference with practice standards.
- Prioritize investments.
- Identify air emissions impacts of potential changes made for other reasons.
- Evaluate land-use decisions.
- Use to confirm that changes and programs can result in real change.
- Provide education about management practices and air emission impacts.

Partners and Funding Sources

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- Pennsylvania State University
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- Western United Dairymen

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Introduction

Feed is a significant cost in milk production. Generally over 50 percent of the production cost may be associated with meeting the nutritional requirements of the lactating cow. Dairies monitor feed cost through feed ingredient purchases, feed delivery records and weigh backs of refused feed. However, actual costs associated with shrink are often ignored. Shrinkage is the loss of feed ingredients that never have a potential for economic return. Generally, shrinkage includes not only storage losses but excessive inclusion rates in rations that are unnecessary to meet the nutritional needs of the animal. Dutton (1998) defined shrink as "the percentage of feed on a farm that is not accounted for by the rations by the animals for which it is intended." Causes may include wind, wildlife (birds and rodents), moisture or spoilage. Brouk (2009) also included delivery weight errors, discarded feed, feed dispersed by tires and tracking, and mixing errors as other contributors to shrink.

Brouk (2009) indicated shrink may represent 15 to 20 percent of the total feed cost with wet and expensive ingredients representing the greatest concern. Dutton (1998) reported 6 to 8 percent shrink on one dairy but felt most of the shrink was due to overfeeding ingredients. He questioned the value of feeding cows more accurately in the northeast United States since many of the overfed ingredients were lower cost per ton. There are limited research reports on the actual shrink occurring on dairies. On-site dairy discussions tend toward considering shrinkage a non-issue or part of normal feed cost, and opportunities for improvement are considered limited. However, a willingness to understand true costs related to shrinkage and addressing these problems can lead to economic benefits.

Brouk (2010) determined the cost of a corn silage based ration equaled $5.49 per head per day assuming zero shrinkage. Daily feed cost increased to $6.05/head when typical shrink values were applied to each feed ingredient in the diet. If shrink losses were reduced by 50 percent for each ingredient, daily feed costs were reduced to $5.75/head. The difference in daily feed cost of $0.30/head due to reduced shrink results in an annual savings of $100 per dairy cow.

Impact of Facilities on Shrinkage

Data in Table 1 shows typical shrink values for different ingredients based on storage type. The storage options shown in Table 1 provide different levels of protection from weather. The minimum expected loss is 10 percentwhen ingredients are stored in uncovered open piles. Storage bins reduce storage losses to 2 to 5 percent. An 8 percent storage loss reduction of soybean meal reduces daily feed cost $0.095/head assuming a daily use of 6 lbs and $400/ton. Designing a feed center to minimize the impact of solar radiation, moisture and wind may have economic returns due to reductions in shrinkage.

Table 1 Percent loss of different ingredients based on type of storage facility

Ingredient	Uncovered Open Piles	Covered 3-sided Bay	Closed Bin
Whole Cottonseed	10 – 20 %	5 -15 %	-------
Dry Meal	5 – 10 %	3 – 8 %	2 – 4 %
Soybean Hulls	12 – 20 %	5 – 10 %	2 – 5 %
Dry Distillers	15 -22 %	7 – 10 %	3 – 5 %
Wet Distillers	15 – 40 %	15 – 40 %	-------

Kertz, 1998

Normal shrinkage for commodity buildings (3-sided bay) is 8 percent. There are many places to reduce shrink when storing ingredients in commodity buildings. Common areas where shrinkage occurs include the following:

- Unloading on concrete slab – wind movement of ingredients, failure to move 100 percent of an ingredient into a bay
- Ration preparation – accuracy of measuring individual ingredients with a bucket loader is limited to about 1 to 2 cubic feet, resulting in over or under feeding individual ingredients
- Weather – building is often oriented based on prevailing wind, leaving feed exposed to blowing precipitation, resulting in spoilage due to rain or snow
- Number of bays – failure to empty bays completely often results in spoilage of ingredient along the back wall due to the inability to use in timely manner
- Management - more emphasis on time or getting cows fed versus accuracy of feed ration
- Feed center layout – efficiency in procurement of ingredients

Table 2 illustrates the impact of shrink on feed cost. Feed is purchased at a given cost per unit weight or volume. However, the actual feed cost may be significantly higher depending on shrinkage. For example, a dairy may pay $30 per ton of silage however, if there are 20 percent losses, the actual cost per ton of silage used in the ration is $37.50. Reducing silage losses to 12 percent saves an estimated $3.43 per ton of silage fed. Realistically, there will always be some shrinkage and loss. Each dairy must have a realistic target and for most ingredients other than forages, 2 to 4 percent is a reasonable target. Fermented forages or grains will have some loss associated with the fermentation process. If this fermentation occurs at the dairy, the goal should be less than 10 percent for fermented forages and below 5percent for fermented grains. Hurbaugh and Moeching (1984) and Hurbaugh et al (1983) reported on and off farm facilities handling whole corn had a shrink of 1 percent or less.

Impact of Moisture on Shrinkage

Feed ingredients are often purchased on a wet basis but formulated into rations on a dry weight bases. The impact of moisture must be considered when evaluating shrink. Table 3 shows the impact on weight of a 1 percent change in moisture content for products at different initial moisture contents. An ingredient such as hay purchased and delivered at 15 percent initial moisture content but dries while in storage to 14 percent has 1.16 percent less moisture. This impacts feed formulation unless moisture content is monitored to ensure a ration contains appropriate ingredients on a dry weight bases. If moisture is not considered, then for every 1 percent reduction in moisture, there is a 1.16 to 2.78 percent increase in dry matter depending on the initial moisture content. Similarly if moisture increases 1 percent due to rain or snow, there is 1.16 to 2.78 percent decrease in dry matter if the diet formulation is not adjusted. Table 4 shows the increase in dry matter per ton of feed based on initial moisture content and moisture losses of 2, 4 and 8 percent.

Table 2 Impact of shrink on feed cost for various ingredient purchase cost

Purchased Feed Cost ($/ton)	Actual Feed Cost w/ 2 % Shrink ($/ton)	Feed Cost Based on Percent Shrinkage (%)				
		4	8	12	16	20
30	$30.60	$31.20	$32.40	$34.09	$34.80	$36.00
50	$51	$52	$54	$56.82	$58	$60
100	$102	$104	$108	$113.64	$116	$120
150	$153	$156	$162	$170.45	$174	$180
200	$204	$208	$217	$227.27	$232	$240
250	$255	$260	$270	$284.09	$290	$300
300	$306	$312	$324	$340.91	$348	$360
350	$357	$364	$378	$397.73	$406	$420
400	$408	$416	$432	$454.55	$464	$480

Table 3 Impact of 1 percent reduction in initial moisture content for ingredients at different initial moisture content

Initial moisture content (%)	15	25	35	45	55	65
Weight change with 1 % reduction in moisture content	1.16 %	1.32 %	1.52 %	1.79 %	2.17 %	2.78 %

Another moisture concern is rain or snow entering the open commodity storage sheds. Table 5 shows the amount of rain entering every linear foot of a commodity shed assuming 1 inch of moisture blows into a bay for different side wall heights. For example, for a commodity shed with a 24 foot high sidewall, 15 gallons of water per linear foot will enter a bay. If a curtain is dropped to reduce the opening to 8 feet (skid steer height), then 10 gallons of moisture are prevented from entering the bay, or a 67 percent reduction. A 50 percent reduction occurs if a curtain is dropped leaving a 12 foot (pay loader height) opening. Lowering a curtain or flexible door at night or upon completion of feeding may prevent significant ingredient losses due to rainfall and subsequent spoilage. Frequency of rainfall events would determine curtain management and frequency of lowering. Curtains also minimize the impacts of wind and potential movement of ingredients between bays without solid dividers. Buildings storing commodities delivered in live bottom trailers may be able to reduce the sidewall height to a 14 foot opening using permanent materials.

Table 4 Increase in dry matter concentration due to moisture loss at different ingredient moisture contents

Delivered Moisture Content (%)	Moisture Loss in Storage (%)	Delivered Dry Matter per Ton (lbs)	Impact of Moisture Lost	
			Weight (lbs)	Percentage Increase in Dry Matter concentration
15	2	1700	1,740	2.4%
	4		1,780	4.7%
	6		1,820	7.1%
25	2	1500	1,540	2.7%
	4		1,580	5.3%
	6		1,620	8.0%
35	2	1300	1,340	3.1%
	4		1,380	6.2%
	6		1,420	9.2%
45	2	1100	1,140	3.6%
	4		1,180	7.3%
	6		1,220	10.9%
55	2	900	940	4.4%
	4		980	8.9%
	6		1,020	13.3%
65	2	700	740	5.7%
	4		780	11.4%
	6		820	17.1%

Impact of Scales on Shrinkage

Table 6 shows the weighing accuracy of scales depending on the mixer capacity and scale accuracy. Producers adding small quantities of ingredients may reduce shrink by using a smaller stationery mixer with more accurate scales to pre weigh these ingredients prior to moving ingredients into a larger mixer. Table 7 shows the typical ingredients in a corn silage based ration. Assuming a 10-ton mixer with 1 percent scale accuracy, the potential error ranges from 2 percent to 195 percent of the ingredient inclusion weights. For example, if 1,230 lbs of almond hulls are added to a 10-ton mix (Table 7), a 1 percent scale accuracy allows for measurement of this amount to the nearest 200 lbs, meaning that the potential exists for a ±16 percent weighing error of this ingredient. There is a familiar expression that someone "measures to the nearest 1/10 of inch, marks with chalk and cuts with an axe." This occurs daily on most dairies as nutritionists formulate rations to the nearest pound, the weight readout may be to the nearest 10 lbs, and the fill mechanism into the mixer is a pay loader which may have an accuracy of 50 to 100 lbs depending on the operator.

Table 5 Amount of water entering a commodity shed per linear foot due to 1 inch rainfall blowing into the open bays

Height of Open Side (feet)	Gallons moisture entering the commodity shed at full opening	Impact of Reducing Opening to 8 feet		Impact of Reducing Opening to 12 feet	
		Reduction in gallons of moisture entering commodity bays	Reduction as compared to fully open side wall	Reduction in gallons of moisture entering commodity bays	Reduction as compared to fully open side wall
8	5.0	na	na	na	na
12	7.5	2.5	33%	na	na
16	10.0	5.0	50%	2.5	25%
20	12.5	7.5	60%	5.0	40%
24	15.0	10.0	67%	7.5	50%
28	17.5	12.5	71%	10.0	57%
32	19.9	15.0	75%	12.5	63%

Table 6 Potential weight (lbs) error depending on mixer capacity and scale accuracy

Mixer Capacity (tons)	Scale Accuracy (%)			
	0.1	0.5	1	2
1	2	10	20	40
3	6	30	60	120
5	10	50	100	200
10	20	100	200	400

Accuracy is not related to the precision with which the scale may be read or set. The scale accuracy is determined by the mechanism (load cells) use to weigh the mixer box not the digital display. A readout device on a mixer may read to the nearest 10 lbs but even with a 1 ton mixer with 1 percent accurate scale, the actual accuracy is only guaranteed to the nearest 20 lbs.

There are two other basic types of scale errors (Ross, 2005). The first type of error (Type 1) is inconsistency of the scale. This type of error occurs when a scale reading is incorrect by a consistent percentage across the range of the scale. With this error the digital display may read and print the correct weights for formulation, but is off by a consistent percentage. Thus the scale may add an extra 25percent to the weight of each individual ingredient. When this error occurs, the ration is still formulated correctly but each group of cows may be overfed by 25 percent. The weight of the proceeding ration may be adjusted down due to excessive weigh-backs, however the nutritionist never knows the exact quantity of feed being consumed by a pen of cows even if the percentage of individual ingredients may be at the right proportion. This can be problematic in part because expensive, low-inclusion ingredients (i.e. feed additives) may be formulated at higher concentrations in the diet in an attempt to achieve a desired intake on a per cow per day basis. The underestimation of feed intake therefore leads to excessive intake of these relatively expensive ingredients.

Table 7 Potential weighing error individual ingredients in a10 ton ration assuming the scale accuracy is 1 percent.

Feed Ingredient	Daily Feed lbs/hd	Ingredient Weight per 10 ton Batch (lbs)	Potential Weighing Error Assuming 1 % Scale Accuracy
Alfalfa Hay	12	2,460	8.1 %
Corn Silage	35	7,180	2.8 %
Flaked Corn	14	2,870	7.0 %
Almond Hulls	6	1,230	16.3 %
Canola Meal	4.5	925	21.7 %
Dry Distillers Grains	4	820	24.4 %
Whole Cotton Seed	3	615	32.5 %
Rumen By-pass Fat	0.5	105	195.0 %
Minerals and Vitamins	1.5	310	65.0 %
Liquid Whey	15	3080	6.5 %
Molasses	2	410	48.8 %

The other error (Type 2) is consistent weight addition or subtraction. The scale adds a fixed amount of weight to every ingredient added to the ration. For example, 25 lbs is added to one ingredient formulated at 500 lb inclusion rate and 25 lbs is added to a second ingredient formulated at a 4,000 lb inclusion rate. In this case, the nutritionist may not realize the ingredients at smaller inclusion rates are being over or under fed in the diet. This type of error may parallel health issues related to ingredients added at lower rates since the percentage of over or under feeding is much greater as compared to an ingredient such as corn silage.

Table 8 compares the impact of Type 1 and Type 2 scale errors. Type 1 shrinkage is uniform and independent of the ingredient inclusion rate. Type 2 shrinkage is inversely proportional to the ingredient inclusion rate; higher shrinkage occurs with lower inclusion rates.

Larger dairies may find it economically beneficial to install a stationery mixer where the operational conditions are more controllable and then use a feed delivery wagon to move feed to the bunks. The other advantage of a stationery mixer is automation and extra time available.

Automation reduces the number of employees actually adding ingredients to the mixer. This increases the accuracy and reduces the variability due to human error in adding ingredients to the mixer.

Automatic control systems may be used to weigh individual ingredients while another batch is being delivered. Many ingredients may be stored in hopper bins reducing shrink. The authors are familiar with one stationery feed system where 2 augers, 12 and 6 inch augers, are installed in the boot of a bin to decrease the fill time. Both augers are started simultaneously; however, as the desired ingredient weight is reached, the 12-inch auger is turned off, allowing more accuracy as the 6-inch auger adds the final quantity of product. This system overcomes the typical concerns with slow fill times using hopper bins.

Table 8 Impact of Type 1 and Type 2 scale errors on shrinkage

Feed Ingredient	Daily Feed lbs/hd	Ingredient Weight per 10 ton Batch (lbs)	Type 1 Error with 10 % extra		Type 2 Error with 30 lbs extra	
			Actual Weight (lbs)	% error	Actual Weight (lbs)	% error
Alfalfa Hay	12	2,460	2,710	10	2,490	1.2
Corn Silage	35	7,180	7,900	10	7,210	0.4
Flaked Corn	14	2,870	3,160	10	2,900	1.0
Almond Hulls	6	1,230	1,355	10	1,260	2.4
Canola Meal	4.5	925	1,015	10	955	3.2
Dry Distillers Grains	4	820	900	10	850	3.7
Whole Cotton Seed	3	615	675	10	645	4.9
Rumen By-pass Fat	0.5	105	115	10	135	28.6
Minerals and Vitamins	1.5	310	340	10	340	9.7
Liquid Whey	15	3080	3385	10	3,110	1.0
Molasses	2	410	450	10	440	7.3
TOTAL		20,000	22,000	10	20,330	1.7

Wind and Shrinkage

Wind breaks (Figure 1) can be used to reduce shrink around 3-sided commodity buildings. A wind break protects an area 10 times the height of the wind break. If the windbreak is 10 ft high, then the protected area is 100 ft. The snow dump area is 4 times the wind break height. The distance between the feed center and windbreak should be at least 4 times the height of the wind to prevent snow from piling in the feed center or covering traffic roads. Normally, it is recommended that windbreaks have 20 percent openings; however, around feed centers this is not as critical. A permanent wind break is recommended since shrink losses due to wind occur year round. Some opt to store hay or bedding around the perimeter of the feed center or pens.

This option limits wind protection to only to those periods when the hay or bedding is being stored.

Dairies located in areas with colder climates or excessive rainfall may benefit from placing the entire feed center under a roof to eliminate moisture and wind problems. Silage is delivered from the silage storage area daily and placed in a bay inside the building. Several bays are also available for ground hay. Hay storage remains in separate buildings until ground or immediately prior to usage. Working with the ingredient suppliers and trucking firms is critical prior to construction, since adequate room must be available inside the building to maneuver semi-trucks. More space is required if trucks are required to back into bays prior to unloading versus unloading on a slab (with the ingredients pushed into a bay).

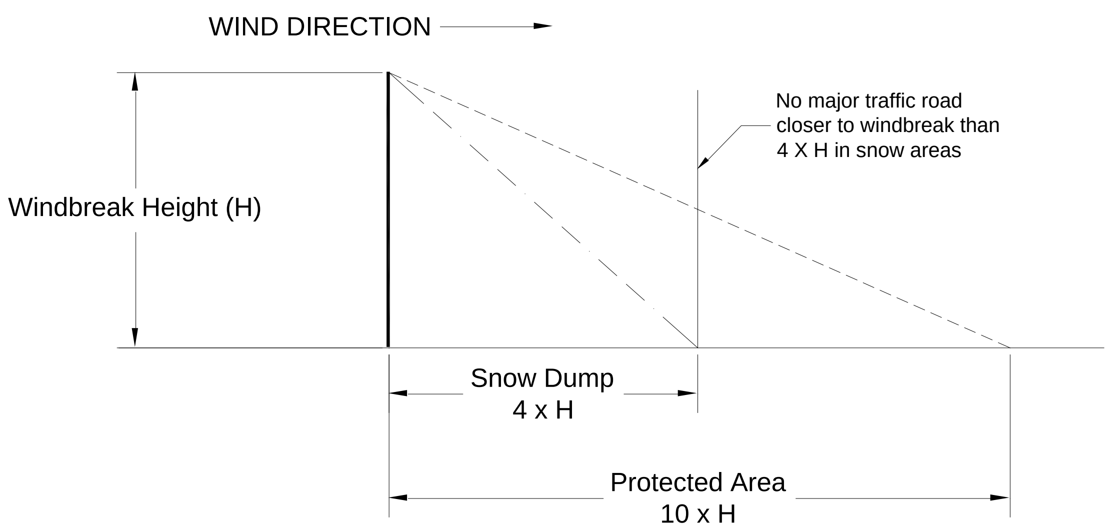

Figure 1 Illustration of impact of wind break on protecting a feed center

Low density feed ingredients should be delivered in self unloading trucks (walking floors) when ingredients are stored in open front commodity buildings. Many dairies have reported significant shrink when low density products are unloaded on an apron prior to transferring into a bay on windy days. If ingredients are unloaded on an apron, the shrink is minimized by immediately moving the materials into a bay.

Wind speeds of 6 mph may cause soil movement in highly erodible fields. Sand with a dry weight density 4 to 10 times that of most feed ingredients begins movement at 12 mph. Reducing wind speeds around the feed center is critical to minimize shrink as well as preventing deposits of soil from adjacent areas into the commodity bays. Assuming feed ingredients begin moving at wind speeds of 5 mph, Table 8 shows the impact of wind speed on potential losses assuming feed particles beginning blow away if stored in an open pile. The impact factor in Table 9 illustrates the potential increase in feed losses due to wind are 8 times greater at 10 mph than 5 mph. As wind speed increases, there is an exponential increase in potential losses due to the cubic relationship between wind speed and particle movement.

Table 9 Potential impact of wind speed on feed losses based on the assumption there are no feed particles losses at winds speeds of 5 mph or less.

Wind Speed (mph)	Potential increases in relative feed losses assuming no ingredient losses at wind speeds of 5 mph or less
5	No losses
10	8
15	27
20	64
25	125

Windbreaks also help minimize soil and foreign matter from accumulating in the feed center area. Feed centers surrounded by large crop acreages often serve as a windbreak, causing materials to settle out in commodity bays during wind storms. This foreign matter is included as part of individual ingredient weights, resulting in feed formulation errors. Average annual soil losses due to wind were reported at 2.5 tons per acre of land (Lyles, 1975). Wind erosion is higher from fields with less surface residue such as corn silage fields. An exterior windbreak causes this material to settle prior to entering the feed center area.

Designing Feed Centers to Minimize Shrinkage

Figure 2 provides an illustration of a windbreak around a feed center. The windbreak should be located at least 4 times the height of the windbreak away from the feed center. This space will serve as a snow dump area. If snow is not an issue, the windbreak may be located closer to the feed center. "L" shaped commodity sheds provide protection from the wind from multiple directions. Feed center protection is increased if the building is oriented such that the prevailing wind is perpendicular to the intersection of the two building sides (corner of "L") than along one side. A single row of commodity bays may be modified along one side to include a 2nd building to provide additional wind protection. Many dairies also need a place to store additional commodities, ground hay or daily silage needs prior to feeding.

Figure 3 provides an illustration of a totally enclosed commodity building. The advantage to this building is that weather related shrinkage losses are minimized. The overall building width is typically 60 to 80 feet wider than a 3-sided commodity building. This is necessary to provide room inside the building to maneuver semi-trucks delivering ingredients. The authors recommend consulting with trucking firms to make sure there is adequate room. Significant reductions in open space may increase feed loading time since feed loading equipment may not have free space to maneuver rapidly.

Figure 4 illustrates a feed center with a stationery mixer. There is room around the mixer to use micro ingredient tanks as well as liquid tanks. Stationery mixers enable more hopper bottom tanks with automated handling equipment to be utilized for low inclusion rate ingredients and liquids. Commodity bays are in close proximity of the stationery mixer, allowing adequate time to secure individual ingredients. Another advantage is minimum losses due to weather shrinkage.

Summary

Minimizing feed shrinkage can improve the bottom line of a dairy. Weather related shrinkage due to wind and moisture may be minimized with proper feed center design. Utilizing existing records can provide an opportunity to explore actual shrinkage on a dairy and the potential economic return to minimizing such losses. There are management opportunities to reduce shrinkage due to weather and spoilage in existing facilities, even without automation.

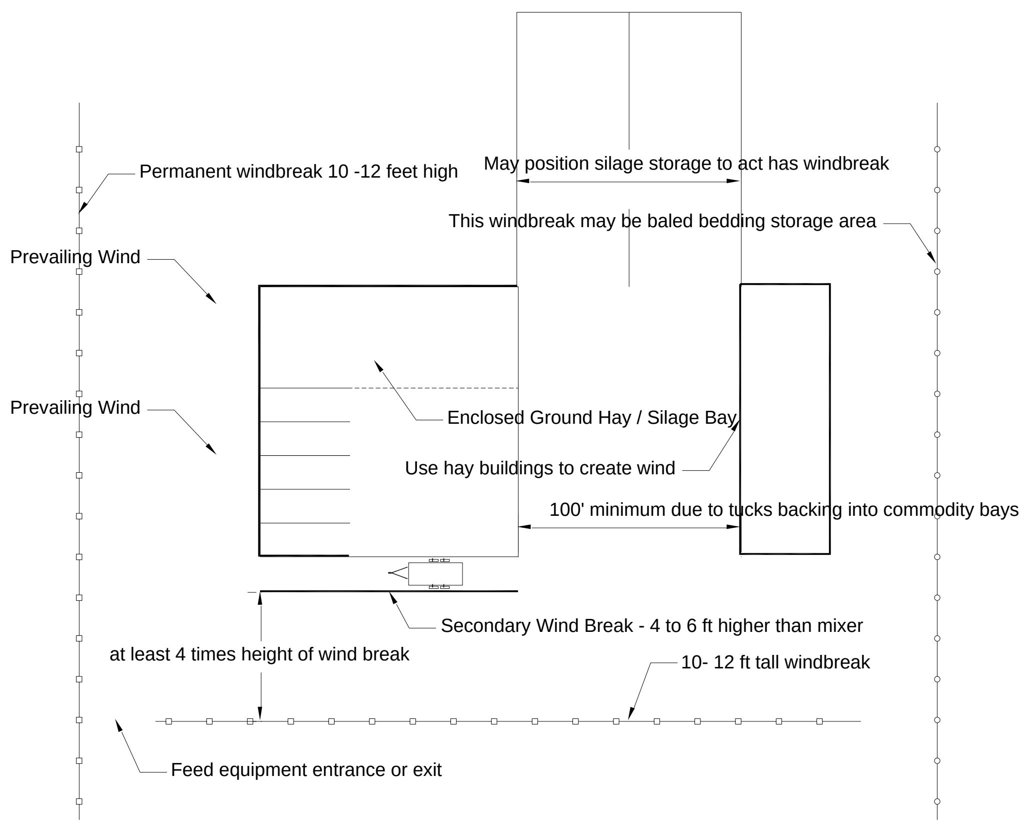

Figure 2 Utilization of buildings and windbreaks to minimize shrinkage due to wind

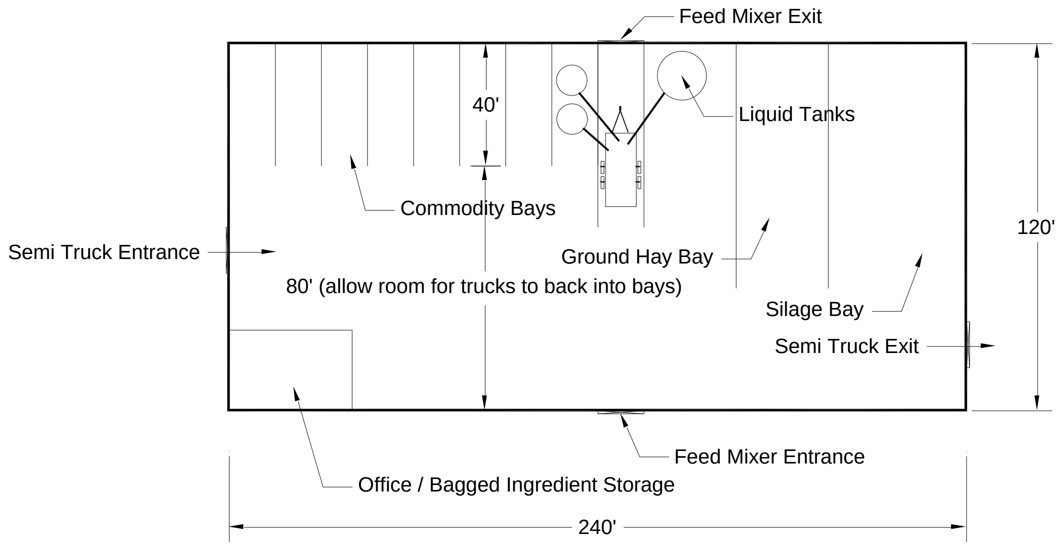

Figure 3 Illustration of totally enclosed commodity building using a portable mixer

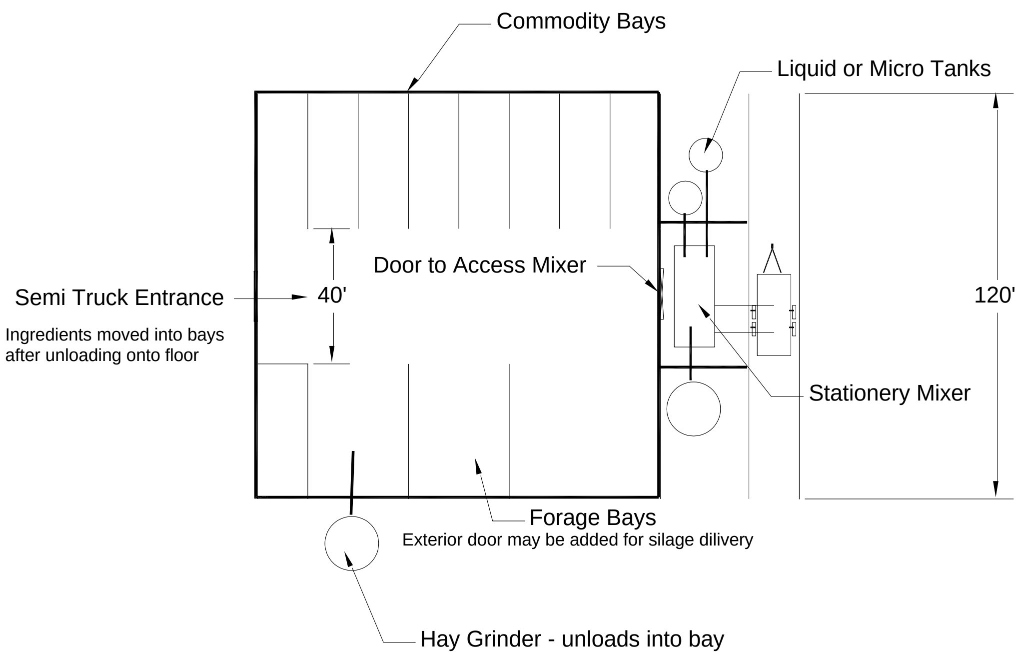

Figure 4 Illustration of a feed center with a stationery mixer

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What We Have Learned About Cross Ventilated Freestalls: A Producer Panel

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Introduction

Low profile cross ventilated (LPCV) freestall buildings are one option for dairy cattle housing. These facilities allow producers to have control over a cow's environment during all seasons of the year. As a result, an environment similar to the thermoneutral zone of a dairy cow is maintained in both the summer and winter, resulting in more stable core body temperatures. LPCV facilities allow for buildings to be placed closer to the parlor, thus reducing time cows are away from feed and water. Other advantages include a smaller overall site footprint than naturally ventilated facilities and less critical orientation since naturally ventilated facilities need to be orientated east-west to keep cows in the shade. Some of the other benefits to controlling the cow's environment include increased milk production, improved feed efficiency, increased income over feed cost, improved reproductive performance, ability to control lighting, reduced lameness, and reduced fly control costs.

Characteristics of LPCV Facilities

The "low profile" results from the roof slope being changed from a 3/12 or 4/12 pitch common with naturally ventilated buildings to a 0.5/12 pitch. Contractors are able to use conventional warehouse structures with the LPCV building and reduce the cost of the exterior shell of the building, but the interior components and space requirements per cow for resting, socializing, and feeding in an LPCV building are similar to a 4-row building.

Providing a Consistent Environment

Constructing a cross ventilated facility ensures the ability to provide a consistent environment year-round, resulting in improved cow performance. These buildings provide a better environment than other freestall housing buildings in the winter, spring and fall months, as well as the summer because of the use of an evaporative cooling system. The ability to lower air temperature through evaporative cooling is dependent upon ambient temperature and relative humidity. As relative humidity increases, the cooling potential decreases, as shown in Figure 1. Cooling potential is the maximum temperature drop possible, assuming the evaporative cooling system is 100% efficient. As the relative humidity increases, the ability to lower air temperature decreases, regardless of temperature. The cooling potential is greater as air temperature increases and relative humidity decreases. Figure 1 also shows that evaporative cooling systems perform better as the humidity decreases below 50 percent.

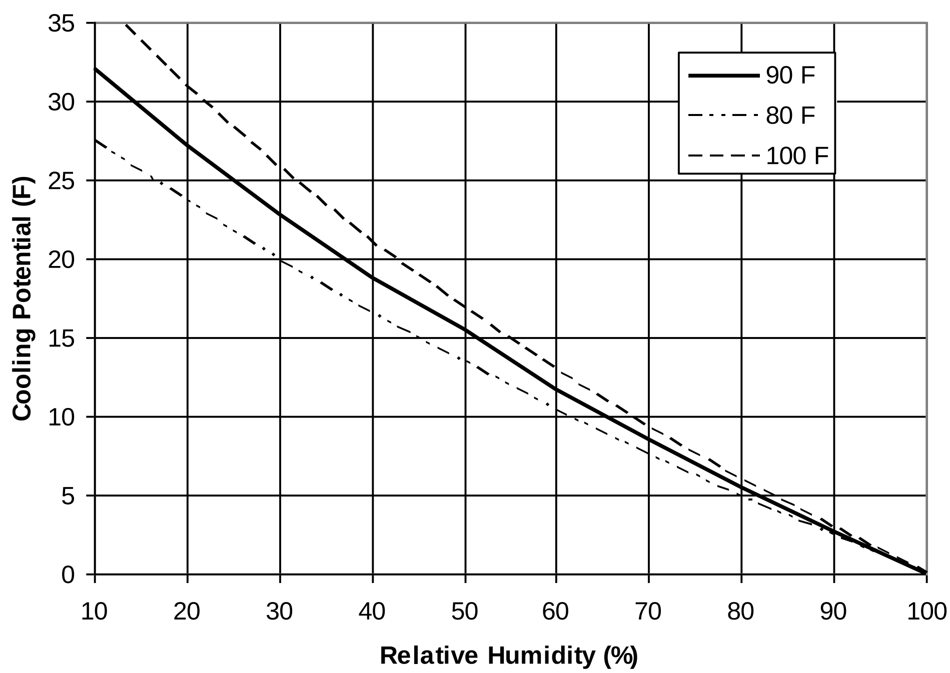

Figure 1: Impact of Relative Humidity and Temperature on Cooling Potential When Using an Evaporative Cooling System

Impact of LPVC Facilities and Core Body Temperature

One of the major benefits of LPCV facilities is the ability to stabilize a cow's core body temperature. A heat stress audit was conducted on a North Dakota dairy to evaluate the impact of a changing environment on the core body temperature of cows. Vaginal temperatures were collected from 8 cows located in the LPCV facility and 8 cows located in a naturally ventilated freestall facility with soakers and fans. Data were recorded every 5 minutes for 72 hours using data loggers (HOBO® U12) attached to a blank CIDR® (Brouk 2005). Environmental temperature and humidity data were collected on individual dairies utilizing logging devices which collected information at 15 minute intervals. The environmental conditions and vaginal temperatures during the evaluation period are presented in Figures 2 and 3. Vaginal temperatures were acceptable in both groups, but the temperatures of cows housed in the LPCV facility were more consistent. Feedline soakers in naturally ventilated buildings are effective in cooling cows, but they require the cows to walk to the feedline to be soaked. On the other hand, cows in an LPCV facility already experience temperatures that are considerably lower than the ambient temperature. Reducing the fluctuations in core body has a dramatic impact on the production, reproduction and health of a dairy cow.

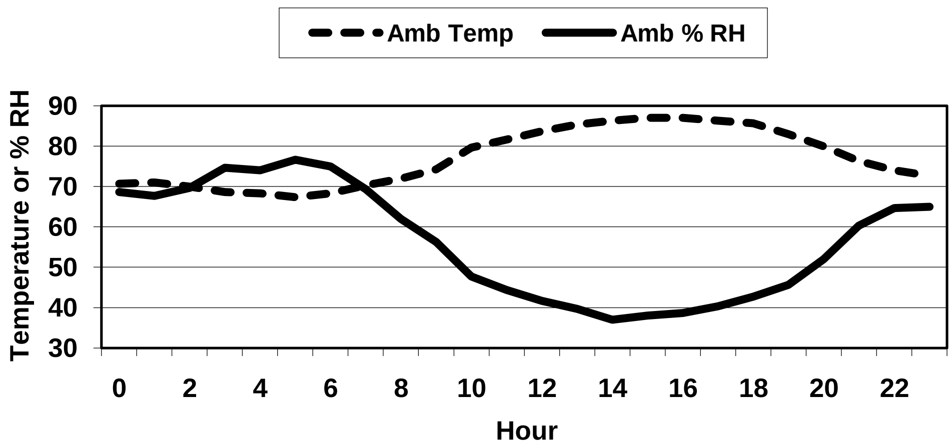

Figure 2: Ambient Temperature and % RH for Milnor, ND (July 6-9, 2006)

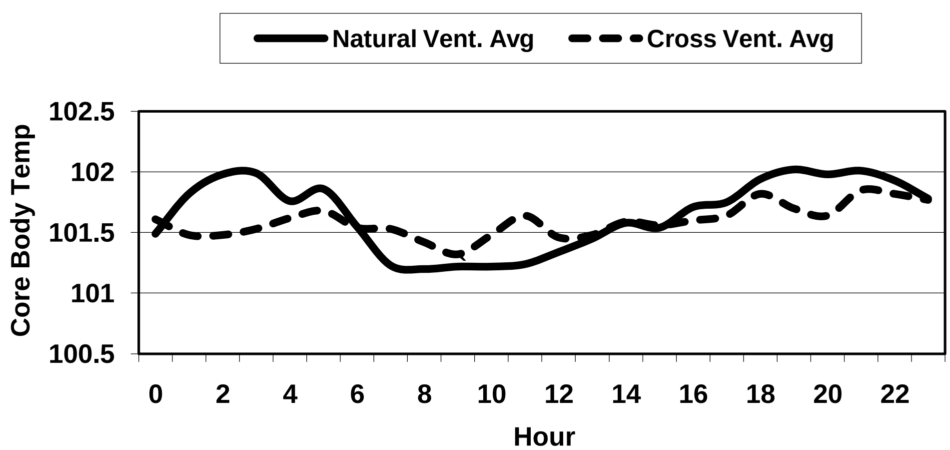

Figure 3. Core Body Temperature of Cows Housed in Naturally Ventilated (Fans & Soakers) and LPVC Freestalls (Evaporative Pads)

Environmental Impact on Nutrient Requirements and Efficiency

Dairy cows housed in an environment beyond their thermoneutral zone alter their behavior and physiology in order to adapt. These adaptations are necessary to maintain a stable core body temperature, but they affect nutrient utilization and profitability on dairy farms.

The upper critical temperature, or upper limit of the thermoneutral zone, for lactating dairy cattle is estimated to be approximately 70 - 80°F (NRC, 1981). When temperatures exceed that range, cows begin to combat heat stress by decreasing feed intake (Holter at el., 1997), sweating, and panting. These mechanisms increase the cows' energy costs, resulting in up to 35% more feed necessary for maintenance (NRC, 1981). When dry matter intake decreases during heat stress, milk production also decreases. A dairy cow in a 100°F environment decreases productivity by 50% or more relative to thermoneutral conditions (Collier, 1985).

Compared to research on the impact of heat stress, little attention has been paid to cold stress in lactating dairy cattle. The high metabolic rate of dairy cows makes them more susceptible to heat stress in U.S. climates; so as a result, the lower critical temperature of lactating dairy cattle is not well established. Estimates range from as high as 50°F (NRC, 1981) to as low at -100°F (NRC, 2001). Regardless, there is evidence that the performance of lactating cows decreases at temperatures below 20°F (NRC, 1981). One clear effect of cold stress is an increase in feed intake. While increased feed intake often results in greater milk production, cold-induced feed intake is caused by an increase in the rate of digesta passage through the gastrointestinal tract. An increased passage rate limits the digestion time and results in less digestion as the temperature drops (NRC, 2001). In cold temperatures, cows also maintain body temperature by using nutrients for shivering or metabolic uncoupling, both of which increase maintenance energy costs. These two mechanisms decrease milk production by more than 20% in extreme cold stress. However, even when cold stress does not negatively impact productivity, decreased feed efficiency can hurt dairy profitability.

To assess the effects of environmental stress on feed efficiency and profitability, a model was constructed to incorporate temperature effects on dry matter intake, diet digestibility, maintenance requirements, and milk production. Expected responses of a cow producing 80 pounds of milk per day in a thermoneutral environment with total mixed ration (TMR) costs of $0.12/lb dry matter and milk value of $18/ hundred weight of milk (cwt) are shown in Figure 4. The model was also altered to assess responses to cold stress if milk production is not decreased. In this situation, the decrease in diet digestibility alone results in an 8% decrease in income over feed cost as temperatures drop to -10°F ($6.94 vs. $7.52/cow per day).

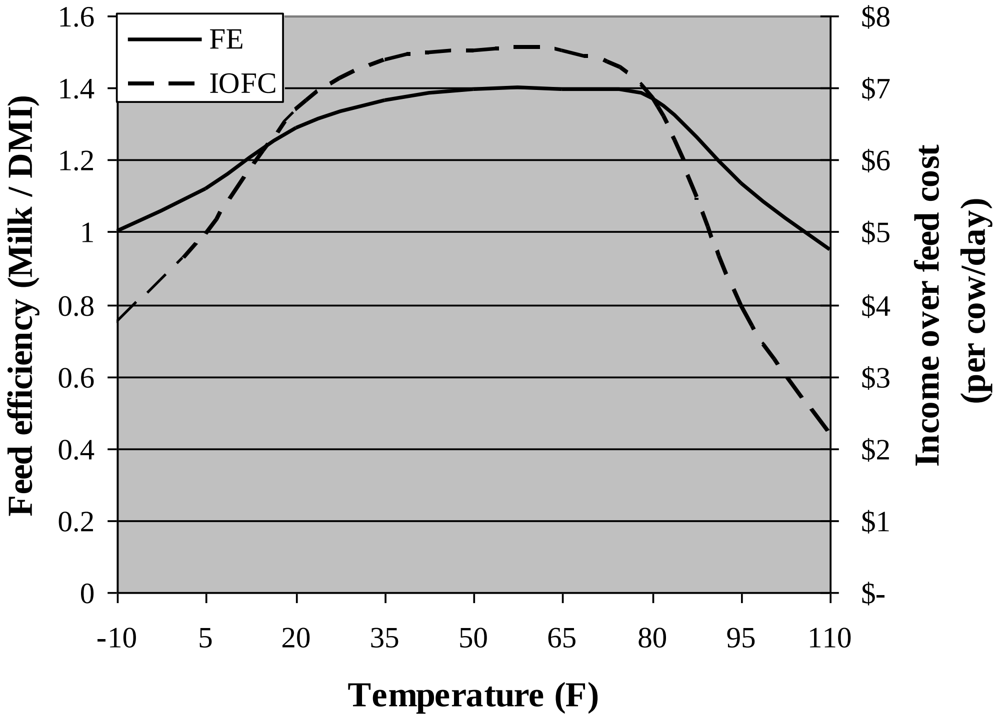

Figure 4. Responses to Environmental Stress, (Thermoneutral Production of 80 lbs/day, TMR Cost of $0.12/lb Dry Matter, and Milk Value of $18/cwt)

With these research results, cost benefits can be estimated for environmental control of LPCV facilities. Benefits of avoiding extreme temperatures can be evaluated by comparing returns at ambient temperatures to temperatures expected inside LPCV barns. For example, the model above predicts that income over feed cost can be improved by nearly $2 per cow/day if the ambient temperature is 95°F and barn temperatures are maintained at 85°F. Likewise, if ambient temperature is 5°F and the temperature inside the barn is 15°F, income over feed cost is expected to increase by $1.15 per cow/day.

Besides effects on feed costs and productivity, heat stress also has negative effects on reproduction, immunity, and metabolic health. These factors represent huge potential costs to a dairy operation. While responses to cold stress are not typically dramatic, increased manure production is a resulting factor. In this model, increased feed intake and decreased digestibility during cold stress also increased manure output by as much as 34%. This is a significant cost factor on many farms, requiring increased manure storage capacity and more acres for manure application.

Environmental Impact on Reproduction

Even though cold stress has little effect on reproduction, heat stress can reduce libido, fertility, and embryonic survival in dairy cattle. Environmental conditions above a dairy cow's thermoneutral zone decreases ability to dissipate heat and results in increased core body temperature. The elevated body temperatures negatively impact reproduction, both for the female and the male.

The impact of heat stress can be categorized by the effects of acute heat stress (short-term increases in body temperature above 103^{o} F) or chronic heat stress (the cumulative effects of prolonged exposure to heat throughout the summer). In acute heat stress, even short-term rises in body temperature can result in a 25 – 40% drop in conception rate. An increase of 0.9^{o} F in body temperature causes a decline in conception rate of 13% (Gwazdauskas et al.). The impact of heat stress on reproduction is more dramatic as milk production increases, due to the greater internal heat load produced because of more feed intake (al-Katanani et al., 1999).

Declines in fertility are due, at least in part, to damage of developing follicles that results in lower production of the follicular hormone estradiol. Also, poor quality ovulatory follicles transition into corpora lutea following ovulation. Corpora lutea are responsible for producing progesterone, a key hormone to the success of reproduction. As a consequence of reduced levels of estradiol and progestone, lower quality, aged follicles are ovulated and the resulting conception rate is decreased (Wolfenson, et al.). The lower estradiol levels also make it more difficult to find cows in heat, since a high level of estradiol is required for a cow to express heat or stand to be mounted. In herds that utilize artificial insemination (AI) and depend entirely on estrus detection, heat detection declines of at least 10-20% are common during the summer months. Timed AI tends to account for a greater percentage of inseminations during the summer months as a consequence of the difficulty in finding cows in heat.

If, despite the reduced follicular quality, cows manage to become pregnant, a greater likelihood exists of embryonic loss due to heat stress. Many times, cows actually achieve ovulation and fertilization, but early embryonic loss often occurs during days 2 to 6 post-insemination and the observer believes that the cow never actually conceived.

Chronic heat stress also negatively impacts follicular and corpora lutea quality and results in reduced estradiol and progesterone levels. One additional impact of chronic heat stress is an increased risk of twinning, especially for cows that become pregnant toward the latter periods of heat stress. The risk of late embryonic loss and abortion is approximately 2 to 2.5 times greater for cows bred during and immediately following heat stress. Chronic heat stress also greatly depresses feed intake and prolongs the period of time required for a cow to reach positive energy balance, thus causing excessive weight loss and delaying days to the first ovulation. Because of the severe challenges of impregnating cows during the summer, some herds decrease their efforts during this time.

Whether the decline in pregnancy rates is voluntary or not, drops in the number of cows that become pregnant create holes in the calving patterns. Often, there is a rebound in the number of cows that become pregnant in the fall. Nine months later, a large number of pregnant cows puts additional pressures on the transition facilities when an above-average group of cows moves through the close-up and fresh cow pens. Overcrowding these facilities leads to increases in post-calving health issues, decreased milk production, and impaired future reproduction.

Environmental Impact on Milk Production

Though the impact of cold stress on milk production is minimal, the impact of heat stress on milk production can be very dramatic. Numerous studies have been completed to evaluate the economic impact of heat stress on milk production (Dhuyvetter et al., 2000), but because so many approaches are used to manage heat stress, standard evaluations are difficult. Heat stress not only impacts milk production during summer months, but it also reduces the potential for future milk production of cows during the dry period and early lactation. For every pound of peak milk production that is lost, an additional 250 pounds of production will be lost over the entire lactation.

A simple sensitivity analysis was conducted to observe the impact of heat stress on gross income. A net milk price of $18/cwt was used for this analysis. The milk production impact of 90-150 days of heat stress on gross income and IOFC per cow is presented in Table 1. When daily milk production is reduced 2 to 12 pounds per day per cow, the gross income loss related to heat stress ranges from $32.40 to $324.00 per cow and IOFC from $22.80 to $228.00.

Table 1.

Reduction of milk production	Total Lost Production Days of Lost Production			Reduction in Gross Income Days in Lost Production			Total Reduced Feed (lbs) Days of Lost Production			Reduction in IOFC* Days in Lost Production		
(lbs/cow/day)	90	120	150	90	120	150	90	120	150	90	120	150
2	180	240	300	$32.40	$43.20	$54.00	80	107	133	$22.80	$30.40	$38.00
4	360	480	600	$64.80	$86.40	$108.00	160	213	267	$45.60	$60.80	$76.00
6	540	720	900	$97.20	$129.60	$162.00	240	320	400	$68.40	$91.20	$114.00
8	720	960	1200	$129.60	$172.80	$216.00	320	427	533	$91.20	$121.60	$152.00
10	900	1200	1500	$162.00	$216.00	$270.00	400	533	667	$114.00	$152.00	$190.00
12	108											
	0	1440	1800	$194.40	$259.20	$324.00	480	640	800	$136.80	$182.40	$228.00

* Assumes feed efficiency remains constant

The impact of heat stress on future milk production is evaluated in Table 2. Gross income per cow per lactation is increased from $90 to $540 per cow/lactation and IOFC is increased from $63.33 to $380.00 as peak milk production is increased from 2 to 12 lbs/cow/day during periods of heat stress.

Table 2.

Increase in Peak Milk Production (lbs/cow/day)	Additional Milk Production (lbs/lactation)	Additional Gross Income (lbs/lactation)	Additional Feed (lbs) (lbs/lactation)	Increase in IOFC* (lbs/lactation)
2	500	$90.00	222	$63.33
4	1000	$180.00	444	$126.67
6	1500	$270.00	667	$190.00
8	2000	$360.00	889	$253.33
10	2500	$450.00	1111	$316.67
12	3000	$540.00	1333	$380.00

*Assumes feed efficiency remains constant

Commonly Asked Questions

As with any new concept or technology there are many questions that will be asked by dairy producers and their employees. The following are list of questions often asked about LPCV facilities.

1. How does the construction cost of naturally ventilated freestall facilities (NV) compare to cross ventilated freestalls (LPCV)? When you compare the two types of facilities do they have similar ability to cool cows, manage long day lighting, etc.?
2. In your experience, how does the feed efficiency and income over feed costs (IOFC) compare in NV and LPCV facilities?
3. How do you manage winter ventilation and at what temperature does it become difficult to manage?
4. Are you able to keep the alleys from freezing during the winter months?
5. Walking distance to the parlor in LPCV's is reduced significantly, does this give you adequate time to remove manure, groom stalls, etc.?
6. What impact does changing the air temperature in a LPCV have on reproduction, milk production and health of cows during the summer months?
7. How often do you clean the fans?
8. If you use evaporative pads, how often do you clean the pads and how do you clean the pads?
9. What type of bedding do you use in the freestalls? Can you use organic bedding in LPCV's?
10. How does the electrical cost in LPCV compare to NV facilities?
11. Are the maintenance costs of fans, baffles, doors, evaporative pads, lights and cleaning higher in LPCV facilities as compared to NV facilities?
12. How do you think NV and LPCV Facilities are perceived from an animal welfare prospective? Have you had questions about animal welfare?
13. Are flies easy to manage in LPCV facilities?
14. What do like and dislike about LPCV facilities?
15. If you could do it all over, what type of facility would you build?

Summary

LPCV facilities are capable of providing a consistent environment for dairy cows throughout the year. Changing the environment to reflect the thermoneutral zone of a dairy cow minimizes the impact of seasonal changes on milk production, reproduction, feed efficiency and income over feed cost. The key is to reduce variation in the core body temperature of the cows by providing a stable environment.

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Notes:

A Re-evaluation of the Impact of Temperature Humidity Index (THI) and Black Globe Humidity Index (BGHI) on Milk Production in High Producing Dairy Cows

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Introduction

The temperature humidity index (THI) was originally developed for humans by Thom (1958) and extended to cattle by Berry et al (1964). It is currently used to estimate cooling requirements of dairy cattle in order to improve the efficiency of management strategies to alleviate heat stress. The Livestock Conservation Institute evaluated the biological responses to varying THI values and categorized them into mild, moderate and severe stress levels for cattle (Whittier, 1993; Armstrong, 1994). However, as pointed out by Berman (2005) the supporting data for these designations are not published. In addition, the index is based on a retrospective analysis of studies carried out at The University of Missouri in the 1950's and early 1960's on a total of 56 cows averaging 15.5 kg/d, (range 2.7-31.8 kg/d). In contrast, average production per cow in the United States is presently over 30 kg/d with many cows producing above 50 kg/d at peak lactation. The sensitivity of cattle to thermal stress is increased when milk production is increased thus reducing the "threshold temperature" when milk loss begins to occur (Berman, 2005). This is due to the fact that metabolic heat output is increased as production levels of the animal increase. For example, the heat production of cows producing 18.5 and 31.6 kg/d of milk has been shown to be 27.3 and 48.5% higher than non-lactating cows (Purwanto et al., 1990). Research has shown that when milk production is increased to from 35 to 45 kg/d the threshold temperature for heat stress is reduced by 5°C (Berman, 2005). The physiological effects based on THI predictions on milk yield are currently underestimating the severity of heat stress on Holstein cattle. Radiant heat load and/or convection effects were not evaluated by Berry et al., (1964) and the majority of dairy cows care currently housed under a shade structure during heat stress months. Shade structures alleviate some of the radiant heat load there is still a conducive effect coming from the metal shade structure. In Israel, a typical shade structure is estimated to add 3°C to the effective ambient temperature surrounding the animals (Berman, 2005). The use of fans for cooling management systems causes varying convection levels under shade structures as well.

An additional factor in utilizing THI values is the management time interval. In past research, the milk yield response to a given THI was the average yield in the second week at a given environmental heat load therefore milk yield measurements were not recorded until two weeks after experiencing the environment (Berry et al., 1964). In order to avoid economic production losses dairy producers need to be informed of the level of cooling to be implemented immediately when heat stress occurs. Research has indicated that the effects of a given temperature on milk production are maximal between 24 and 48 hours following heat stress (Collier et al., 1981; Spiers et al., 2004). It has also been reported that ambient weather conditions two days prior to milk yield measurement had the greatest correlation to decreases in milk production and dry matter intake (West et al., 2003). Research has shown that the total number of hours when THI is greater than 72 or 80 over a 4 day interval had the highest correlation with milk yield (Linville and Pardue, 1992). Collectively, these findings indicate that current THI values for lactating dairy cows underestimate the impact of a given thermal load on animal productivity and have an inappropriate time interval associated with a cooling management decisions. Avoiding a decline in milk production over a 48 hour period will automatically prevent a decrease in lactation persistency two weeks later. Utilizing the THI in order to reduce milk production losses has been effective however; the current THI is in need of updating on an appropriate time scale with data from higher producing animals. The pattern of stress application is a final component of the THI to be considered. In the research conducted for the current THI, animals were exposed to given THI conditions continuously meaning, with no daily circadian environmental fluctuations, for the entire two week period (Berry et al., 1964). Under natural dairy management conditions, temperatures are not kept constant rather they follow a circadian pattern which rises and falls during a normal 24 hour day. It is important to establish THI under conditions normally experienced by lactating dairy cows. In addition, the most appropriate parameters need to be identified. For example, average, minimum, maximum, and hours above a certain THI all need to be examined. Research has reported that minimum THI is more highly correlated with a reduction in feed intake compared to maximum THI (Holter et al., 1996). When evaluating test day yields results showed a decrease of 0.2 kg per unit of THI increase above 72 when THI was composed of maximum temperature and minimum humidity (Ravagnolo et al., 2000).

The effects of radiant heat load can be evaluated using the BGHI (BGHI = t_{bg} + .36t_{dp} + 41.5 where t_{bg} = black globe temperature $^{\circ}$C and t_{dp} = dew point temperature, $^{\circ}$C), developed by Buffington et al. (1981). Research has demonstrated that BGHI had increased correlations to rectal temperature increases and milk yield decreases compared to THI (Buffington et al., 1981). It has also been shown that the correlation of BGHI to milk yield is greater (r^2 = .36) under conditions of high solar radiation (no shade) than under a shade structure (r^2= .23; Buffington et al., 1981). However, milk production in this study was considered to be low (average 15 kg/cow). Therefore, correlations of BGHI to milk yield under shade structures might be higher with higher producing dairy cows (which are more sensitive to increased heat loads). It is also apparent a great deal of variation is not explained by BGHI. This might be improved by determining the impact of an additional factor like skin temperature.

Another option in measuring radiant environmental temperature is by using infrared technology to measure skin surface temperature. In doing this we can account for differences in microenvironment around the animals and have a greater accuracy of measuring environmental heat load. Creating a skin temperature humidity index (STHI = $t_s + .36\ t_{dp} + 41.5$ where t_s = infrared skin surface temperature ^{0}C and t_{dp} = dew point temperature,$^\circ$C), might allow for greater prediction of an animal's heat stress compared to BGHI or THI. Using infrared thermography guns it is possible obtain rapid and reliable skin surface temperatures. These parameters would be best to evaluated under controlled environmental conditions and confirmed under practical management conditions. Under commercial dairy conditions vaginal temperatures can be used to continuously record core body temperatures as other researchers have conducted (Araki et al., 1985; Ominski et al., 2002). Obtaining core body temperature in addition to simultaneous recording of black globe and dry bulb temperatures and humidity as well as milk yield will permit determining relationships between ambient heat load, core body temperature and subsequent milk yields.

Conducting studies where temperature and humidity are controlled in a circadian manner, in order to mimic natural environmental conditions, has not been conducted. Feed intake and milk yield under natural conditions has resulted in mean THI two days prior to milk production to have the greatest effect on both intake and yield (Collier et al., 1981, West et al., 2003). Unfortunately, because these results were not obtained in controlled environment researchers were unable to quantify the relationship between THI and milk yield.

The goal of this study was to utilize high producing dairy cows and including radiant energy impacts on animal performance. Specific objectives were to determine the effects of minimum, maximum, average THI and the number of hours at a given THI on milk production of high producing dairy cows.

Materials and Methods

The data analyzed in this study was taken from 8 different studies over the course of three years. One hundred multiparous Holstein cows were housed in individual tie stalls in one of two environmentally controlled chambers in the William Parker Agricultural Research Center at the University of Arizona. The University of Arizona's Institute of Animal Care and Use Committee approved all protocols and use of animals in the current study. Temperature humidity Index (THI) was calculated using dry bulb temperature ($T_{db,}$ °F) and relative humidity (RH), (T_{db}-(0.55-(0.55*RH/100)*(T_{db}-58); Buffington et al., 1977). Black globe humidity index was calculated by using black globe temperature (T_{bg}, °C) and RH (Buffington et al., 1981). Milk yields, feed intake, water intake, skin temperature, rectal temperature, respiration rate and sweating rate was measured in all cows daily.

Groups 1-4

Forty-eight multiparous lactating Holstein cows were balanced for parity and stage of lactation and assigned to an incomplete crossover design involving two levels of radiant heat load, 2 levels of dry bulb temperature, and two levels of humidity. These parameters were then combined to produce eight experimental environments . Each of these eight environments have a range of dry bulb temperature, radiant energy, relative humidity, and THI values mimicking a possible 24 hour period under shade structures during summer months in the southern part of the United States. Cows were housed at the University of Arizona, William J. Parker Research Complex, in two environmental chambers, with only one room capable of producing radiant heat load. Six cows were housed in each environmental chamber, each group consisted of 12 cows therefore, four groups of animals (n=12) were brought to the facilities at separate times in order to reproduce eight environments. Each group of animals experienced a minimum of two and a maximum of three environments over a 22 d period. Animals entering the facility were provided seven days to acclimate to the chambers in a thermal neutral environment (Environment #3). Followed by a four day experimental environment, then cow's switched environmental chambers and were provided seven days to acclimate to the new chamber in a thermal neutral environment (Environment #3). After seven days, cows experienced the opposite experimental environment for four days. Cows were milked and fed twice daily with orts measured once a day prior to the morning milking. During adjustment periods, respiration rates (RR), surface temperatures (ST), evaporative heat loss (EVHL), rectal temperatures (RT), and heart rate (HR) were measured. Skin temperatures and sweating rates were measured from the shoulder, ribs, and rump of the animal twice a day (0500 and 1700 h). These same heat parameters were measured four times a day (0500, 1000, 1400, and 1700 h) during the four day experimental periods. On the 3rd d of each 4 d period a 24 h recording of these same observations were made every hour on the hour. Skin temperatures were measured with an infrared temperature gun (Raynger® MX™ model RayMX4PU Raytek C, Santa Cruz, CA). Rectal temperatures were measured using a digital thermometer (GLA M700 Digital Thermometer, San Luis Obispo, CA). Respiration rates were obtained by visually counting flank movements during a 15 sec interval and multiplying by 4 and evaporative heat loss was measured using an evapometer (Delfin Technologies, LTD., Finland). Heart rate was measured by cardiac auscultation. Environmental parameters recorded hourly and used for calculations of BGHI and THI are ambient temperature (T_{db}), relative humidity (RH), black globe temperature (T_{bg}), and radiant energy.

Group 5

Twelve multiparous mid lactation cows were assigned to one of two studies in January or June of 2004. Animals were balanced for parity and assigned to one of two environmental chambers at the University of Arizona, William J. Parker Research Complex. Environmental treatments consisted of one thermal neutral environment (8-15°C, 8-40% humidity) and two heat stressed environments 1) 30-40°C, 8-40% humidity and 2) the same heat stress conditions with the addition 4 h of solar radiation at 600 watts/h/m^2 from 1100 to 1500 h). Animals were provided seven days to adjust to the facilities and then experienced 3 14 d periods in an incomplete, crossover design. Solar lamps were only available in one of the environmental chamber rooms; cows had to switch rooms prior to the third period so that all animals experienced all environments. Once animals switched rooms they were provided 7 d to re-adjust to their new environmental chamber prior to period 3. Cows were milked two times a day (0600 and 1800 h) and milk weights recorded at each milking. Animals were fed a total mixed ration two times a day (0700 and 1700 h) and orts were weighed and recorded prior to the morning feeding.

Heat parameters were measured bihourly on d 6 of each period. Skin temperatures were measured with an infrared temperature gun on the right and left side of the animal on the middle of the rump and loin (Raynger® MX™ model RayMX4PU Raytek C, Santa Cruz, CA). Rectal temperatures were measured using a digital thermometer (GLA M700 Digital Thermometer, San Luis Obispo, CA). Respiration rates were obtained by visually counting flank movements during a 15 sec interval and multiplying by 4 and evaporative heat loss was measured using an evapometer (Delfin Technologies, LTD., Finland). Heart rate was measured by cardiac auscultation.

Group 6

A total of twelve lactating multiparous Holstein cows averaging 140 ± 13 DIM were assigned randomly to one of two environmental chambers at the William J. Parker Agricultural Research Complex at The University of Arizona. Cows were milked twice a day and recorded for daily milk yield. A total mixed ration was fed twice daily and weigh backs were measured once a day prior to the morning feeding. Dairy Nutrition Services (Chandler, AZ) formulated the TMR to meet or exceed energy requirements according to NRC, 2001. All studies were approved by the University of Arizona Institutional Animal Care and Use Committee. Cows were given seven days to acclimate in the environmental chambers and both groups regardless of treatment were exposed to thermal neutral conditions (20°C, 20% humidity, THI = 64). Following acclimation, cows continued to experience the same thermal neutral conditions for an additional 9 d and allowed to eat ad libitum (Period 1; P1). Period 1 and period 2 (P2) were separated by a 7 d where cows remained in the same thermal neutral condition. During P2, cows in group 1 remained in the same thermal neutral condition while cows in group 2 experienced heat stress (HS) and were fed ad libitum. In order to mimic daily variations, during HS cyclical temperatures ranged from 29.4 to 38.9°C with humidity held constant at 20%, THI ranged from 73 to 82 daily. Respiration rate (RR), skin temperatures (ST) and rectal temperatures (RT) were measured and recorded four times daily (0600, 1000, 1400, and 1800 h). Measuring RR was done by counting flank movements for 60 sec. On a shaved section on the shoulder of the cow skin temperatures were measured with an infrared temperature gun (Raynger® MX™ model RayMX4PU Raytek C, Santa Cruz, CA). Rectal temperatures were measured using a digital thermometer (GLA M700 Digital Thermometer, San Luis Obispo, CA).

Group 7

Ten lactating multiparous Holstein cows averaging 99.8 ± 20.2 DIM were randomly assigned to one of two environmental treatments over the course of three experimental periods. All animals were housed at The University of Arizona, William J. Parker Research Complex in tie-stall stanchions in the environmental chambers. Animals were exposed to three experimental periods, period 1 (P1), 7 d of thermal neutral conditions, period 2 (P2), 7 d of heat stress, and period 3 (P3), 7 d of heat stress; totaling 21 d to complete the entire study. Period 1 consisted of thermal neutral conditions (20°C, with humidity held constant at 20% with a 12 and 12 h light and dark cycle). Period 2 and P3 environments consisted of heat stress with cyclical daily temperatures in order to mimic daily variations (ranging from 29.4 to 38.9°C with humidity being held at 20%, THI = 72.4 to 82.2, with a 12 and 12 h light and dark cycle). All cows were fed a total mixed ration three times a day (0500, 1200, and 1700 h) and orts were recorded once a day prior to the morning feeding. All cows were allowed to eat ad libitum. All cows were milked two times a day (0500 and 1700h) and recorded at each milking.

Heat parameters such as respiration rate, surface temperature (from the shoulder, rump, and tail head), and rectal temperatures were measured four times a day (0600, 1000, 1400, and 1800 h). Surface temperatures were measured using an infrared temperature gun (Raynger®MX™ model RayMX4PU Raytek C, Santa Cruz, CA). Rectal temperatures were obtained using a standard digital thermometer (GLA 525/550 Hi-Performance Digital Thermometer, San Luis Obispo, CA).

Group 8

Eighteen second lactation Holstein cows averaging 89.2 (± 8.1) DIM were randomly assigned to an environmental chamber room into individual tie stalls located at the University of Arizona William J. Parker Research Complex. The chamber rooms only house six cows at a time therefore the study was replicated three times and one cow was removed from the study due to temperament issues in the facilities. All cows were milked two times a day and milk weights were recorded at each milking (0500, 1700 h). All cows were fed a totally mixed ration (TMR) two times day at milking times and orts were recorded prior to the morning feeding. Cows were housed at the University of Arizona dairy for 19 days prior to entering the environmental chambers. While at the dairy, cows received one of two dietary treatments 1) Control diet with 0 g/ton Rumensin or 2) the control diet top dressed with Rumensin at 450 mg/cow/d. Once they entered the facility they were provided 3 d to adjust however, continued on their dietary treatment. All cows regardless of dietary treatment experienced a constant thermal neutral environment (20% humidity, THI = 64, with 14 h light and 10 h dark cycles) and allowed to eat ad libitum for 9 d (experimental period [P] 1). They were then given 2 d in the same thermal neutral environment prior to experiencing P2 (experimental period [P] 2) which consisted of cyclical temperatures (29.4 to 38.9°C with constant 20% humidity, THI ≥73, ≤ 82 and 14 h light and 10 h dark cycles) and were fed ad libitum. This environment was made to replicate daily variations in temperatures throughout the day. Heat parameters were collected three times a day (0600, 1500 and 1800 h). Respiration rates were obtained by counting flank movements for 15 sec and multiplied by 4 for a total of breaths per minute. Surface temperatures were measured on a shaved patch (~5 cm^2) of skin on the shoulder of the animal using an infrared temperature gun (Raynger®MX™ model RayMX4PU Raytek C, Santa Cruz, CA). Using a standard digital thermometer (GLA M700 Digital Thermometer, San Luis Obispo, CA) rectal temperatures were measured. Environmental parameters recorded hourly and used for calculations of THI are ambient temperature (T_{db}) and relative humidity (RH).

Statistics

Data was analyzed using ANOVA and REGRESSION procedures of SAS (SAS, 1999). Milk yields were recorded during the acclimation periods and prior to environment initiation and were included as a covariate in the analysis. The dependent variable analyzed was milk yield, RR, ST, RT, HR, and EVHL. The independent variables included daily THI, ST, STHI and BGHI. The level of significance was set at $P < 0.05$ for all main effects and interactions and the LSMEANS test was conducted when significance was detected.

Results

As expected, as THI values increased the rectal temperatures and respiration rates of cows increased, (figures 1 and 2)

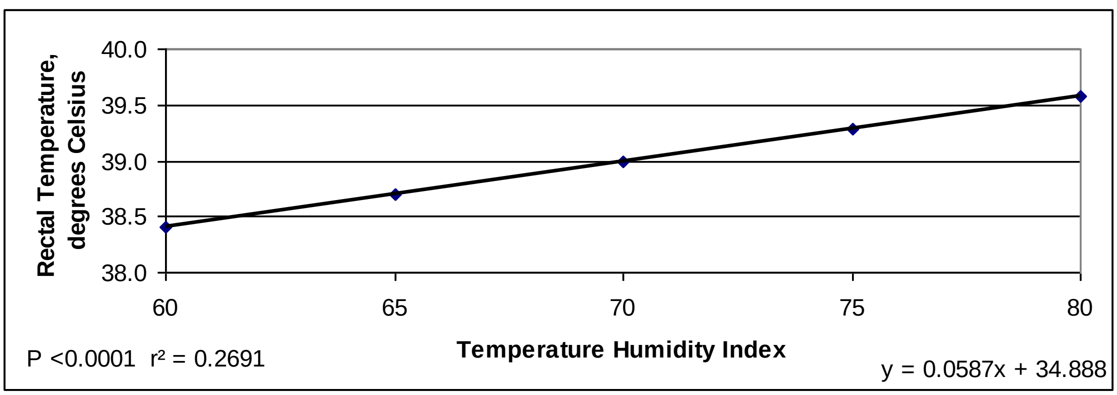

Figure 1. Effect of increasing temperature humidity index on rectal temperatures in lactating Holstein cows.

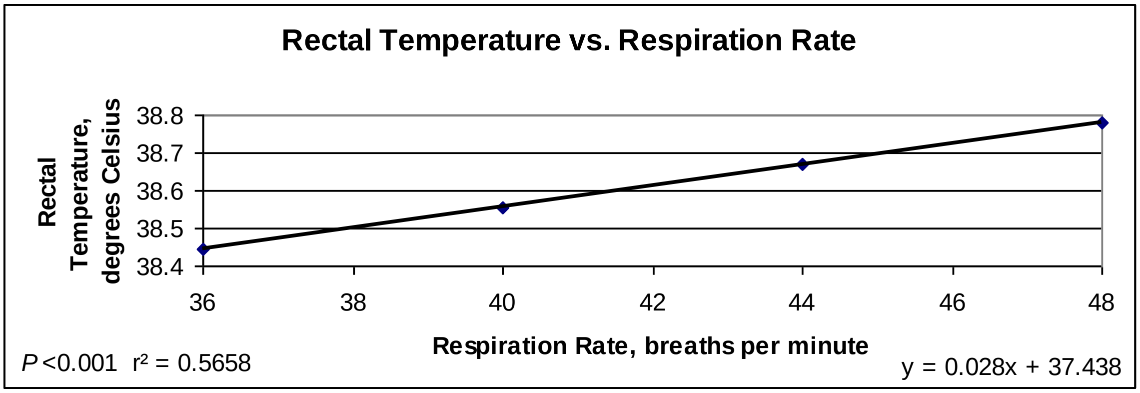

Figure 2. Rectal temperature vs. respiration rate.

Respiration rates increased by 2.0 breaths per minute per increase in THI unit ($P < 0.001$; $r^2 = 0.4343$). Evaporative heat loss at the skin was also found to increase as rectal temperatures were increased (Figure 3, $P < 0.001$; $r^2 = 0.0556$;). These increases in evaporative heat loss indicate that the cow is at or above its upper critical temperature.

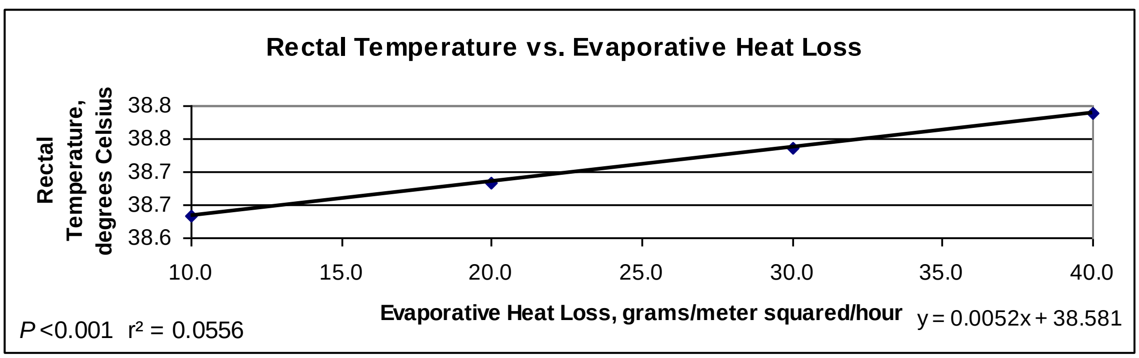

Figure 3. Rectal temperature vs. evaporative heat loss.

As THI, rectal temperatures and evaporative heat loss increased milk yields were shown to decrease linearly (Figures 4 and 5). This decrease in milk yield was linear between THI values of 60 and 80 indicating that milk yield losses were occurring well below a THI threshold of 72.

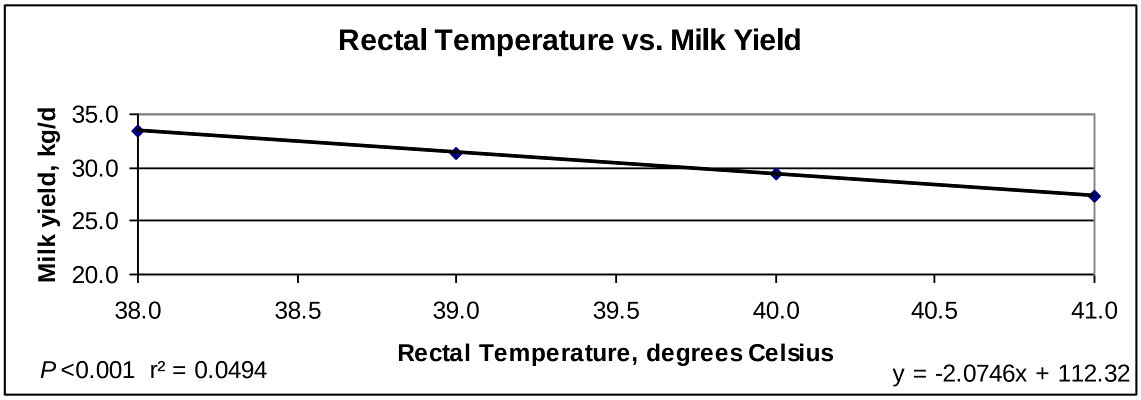

Figure 4. Rectal temperature vs. milk yield.

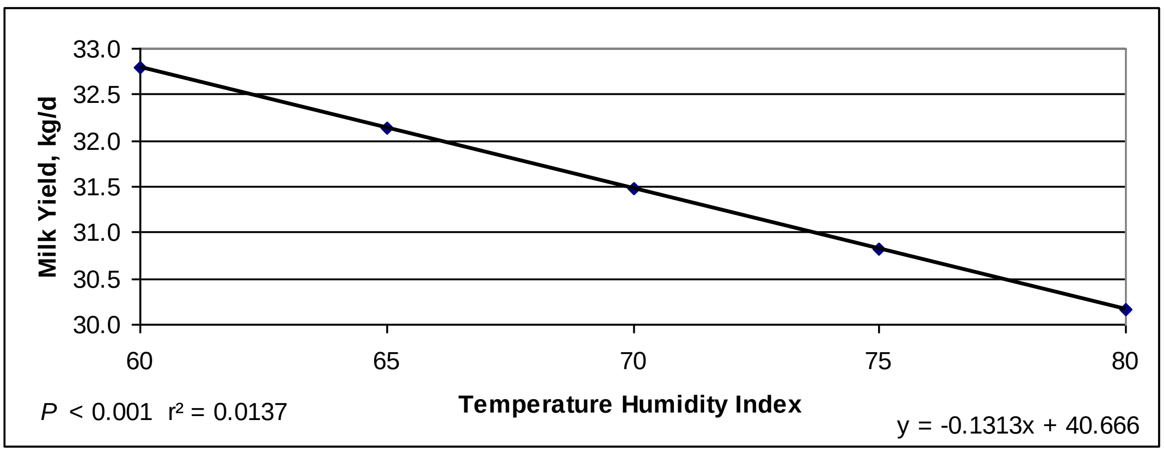

Figure 5. Effect of increasing temperature humidity index on milk yield in lactating Holstein cows.

Evaluation of data on minimum THI indicates that milk yield losses become significant when minimum THI on any given day is 65 or greater. Average losses in milk yield per day were 2.2 kg per day between a minimum THI of 65 and 73. Thus suggests that cooling of dairy cows should be initiated anytime minimum THI is 65 or above or when average THI is 68.

Table 1. Effect of minimum temperature humidity index (THI) on milk yield in lactating Holstein Cows producing greater than

35 Kg milk per day

Min THI	Slope	P-value
49	-1.01	0.26
50	0.55	0.72
51	0.21	0.52
55	-0.28	0.76
63	-0.09	0.86
64	-0.04	0.91
65	-2.63	0.0007
66	-2.04	<0.0001
70	-3.250	0.006
73	-1.08	0.015

We also investigated the time interval required at an average THI of 68 before milk yield losses became significant. This data indicated that milk yield losses became significant after 17 hours of exposure to an average THI of 68 and equated to a 2.2 kg per day loss in milk yield. Thus, our data indicates that for dairy cows producing more than 35 kg/day need additional cooling when minimum THI is 65 or greater or when average THI is 68 for more than 17 hours per day.

Discussion

Although current cooling standards utilize a THI thresh hold of 72 before initiation of cooling, our research indicates that adverse affects can be shown as early as a THI of 68. During this study we found that physiological parameters and milk yields were affected at THI values well below 72. When analyzing the data it was observed that between a THI of 64 and 72 there were large reduction in milk yields therefore chose to analyze hours above a given THI between 65 and 72 to get a more precise estimate of the threshold and subsequently arrived at a threshold of 68. When researchers analyzed data of on farm studies they have also concluded that at an average THI of 68 milk production begins to decline however, based on entire analysis of the data they still summarize that a THI of ≥ 72 is when adverse affects are seen (Ravagnolo et al., 2000). Our results indicate that a daily THI equal to 68 results in a milk loss of 2.2 kg/day for each 24 hours. Another study reported milk yield decreases by 0.2 kg per day per unit of THI as THI increased above 72 (Ravagnolo et al., 2000). In the current study milk yield decreases averaging 2.2 kg were observed when animals experienced a minimum THI of 65 or greater (P <

0.05). Johnson et al., (1963) summarized that DMI and milk yield were shown to decrease significantly when maximum THI reached 77, this was later re-assessed and values of 64, 72, and 76 for minimum, average, and maximum THI were given respectively (Igono et al., 1992).

The black globe humidity index may perhaps be a more ideal measurement of heat stress due to the fact that solar radiation is incorporated. When calculating the black globe humidity index from these studies, only four out of the eight studies actually recorded the appropriate values in order to produce the BGHI. Therefore, small numbers of observations are attributed to the lower values and correlations observed were very small. Thus, we did not produce evidence that BGHI was superior to THI for estimating the threshold temperatures for milk yield loss.

The next question is a practical one. What is the cost return to the producer for cooling beginning at an average THI of 68 versus 72? If we use an example employing 100 dairy cows which are being cooled by a Korral Kool cooler we should expect a milk yield gain of 2.2 kg of milk per day beginning cooling at 68 versus 72. For 100 dairy cows, that would equate to a milk yield gain of 4.84 CWT's. Using a milk price of $17.00 and a feed price of $14.00 the income above feed costs would be $14.52. The cost of using the coolers is shown in Table 2 from Burgos et al. 2007. Using a variable cost of $0.14 per cwt of milk produced and assuming each cooler would cool 10 cows the total cooler variable cost would be $6.8 producing an income of $7.09 per 100 cows or $0.071 per cow per day. In a herd of 3000 lactating dairy cows the potential income would equate to $213 per day or $1491 per week. This does not take into account any beneficial effects on reproductive performance in these cows.

However, the cost of cooling could be reduced dramatically by using geothermal conductive cooling of cows. Bastian and co-workers 2003 demonstrated that waterbeds filled with chilled water offered an alternative cooling method for dairy cows. However, there was considerable condensation on the surface of the cooled waterbed which would represent a mastitis risk to dairy cows. Recently collaborative work by Agriaire Industries and the University of Arizona has demonstrated that heat exchangers could be buried 12 inches below the surface of a freestall bed and still provide significant conductive cooling to dairy cows. Geothermal cooling would represent significant cost reduction in reducing heat stress on dairy cows and offers the additional opportunity of using the same approach to warm cows during cold winter months in northern dairy locations. Field testing of this concept is currently underway.

Table 2. Summary of investment and operating costs KK system.[1]

Variable	
Cooling System Investment, $[2]	118,067.51
Cooling System Investment, $/cow	472.00
Electrical Usage, KWh/d	723
Electrical Cost, $/d	32.33
Electrical Cost, $/cow/d	0.13
Water Usage, L/d	305
Water Cost, $/d	4.03
Water Cost, $/cow/d	0.016
Variable Cost, $/d[3]	36.36
Variable Cost, $/cow/d	0.15
Variable Cost, $/cwt/d	0.14

[1]Adapted from Burgos et al. 2007. Daily computations were divided by 119 days and per cow computation were divided by 250,
[2]Seventeen 0.72m ADS-ST fans and twenty 1.2m KK coolers (curtains included),
[3]Water ($0.01/liter) and electrical (0.0446/KWh) rates were calculated from Stotz Dairy, Buckeye, AZ.

Conclusion

Re-evaluation of the temperature humidity index provides the industry with solutions for tomorrow. Through this study it proved to be underestimated for current high producing dairy cows. Results show that THI beginning at 68 affect dairy cows adversely during heat stress. Therefore, cooling methods on commercial dairy farms should be implemented earlier to prevent these effects. Parameters indicative of heat stress were also shown to be correlated with THI and therefore are measurements that can be obtained to evaluate the degree of heat stress in the animal. Further research should be conducted to evaluate the relationship between BGHI and physiological parameters as with the addition of solar radiation effects perhaps the correlations would be greater; especially after arithmetic means demonstrate strong correlations between BGHI or THI to skin surface temperature and respiration rate.

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Using Genomics on the Farm

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Introduction

In the past three years, tens of thousands of North American dairy cattle have been genotyped using the Illumina BovineSNP50 BeadChip, and alternative high-density and low-density genotyping chips have recently become available. These technologies became possible due to sequencing of the bovine genome and were developed via collaboration between Illumina Inc., the USDA Agricultural Research Service, the National Association of Animal Breeders, and other commercial and academic partners. A key breakthrough is the ability to carry out thousands of DNA marker tests simultaneously, for a cost of less than ½ ¢ per marker. Single nucleotide polymorphism (SNP) markers represent base changes (A, T, C, or G) within the DNA sequence of a cow or bull – a sequence that consists of approximately 3 billion base pairs distributed over 30 pairs of chromosomes. These SNP markers can be genotyped in an efficient and automated manner, in contrast to the labor-intensive genotyping methods that were used previously. Another key breakthrough is the finding that, once a large number of genetic markers become available for an individual animal, it is possible to estimate that animal's breeding value based on associations between marker genotypes and milk yield, somatic cell score, productive life, daughter pregnancy rate, and other key traits that were observed in other animals of the same breed. The most important animals in this process are the dairy bulls represented in the Cooperative Dairy DNA Repository, which was formed more than 15 years ago, when ABS Global, Accelerated Genetics, Alta Genetics, Genex Cooperative, Select Sires, Semex, and Taurus Service began storing semen samples from young bulls entering their progeny testing programs for the purpose of genetic research.

Validation of Genomic Predictions by USDA

In a widely cited study by scientists at the USDA-ARS Beltsville Agricultural Research Center, a total of 5,369 Holstein bulls and cows that were born from 1952 to 1999 were genotyped with the Bovine SNP50 BeadChip (VanRaden et al., 2009; Cole et al, 2009). Genotypes and phenotypes of these animals were used to estimate the effects of 38,416 SNP markers on production, type, longevity, udder health, and calving ability. Next, the estimated SNP effects were used to compute the genomic predicted transmitting abilities (PTAs) of 2,035 young Holstein bulls born from 2000 to 2003 that had no progeny of their own. Finally, the 2009 PTAs of bulls in the latter group, which were based on information from their progeny, were compared with their traditional parent averages and the genomic PTAs computed from 2004 data. The same process was repeated in Jerseys (using 1,361 older bulls and cows for prediction and 388 young bulls for validation) and Brown Swiss (using 512 older bulls and cows for prediction and 150 young bulls for validation). Results in Table 1 show the increase in reliability due to genomic information, as compared with the reliability from pedigree information only.

Table 1. Reliability changes due to the inclusion of genomic data in national genetic evaluations in the validation study of VanRaden et al. (2009).

Trait	Increase in Reliability due to Genomics		
	Holstein	Jersey	Brown Swiss
Lifetime Net Merit	+24%	+8%	+9%
Milk Yield	+26%	+6%	+17%
Fat Yield	+32%	+11%	+10%
Protein Yield	+24%	+2%	+14%
Fat Percentage	+50%	+36%	+8%
Protein Percentage	+38%	+29%	+10%
Productive Life	+32%	+7%	+12%
Somatic Cell Score	+23%	+3%	+17%
Daughter Pregnancy Rate	+28%	+7%	+18%
Final Classification Score	+20%	+2%	+5%
Udder Depth	+37%	+20%	+8%
Foot Angle	+25%	+11%	-1%

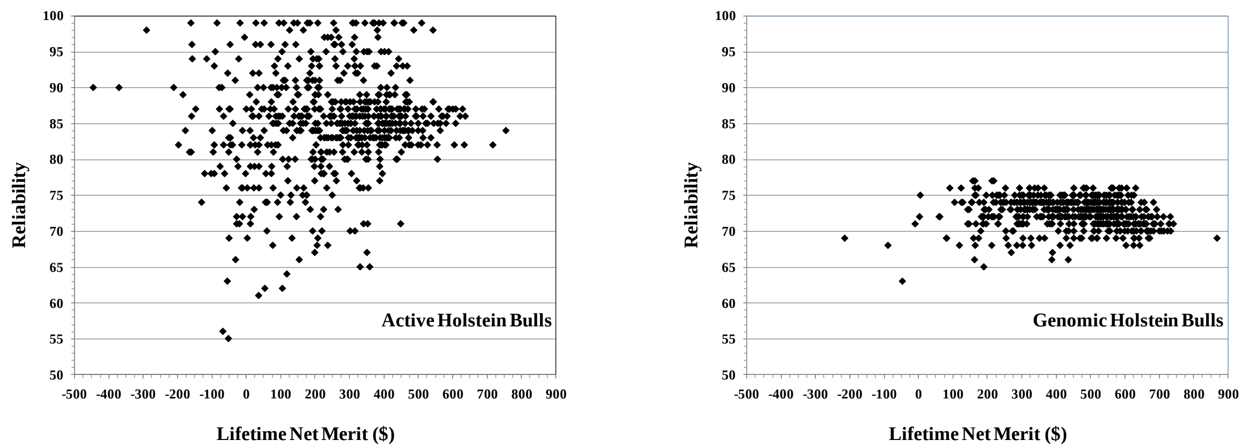
As shown in Table 1, gains in reliability from genomic information were significant for almost all traits and breeds, ranging from -1% for foot angle in Brown Swiss to +50% for fat percentage in Holsteins. Gains were largest for traits for which single genes with large effects had already been discovered, such as fat percentage (DGAT1 gene on chromosome 14; Grisart et al., 2004) and protein percentage (ABCG2 gene on chromosome 6; Cohen-Zinder et al., 2005). For each trait, we can combine a young animal's pedigree with information regarding its SNP genotypes to obtain a genomic PTA of much greater accuracy. For a heifer calf, reliability of the genomic PTA is greater than the information we could obtain by measuring several lactation records on the animal and its daughters. For a young cow, genomic information can be combined with her lactation records to obtain a genomic PTA that is significantly more informative than her traditional PTA. For a bull calf, reliability of the genomic PTA is equivalent to what we could obtain by measuring performance on 25 or 30 of his progeny test daughters. Improvements in accuracy can even be obtained for bulls that have completed progeny testing, although the gain in information for a bull that already has performance data from 80 to 100 daughters is much smaller. Gains in reliability for Jerseys and Brown Swiss have not been as great as for Holsteins. However, this difference is largely due to the fact that fewer progeny tested bulls have been genotyped, and results for these breeds will be improved by combining information from North American sires with that of key populations internationally.

Impact on Sire Selection Decisions

The artificial insemination (AI) studs are in the midst of tremendous change because of this technology. Virtually every young bull entering an AI company today is DNA tested on the farm and selected from a group of 5 to 10 young bulls with similar pedigrees. Therefore, we know that each of these bulls has received a favorable sample of genes from its parents. The genomic PTA for a young bull typically has reliability in the range of 60 to 75%, as opposed to only 30 to 40% for its traditional parent average. North American AI companies are now marketing semen from hundreds of young bulls that have genomic PTAs but no daughters of their own. These young bulls have replaced older, proven bulls that were at the low end of the sire line-up, and many of these bulls are being used for contract matings. Because buyers now have the ability to distinguish between sets of full siblings that have the same parent average, the premium for securing first choice from a flush is much greater, and buyers at consignment sales and dispersals now pay a premium for young animals with favorable genotypes.

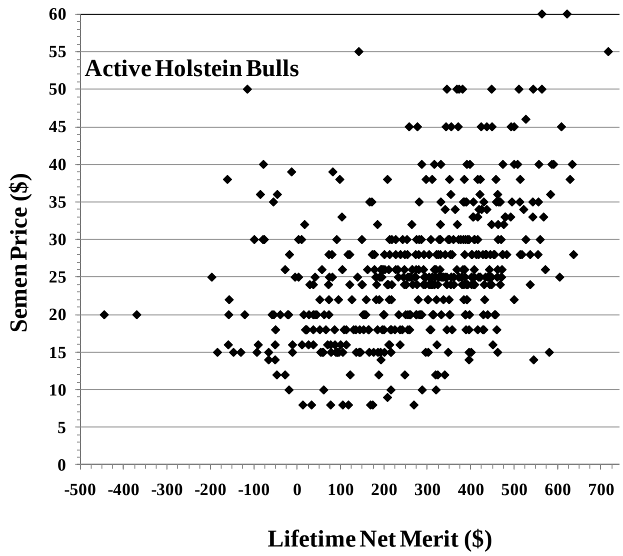
What about commercial producers? While these producers may not yet be genotyping young females on their farms, they are seeing semen on the market from hundreds of young bulls with genomic breeding values and no progeny. These bulls have attractive pedigrees, because they're younger than the current proven bulls, but their reliabilities are lower, as shown in Figure 1.

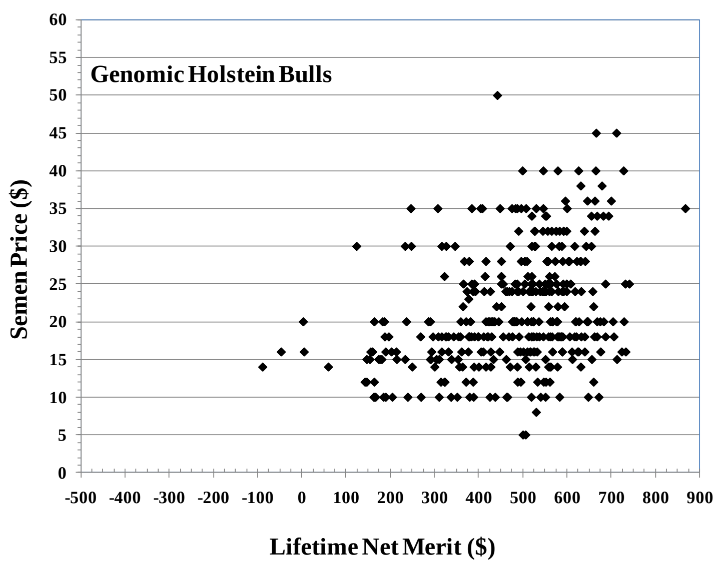
Figure 1. January 2011 PTA for Lifetime Net Merit versus reliability for Holstein bulls with active status based on progeny testing (left) and genomic status based on DNA testing (right).



Because reliabilities of young, genome-tested bulls are lower, producers should avoid heavy use of one or two top bulls and should spread out their risk by using a larger group of bulls. Avoiding these bulls entirely is a bad idea, even for risk-averse producers, because their genetic merit is high relative to their semen price, as shown in Figure 2.

Figure 2. January 2011 PTA for Lifetime Net Merit versus semen price for Holstein bulls with active status based on progeny testing (left) and genomic status based on DNA testing (right).





Development of Inexpensive, Low-Density Genotyping Platforms

Because the cost of the BovineSNP50 BeadChip has largely limited its application to males and elite females, attention has focused on development of inexpensive alternatives that can capture the majority of the gain for a fraction of the price. Initially, we attempted to select the most important SNPs based on magnitude of their estimated effects (Weigel et al., 2009). Using August 2003 progeny test PTAs for Lifetime Net Merit of 3,305 Holstein bulls born from 1952 to 1998, we evaluated the ability of various subsets of SNPs to predict April 2008 progeny test PTAs for 1,398 Holstein bulls born from 1999 to 2002. Subsets were created by sorting the original 32,518 SNPs by the absolute values of their estimated effects and choosing the top 300, 500, 750, 1,000, 1,250, 1,500, or 2,000 SNPs. For reference purposes, subsets of 300, 500, 750, 1,000, 1,250, 1,500, or 2,000 equally spaced SNPs were also created. Correlations between these genomic predictions and corresponding PTAs from progeny testing are shown below, in Table 2.

Table 2. Correlations between progeny test PTAs for Lifetime Net Merit and genomic predictions from various subsets of SNPs in a population of 1,398 Holstein bulls, where SNPs were chosen based on spacing or size of estimated effect (Weigel et al., 2009).

Number of SNP Markers Genotyped	SNPs with Largest Effects	Equally Spaced SNPs
300	0.428	0.253
500	0.485	0.333
750	0.519	0.435
1,000	0.537	0.422
1,250	0.554	0.477
1,500	0.559	0.518
2,000	0.567	0.539
32,518	0.612	

The reference model with 32,518 SNPs provided a correlation of 0.612, whereas correlations between progeny test PTAs and genomic predictions derived from 300 to 2,000 selected SNPs ranged from 0.428 to 0.567. Correlations for sets of selected SNPs were consistently greater than for sets of equally spaced SNPs. In a related study, Vazquez et al. (2010) noted that low-density chips containing SNPs with the largest estimated effects for Lifetime Net Merit would provide greater predictive ability for production traits than for fitness traits. Furthermore, low-density assays composed of selected SNPs would be breed-specific and trait-specific. For these reasons, we determined that it would be more efficient to genotype a slightly larger set of equally spaced SNPs that would facilitate imputation of missing high-density genotypes, as suggested by Habier et al. (2009), rather than focus on a few hundred selected SNPs with large effects.

To determine if imputation of high-density (i.e., BovineSNP50 BeadChip) genotypes from subsets of a few hundred or a few thousand equally spaced SNPs was feasible, we used a population of 2,656 Jersey bulls and 490 Jersey cows and heifers that had been genotyped for 43,385 SNPs. This population was divided into a reference panel, consisting of 2,542 animals born from 1953 to 2006, and a study sample, consisting of 604 animals born from 2007 to 2009. For animals in the study sample, genotypes were "masked" (i.e., hidden) for a randomly chosen 20, 60, 80, 90, 95, 98, or 99% of SNP markers. Three chromosomes were considered (BTA1, BTA15, and BTA28), but results are shown only for BTA15, which contained 1,377 SNP markers. After masking 20 to 99% of the SNPs, the number of SNPs available for imputing missing genotypes ranged from 14 to 1,102. Many algorithms have been developed for constructing haplotypes and imputing genotypes in humans, and in this study we used the method of Scheet and Stephens (2006), which was implemented via fastPHASE 1.2 software, and the method of Howie et al. (2009), which was implemented via IMPUTE 2.0 software. The proportion of masked SNP genotypes that were imputed correctly is shown in Table 3.

Table 3. Proportion of SNP genotypes that were imputed in a sample of 604 Jersey cattle, using a reference panel of 2,542 Jersey cattle, according to method of imputation and percentage of SNPs that were actually genotyped (Weigel et al., 2010b).

Percentage of SNP Markers Genotyped	Method 1 (fastPHASE 1.2)	Method 2 (IMPUTE 2.0)
1%	0.701	0.730
2%	0.726	0.780
5%	0.780	0.890
10%	0.874	0.924
20%	0.951	0.932
40%	0.984	0.935
80%	0.992	0.930

The proportion imputed correctly ranged from 0.66 to 0.73 when only 1% or 2% of genotypes were unmasked in the study sample, versus 0.75 to 0.89 when 5 to 10% of genotypes were unmasked, as would be the case for a medium-density panel with 2,000 to 4,000 SNPs. This suggested that a low-density chip with approximately 3,000 equally spaced SNPs would be adequate for imputing high-density genotypes from reference animals of the same breed.

Next, we sought to determine the impact of imputing (more specifically, the impact of imputing errors) on the accuracy of genomic predictions for economically important traits in dairy cattle. Genotypes of 1,762 Jersey sires, with 42,552 SNP markers apiece, were used in conjunction with progeny test PTAs for milk yield, protein percentage, and daughter pregnancy rate. A group of 1,446 sires with ≥ 10 milking daughters in May 2006 were used as the reference panel, and the accuracy of genomic PTAs based on imputed genotypes was evaluated using 316 sires with 0 milking daughters in May 2006 and ≥ 10 milking daughters in April 2009. Next, we created equally spaced subsets in which all but 366, 741, 1,468, or 2,942 of the original SNP genotypes were masked. Masked genotypes were imputed using the method of Howie et al. (2009), implemented via IMPUTE 2.0 software. After imputation, genomic predictions for milk yield, protein percentage, and daughter pregnancy rate were computed, and these were compared with the traditional PTAs of these bulls resulting from progeny testing. Results are shown in Table 4.

Table 4. Correlations between progeny test PTAs for milk yield, protein percentage, and daughter pregnancy rate and genomic predictions for these traits based on 366, 741, 1,468, 2,942, or 42,552 SNP markers, with imputation of missing genotypes, in a population of 316 Jersey bulls (Weigel et al., 2010a).

Number of SNP Markers Genotyped	Milk Yield	Protein Percentage	Daughter Pregnancy Rate
366	0.367	0.468	0.470
741	0.525	0.546	0.572
1,468	0.649	0.676	0.619
2,942	0.673	0.740	0.642
42,552	0.673	0.770	0.674

As shown in Table 4, a low-density genotyping chip consisting of approximately 3,000 equally spaced SNPs (i.e., the so-called "3K chip") can provide genomic predictions for milk yield, protein percentage, and daughter pregnancy rate that are roughly 95% as accurate as predictions from the BovineSNP50 BeadChip, for a small fraction of the price.

Cost-Effective Strategies for Genotyping Females on Commercial Dairy Farms

To investigate whether low-density genotyping of females on commercial dairy farms would be cost effective, and to determine the conditions under which a producer could maximize the benefits of this technology, a simulation study was carried out. We created 100 dairy herds, each comprised of 1,850 animals; these included 850 replacement heifers (450 heifer calves and 400 yearling heifers) and 1,000 milking cows (350 in first lactation, 250 in second lactation, 170 in third lactation, 120 in fourth lactation, 70 in fifth lactation, and 40 in sixth lactation). Each animal's genetic potential for Lifetime Net Merit was simulated, using an average of $45 and a standard deviation of $146; these values correspond to the current mean and standard deviation for sire-identified, milk-recorded Holsteins in the US national genetic evaluation system (http://aipl.arsusda.gov/eval/summary/pctl.cfm). Genetic improvement over time was taken into account by adjusting the average PTA by $26 per year, according to age of the animal. Reliability of genetic predictions varied, according to the availability (or lack thereof) of pedigree information, performance (milk-recording) data, and low-density (3K) DNA test results for a given animal, as shown below.

Table 5. Assumed reliability values for predictions of Lifetime Net Merit based on pedigree, performance, and low-density genotyping data ("Traditional" = no DNA testing, "Genomic" = DNA testing with 3K chip) for simulated animals in each age group.

Age Group	Ancestry Unknown		Sire-Identified		Full Pedigree	
	Traditional	Genomic	Traditional	Genomic	Traditional	Genomic
Heifer calves	0.00	0.50	0.20	0.57	0.34	0.67
Yearling Heifers	0.00	0.52	0.21	0.59	0.35	0.68
1st Lactation Cows	0.18	0.56	0.40	0.63	0.52	0.71
2nd Lactation Cows	0.22	0.59	0.44	0.66	0.55	0.73
3rd Lactation Cows	0.25	0.62	0.46	0.68	0.57	0.74
4th Lactation Cows	0.27	0.64	0.48	0.69	0.58	0.74
5th Lactation Cows	0.29	0.65	0.49	0.70	0.59	0.75
6th Lactation Cows	0.30	0.65	0.50	0.70	0.60	0.75

After generating true and estimated breeding values for these animals, where accuracy of the estimated breeding values varied according to age, extent of known ancestry, and presence or absence of genomic testing information, we carried out selection and culling decisions within in each herd. Producers selected the top 10, 20, 30, . . ., 90% of animals within each age group based on the aforementioned estimates of genetic merit, and the remaining animals were culled. Next, the average breeding value for Lifetime Net Merit of animals that were selected using pedigree plus genomic information was compared with that of animals that were selected from the same age group using pedigree information only. The average gain in genetic merit due to DNA testing was then compared with the cost of the test, which was assumed to be $35 per animal. This cost was prorated over the number of animals that were selected from a given age group, such that the break-even gain in breeding value was $350, 175, 117, 88, 70, 58, 50, 44, or 39 when the top 10, 20, 30, 40, 50, 60, 70, 80, or 90% of animals were selected, respectively. The fraction of genetic merit that was passed along to future generations was also considered, assuming that each female generated her own replacement, and that one-half, one-quarter, and one-eighth of her genetic superiority or inferiority would be passed along to her daughter, granddaughter, and great-granddaughter, respectively. When future generations were considered with a discount rate of 5% per year, the net present value of the break-even gain in breeding value was $206, 103, 69, 52, 41, 34, 29, 26, or 23, respectively, depending on the proportion of animals selected. Lastly, strategies were considered in which the producers pre-sorted animals based on pedigree information (if available) and then DNA tested the top 50% or bottom 50% of animals in each age group, rather than DNA testing the entire herd. Results are shown below.

Table 6. Average Lifetime Net Merit breeding values ($) for **heifer calves** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	245	**612**	**531**	389	474	628	630	503	550	664	667	563
Top 20	247	**537**	**443**	**361**	429	554	**540**	459	485	580	**577**	502
Top 30	245	**487**	**382**	**346**	395	501	**475**	427	444	523	**511**	462
Top 40	245	**445**	**344**	**334**	370	**458**	**419**	402	410	477	450	432
Top 50	246	**410**	**320**	**322**	350	**422**	381	382	381	436	404	405
Top 60	246	**378**	**302**	**312**	329	387	351	**364**	354	399	368	382
Top 70	246	**347**	**287**	**306**	311	355	324	**346**	329	364	338	**359**
Top 80	246	**318**	**274**	**296**	292	323	299	**320**	305	329	309	**329**
Top 90	246	**286**	261	**278**	272	289	275	289	279	293	280	293

As shown in Table 6, genomic testing of all heifer calves seems to be cost-effective if pedigree information is unavailable. This could be the case if replacements were purchased (or were about to be purchased) from a source that could not provide accompanying pedigree information, or if recording of ancestry had lapsed within a given herd. As expected, the value of genomic testing is lower in herds that routinely record sire identification, and lower yet in herds with several generations of pedigree data for every animal. Nonetheless, genomic testing of heifer calves may be cost-effective in such herds, particularly if animals are pre-sorted prior to testing.

Table 7. Average Lifetime Net Merit breeding values ($) for **yearling heifers** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	194	**569**	**489**	336	433	592	590	461	505	621	626	516
Top 20	193	**491**	**399**	**309**	385	510	**501**	413	439	534	**532**	455
Top 30	194	**440**	**334**	**293**	352	458	**435**	382	395	477	**464**	414
Top 40	197	**400**	**297**	**282**	328	412	**376**	357	362	429	403	383
Top 50	197	**365**	**272**	**273**	305	375	335	335	334	389	357	357
Top 60	196	**332**	**254**	**265**	283	340	303	**316**	307	351	321	335
Top 70	197	**301**	**239**	**256**	263	308	274	**298**	283	315	289	**311**
Top 80	197	**270**	**225**	**247**	242	274	250	**272**	257	280	260	**280**
Top 90	197	**237**	211	**229**	222	240	225	239	230	243	231	243

As shown in Table 7, testing yearling heifers can also be cost-effective, particularly if pedigree information is lacking, or if testing is targeted toward a group of animals that are "at risk" for selection or culling based on pedigree data. For example, a buyer who seeks to purchase the top 20% of heifers from a herd will find little value in testing animals that rank in the bottom half of the herd based on pedigree data, because few of these animals will rank among the top 20% after testing. Conversely, a producer who has used gender-selected semen and seeks to cull the bottom 30% of heifers based on genomic testing will find little value in testing animals that rank in the top half of the herd based on pedigree data, because most of them will be kept anyway.

Table 8. Average Lifetime Net Merit breeding values ($) for **first lactation cows** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	359	524	516	393	465	545	556	470	508	571	577	505
Top 20	317	447	**428**	353	403	466	469	411	435	484	489	437
Top 30	286	393	**366**	320	355	409	407	368	384	426	428	390
Top 40	262	**352**	**312**	296	317	365	349	333	343	379	369	352
Top 50	239	**315**	273	**275**	287	326	303	304	309	337	321	321
Top 60	220	**281**	242	**256**	259	290	267	279	277	299	282	293
Top 70	202	249	216	**237**	233	256	237	256	246	263	247	264
Top 80	184	217	193	**214**	206	221	208	224	215	227	215	229
Top 90	166	184	169	183	178	186	178	187	182	189	182	190

Table 9. Average Lifetime Net Merit breeding values ($) for **second lactation cows** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	344	493	492	364	433	514	523	437	484	537	544	481
Top 20	293	413	**403**	320	366	432	437	372	400	446	453	403
Top 30	257	357	**336**	287	321	373	371	328	346	385	388	349
Top 40	228	314	**277**	259	283	325	312	294	303	336	329	310
Top 50	203	**274**	235	236	248	284	264	265	266	293	278	278
Top 60	181	238	202	**215**	218	246	225	240	233	254	238	249
Top 70	162	205	173	**195**	189	211	193	211	200	216	202	218
Top 80	141	171	147	**168**	161	175	162	177	168	180	168	181
Top 90	119	136	122	135	130	138	130	139	134	141	134	142

Table 10. Average Lifetime Net Merit breeding values ($) for **third lactation cows** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	288	438	438	308	382	459	467	385	422	474	481	421
Top 20	242	362	**352**	264	317	375	380	320	347	389	396	345
Top 30	207	303	**286**	231	270	316	319	275	296	330	333	297
Top 40	181	259	**226**	206	233	272	261	242	253	281	273	260
Top 50	155	221	184	183	199	230	212	213	214	238	224	226
Top 60	131	185	152	**164**	168	193	173	186	180	200	185	196
Top 70	112	152	123	**143**	137	157	140	158	148	163	149	164
Top 80	91	119	97	**116**	107	122	108	124	115	126	115	127
Top 90	67	83	69	83	76	85	77	86	81	87	81	87

As shown in Tables 8, 9, and 10, the value of testing young cows depends heavily on the availability (or lack thereof) of pedigree data. One or two lactation records on a young cow cannot provide an accurate assessment of her genetic value if her ancestry is unknown, and in this case there is an opportunity to add significant accuracy through genomic testing. On the other hand, the amount of additional information provided by genomic testing is relatively small for a pedigree-recorded cow that has lactation records of her own, and in this situation a producer should pre-sort the herd (perhaps more precisely than in this study, such as into thirds or quartiles) and test only those animals that are “on the bubble” with respect to a selection or culling decision. Although the value of genomic testing is greater if pedigree information is lacking, we do not advocate the use of genomic testing as a substitute for recording of ancestry. In fact, one cannot pre-sort the herd with any degree of accuracy without knowledge of each animal's sire, and preferably its maternal grandsire as well. Therefore, producers who keep accurate records of ancestry can more effectively target animals for DNA testing, and in this manner they can reap greater benefits from the technology.

Table 11. Average Lifetime Net Merit breeding values ($) for **fourth lactation cows** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	246	387	391	267	334	413	421	336	371	427	433	371
Top 20	197	311	**305**	215	266	324	332	267	293	336	341	293
Top 30	160	256	**236**	185	220	267	267	224	243	276	279	245
Top 40	130	211	**176**	158	182	220	211	189	199	225	220	205
Top 50	108	171	135	135	149	179	163	160	162	184	170	171
Top 60	84	134	100	**113**	118	142	122	135	126	146	131	143
Top 70	61	100	71	**93**	86	105	88	107	95	110	97	111
Top 80	38	66	44	**64**	56	70	57	71	63	73	62	74
Top 90	15	31	18	31	25	32	25	34	28	34	28	35

Table 12. Average Lifetime Net Merit breeding values ($) for **fifth lactation cows** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	208	334	333	226	288	350	359	289	318	371	374	318
Top 20	147	253	**246**	170	220	267	274	220	241	282	288	240
Top 30	108	202	**184**	135	170	212	213	175	185	221	226	188
Top 40	80	159	**127**	107	129	167	155	140	145	175	170	148
Top 50	56	121	80	83	96	128	107	110	110	133	121	118
Top 60	29	85	48	**62**	65	88	70	84	77	95	81	91
Top 70	8	51	20	**41**	35	54	37	54	44	59	45	60
Top 80	-12	16	-7	**13**	6	18	7	20	11	22	11	24
Top 90	-35	-20	-33	-20	-25	-20	-26	-19	-23	-17	-24	-16

Table 13. Average Lifetime Net Merit breeding values ($) for **sixth lactation cows** selected based on genetic predictions from pedigree, performance, and low-density genotyping data (Trad = no DNA testing, All = DNA testing whole herd with 3K chip, Top = DNA testing top half of herd, Bot = DNA testing bottom half of herd) for simulated herds in this study. Cases in which testing costs are offset by gains in genetic merit in the current generation (underlined and bold) or in current plus future generations (underlined) are highlighted.

%	Unknown Ancestry				Sire-Identified				Full Pedigree			
Selected	Trad	All	Top	Bot	Trad	All	Top	Bot	Trad	All	Top	Bot
Top 10	161	288	<u>285</u>	173	223	299	304	226	261	322	330	263
Top 20	109	205	<u>195</u>	134	158	218	<u>221</u>	158	184	231	235	185
Top 30	63	<u>150</u>	<u>**130**</u>	91	117	157	<u>158</u>	119	135	165	168	135
Top 40	37	<u>104</u>	<u>75</u>	57	76	109	101	86	94	117	113	100
Top 50	7	<u>66</u>	<u>30</u>	<u>36</u>	40	71	57	54	55	78	66	65
Top 60	-17	<u>31</u>	-3	<u>**13**</u>	11	35	17	<u>28</u>	24	41	26	37
Top 70	-41	<u>-3</u>	-32	<u>**-9**</u>	-19	0	-16	<u>-1</u>	-9	5	-7	<u>6</u>
Top 80	-63	<u>-37</u>	-58	<u>**-39**</u>	-49	-34	-47	<u>-34</u>	-40	-31	-40	-30
Top 90	-88	-73	-86	<u>-73</u>	-80	-71	-79	-71	-75	-70	-75	-69

As shown in Tables 11, 12, and 13, the value of testing older cows within a herd is less than that of testing younger cows, and substantially less than that of testing yearling heifers and calves. Many animals have already culled themselves from the herd prior to fourth or fifth lactation, through poor performance, impaired health, or infertility, and therefore additional opportunities for culling are limited. Furthermore, using older animals to produce additional replacements, such as through embryo transfer or the use of gender-selected semen, will not be particularly beneficial, because these animals have fallen victim to genetic trend and are not genetically competitive with their daughters' and granddaughters' generations.

Conclusions

In summary, it is clear that genomic information can enhance the accuracy of genetic evaluations for bulls, cows, heifers, and calves. Breeding companies are now marketing hundreds of young bulls based solely on genomic information. These bulls have higher average genetic merit than older bulls that have completed progeny testing, but reliability values are lower. Using a single genome-tested bull very heavily is a significant risk, but ignoring these young bulls as a group has a heavy opportunity cost. To date, price has largely limited genotyping to males and elite females. However, the recent development of low-density assays that facilitate imputation of high-density genotypes from a reference population of AI sires allows users to capture the majority of benefits for a fraction of the price. This may lead to widespread adoption of genomic testing of cows, heifers, and calves on commercial farms, particularly in herds that lack pedigree information or herds that can effectively pre-sort animals based on pedigree data. Potential applications include selection among heifer calves or springing heifers on farms that have used gender-selected semen, screening of heifers or cows prior to purchase by herds that are expanding, evaluation of potentially elite heifers and cows that could provide added revenue through sale of breeding stock, and eventually value-added services such as genome-enhanced mate selection and genome-guided management protocols.

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Notes:

Taking the Long View: Treat Them Nice As Babies and They Will Be Better Adults

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Introduction

Discussing the topic of calves and calf management over the last 40 years traditionally involved dry cow management, colostrum, scours, rumen development and early weaning. In the last ten years, the concept of "intensified feeding or accelerated growth" has become a focus of discussion and during that time the concept has been applied to research programs and on-farm in various ways. Much of this discussion involves differences in perspectives about how to best manage the nutrition and nutrient intake of the pre-weaned calf. There are teleological arguments for providing a greater supply of nutrients from milk or milk replacer, e.g. what would the dam provide, and there are also arguments for improving the welfare status of the animals by following the same concept (Jasper and Weary, 2002; de Paula Vieira et al., 2008). At the 15th American Dairy Science Association Discover Conference on Calves (Roanoke, VA) the overwhelming consensus of the participants was that we need to feed calves for a specific rate of daily gain, much higher than the traditional industry standards, and that is significant change in industry perspective.

Requirements - Maintenance

The calf has a requirement for maintenance and once maintenance requirements are met, growth can be achieved if enough nutrients and the proper balance of nutrients are provided to the calf. The nutrient requirements of the calf have been described in the current Nutrient Requirements of Dairy Cattle 7th edition (NRC, 2001) publication. The requirements can be easily actualized and are very useful for diagnosing the impact of temperature on the maintenance requirements of the calf through the computer program that accompanies the publication.

The maintenance requirements estimated by 2001 NRC appear to be excellent and reflect our field observations for overcoming negative energy balance brought about by cold stress conditions. Example requirements are demonstrated in Table 1 based on body weight and ambient temperature. The user needs to remember that these values are the basal requirements for energy to maintain core body temperature with no growth or with no wind or wet conditions, which would exacerbate the requirements. The long-term consequences of not altering these values will be discussed throughout the paper. Our recent data suggests there is a significant lifetime milk loss associated with not meeting these requirements appropriately.

For many years the National Animal Health Monitoring System (NAHMS) has published reports describing the morbidity and mortality of calves and heifers on representative U.S. dairy farms. In a recent report, pre-weaning death loss was reported at 8% (NAHMS, 2004), whereas the previous survey reported 11% (NAHMS, 1996). In a thorough review of calf management practices, Otterby and Linn (1981) indicted mortality was approximately 11.3%, which indicates we have not made much progress over the last 25 years. Also, a previous report indicated that sickness (or the percent of calves treated) ranged between 30 and 40% on most farms.

Table 1. The amount of milk replacer or milk dry matter required to meet the maintenance requirements of calves at varying temperatures. The calculations assume 2.45 Mcal ME per lb of dry matter.

	Temperature, degrees F						
Bodyweight, lb	68	50	32	15	5	-5	-20
60	0.6	0.8	0.9	1.0	1.1	1.2	1.4
80	0.8	0.9	1.1	1.3	1.4	1.5	1.7
100	1.0	1.1	1.3	1.6	1.7	1.8	2.0
120	1.1	1.3	1.5	1.7	1.9	2.0	2.3

A study by Godden et al. (2005) replicated the mortality and morbidity values from the NAHMS survey and their data suggested the outcome was a function of the amount and type of diet fed. In their study, calves were fed either batch pasteurized whole milk at approximately 1 gallon per day, or 1 lb of 20% CP, 20% fat milk replacer reconstituted at 12.5% solids. The length of the study encompassed all of the seasons. Calves fed the whole milk had significantly less death loss and treatments (Table 2) suggesting that the difference in nutrient intake, approximately 18% greater ME intake per day from whole milk compared to the milk replacer, had a profound impact on the survival and disease resistance of the calves. The bottom line is that calves provided

Table 2. Effect of feeding calves one gallon of pasteurized whole milk or one pound of 20:20 milk replacer on morbidity and mortality (Godden et al., 2005).

	Milk replacer treatment	Pasteurized whole milk treatment
N	215	223
Morbidity, % of calves		
All months	32.1	12.1
Winter	52.4	20.4
Summer	12.7	4.4
Mortality, % of calves		
All months	11.6	2.2
Winter	21.0	2.8
Summer	2.7	1.7

more nutrients had less death loss and that the morbidity and mortality observed on this study is consistent with the NAHMS data and suggests we need to do a better job managing cold stress and other stressors in calves. This should not be confused with the notion that milk replacer is not as good as whole milk. It demonstrates that adjustments need to be made when feeding any diet if the requirements of the calf change due to the environmental temperature or stress conditions.

Calves are born with about 4% body fat, of which about 50% can be mobilized, and much of that is brown adipose tissue needed for thermogenesis. This gives the calf up to four days of fat reserves depending on the ambient conditions and once depleted, the calf has to rely on either dietary intake or body protein to generate heat and mount an immune response if nutrient intake is below maintenance requirements. This sets up a situation that encourages failure of the immune system unless additional calories from protein, carbohydrates and fat are provided. Body protein reserves are very low in neonatal calves and are not good sources of calories for maintaining body heat and mounting immune responses. An additional factor to be considered is what calves use to deposit body fat. Data from several studies demonstrate that calves cannot make fat from carbohydrate very effectively, if at all, thus any increase in adiposity must be from dietary fat intake (Tikofsky et al. 2001; Joost et al., 2007). Thus, under cold stress conditions or situations where feed intake is compromised due to illness, the only way to provide greater calories and energy reserves is through the increased intake of dietary fat. Compared to most milk replacers, this is likely why calf managers see significant increases in calf performance when whole milk is fed, especially in cold weather conditions.

Energy and Protein Requirements

Prior to and since the release of the Nutrient Requirements for Dairy Cattle (NRC, 2001), new data were being developed and are now available that help us refine those predictions (Bartlett, 2001, Diaz et al., 2001, Tikofsky et al., 2001; Bascom et al., 2007; Blome et al., 2003; Brown et al, 2005; Meyer, 2004; Mills, 2009). Table 3 summarizes the current knowledge about the requirements for growth of the calf based on the body composition data derived since the 2001 NRC was published.

These values are consistent with the current publication (NRC, 2001), but have slightly lower energy requirements per unit of gain because the original equations were based on heavier veal type calves fed higher fat diets and depositing more fat per unit of weight gain. These predictions for energy requirements are consistent with dairy replacement calves being fed diets more typical of our system. The protein requirements are higher than the NRC (2001) publication because of updated data on the efficiency of use of absorbed protein. The 2001 NRC (NRC, 2001) calculations suggested that absorbed protein was used with an efficiency of 0.80, whereas our latest calculations suggest the efficiency is closer to 0.70, thus the protein requirements are at least 10 to 12% higher than the NRC (2001) predictions and very energy dependent e.g. the more energy they consume, the greater the potential protein synthesis, and the higher the protein requirement.

Table 3. The energy and crude protein requirements of calves from birth to weaning (Van Amburgh and Drackley, 2005)

Rate of gain, lb/d	Dry matter intake, lb/d	Metabolizable energy, Mcal/d	Crude protein, g/d	Crude protein, %DM
0.45	1.2	2.4	94	18.0
0.90	1.4	2.9	150	23.4
1.32	1.7	3.5	207	26.6
1.76	2.0	4.1	253	27.5
2.20	2.4	4.8	307	28.7

These requirements reinforce the idea that what the cow would normally provide to the calf is a more appropriate combination of protein and energy required by the calf. Thus, many milk replacers are not really replacing milk because they don’t contain the same nutrient levels and they are rarely fed to equal the nutrient intake of whole milk. It further suggests that least cost milk replacer formulations should not be expected to provide much beyond maintenance energy supply and the feeding of such milk replacers at previously recommended levels might exacerbate the lack of immune system responsiveness and energy reserves needed in support of an illness event. Dietary fat levels will be dependent on the ambient temperatures. The body composition data would indicate that 15% fat is adequate when the calves are not under cold stress conditions, and that as temperatures decrease, fat needs to increase to offset the oxidation for thermogenesis. In addition, attention should be made to the inclusion of essential fatty acids in the diet of neonatal and weaned calves since it appears traditional calf diets have been deficient in essential fatty acids required for proper growth (Hill et al. 2009)

However, to further this idea that calves have “requirements” beyond those for growth and thus need enhanced nutrient intakes, data are available and emerging that suggest factors such as colostrum status and nutrient intake and growth rates up to at least 8 weeks of age have life-time effects that can be measured in the first lactation. Just like other neonates, it appears that early life events may serve as a catalyst for metabolic programming (or imprinting) generating epigenetic changes in the calves that will remain with them for their entire life, therefore “compensatory mechanisms” don’t really exist for this stage of development.

It also suggests that we need to alter how we view this stage of development especially as it relates to future productivity. The concept and data to support it are still being developed, but there appears to be a positive relationship with early life nutrient intake.

Early Development and Productivity:

Colostrum Status

To maximize calf survival and growth, plasma immunoglobulin (Ig) status and thus colostrum management is of utmost importance. This is obviously not a new concept and there are hundreds of papers describing the management and biology surrounding colostrum quality, yield and Ig absorption by the calf although some recent research in colostrum handling and management suggest we can still make improvements (Godden, 2008). A proper discussion of colostrum includes factors other than Ig and should include the myriad of other factors in colostrum that have shown to be beneficial to the calf. Factors like insulin, insulin l-like growth factor-I (IGF-I), maternal leukocytes, oligosaccharides, other growth factors and many other useful compounds are found in colostrum and are most likely very important in the response of the calf to ingestion of the secretion. Minimizing the bacterial load of colostrum is probably one of the major management concerns with many farms and is usually a factor not considered or analyzed for. Data demonstrate that the presence of bacteria in the gut prior to colostrum ingestion or in the colostrum reduces the uptake of Ig, thus increasing the incidence of failure of passive transfer (James et al. 1981, Godden, 2008). Thus excellent udder health and proper post-harvest colostrum handling is as important, or even more important, than vaccination programs to prevent diseases.

Of interest for this paper are the studies that have described decreased growth rate and increased morbidity of calves with low serum immunoglobulin status (Nocek, et al., 1984; Robison et al.,

1988) and some have even indicated that milk yield during first lactation can be affected (DeNise et al., 1989). Robison et al. (1988) indicated that calves with higher Ig status were able to inactivate pathogens prior to mounting a full immune response which allows them to maintain energy and nutrient utilization for growth, whereas calves with low Ig status must mount an immune response which causes nutrients to be diverted to defense mechanisms. How severe is this difference or for how long does it persist? The data of DeNise et al., (1989) demonstrated that for each unit of serum IgG concentration, measured at 24 to 48 hrs after colostrum feeding, above 12 mg/mL, there was an 18.7 pounds increase in mature equivalent milk. The implication is that calves with lower IgG concentration in serum were more susceptible to immune challenges which impacted long term performance. As with all longitudinal and epidemiological studies there are inconsistencies. Donovan et al. (1998) found indirect effects of colostrum status on growth and performance of calves, but concluded it was caused by increased morbidity and not a direct effect. The calculations of growth and feed efficiency should in many cases include the calves that were lost to study, thus providing a more applicable value.

A more recent study suggested that impact of serum Ig concentrations was not nearly as great as the DeNise et al. (1998) study, but did affect milk yield and survival through the second lactation (Faber et al., 2005). Brown Swiss calves were provided either 2 or 4 L of colostrum just after birth with some additional meals over a 4 day period. The calves were monitored after calving for two lactations. At the end of the second lactation three major observations were made, first there was a 30% increase in pre-pubertal growth rates based on colostrum feeding level, under identical feeding conditions. Second, there was a 16% increase in survival to the end of the second lactation of calves fed the four liters of colostrum. Finally, the surviving calves fed the 4 L of colostrum produced 2,263 lbs more milk by the end of the second lactation. Although somewhat subtle, these differences suggest that early life colostrum status was important for long-term productivity. If part of the mechanism is related to maintaining nutrient partitioning towards growth via high immunoglobulin status, then the concept of nutrient status should also demonstrate responses beyond the Ig status of the calf. This difference in growth rate has been observed in studies comparing colostrum with colostrum replacement. Calves fed colostrum replacer had nearly identical plasma IgG concentrations, but grew at a rate 30% less than the colostrum fed calves (Mowrey, 2001). This would indicate there are components of colostrum important for growth and feed efficiency independent of the Ig content and understanding which factors are important is an active area of research.

Nutrient Status and Long-Term Productivity

There are several studies in various animal species that demonstrate early life nutrient status has long-term developmental effects. For a more extensive discussion of this topic, a recent review of these concepts was conducted by Drackley (2005). Aside from the improvement in potential immune competency, there appears to be other factors that are impacted by early life nutrient status.

There are several published studies and studies in progress that have both directly and indirectly allowed us to evaluate milk yield from cattle that were allowed more nutrients up to eight weeks of age. The earliest of these studies investigated either the effect of suckling versus controlled intakes or ad-libitum feeding of calves from birth to 42 or 56 days of life (Foldager and Krohn, 1994; Bar-Peled et al, 1997; Foldager et al, 1997). In each of these studies, increased nutrient intake prior to 56 days of life resulted in increased milk yield during the first lactation that ranged from 1,000 to 3,000 additional pounds compared to more restricted fed calves during the same period (Table 4). Although they are suckling studies, milk is most likely not the factor of interest, but nutrient intake in general and this is demonstrated in the more recent data.

In a study conducted at Miner Institute, Ballard et al. (2005), reported that at 200 days in milk, the calves fed milk replacer at approximately twice normal feeding rates produced 1,543 pounds milk more than the calves that received one pound of milk replacer powder per day. Calving age in that study was not affected by treatment. Overall, averaging the studies, there is a 1,500 pound response to increasing nutrient intake prior to weaning for first lactation milk yield. The significant observation is that the effect of intake level needs to be accomplished through liquid feed intake.

The response in the studies of Shama et al. (2005) and Moallem et al. (2010) are sis significant, specifically because they suggests that milk replacer quality is important to achieve the milk response, as is protein status of the animal post weaning. In that study, the calves were fed a 23% CP, 12% fat milk replacer containing some soy protein or whole milk. Further, post-weaning the calves were fed similarly until 150 days of gain, and the diets were protein deficient (~13.5% CP). Starting at 150 days, calves from both pre-weaning treatments were supplemented with 2% fish meal from 150 to 300 days of life. The calves allowed to consume the whole milk (ad libitum for 60 minutes) and supplemented with the additional protein produced approximately 1,700 pounds more milk in the first lactation indicating that the early life response could be muted by inadequate protein intake post-weaning.

Table 4. Milk production differences among treatments where calves were allowed to consume approximately 50% more nutrients than the standard feeding rate prior to weaning from liquid feed.

Study	Treatment Difference, lb
Foldager and Krohn, 1994	3,092
Bar-Peled et al., 1998	998
Foldager et al., 1997	1,143
Ballard et al., 2005 (@ 200 DIM)	1,543

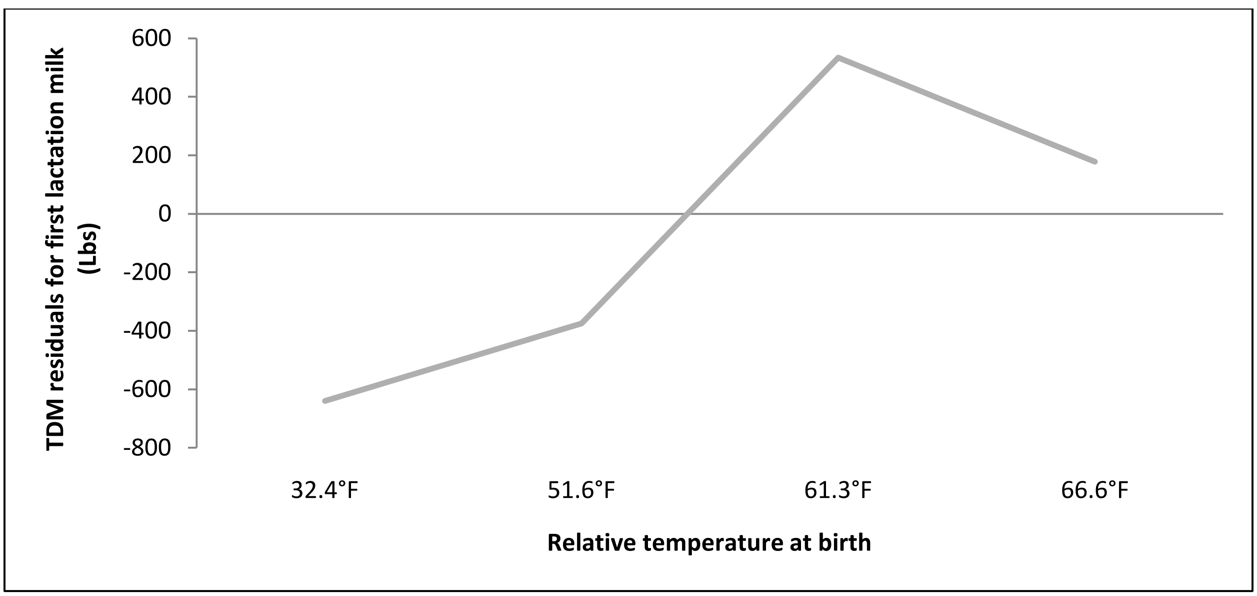
Shamay et al., 2005 (with added post-weaning protein)	2,162
Rincker et al., 2006 (proj. 305@ 150 DIM)	1,100
Drackley et al., 2007	1,841
Morrison et al., 2009	0
Moallem et al., 2010 (with added post-weaning protein)	1,613

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

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

We analyzed the lactation data of the 1,244 heifers with completed lactations using the TDM approach and statistically analyzed several factors related to early life performance and the TDM milk yield residuals (Soberon et al. submitted). The factors analyzed were birth weight, weaning weight, height at weaning, BW at 4 weeks of age and several other related and farm-measurable factors. From a management perspective, the most interesting observation was the relationship among two factors: growth rate prior to weaning and intake over maintenance and first lactation milk yield. In these analyses, the strongest relationship associated with first lactation milk production was growth rate prior to weaning and the findings are consistent with the data presented in Table 4. In our data set, for every 1 pound of average daily gain (ADG) prior to weaning (or at least 42 to 56 days of age), the heifers produced approximately 937 pounds more milk (P < 0.01). The range in pre-weaning growth rates among the 1,244 animals were 0.52 to 2.76 pounds per day and the range was actually quite puzzling to us. Our feeding program at the research farm is straightforward: 1.5% BW dry matter from day 2 to 7 and then 2% of BW dry matter from day 8 to 42 of a 28:15 or 28:20 milk replacer mixed at 15% solids. Free choice water is offered year around and starter is offered from day 8 onward. At that feeding rate, we are offering twice the industry standard amount and had assumed it was enough for overcoming the maintenance requirement and provide adequate nutrients for growth, even in the winter. However, when we analyzed the TDM residuals by temperature at birth, a very significant observation was made (Figure 1.

Figure 1. Test Day Model residuals in pounds of milk, averaged by temperature at time of birth with mean temperature in Fahrenheit. (*P* < 0.001)



This data very much suggests that although we are meeting the maintenance requirements of the calves from a strict requirement calculation, we are not providing enough nutrients above maintenance to optimize first lactation milk production. We need to remember that the thermoneutral zone for calves is 68° to 82° F and that when the temperature drops below that level, intake energy will be used to generate heat instead of growth. In addition, when we analyzed the data by lactation, the response increased as the animals matured (Table 5).

Table 5. Predicted differences by TDM residual milk (lb) for 1st, 2nd, and 3rd lactation as well as cumulative milk from 1st through 3rd lactation as a function of pre-weaning average daily gain and energy intake over predicted maintenance for the Cornell herd.

Lactation	n	Predicted difference in milk per lb of pre-weaning ADG	P value	Predicted difference in milk (lb) for each additional Mcal intake energy above maintenance	P value
1st	1244	850	< 0.01	519	< 0.01
2nd	826	888	< 0.01	239	0.26
3rd	450	48	0.91	775	< 0.01
1st - 3nd	450	2,280	0.01	1,991	< 0.01

This data demonstrates there are metabolic programming events being affected in early life that have a lifetime impact on productivity. When we evaluated the 450 animals that had completed a third lactation, we found a lifetime milk effect of pre-weaning average daily gain of over 6,000 lb of milk depending on pre-weaning growth rates. Further, 22% of the variation in first lactation milk production could be explained by growth rate prior to weaning. This suggests that colostrum status and nutrient intake and or pre-weaning growth rate have a greater effect on lifetime milk yield and account for more variation and progress in milk yield associated with the management of the calf than genetic selection. Generally, milk yield will increase 150 to 300 lbs per lactation due to selection whereas the effect of management is three to five times that of genetic selection.

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

What changes in the animal are allowing for these differences? There is no one answer to that question but investigations are looking for several factors. Although mammary development as previously measured is probably not the appropriate factor (Meyer et al., 2006a, 2006b), it is intriguing to look at very specific cells within the mammary gland. There are a couple sets of data that demonstrate increased mammary cell growth based on early life nutrient intake. Brown et al. (2005) observed a 32 to 47% increase in mammary DNA content of calves fed approximately 2 versus 1 pound of milk replacer powder per day through weaning. Just like the milk production increases discussed earlier, this mammary effect only occurred prior to weaning.

In fact, this increase in mammary development was not observed once the calves were weaned, indicating the calf is more sensitive to level of nutrition prior to weaning and that the enhancement mammary development cannot be “recovered” once we wean the animal.

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

Economics

An in depth economic analyses of a program designed to double the birth weight and decrease age at first calving by almost 3 months was conducted by Dr. Mike Overton with input from Dr. Bob Corbett (Overton, 2010). In his analyses he utilized both research and herd data to characterize the costs and potential income associated with feeding and managing calves in a manner to promote a milk yield response. In his analysis, the first lactation profit was $190 per heifer without accounting for the increase in inventory and what that means to changes in either voluntary culling or heifer sales. The change in profitability was due to the average 1,700 lb milk response observed from the studies described in Table 4 and was adjusted for net present value of the investment today relative to the income two years from now.

We conducted our own analysis of the response using calf and heifer performance data from a herd used in a heifer cost benchmarking study from New York (Table 6). There are many terms for the difference in management of the calves – in this analyses we will call it intensified but it really represents more biologically normal growth. Actual health data, feed costs and total costs of rearing were included in the estimation. Age at first calving was a function of getting heifers pregnant at 55% of the mature body weight and then calving at a minimum of 82% in both systems. In our analyses, AFC was reduced by 2.3 months, but the costs associated with achieving the same body weight post calving were nearly identical due to the higher costs of feeds and the amount of feed consumed to achieve the earlier AFC.

While the cost per heifer completing the system did not change, there are several other areas where there is economic value associated with the decreased calving age and the decrease in non-performance expense. If starting? the same number of heifer calves each month, there will be on average 2 more animals completing the system each year. There is also a decrease in the total number of animals in the replacement program, dropping 8%. This could allow the dairy to grow larger with the same replacement system, or allow the dairy to investment in a replacement program that was 8% smaller than before. The third area to impact profitability is the increased performance of the heifer in the dairy herd.

Table 6. Cost assessment of conventional versus intensified calf and heifer programs

	Conventional	Intensified
Pre-weaning cost per pound gain, $	2.73	2.91
Total pre-weaning gain, lb	64	102
Age at pregnancy, mo.	15.4	12.2
Age at first calving, mo	24.5	22.2
Overall average daily gain from birth, lb	1.70	1.89
Body weight at calving, lb	1,350	1,350
Percent non-completion rate, % entering replacement program	10.2	7.5
Total cost per heifer, $	1,738	1,740
Total investment per heifer, $	1,887	1,890

Using a model that treats the replacement program as a separate enterprise within the dairy, we looked at the combined changes for this herd, decreasing the calving age to 22.2 months, decreasing the non-performance rate to 7.5%, and fully transferring the increased value of production in the lactating herd. The non-completion rate was reduced due to a reduction in death loss with greater nutrient intake prior to weaning with no changes post-weaning indicating there will be more heifers available to enter lactation. The base replacement enterprise was generating a return of 0.87% on assets invested in the replacement program. With all the changes, the return increased to 7.2%.

Table 7. Replacement enterprise impact for selected management changes for a 250 cow herd. These values represent the differences in expenses associated with the heifer rearing enterprise associated with the calf raising program.

	Base	Lower Calving Age	Lower Non-Completion Rate	Combined Changes
Heifers to cows ratio, %	76	68	74	69
Total rearing costs, $	1,736	1,739	1,701	1,724
Income per animal, $	1,900	1,900	1,900	2,104
Completing system total investment, $	223,142	202,348	217,508	211,692
% Return on Capital	0.87%	0.53%	1.75%	7.27%

The profitability increase is due to the potential decrease in inventory due to calving approximately 3 months earlier and the milk yield increase due to improved nutrition and management from birth. The management decisions associated with the inventory change due to AFC are difficult to generalize among all herds and it is really a one-time adjustment to the cost of production. However, given the potential change in milk yield over the life-time of the animal, the change in calf management in a program that maintains the targets throughout the growing phase is worth approximately $211, assuming a discount of 7% per year over the three year period, a $15 milk price, an income over feed costs of $10.50. This value is similar to the profit calculation of Mike Overton and an outcome of the average milk response we are using to make the estimation along with the individual assumptions about costs of management.

Summary

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

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Labor Management Panel

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Introduction

The Labor Management Panel for this year's WDMC is composed of two individuals that are engaged with the dairy industry in Colorado. Ms. Mary Kraft is a highly valued partner in the Quail Ridge/Badger Creek Dairy Farms operations in Fort Morgan, Colorado. Often called the "Flow Dairy" in trade journals, Quail Ridge Dairy was designed and constructed by Chris and Mary Kraft with the flow of everything in mind. The Kraft's 4000 cow dairy in Northeast Colorado opened January 2007, even though construction on the facility wasn't complete until July. The ramp up began with extensive training at Badger Creek Farm (the home dairy, milking 1500 head with a double 22 parallel) to set up new managers before Quail Ridge opened. Traffic patterns for moving cows, milk trucks, feed trucks, air, commodities and people make the 5- 800 cow free stalls and double 50 parallel parlor highly efficient.

The second individual is Dr. Roman-Muniz whom is an assistant professor; Department of Animal Sciences at Colorado State University, Fort Collins, CO. Dr. Roman is starting her third year in the department and is very engaged with undergraduate teaching and is also the extension dairy specialist for Colorado. Noa received her DVM at the University of Wisconsin and an MS in Clinical Sciences with an emphasis in adult education at Colorado State University. Noa grew up on a dairy farm in Puerto Rico prior to her education in Wisconsin and Colorado. She is a highly valued faculty member at Colorado State and will have an exemplary career with the dairy industry in Colorado as Colorado's dairy industry expands in the next few years.

Identifying and Developing Middle Managers

Mary Kraft

Look Inside

The first step is to look at you, your goals, and your dedication to them. Are you a cow manager or a people manager? Are you willing to relinquish the actual cow handling activities and let others be responsible? Do you feel you have to win every point, or can you get excited about the successes of your people? Are you interested in other people’s growth, and how much are you willing to put into their development? If you are a successful family person, you do these already, it’s simply a matter of paradigm shift to raise your employees like you raise your family- and we all know it’s sometimes a hard, thankless job. But then some days, it’s amazing! Raising kids and raising employees is like eating an elephant- absolutely overwhelming if you try to eat the whole thing at once, yet completely doable if you take it one bite at a time!

Start With the Right Ingredients

You know that it takes just as much feed, space and resources to have an underachieving cow as it does to have a good one. Why do we think it’s any different with the people working at our dairies? The most important aspect to finding good people is to not hire the bad ones to begin with. That means not settling for a warm body, but choosing EVERY new employee based on the following criteria:

1. Are they motivated (look for a new pick up, or an expecting wife)?
2. Did they take care of themselves – if they don’t take care of that, what do you think they will do with your stuff?
3. Did they show up on time for the interview, and with the proper documents already in hand?
4. Did they pay attention during the hiring process, and behave respectfully (sit up in the chair, turn their cell phone off, keep their family in order, etc.)?
5. Did they really understand what you said about their role in the job, and if they didn’t, did they ask respectful questions?
6. Do they have an attitude- a good one or a bad one?

Put Them in the Right Place

Chris and I were among the first few crops Tom Fuhrman turned out in his management seminars. He helped us design the hierarchy for our dairy. Knowing where each person belonged in the chain of command and responsibility simplified the training and oversight processes. No one manages more than 6 people DIRECTLY. More than that and the system stalls.

Begin the Shaker Box Program

New employees are put in with a trainer in their area. When we have a class for that area EVERYONE goes and we repeat the classes every 6 months or so if we can. This is the beginning of our shaker box program. We use these programs to sift out the various levels of employees. Who listened and applied the information, who slept or was not engaged. Who went to the class and got all of their work done, and who complained that they didn't have time to learn. Who followed or even added to the protocols being developed through the training? All that said, it is also of vital importance that you clearly stated (and believed) that you valued education and that this is part of their job. Then you can see how they embrace it (or not).

The Dog Whisperer

I trained horses, and enjoyed a horse trainer named John Lyons, who could take an unbroken maverick and have it happily loping around with a rider in a few hours. He managed to convey his intentions and directions to a 1200-pound beast that didn't speak his language. I figured if he could train without English- through body language, positive rewards and consistency, I could easily do it with my children. Using them as guinea pigs, I practiced using those tools. I use it now to train our people. Cesar Milan, the Dog Whisperer, does the same thing with snarling, timid or territorial dogs, too. He calls this Calm Assertive Energy. Watch his show -the language and culture barriers dissolve whether you are dealing with people or animals!

Supporting Your Employees: Mentors, Meetings, and Resources

All of the employees we have that have risen to the top have had a mentor – a father back on the rancho that made them do the whole job, and made them understand the families economic consequence when the job wasn't done well, an uncle on a US dairy farm or good manager in previous employment. These people have already begun to change their culture from communal people in which the elements acted upon them, to people who take charge of their own destiny. We assign a mentor to our up and coming employees, too. There have been dozens of articles about the value of mentors in publications like the Harvard Business Review, which are developing leadership in mainstream companies. It takes time and dedication to be a mentor, but you get what you put into it.

We have weekly meeting (all department heads) in which everyone comes to present about their area- issues, concerns and triumphs. It helps us keep a pulse on a large operation, but also is a means of teaching responsibility, preparation, communication and problem solving. For many of our employees, who perhaps achieved a 6th grade education, this is new ground!

We use several tools (all available on Amazon.com) to help that cultural paradigm shift. These American culture how-to books: One minute manager, 7 Habits of Highly Effective People, 21 Indispensible Qualities of Leadership, are in Spanish, but are from the Anglo culture (we got some of them in CD form for the people that weren't that keen on reading). We offer elective English classes with our local community college (the teacher comes to the dairy, and delivers the classes after the employees' work). The people who are willing to take the extra time and understand the value of these tools will be the ones you can and should be cultivating.

Training the Trainers: How to Facilitate the Development of the Middle Manager's Training Skills

Noa Roman-Muniz, DVM, MS

Experts are Not Necessarily Effective Teachers

Being the best at milking cows does not necessarily make you great at teaching new milkers how to do their job. Often times we assume that an expert should make an outstanding teacher, yet we have all experienced a parent with little patience trying to teach his adolescent son how to drive, or a college professor leaving a classroom full of students confused and in the dark after a lecture on general chemistry. Teaching chemistry or providing driving lessons is not that different from teaching how to milk cows, or how to assist with difficult calvings. Although the skills being taught are extremely different, the process of teaching, of making information available for others to understand and use later on is very similar across subjects.

Teaching Is a Science; Teaching Is An Art

Effective teachers develop their own methods and look for ways to improve how a training session flows, and how to make main concepts easier to grasp. Effective teachers must be very familiar with the concepts presented and understand all the reasons behind protocols and decisions to be made. In this respect, teaching is a science. It requires preparation, practice and much discipline. But if teaching is seen as just science, teaching effectiveness will be limited. Teaching is also an art. It is about telling a story and keeping the audience interested in little details and able to understand the key message(s) at the same time. An effective teacher will create an atmosphere conducive to learning and will find innovative ways to deliver a message. An effective teacher will motivate students and will facilitate a more enjoyable learning experience.

On the dairy, many times we expect the person with most years of experience to motivate new hires and train them how to do their job properly. Do we evaluate that person's ability and desire to teach? What if that person doesn't have the right attitude anymore about the tasks that she or he performs for the dairy? What if that person doesn't know how to explain to others why we need to forestrip and clean the teats as preparation for milking? He or she may be the best milker, and yet not understand the science behind each step of milking. He or she may be the best milker and yet have no desire or the aptitude to share that knowledge with newcomers.

Training the Trainers

As part of the dairy management team, we should identify those individuals with the potential to be effective trainers. People with a desire to understand the science behind procedures and daily tasks, and with good communication and people skills are good candidates. Effective trainers must exhibit patience and should be respectful and fair with all. Many times, middle managers are great as trainers, but some times, this responsibility will be given to another worker with greater training skills. To ensure a consistent message, the area manager should still be involved in the training process, providing technical knowledge and answering questions related to human resource management and dairy policies.

Once a potential trainer has been identified, that person should be trained properly. Training seminars and conferences offered by universities and private entities are great opportunities to provide trainers-to-be with background knowledge. Background information on anatomy of the mammary gland, sexual harassment laws or common ailments of fresh cows, for example, will allow area managers to answer co-workers' questions during on-farm training sessions.

Why is "Why" So Critical?

One critical aspect of properly training the trainers is to explain to them the "why" behind decisions made on the dairy. For example, if we ask them to train others about forestripping, but neglect to explain why forestripping is important to cow health, milk quality and parlor efficiency, the trainer will lose the argument if confronted with the question "why should I add one more step to the milking routine, if we already do so much in the parlor?" A trainer should always be able to answer "why". That tells the students that he or she is knowledgeable and has thought through the benefits and possible challenges of a change in protocols or a new way of performing a dairy task. I will go further and say that a trainer should share the "why" with students as a way of motivating them and explaining the significance of their job performance. "Why", if adequately used, is a great tool for keeping students interested, and puts the concepts presented in context. By explaining the "why" I am not just asking a group of maternity area workers to wash their hands, for example. Instead, I am sharing with them the fact that what we do while we are tending to a dystocia cow will impact her future reproductive health and milk production. I am telling them that taking a few minutes to clean our hands and arms will save us many days or weeks of treating a sick, non-productive cow. Sharing the "why" allows workers to understand the magnitude of what they do as part of their job; it allows them to get a sense of accountability; it motivates good employees to do a better job.

Classroom Atmosphere

On-farm trainers should not only have technical knowledge, they should also understand the power of a fair and inclusive classroom atmosphere. Multicultural audiences can be a challenge to even the most experienced instructors. When some workers are harassed due to language differences, gender, physical traits, or the region of the country where they are from, their ability to learn will be affected. On-farm trainers must be aware of potential conflicts and try to minimize instances of exclusion and harassment by setting guidelines for interactions during training sessions.

It is important to note that classroom interactions will also be affected by the culture of a dairy as a whole. Dairy managers should strive to provide a working environment free of harassment of any kind. If management shows a commitment to fairness and respectful interactions, this will become part of the dairy’s culture and will be reflected in teacher-student and student-student interactions.

One of the courses that Colorado State University offers to Colorado dairy managers covers several topics under the umbrella of Human Resource Management. Topics include harassment in the work place, conflict resolution, worker safety, and how to effectively train multicultural populations. It is surprising how many middle managers that have been training new hires for years are not familiar with harassment laws, or with how to solve conflicts among workers in a constructive manner. Our training sessions on this topic have been well received and much appreciated by attendees.

Assessing Training Effectiveness and Feedback

One of the advantages of having on-farm trainers is that following a training session they could provide feedback to the employees in their area. Immediate, constructive feedback is a critical and often neglected step in the training process. Timely feedback is very important, if we desire to keep workers motivated and engaged. Following a training session, follow-up meetings should be held to discuss worker progress and performance. Worker and area performance should be measured by parameters chosen ahead of time by the management team. It is extremely important that workers are able to understand how their work affects the parameters being measured and how their improved performance benefits the dairy and themselves.

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Dairy Management Inc. Panel

Moderated By: Stan Erwine

Dairy Management, Inc.

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Control of Energy Intake Through Lactation

Michael S. Allen and B. J. Bradford[1]
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Summary

Feed intake is affected by the interaction of diet characteristics, physiological state of animals, and environmental stressors and the signals controlling feed intake likely change throughout lactation. Control of feed intake is likely dominated by hepatic oxidation of NEFA during transition and propionate in late lactation, while ruminal distension likely controls feed intake of peak lactation cows. Thus, optimizing feed intake requires different diets through lactation (i.e. grouping cows). Controlling mobilization of body fat stores during transition and limiting diet fermentability are keys to maximize feed intake during transition. Peak milk yield is maximized by feeding low-fill diets that are highly fermentable. The filling effect of diets is affected most by concentration, digestibility, and fragility of forage NDF. Diets should be formulated to limit diet fermentability to provide consistent supply of fuels as milk production declines post-peak and plasma insulin concentration and insulin sensitivity of tissues increase.

Introduction

Feed intake is determined by many interacting factors and prediction of feed intake is the "Achilles heel" of diet formulation. Many different diet characteristics interact with environment and physiological state of cows, making it difficult to predict feed intake accurately. However, understanding the factors controlling feeding allows us to manipulate diets to optimize feed intake. Eating is controlled by the integration of peripheral signals in brain feeding centers. Dairy cow diets must contain a minimal concentration of relatively low-energy roughages for proper rumen function and signals from ruminal distension can control feed intake when the drive to eat is high and metabolic control of feed intake is diminished (e.g. cows at peak lactation). Signals derived from metabolism of fuels dominate the control of feed intake when signals from distension diminish (e.g. cows in late lactation). Therefore, effects of diet on feed intake vary with the physiological state of the animal. Furthermore, they interact with environmental stressors such as social (e.g. overcrowding) and thermal stress. The objective of this article is to discuss factors controlling feed intake in lactating cows and how they can be manipulated to optimize feed intake. "Optimal" feed intake might mean the maximum to attain higher milk yields for high-producing cows or less than maximum to increase efficiency of feed conversion for lower producing cows.

[1] Currently at Kansas State University

Hepatic Oxidation Theory (HOT)

There is a large body of evidence (mostly in non-ruminant species) that food intake is controlled by oxidation of fuels in the liver. This has been reviewed previously (Allen et al., 2005; Allen and Bradford, 2006) and will be only briefly discussed here. The liver is "hardwired" to feeding centers in the brain via the hepatic vagus nerve.

Feeding behavior is controlled by the firing rate of the nerve, which is determined by oxidation of fuels in the liver; increased firing rate is associated with hunger, and decreased firing rate is associated with satiety. Feeding behavior has been linked to ATP (a form of energy currency within cells) concentration in the liver with satiety occurring as fuels are oxidized and ATP is produced, and hunger occurring as oxidation decreases and ATP is depleted. The mechanism by which ATP concentration affects the firing rate of the hepatic vagus nerve has not yet been determined. Fuels oxidized in the liver vary across species but for ruminants they include fatty acids (from the diet or mobilized from body reserves), propionate (produced by microbial fermentation in the gut), lactate (produced by muscle and gut tissues from glucose), and amino acids (from protein degradation). It is important to realize that the pattern of oxidation of fuels (minute to minute) is what affects feeding behavior because the amount of oxidation over longer periods of time (hours or days) is relatively constant (but changes greatly over a lactation).

Physiological Changes Through Lactation

Because fatty acids are readily oxidized in the liver, the supply of NEFA from mobilization of body fat reserves likely suppresses feed intake in the transition period. The degree of fat mobilization is affected by changes in plasma insulin concentration and sensitivity of tissues to insulin. Plasma insulin concentration signals tissues to synthesize fat if elevated, or mobilize fat if lowered. Changes in sensitivity of tissues to insulin through the lactation cycle modify this signal; decreased sensitivity (increased resistance) results in greater fat mobilization and increased sensitivity results in greater fat deposition at the same insulin concentration. Plasma insulin concentration decreases 50% or more by calving, beginning several weeks prepartum. Plasma NEFA concentration increases because fat is mobilized in response to decreased plasma insulin concentration. In addition, tissue sensitivity to insulin decreases in late pregnancy contributing to increased fat mobilization. Decreased plasma insulin concentration and sensitivity help the cow maintain constant plasma glucose concentration despite declining feed intake in the last week or so before calving. This is because utilization of glucose by tissues decreases, and utilization of NEFA by muscle increases, sparing glucose.

Plasma glucose concentration drops precipitously at calving and partially recovers over the course of the next several weeks. Plasma insulin concentration and sensitivity of tissues to insulin remain low in early lactation so plasma NEFA concentration remains elevated for several weeks or more. The length of time that NEFA remains elevated varies greatly among cows and depends upon the rate of mobilization and removal from the blood by the liver and mammary gland. Transfer of NEFA to milk fat by the mammary gland is highly desirable because storage of NEFA as triglycerides in the liver results in fatty liver, compromising glucose production, and oxidation of NEFA in the liver likely decreases feed intake according to HOT. This, in turn, delays the increase in plasma glucose concentration following calving, extending intake suppression. This is because glucose stimulates insulin secretion by the pancreas, and plasma insulin concentration remains low, extending the period of fat mobilization, and therefore extending the period that feed intake is suppressed by oxidation in the liver. In addition, low plasma glucose likely limits milk yield because glucose is required by the mammary gland for the production of milk lactose, the primary determinant of milk volume.

Hepatic oxidation of NEFA is a two-stage process; long carbon chains of fatty acids are partially oxidized to acetyl CoA, a two-carbon molecule, which is either completely oxidized or exported as ketones. The ability of the liver to completely oxidize NEFA is limiting, so ketones are exported and their concentration in plasma is elevated when fat mobilization is high. Ketones can be beneficial because they can be used by some tissues for energy, sparing glucose, but can cause keto-acidosis if concentrations are very high.

Further increases in lipolysis following parturition, combined with higher starch diets, likely suppress feed intake because rapid production and absorption of propionate stimulates oxidation of acetyl CoA (see below). Because feed intake of fresh cows is likely controlled primarily by hepatic oxidation, diets with moderately high forage fiber concentrations might benefit cows. Forage fiber increases rumen fill, decreasing the risk of abomasal displacement, and increases acetate production, sparing glucose utilization by extrahepatic tissues. While research is needed to evaluate effects of concentration and fermentability of starch on feed intake response, starch sources with moderate ruminal fermentability and high digestibility in the small intestine such as dry ground corn will likely provide more glucose precursors by increasing feed intake.

Milk yield increases rapidly following parturition and NEFA is exported as milk fat. Also, over the next several weeks, increasing plasma glucose stimulates insulin secretion, thereby decreasing lipolysis and plasma NEFA concentration. Because less NEFA is available for oxidation, the acetyl CoA concentration in the liver decreases, decreasing ketone output by the liver. Lack of acetyl CoA and high glucose demand limit ATP accumulation in the liver, and satiety signals to the brain decrease. <u>As milk yield increases further and feed intake control by hepatic oxidation diminishes, control is dominated by distension from gut fill and cows should be offered a diet that is less filling and more fermentable</u>. This change in the dominant mechanism of intake regulation might occur only 7 to 10 days after calving for some cows in the herd or more than 3 weeks for others; signs that hepatic oxidation is less limiting are lower plasma NEFA and ketone concentrations, increased gut distension, and steadily increasing feed intake.

As energy requirements decrease following peak milk yield, control of feed intake by gut distension gradually diminishes and control by hepatic oxidation increases. Plasma insulin concentration and sensitivity of tissues to insulin increase as lactation progresses and affect the feed intake response to highly fermentable diets. Higher plasma insulin concentrations that are indicative of adequate nutritional status likely provide negative feedback on hepatic gluconeogenesis. This relationship is consistent with HOT because decreased use of propionate for glucose production leads to greater propionate oxidation and decreased feed intake. Individual cows with an adequate supply of glucogenic precursors may respond to a further increase in supply by decreasing DMI. Greater sensitivity of tissues to insulin will likely increase clearance of fuels from the blood sooner, partitioning more energy to body reserves and decreasing the interval between meals.

Optimizing Fat Mobilization

Plasma NEFA are used as an energy source by maternal and fetal tissues, thereby sparing glucose, and also enrich the fat content of milk. However, plasma NEFA concentrations should be limited because elevated NEFA can depress feed intake and suppress immune function. To limit plasma NEFA concentrations, rate of fat mobilization must be controlled. Rate of fat mobilization is dependent upon the amount of fat reserves available for mobilization as well as insulin concentration, tissue sensitivity to insulin, and stress. The importance of controlling body condition at calving is well recognized. Cows with excessive body condition generally mobilize fat very rapidly through transition because their tissues are more insulin resistant and they have greater fat stores to mobilize. Therefore it is very important to manage body condition to limit over-conditioned cows by reproductive management, grouping lactating cows, diet formulation, use of rBST to partition energy to milk, etc. Recent research indicates that allowing cows to consume more energy than required during the dry period results in increased NEFA concentrations in early lactation (Holtenius et al., 2003). Controlling energy intake by feeding high-fill diets during this relatively short period might reduce depots of readily mobilized fat reducing the rate of fat mobilization after calving. Fat mobilization will be reduced by increasing sensitivity of fat tissues to insulin (decreasing insulin resistance). Chromium increases insulin sensitivity and supplemental chromium has been demonstrated to decrease plasma NEFA concentrations in lactating cows. A more rapid increase in plasma glucose following calving will likely increase insulin and decrease NEFA concentrations sooner. However, increasing insulin sensitivity of fat tissue is preferable to increasing insulin concentration because insulin can reduce glucose production by the liver. Hormones released during stress increase fat mobilization, elevating plasma NEFA concentration further. Therefore, great attention should be paid to reduce all potential stressors of cows including stressful interactions with farm workers, management procedures, and facilities (e.g. bedding, ventilation, bunk space).

Propionate Control of Feed Intake

Propionate, produced by microbial fermentation in the gut, is a primary fuel controlling feed intake in ruminants fed diets containing high grain concentrations. It is a primary end-product of starch fermentation, and production rates vary greatly among diets. Propionate can be produced and absorbed at very high rates and very rapidly taken up by the liver, where it is a major fuel used to produce glucose. However, when propionate is absorbed faster than it can be utilized to produce glucose in the liver, it will likely be oxidized, generating ATP and a satiety signal to the brain. The capacity of the liver to produce glucose is affected by glucose demand (the difference between glucose required and glucose produced) because limiting enzymes in the liver are up-regulated to meet demand. Because of this, propionate is less likely to be oxidized (and decrease feed intake) at peak lactation when glucose demand is high, than in late lactation when glucose demand is lower. Although propionate might be expected to have little effect on feed intake of fresh cows because they have high glucose demand, decreasing oxidation of propionate *per se*, propionate also stimulates oxidation of acetyl CoA. Fresh cows have a large supply of acetyl CoA in the liver from partial oxidation of NEFA. Some acetyl CoA is exported as ketones, but it is also readily oxidized when propionate is taken up by the liver, quickly generating ATP and a satiety signal (see Allen et al., 2009 for more details). This is an apparent conundrum: propionate is a primary fuel used to produce glucose, which is needed to increase insulin and decrease NEFA, thereby alleviating the depression in feed intake by NEFA oxidation in fresh cows, but propionate suppresses feed intake by stimulating oxidation of acetyl CoA in fresh cows. However, there are diet formulation options which help prevent the depression in feed intake, including manipulating the rate of propionate production to extend meal length, supplying other glucose precursors that stimulate oxidation of acetyl CoA to a lesser extent, and providing alternate energy sources for tissues to spare glucose. **The goal is to maximize the amount of glucose produced or spared per unit of ATP generated in the liver over time.** Manipulating the pattern of oxidation of fuels in the liver can increase plasma glucose and insulin concentrations, decreasing fat mobilization and the period of time feed intake is suppressed by oxidation of NEFA in the liver.

Altering Propionate Flux to the Liver

Rate of propionate production can be decreased by reducing starch concentration and fermentability and by increasing efficiency of microbial protein production from organic matter, while absorption rate is likely to be reduced by inhibiting ruminal motility.

Dietary Starch Concentration. Starch concentration of diets is often reduced by substituting forage or non-forage fiber sources (NFFS) such as beet pulp or soyhulls for cereal grains. Dilution of starch in the diet has the added benefit of reducing the fermentation rate of the starch remaining when starch concentration is decreased by adding forage or NFFS, reducing the rate of propionate production. The optimal strategy depends upon the relative cost of ingredients, efficiency of feed utilization, and animal production response. For instance, longer fiber particles from forage compared to NFFS might increase fiber digestibility by increasing ruminal pH through stimulation of rumination and by increasing ruminal retention of fiber; however, forage fiber is very filling and forages might limit feed intake compared to NFFS. Therefore, when ruminal distension contributes to the control of feed intake, substitution of NFFS for grain might be a better choice than substitution of forage.

Site of Starch Digestion. Substitution of a less fermentable starch source is an option when feed intake is depressed by a rapidly fermented starch source. Altering dietary starch fermentability will likely be more desirable than replacing starch with fiber for ruminants with high glucose demand, such as early lactation cows, because post-ruminal starch digestion yields more glucose precursors than ruminal fermentation of fiber. It is important to note that the fraction of glucose precursors provided by starch fermentation in the large intestine is much lower than in the rumen or small intestine because microbial cells containing starch are lost in the feces. Therefore, careful consideration of site of starch digestion is very important to maximize the yield of glucose precursors over time. Starch sources with lower ruminal digestibility should be highly digestible in the small intestine to provide the greatest yield of glucose precursors. For instance, dry ground and cracked corn both slow the rate of propionate production in the rumen compared to high moisture corn, but the ground corn will provide more glucose precursors because of greater digestibility in the small intestine and total tract.

Rate of Propionate Absorption. Ruminal motility affects the rate of propionate absorption because mixing of ruminal contents is required to replenish its supply at the ruminal epithelium where it is absorbed. Therefore, rumen motility likely affects the rate at which propionate stimulates oxidation within meals. Ruminal motility is affected by diet and is likely increased by physically effective fiber and decreased by long-chain fatty acids and butyrate. Butyrate production increases when feed ingredients containing sugars are consumed. Therefore, other diet components can alter feed intake by affecting flux of propionate to the liver.

Nitrogen Metabolism. Consumption of ruminally degraded protein or total protein in excess of that required can decrease feed intake. Hepatic oxidation of ketogenic amino acids can contribute to satiety according to HOT and urea production from excess ammonia produces a carbon skeleton that can be oxidized. However, greater dietary protein concentration can also increase feed intake by reducing propionate production. Increasing protein concentration could dilute diet starch concentration and decrease energy spilling by ruminal microbes, thus converting a greater fraction of fermented organic matter into microbial cells and less into VFA.

Gut Fill

As feed intake increases in early lactation, control of feed intake is dominated by ruminal distention and the extent to which ruminal distention limits feed intake is linearly related to milk yield (Voelker Linton and Allen, 2007). High producing dairy cows should be fed diets with lower filling effect to maximize feed intake. The filling effect of a diet is determined primarily by the initial bulk density of feeds as well as their filling effect over time in the rumen. The overall filling effect is determined by forage NDF content, forage particle size, fragility of forage NDF determined by forage type (legumes, perennial grasses, annual grasses), and NDF digestibility within a forage family (Allen, 2000). Forage NDF is less dense initially, digests more slowly, and is retained in the rumen longer than other diet components. Feed intake of high producing cows is often dramatically reduced by increasing the forage NDF concentration of the diet. Several studies in the literature reported a decrease in DMI of up to 4 kg/d when diet NDF content was increased from 25 to 35% by substituting forages for concentrates (Allen, 2000). Although most studies reported a significant decrease in DMI as forage NDF increased, the DMI response was variable, depending upon the degree to which intake was limited by ruminal fill. Higher producing cows are limited by fill to the greatest extent and the filling effect of forage fiber varies depending upon particle size and fermentation characteristics.

Experiments that have evaluated effects of forage particle size have generally shown small effects on DMI (Allen, 2000). However, one experiment showed little effect of particle size of alfalfa silage when fed in high grain diets but a large reduction in DMI for the diet containing longer alfalfa silage when fed in a high forage diet (Beauchemin et al., 1994). Feed intake might have only been limited by ruminal fill in the high forage diet, which could explain the interaction observed.

Increasing diet NDF content by substituting non-forage fiber sources for concentrate feeds has shown little effect on DMI in studies reported in the literature (Allen, 2000). Non-forage fiber sources include byproduct feeds with significant concentrations of NDF such as soyhulls, beet pulp, cottonseeds, corn gluten feed, and distiller's grains. Fiber in non-forage fiber sources is probably much less filling than forage NDF because it is less filling both initially (smaller particle size) and over time in the rumen because it digests and passes from the rumen more quickly.

Forage NDF has a much longer ruminal retention time than other major dietary components. Retention time in the rumen is longer because of longer initial particle size, and greater buoyancy in the rumen over time, which differs greatly across forages. As forages mature, the NDF fraction generally becomes more lignified. Lignin is a component of plant cell walls that helps stiffen the plant and prevent lodging. It is also essentially indigestible by ruminal microbes and limits fermentation of cellulose and hemicellulose. Within a forage type, the degree to which NDF is lignified is related to the filling effects of the NDF. Fiber that is less lignified clears from the rumen faster, allowing more space for the next meal. However, ruminal retention time of NDF from perennial grasses is generally longer than for legume NDF in spite of being less lignified (Voelker Linton and Allen, 2008). Because of this, it is more filling and should not be included in high concentrations in diets of cows for which feed intake is limited by ruminal fill, unless it is of exceptionally high quality. Corn is an annual grass, and corn silage NDF digests and passes from the rumen quickly and can be an excellent source of forage NDF for high producing cows.

While ruminal distention becomes a primary limitation to feed intake as milk yield increases, it likely has little effect on feed intake during the transition period if feed intake is controlled primarily by oxidation in the liver (Allen and Bradford, 2005). Diets can be formulated to meet requirements for energy and nutrients with large differences in the amount and turnover rate of ruminal digesta. Formulating diets to maintain gut fill with ingredients that are retained in the rumen longer, and have moderate rates of fermentation and high ruminal digestibility will likely benefit transition cows several ways. The ruminal digesta will provide more energy over time when feed intake decreases at calving or from metabolic disorders or infectious disease. This will help maintain plasma glucose and prevent even more rapid mobilization of body reserves compared to when diets are formulated with ingredients that disappear from the rumen quickly. Ruminal digesta is very important to buffer fermentation acids and buffering capacity is directly related to the amount of digesta in the rumen. Therefore, diets formulated with ingredients that increase the amount of digesta in the rumen will have greater buffering capacity and will maintain buffer capacity longer if feed intake decreases. Inadequate buffering can result in low ruminal pH, decreasing fiber digestibility and acetate production, and increasing propionate production, possibly stimulating oxidation in the liver and decreasing feed intake. Low ruminal pH also increases risk of health problems such as ruminal ulcers, liver abscess, and laminitis, and causes stress, likely increasing mobilization of body reserves even further. Diets formulated with ingredients that maintain digesta in the rumen longer when feed intake decreases will likely decrease risk of abomasal displacement.

Unsaturated Fatty Acids

Feed and energy intake can be depressed by supplementation of fat and the extent of depression is dependent upon fat type (Allen, 2000). Fat sources with more unsaturated fatty acids reduce intake to the greatest extent and fatty acids that are highly saturated have less effect.

Recommendations

Limit mobilization of body fat by controlling body condition during mid to late lactation and limiting feed intake of dry cows by feeding diets with high forage NDF concentration. Limited concentration of highly fermentable starch might reduce NEFA concentration prepartum.

Maintain rumen fill through transition. Diets with high concentrations of grain, non-forage fiber, and finely chopped forages fed through the transition period should be avoided. Feeding high-fill diets prior to calving to control feed intake might reduce depots of readily mobilized fat and provide energy to help sustain plasma glucose through calving. Increased amounts of ruminal digesta also decrease risk of displaced abomasum and increase buffering capacity, decreasing risk of acidosis. Forage fiber is much more filling than non-forage fiber or other diet components but the filling effect of forage fiber varies greatly. Some long fiber particles are necessary to form a mat and increase digesta retention in the rumen, but excessive length of cut can increase sorting and can decrease feed intake. Digestion characteristics of forage fiber vary greatly by forage type and maturity and have a large effect on retention time in the rumen. Wheat straw digests and likely passes from the rumen slowly and it has been used to dilute energy density of corn silage in TMRs for dry cows. Grass silage or hay is likely more beneficial because the fiber is more digestible and it provides energy for a longer time when feed intake decreases at calving. However, grass with high potassium concentrations might require anionic salts in prepartum diets to reduce milk fever following calving.

Avoid feeding highly fermentable starch sources to fresh cows because rapid production and absorption of propionate will stimulate oxidation of acetyl CoA and suppress feed intake. Starch sources with moderate ruminal fermentability and high digestibility in the small intestine, such as dry ground corn, will provide glucose precursors and less propionate to stimulate oxidation and suppress feed intake.

Feed a less filling and more fermentable diet as gut fill begins to dominate the control of feed intake. This might be only 7 to 10 days after calving for some cows in the herd or more than 3 weeks for others and is likely indicated by lower plasma NEFA and ketone concentrations, visual observation of cow gut distension, and steadily increasing feed intake. While group housing prevents measurement of feed intake for individual cows, kits are available to measure NEFA and ketones concentrations on the farm. Because feed intake is limited by ruminal fill, feed ingredients that can depress ruminal motility such as fat and sugar sources should be limited.

Feed a more filling, less fermentable diet as milk yield declines. As lactation progresses past mid-lactation, the highly fermentable diet that is optimal for high-producing cows can depress feed intake as milk yield and glucose demand decreases. Propionate is likely oxidized when it is produced faster than it can be utilized, generating ATP and a satiety signal. Therefore, cows should be switched to a less fermentable and more filling diet as milk yield declines. This will increase feed intake and provide a more consistent supply of fuels, reducing insulin and partitioning more energy to milk rather than body condition. Furthermore, the less fermentable, more filling diet will decrease risk of milk fat depression and late lactation abomasal displacement. Unsaturated fats likely decrease feed intake and should be limited. Limit highly fermentable starch sources (e.g. high moisture corn, ground barley) by substituting less fermentable feeds such as dry ground corn or non-forage fiber sources.

Conclusions

Consideration of physiological changes occurring through lactation and the physical and digestion characteristics of feeds beyond their nutrient composition is required to optimize feed intake for lactating cows. Understanding the control of feed intake is critical to diet formulation and the Hepatic Oxidation Theory is exciting for its potential contribution to our ability to formulate diets. While more research is needed to better understand animal response to diets, the theory and concepts presented in this paper will help to formulate diets to improve animal health and farm profitability.

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The Nutritional Chemistry of Dry and High Moisture Corn

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Introduction

When fed to lactating dairy cows, management practices such as grinding corn, (Remond et al., 2004), steam flaking corn (Callison et al., 2001), feeding high moisture corn (Oba and Allen, 2003), or feeding floury corn (Allen et al., 2008), have been demonstrated to improve starch digestion and milk production of lactating dairy cows. The aforementioned management practices are common in the dairy industry and are deemed necessary to improve the feeding characteristic of corn grain. The use of these management practices brings to light a broader question—why is corn starch within the native corn kernel only partially digestible by dairy cows? This paper will review the nutritional chemistries of corn which are potentially related to starch digestibility in dairy cows.

Corn is a Seed

Corn per se is not a feed, it is a seed, and some understanding of corn seed anatomy and physiology are required to better understand chemical factors that potentially influence starch digestibility in ruminants. The corn seed is comprised of three basic morphological parts: pericarp, germ, and endosperm. The endosperm represents approximately 75-80 percent of the corn kernel by weight and is the morphological structure that contains starch. The endosperm contains primarily starch and protein but does contain small amounts of fat as phospholipids and ash. The endosperm of corn is virtually devoid of fiber (ADF or NDF). Specifically, corn endosperm contains < 4% NDF and 0.09% P (phosphorus), as compared to the germ which contains 17% NDF and 0.97% P, and pericarp with 33% NDF and 0.29% P (Van Kempen et.al., 2003). Corn endosperm contains abundant storage proteins (albumins, globulins, prolamins, and glutelins) which will be discussed in detail later in this paper.

The endosperm in cereal grains surrounds the germ and serves as the primary nutrient source for the germ which contains living tissue (roots, leaves, etc). Seed germination is initiated by water absorption and the seed undergoes renewal of enzymatic activity that results in cell division and ultimately embryo emergence through the pericarp. The endosperm's biological function is to serve as the primary nutrient source for the embryo until photosynthesis is initiated upon seedling emergence (Buchanan, et al., 2000; Mohr and Schopfer, 1995).

Corn Endosperm

Corn is an annual plant, reproducing only by seed, facilitated by the seed falling onto the ground where germination is reinitiated. Plant reproduction by seed requires protection of the embryo from improper environmental conditions until proper environmental conditions (moisture, temperature, seed coverage, dark) exist for germination. The fibrous pericarp is the primary morphological structure protecting the embryo but the starch in corn endosperm is also protected by hydrophobic (repels water) proteins called prolamins. Pure starch cannot be efficiently stored in corn endosperm because pure starch is highly hydrophilic (attracts water) and premature hydration of the endosperm would not properly facilitate germination. The combination of starch, prolamins and other proteins (albumins, globulins, glutelins) in corn endosperm is often referred to as the starch-protein matrix. Differences in the starch protein matrix can be visibly seen in dissected kernels of yellow dent corn. The visual appearance of all or portions of the starch-protein matrix in corn endosperm have historically been given visually descriptive classifications. Starch-protein matrices appearing white are commonly given the names floury, opaque or soft endosperm. Starch-protein matrices appearing yellow, shinny or glassy are classified as horny, translucent or vitreous (Kempten, 1921). The word vitreous means to exist in an amorphous, glassy-like state. A common example of something existing in a vitreous state would be a ceramic vase. The term vitreous is presently important because over the past decade animal and dairy scientist have adopted the word to semi-quantitatively define corn endosperm types in ruminant nutrition trials.

Vitreous Endosperm and Negative Effects on Starch Digestibility

Vitreousness of corn can be quantified in whole corn kernels by manual dissection (Correa et al., 2002). Corn kernels are soaked in water, the pericarp and germ are removed with a scalpel and the remaining endosperm is weighed. Using visual judgment, the floury (white, opaque) endosperm is separated from vitreous (yellow, glassy) endosperm with a scalpel and the weight of the vitreous endosperm is weighed and expressed as a percentage of the total endosperm.

Recent research has evaluated the relationship between in situ starch or DM degradability of corn (Philippeau and Michalet-Doreau, 1998; Correa et al., 2002; Ngonyamo-Majee, et al., 2008) and endosperm vitreousness. All studies have observed a strong negative relationship between endosperm vitreousness and in situ starch or DM degradability, meaning as endosperm vitreousness increases in situ starch or DM degradability decreases. Ngonyamo-Majee, et al. (2008) evaluated in situ DM degradability of 31 corns differing in vitreousness. Corn kernels were ground through a 6-mm screen, placed in dacron bags and incubated for 14 h in cannulated steers. The negative relationship ($R^2 = 0.72$) between endosperm vitreousness and in situ DM degradability of corn observed by Ngonyamo-Majee, et al. (2008) is presented in Figure 1.

Lebaka et al., (2007) reported the opaque (o2) gene alters vitreousness and endosperm storage protein composition of corn. The less-vitreous kernel texture of *o2* grain directly improved in situ starch degradability, but adversely affected agronomic performance. Lebaka et al. (2007) evaluated 140 recombinant inbred lines of corn for in situ starch degradability in combination with quantitative trait loci markers (QTL) to assess regions of the corn genome negatively or positively related to corn in situ DM degradability. Ruminal starch degradability of corns was negatively related QTLs on 2 primary chromosomes which have been previously associated with endosperm storage proteins (prolamin-zein) in corn. Similar results were observed in vivo by Allen et al. (2008). Allen et al., (2008) fed eight ruminally and duodenally cannulated lactating dairy cows, corns with 25 or 66 % vitreous endosperm. Feeding cows 66 % vitreous endosperm corn reduced ruminal and total tract starch digestion by 19.1 and 7.1 percentage units respectively (Figure 2).

Prolamins Make Corn Vitreous

Prolamins are endosperm storage proteins high in proline (amino acid) found in the seed of all cereal grains. Prolamins for each cereal grain have specific and historical names: wheat (gliadin), barley (hordein), rye (secalin), corn (zein), sorghum (kafirin) and oats (avenin). The small grains (wheat, oats, barley) have lower prolamin contents as compared to corn although modified endosperm types exist in corn which are low in prolamins. Prolamins are characterized by a high glutamine and proline content. Proline is a highly hydrophobic amino acid capable of complex folding and thus proteins with high proline contents develop tertiary structures that are intensely hydrophobic and are soluble in aqueous alcohol solutions (Momany, et al., 2006; Lasztity, 1984).

In corn, prolamin proteins are named zein and comprise 50-60 % of the total protein in whole corn (Hamaker et al., 1995). Prolamin-zein, defines a class of hydrophobic proteins synthesized on the rough endoplasmic reticulum of the amyloplast (starch producing organelle) envelope consisting of four zein sub-classess (ά,β,γ,δ), (Buchanan, et al., 2000). Because prolamin-zein proteins are synthesized on the rough endoplasmic reticulum within the amyloplast without the presence transit genes (Buchanan et al., 2000) prolamin-zein proteins are not intrinsic within the starch granule but are primarily surface localized on the exterior of starch granules (Mu-Forster and Wasserman, 1998). As prolamin-zein proteins enlarge and distend with advancing maturity β- and γ- zeins cross-link and ά- δ-zeins penetrate their network and occupy a more central position encapsulating starch into a starch-hydrophobic protein matrix (Buchanan et al., 2000, Mu-Forster and Wasserman, 1998).

The degree, amount, mechanisms and genetics associated with starch encapsulation by prolamin-zein in corn have been extensively investigated by plant physiologist and cereal chemist (Buchanan et al., 2000; Landry et al., 2000; Mu-Forster and Wasserman, 1998; Lasztity, 1984).

It is well defined that floury and opaque corn endosperm types have significantly lower prolamin-zein content as compared to flint or normal dent corn endosperms (Hamaker et al., 1995, Landry et al., 2000, and Wallace et al., 1990). The lower prolamin-zein content of floury, opaque or modified opaque corn is regulated by ά, and γ, prolamin-zein gene expression (Wallace et al., 1990). Philippeau et al. (2000) quantified the relationship between vitreousness and prolamin-zein content with vitreous flint corns containing more prolamin-zein than less vitreous dent corns. These data define differences in the chemical composition between vitreous endosperm (glassy, translucent) and floury or opaque endosperm. The starch in vitreous corn endosperm is more extensively encapsulated by prolamin-zein as compared to floury or opaque corn endosperm. Differences in corn starch encapsulation by prolamin-zein can be seen using scanning electron microscopy. Presented in Figure 3 are scanning electron micrographs of corn starch granules, (A) heavily encapsulated in a prolamin-protein matrix and (B) starch granules in opaque corn endosperm with less extensive encapsulation by prolamin-proteins (Gibbon et al., 2003).

The significance of prolamin-zein protein and it's chemistry in corn to ruminant nutrition implies sequential logic. Prolamin-zein is not soluble in water (hydrophobic) nor soluble in solvents normal to the innate rumen environment (Lawton, 2002). Potentially, starch digestion requires rumen bacteria to first degrade prolamin-zein via proteolysis before amylolytic activity in the rumen (Cotta, 1988) can actively hydrolyze starch to glucose. Because glucose uptake by rumen bacteria is momentary (Franklund and Glass, 1987) and the rumen has extensive amylotyic capacity (Cotta, 1988) to hydrolyze starch to glucose, proteolysis of hydrophobic prolamin-zein proteins in the rumen should therefore be a rate limiting step associated with starch digestion. The synergism between prolamin-zein and starch digestion in ruminants is compounded by poor attachment and slow degradation potential of prolamin-zein proteins by rumen bacteria. Romagnolo et al., (1994) observed the ruminal degradation rate of zein to be 0.026 %/h as compared to corn globulin-albumin proteins at 0.06 %/h.

McAllister et al., (1993) defined the influence of starch protein matrix on starch digestion in a classical study. McAllister et al., (1993) observed that when corn was treated with a protease (pronase E, Sigma Chemical) in vitro starch digestion increased approximately two fold and concluded the protein matrix in corn was a major factor in ruminal starch digestion. Lichtenwalner et al., (1978) executed as similar study treating sorghum (prolamin = kafirin) with a protease followed by incubation with glucoamylase and observed a marked increase in starch hydrolysis.

Measuring Prolamins in Corn

Prolamin-zein was first quantified by it's solubility in aqueous ethanol by Osborne, (1897). Presently, the methods of Landry and Moureaux (1970) are a recognized, but not the sole method to quantify prolamin-zein in corn endosperm. Modifications of Landry and Moureaux (1970) have been evaluated (Hamaker et al., 1995, Landry et al., 2000, and Wallace et al., 1990) resulting in permutations. The basis of Landry and Moureax (1970) and other aforementioned methods consist of sequentially solubilizing corn endosperm proteins with saline, H_2O, aqueous alcohol and an alkali. The methods of Landry and Moureaux (1970) are arduous and designed to divide corn endosperm proteins into multiple fractions (albumins, globulins, prolamins, and glutelins), which may be over extensive for ruminant nutrition because only prolamins have been recognized to be negatively associated with starch degradability (Philippeau et al., 2000) in ruminants.

Due to labor, expense, procedural metamorphosis, and prolamin-zein analysis of isolated corn endosperm, laboratory methods to quantify prolamin-zein (Hamaker et al., 1995, Landry et al., 2000, and Wallace et al., 1990) in whole corn for ruminant nutrition trials or for routine feed analysis are not employed. Turbidimetric methods (Paulis et al., 1974, Aboubacar et al., 2003; Olakojo et al., 2007) to quantify prolamin-zein periodically occur in the literature and have been successfully used to singularly quantify prolamins zein or kafirin in ground whole corn or sorghum. Larson and Hoffman, (2008) coalesced advances in cereal chemistry and rapid turbidimetric methods to quantify prolamin-zein in dry and high moisture corns. Prolamin-zein(s) were solubilized with 55.0 % aqueous isopropyl and turbidity of prolamin-zein(s) was achieved by addition to a turbidity solvent. Degree of turbidity was measured on a spectrophotometer and prolamin-zein was quantified using a standard absorbance curve developed form purified zein. The procedure of Larson and Hoffman, (2008) delineated prolamin-zein encapsulation of starch across corn endosperm type. Dry flint and dent corns contained significantly more prolamin-zein/100 g of starch as compared to floury or opaque corns.

Prolamins and High Moisture Corn

The starch-protein matrix in corn has been previously defined as a physio-chemical impediment to starch digestion in ruminants (Owens et al., 1986), but the role of the starch- protein matrix in the digestion of HMC starch in ruminants has only recently been defined. Because prolamin-zein increases with advancing maturity (Murphy and Dalby, 1971), lower prolamin-zein contents in HMC at ensiling could be expected. This argument is somewhat illogical because Murphy and Dalby (1971) observed that maximum prolamin-zein accretion occurred near black layer formation (± 30 % moisture), which is similar to typical ensiling moisture contents of HMC. In addition, HMC and dry corn are often harvested (combined) at very similar moisture contents with only post-harvest handling and storage of the corn being different thereafter. Specifically, corn is commonly combined at 25%-30 % moisture and mechanically dried thereafter yielding dry corn.

A more plausible explanation for greater and more rapid starch digestion of HMC starch is that fermentation acids or proteolysis degrade prolamin-zein proteins during the ensiling process. Bacterial proteolysis is an intrinsic mechanism in corn-grain fermentation which induces degradation of corn proteins (Baron et al., 1986). Philippeau and Michalet-Doreau (1998) observed that ensiling grains increased ruminal starch degradability and hypothesized that ensiling increases accessibility of starch granules to rumen microorganisms, because hydrophobic prolamin-zein proteins encapsulating starch granules were partially degraded by proteolysis. Likewise, Jurjanz and Monteils (2005) observed the effective ruminal degradability of starch to be lower in corn kernels before (70.2%) than after (92.3%) ensiling. The ensiling process improved starch degradation by significantly altering the rapidly-degradable starch fraction (80.7% versus 65.6 %) and the starch degradation rate (12.4 vs 8.0 %/h). Combined, these data (Baron et al., 1986; Philippeau and Michalet-Doreau, 1998; Jurjanz and Monteils, 2005) result in a very plausible hypothesis as to why higher ruminal and total tract starch digestibility is observed for HMC as compared to dry corn (Firkins, et al., 2001).

In a recent study, (Hoffman et al., 2010a) we monitored the fate of the starch-protein matrix in HMC across a long storage period (240 days). Two random HMC(s), containing 25.7% and 29.3 % moisture were ground, ensiled and stored for 0, 15, 30, 60, 120 and 240 d. The HMC(s) were also inoculated with or without 600,000 cfu/g of *Lactobacillus buchneri* 40788 (Lallemand Inc., Milwaukee, WI). Inoculation improved fermentation of the HMC with inoculated HMC having lower pH and greater acetate contents but changes in fermentation acids did not affect proteins in the starch protein matrix. However, ensiling time greatly affected the starch-protein matrix of HMC and data are presented in Figure 4. Ensiling time (0 vs 240 d) reduced all α, β and δ prolamin-zein subunits of the starch-protein matrix from 10%-40 %. The degradation of the γ prolamin-zein subunits of the starch-protein matrix of HMC was more extensive with a 60 % reduction. Because γ prolamin-zeins are primarily responsible for cross-linking starch granules together, the degradation of γ zeins in HMC would suggest that clusters of starch granules should disassociate (fall apart) as a result of fermentation since the cross links holding starch granules together are being degraded. This was confirmed by electron microscopy (photos not shown) of HMC starch granules at 0 and 240 d. Upon fermentation and storage for 240 d, the disassociation of starch-granule clusters in HMC could be readily seen using electron microscopy. Fermentation resulted in a greater number of individual starch granules (and surface area) for potential attack by rumen bacteria. Electron micrographs also revealed no alteration in individual starch granules in HMC prior to fermentation or after 240 d of storage. Inferences from this investigation (Hoffman et al., 2010a) also suggested the proteins in the starch-protein matrix were more likely altered by bacterial proteolysis and may not have been simply solubilized by fermentation acids.

In second study (Hoffman et al., 2010b), the digestibility of HMC fermented and stored for 0, 15, 30, 60, 120 and 240 d inoculated with or without 600,000 cfu/g of *Lactobacillus buchneri* 40788

(Lallemand Inc., Milwaukee, WI) was evaluated using an in vitro gas production system. Gas production and rate (kd) of gas production by rumen bacteria during the first 12 h of incubation increased with increasing storage time, which indirectly validates the observations of greater ruminal starch digestion of HMC as compared to unfermented corn. Increases in 12 h gas production and rate (kd) of gas production increased chronically over the entire HMC storage periods suggesting that the increase in HMC (DM) digestion is not an acute event. Similar results were reported by Benton et al. (2005) who evaluated in situ DM degradation of two HMC(s) and two reconstituted HMC(s) of varying moisture content; a chronic increase in DM degradation across a 300(+) day ensiling period was observed.

Grain Quality: Simple Test

Vitreousness. Vitreousness of corn can be quantified in whole corn kernels by manual dissection but the task is tedious. A semi-quantitative method is to determine vitreousness of whole corn kernels (i.e. from a specific corn hybrid) is use of a light box scoring system. Because vitreous endosperm is translucent, light shines through it as opposed to opaque endosperm which is not translucent. A complete guide to light box scoring of corn grain for vitreousness is available in *Breeding Quality Protein Maize (QPM): Protocols for Developing QPM Cultivars.* **http://ideas.repec.org/p/ags/cimmma/56179.html**

Crude Protein: Crude protein in corn grain is of benefit and detriment to dairy cows. Greater crude protein content in corn grain reduces the need for supplemental protein but proteins in corn grain also serve a lignin-like function because hydrophobic (prolamin-zein) proteins encapsulate starch reducing starch digestibility. Crude protein content of dry corn grain has been demonstrated to be negatively related to starch degradability. It is very simple to measure crude protein in corn grain and crude protein analysis is widely available at numerous commercial feed and forage testing laboratories. The crude protein content of corn grain averages 9.2 % but ranges from 7.5-11.5%. Crude protein and the amount of starch encapsulating prolamin proteins are highly related. Corn grain from hybrids with crude protein contents > 10.0 % are likely more vitreous, may contain more flint genes, or are short relative maturity hybrids (more flint genes). Corns with lower crude protein < 8.0 % maybe unique opaque-floury hybrids or have a portion of these endosperm types in their genetic makeup. Nitrogen fertility has also been demonstrated to have an effect on grain crude protein content therefore crude protein content of grains grown under nitrogen deficient growing conditions should be interpreted with caution.

Prolamin Protein: A commercial test is available to determine the concentration of hydrophobic prolamin proteins that encapsulate corn starch. The prolamin protein assay is available at a number of commercial feed and forage testing laboratories. The prolamin content of dry corns ranges from 2.5-5.5 % of dry matter. Corns > 4.5 % prolamin as a % of DM are likely more vitreous, may contain more flint genes, or are short relative maturity hybrids (more flint genes). Corns with lower prolamin protein < 3.0 % maybe unique opaque-floury hybrids or have a portion of these endosperm types in their genetic makeup.

Soluble Protein: The relationships between crude or prolamin protein and starch digestibility in lactating dairy cows applies primarily to dry corn. In ensiled corn (HMC) it is important to ascertain whether the hydrophobic proteins in the starch protein matrix have been degraded in the ensiling process. Prior to ensiling about 20 % of the protein in corn is soluble in a buffer solution. In extensively fermented high-moisture corns, more than 70% of the protein maybe soluble. The change in soluble protein is a marker of the degradation process of starch matrix proteins. As silage bacteria degrade hydrophobic proteins they become more soluble in buffer solutions.

Ammonia Nitrogen: Ammonia nitrogen may also be a marker of the status of starch-matrix proteins in high-moisture corn. At ensiling, corn has virtually no ammonia nitrogen and the appearance of ammonia in high moisture corn means that amino acids associated with the starch protein matrix are being degraded by silage bacteria. In extensively fermented high-moisture corn, ammonia nitrogen may represent >7% of the total nitrogen (or protein). High-moisture corns with <2% of the total nitrogen (or protein) as ammonia nitrogen indicate the degradation of starch-matrix proteins is probably minimal.

Starch: As compared to test weight or density, determination of starch content of corn grain prior to feeding is important. Corns harvested at immature stages due to late planting, early frost or lack of growing degree days will likely be lower in total starch content. High moisture corns harvested with cob or husk as a part of the feed will also be lower in starch content. Starch contents of corn fed to dairy cows ranges from 60-74 % of DM. Diets can easily be adjusted for starch content if the starch content of the grain is known.

In Vitro Starch Digestibility: Numerous feed and forage testing laboratories offer in vitro starch digestibility. There is no standardized method. Typical whole grains are ground through a mill fit with a 4-8 mm screen and incubated in rumen fluid from 6-12 h. More specialized in vitro gas production procedures are also available. These procedures result in lab specific numbers but are useful in ranking or indexing relative starch digestibility potential by dairy cows.

Conclusions

- Corn is a seed and is comprised of three basic morphologic parts, pericarp, germ and endosperm. Starch is contained in the endosperm and the biochemistry of the endosperm influences starch digestibility in dairy cows.
- Vitreous endosperm is negatively related to starch degradability in dairy cows.

- Vitreous endosperm is translucent and can be indexed using a light box scoring system.
- Dry flint and dent corns contain more hydrophobic prolamin-zein as compared to floury or opaque corns.
- The higher ruminal starch digestibility potential of high moisture corn is the result of degradation of starch encapsulating proteins by proteolysis during fermentation and not solely due to moisture or harvest maturity per se.
- The crude protein, prolamin protein or vitreousness of dry corn grain is negatively related to starch degradability in dairy cows.
- In high moisture corn the extent of degradation of the starch protein matrix can be evaluated using soluble crude protein or ammonia nitrogen as a marker.

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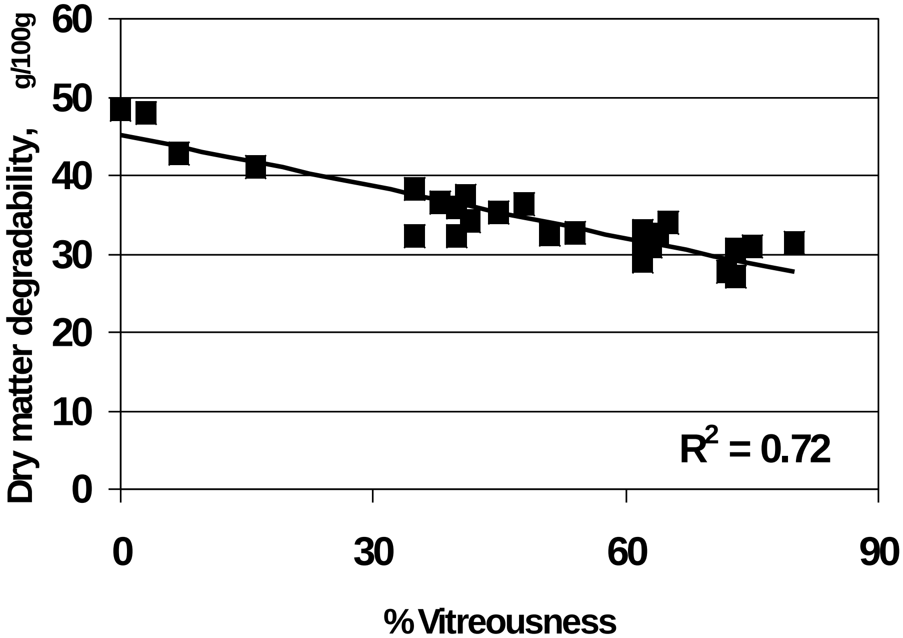

Figure 1. The relationship between kernel vitreousness and in situ DM degradability of corn (Ngonyamo-Majee, et al., 2008).

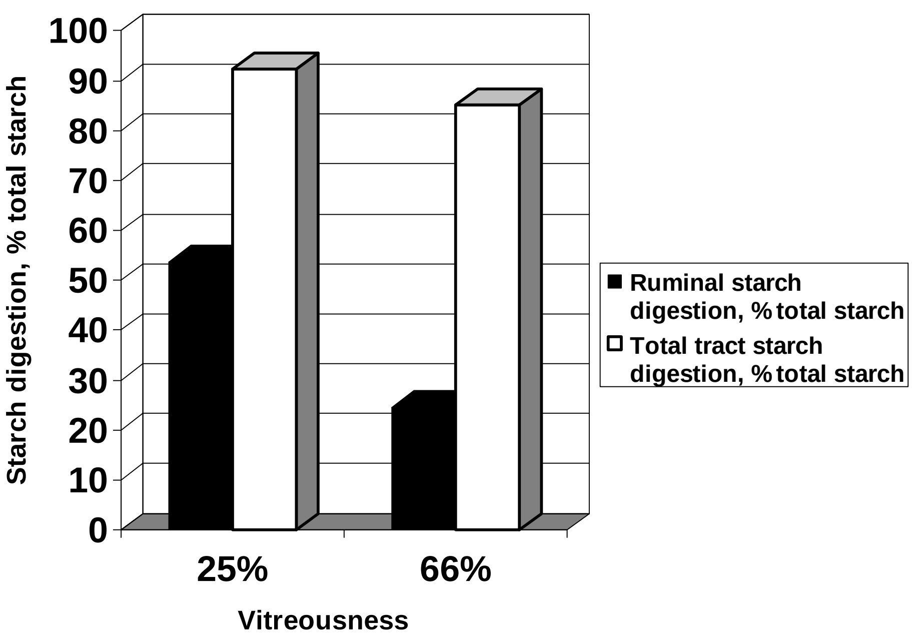

Figure 2. Effect of kernel vitreousness on ruminal and total tract starch digestibility in lactating dairy cows (Allen et al., 2008).

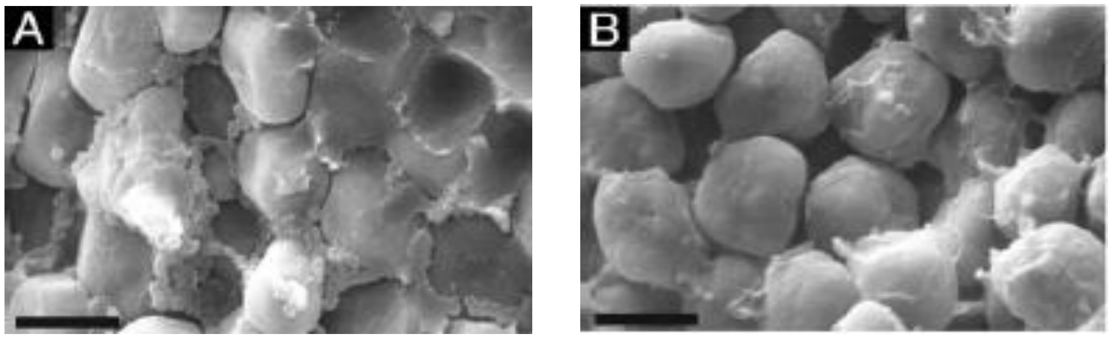

Figure 3. Scanning electron microscopy of starch granules in corn: A) starch granules heavily imbedded in prolamin-protein matrix, B) starch granules in opaque corn endosperm with less extensive encapsulation by prolamin-proteins (Gibbon et. al., 2003). Published with permission: *Copyright (2003) National Academy of Sciences, U.S.A.*

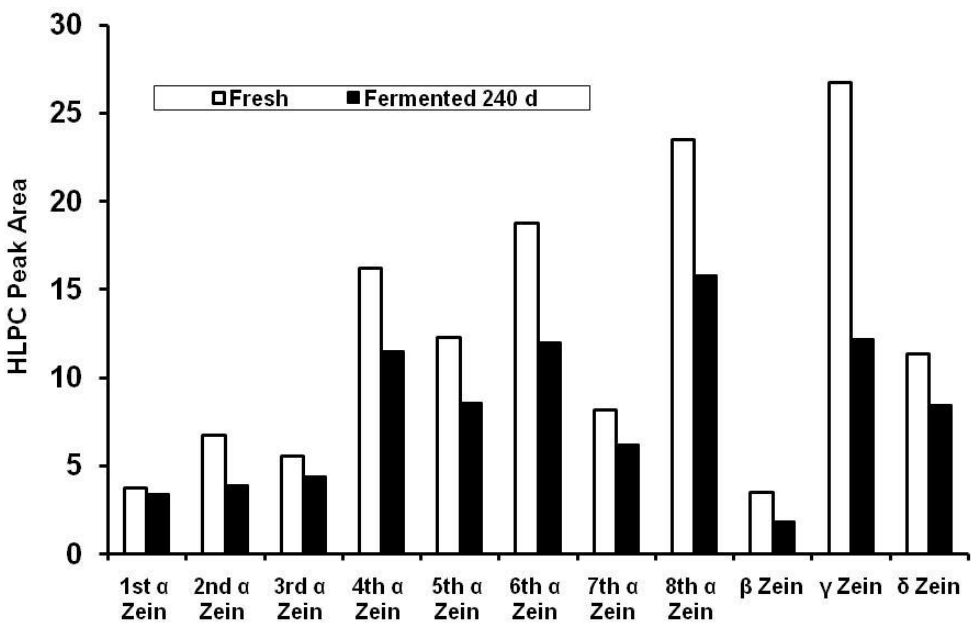

Figure 4. The effect of storage period (240 d) on hydrophobic prolamin-zein proteins in the endosperm of high moisture corn (Hoffman et al., 2010a).

Notes:

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Optimizing Intake in Dry and Prefresh Cows

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Introduction

Achieving high dry matter intake (DMI) during early lactation is a major determinant of transition cow management success, as energy balance is tightly linked with reproductive performance (Butler and Smith, 1989) and aspects of health and immunity (LeBlanc, 2010). Although a common notion is that milk yield is the major driver of negative energy balance, several data summaries (reviewed by Grummer et al., 2010) suggest that the relationship of negative energy balance is actually greater with DMI than with milk yield.

Clearly, nutritional and environmental management of dairy cattle during the dry and transition period have important carryover ramifications both for DMI during early lactation and overall lactational and reproductive performance along with health in early lactation. The purpose of this paper is to briefly overview intake regulation in dairy cattle, describe key metabolic changes in transition cows as they integrate with intake regulation and then to review key nutritional and environmental management factors that impact DMI so that we can optimize energy and nutrient intake and subsequent outcomes.

Intake Regulation in Dairy Cattle

The first key concept to understand is that intake regulation in dairy cattle is complex. The various metabolic factors that influence DMI in dairy cattle were well-reviewed by Ingvartsen and Andersen (2000) and includes a variety of direct and indirect signals related to the environment, immune system, adipose tissue, signals from the gut and pancreas, and energy sensing of the liver relative to overall energy demand (Figure 1). It is likely that changes in these signals (and cow-to-cow variation in response to various environmental and metabolic stimuli) are responsible both for changes in overall average pen DMI but also variation in cow to cow DMI that likely is more associated with transition management challenges than average pen DMI per se.

More recently, Allen and coworkers (Allen et al., 2005; Allen et al., 2009) proposed that a major regulator of DMI in ruminants, and particularly dairy cattle, was hepatic energy status based upon the oxidation of fuels such as propionate derived from ruminal fermentation of rapidly fermentable carbohydrates and nonesterified fatty acids (NEFA), which are increased in the bloodstream during periods of negative energy balance and body fat mobilization (Figure 2). In periods when oxidative fuel metabolism by the liver exceeds liver energy requirements, the brain is signaled to decrease DMI. As will be discussed more in detail below, this theory is particularly attractive in explaining metabolic influences on DMI during the prepartum period. My opinion is that the actual modulation DMI by these pathways during the immediate postpartum period is much less likely, in part because of the large increase in demand for oxidative fuel by liver to support the dramatic increases in hepatic gluconeogenesis that occur postpartum (Reynolds et al., 2003) along with the increased capacity of liver to utilize propionate during the postpartum period (Drackley et al., 2001).

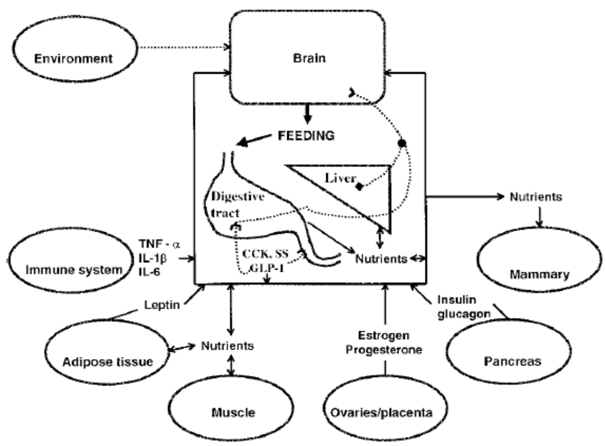

Figure 1. “Simplified” diagram on intake regulation in dairy cattle. From Ingvartsen and Andersen, 2000.

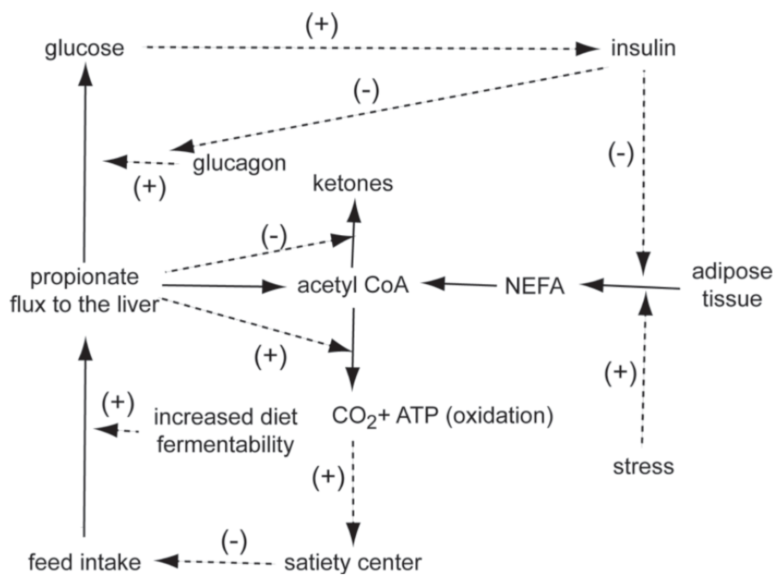

Figure 2. Mechanisms of intake regulation according to the hepatic oxidation theory. From Allen et al., 2009.

Metabolic Adaptations in the Transition Cow

It is well-recognized that dairy cows undergo important metabolic adaptations during late pregnancy to support fetal demands and at the onset of lactation to support milk production. These homeorhetic adaptations involved in the regulation of nutrient and energy partitioning during late pregnancy and early lactation occur in a variety of target tissues, and typically involve changes in responses of tissues such as adipose tissue and muscle to homeostatic signals such as insulin and epinephrine (Bauman and Currie, 1980; Bell, 1995). As described above, one major adaptation includes a large increase in glucose demand by the mammary gland that is supported by dramatically increased glucose output by the liver (Reynolds et al., 2003). In addition, peripheral tissues (primarily skeletal muscle) decrease their use of glucose for fuel (Bauman and Elliot, 1983; Petterson et al., 1993), thereby sparing glucose for use by the gravid uterus and lactating mammary gland. Furthermore, increased mobilization of body fat stores facilitated by changes in adipose tissue metabolism contributes to meeting increased whole-body needs for energy at the onset of lactation (Petterson et al., 1994). The net result of these adaptations is coordinated support of fetal needs and subsequent high milk production in the face of decreasing and eventually insufficient dry matter intake (DMI) during late pregnancy and early lactation.

These changes in tissue metabolism that occur in dairy cows during the transition period are mediated largely by changes in responses to hormonal signals such as insulin. Decreased responses of these tissues to insulin are referred to in general terms as insulin resistance. As referenced above, some aspects of insulin resistance (such as those related to skeletal muscle) are very favorable for support of pregnancy and lactation because of glucose sparing for the fetus and lactating mammary gland (Bell, 1995). At the same time, we believe that insulin resistance in adipose tissue may contribute to the increasing circulating concentrations of NEFA and decreasing DMI as cows approach calving. As indicated above, Allen et al. (2005) suggested that the increased circulating concentrations of NEFA during late pregnancy and subsequent oxidation of these NEFA by the liver is the cause of the decreased DMI as cows approach calving. Increased resistance of adipose tissue to insulin would predispose to the cow to mobilize NEFA, hence potentially creating a vicious cycle of NEFA mobilization and DMI reduction during the late prepartum period. This would also help to explain metabolically why high BCS cows have lower DMI and more rapid decreases in DMI during the prepartum period than cows of moderate or low BCS (Grummer et al., 2004).

Several years ago, we became interested in further understanding the nature and timing of insulin resistance, with specific focus on determining whether the relationships of NEFA and DMI could be modulated during the transition period. Initial research conducted in our lab (Smith, 2004) suggested that adipose tissue in periparturient dairy cows actually may be more refractory to insulin during the prepartum period than during the postpartum period. Subsequent work also generally supported the concept that insulin resistance may be greater during the prepartum period than the postpartum period (Smith et al., 2006).

As a result of this work and other circumstantial evidence that accentuated insulin resistance during the prepartum period contributes to lower peripartal DMI, elevated NEFA concentrations, and increased body condition score (BCS) loss during early lactation, we wanted to determine whether specific modulation of insulin resistance in adipose tissue during the prepartum period would decrease NEFA mobilization and change the patterns of DMI and NEFA during the transition period. Using an experimental approach, we administered compounds (thiazolidinediones; TZD) analogous to those used to treat Type II diabetes in humans to dairy cows during the prepartum period. In the first study, TZD administration tended to decrease circulating concentrations of NEFA and tended to increase DMI during the period from 7 days before calving until 7 days after calving (Smith et al., 2007). Importantly, TZD administration did not appear to interfere with the glucose sparing by peripheral tissues that is important for support of pregnancy and lactation.

In a second study (Smith et al., 2009) conducted using larger numbers of cows, we replicated the results of the first experiment in that TZD administration during the prepartum period decreased circulating NEFA concentrations and increased DMI during the immediate pre- and postpartum periods. In addition, TZD administration improved postpartum energy balance, decreased BCS loss, and decreased days to first ovulation in treated cows. These results suggested that specific modulation of insulin resistance in adipose tissue could have very positive effects on metabolic changes during the transition period and have substantial carryover effects on the dynamics of metabolism and performance during early lactation. It should be noted that this work was conducted as proof of concept relative to the mechanisms of metabolic regulation; TZD currently is not available in a form that can be used practically in the dairy industry and would require regulatory approval before such use.

Nutritional Management and Its Relationship to Insulin Resistance and Metabolic Health

Although modulation of insulin resistance using pharmaceutical approaches is intriguing, it causes us to ask questions regarding which aspects of nutritional management may influence insulin resistance. During the past few years, energy nutrition of cows during the dry period has received substantial renewed attention (Drackley and Janovick-Guretzky, 2007) and an increasing body of information suggests that energy nutrition may interact with insulin resistance during the late prepartum period.

For many years, the emphasis of researchers and industry professionals was to maximize DMI in order to ensure that cows consumed enough energy during the dry period. This strategy was supported in part by research that demonstrated that cows with lower NEFA concentrations during the last two weeks before calving on commercial dairy farms had decreased incidence of most postcalving metabolic disorders (displaced abomasum, ketosis, retained placenta, mastitis; Dyk, 1995). Given that higher DMI typically results in lower circulating NEFA, the association between higher DMI and improved health and performance was implied. Our experience would suggest that many farms indeed had improved health and performance when management changes were implemented that increased DMI of cows, particularly during the close-up period.

On the other hand, increasing evidence suggests that plane of nutrition, in particular energy intake during the prepartum period, modulates the degree of insulin resistance and hence the relationships between NEFA and DMI during the immediate peripartal period. Mashek and Grummer (2003) reported that cows that had larger decreases in DMI during the prepartum period, generally because of higher DMI during weeks 3 and 4 before calving, had higher concentrations of plasma NEFA and liver triglycerides during the postpartum period. More direct experimental evidence was provided by Douglas et al. (2006), who reported that cows fed at 80% of calculated energy requirements for the entire dry period had lower NEFA concentrations during the postpartum period, lower concentrations of both circulating glucose and insulin during the prepartum period, and higher DMI during the postpartum period than cows consuming 160% of predicted energy requirements throughout the dry period. Similarly, Holcomb et al. (2001) reported that cows subjected to feed restriction during the late prepartum period had blunted NEFA curves during the periparturient period. In addition, Holtenius et al. (2003) determined that cows that were dramatically overfed (178% of calculated energy requirements) for the last 8 weeks before calving had higher concentrations of insulin and glucose during the prepartum period, greater insulin responses to glucose challenge during the prepartum period, and higher concentrations of circulating NEFA during the postpartum period than cows fed for 75 or 110% of calculated energy requirements. Furthermore, Agenas et al. (2003) reported that the same cows fed for 178% of calculated energy requirements prepartum had lower DMI and prolonged negative energy balance during the postpartum period compared with cows assigned to the other two prepartum treatments. Recently, Dann et al. (2006) demonstrated that overfeeding (150% of calculated energy requirements) during the far-off period may have exacerbated insulin resistance as cows approached calving, resulting in higher NEFA and BHBA and lower DMI and energy balance during the first 10 days postcalving.

This knowledge has led to an evolution in recommendations for energy nutrition of dairy cows during both the far-off and close-up periods during the past several years, with the goal of meeting, but not dramatically exceeding, energy requirements. My target range for both the far-off and close-up periods is between 110 and 120% of energy requirements. In practice, this can be achieved by formulating diets during the far-off period to contain no more than 0.59 to 0.63 Mcal/lb of NEL in order to achieve the target NEL intake of approximately 15 to 17 Mcal for Holsteins during this timeframe. During the close-up period, conventional recommendations as described above have been to maximize DMI, and hence energy intake. Although this still applies in many herd situations, we believe that some well-managed herds in which close-up cows consume large amounts of feed (> 31 to 32 lbs/day of dry matter in comingled cow/springing heifer groups) have increased rates of metabolic disorders because of excessive energy intake during the close-up period. Accordingly, some of these herds have had success in moderating energy intake during the close-up period in group-feeding situations by incorporating straw or other low potassium, low energy forage to lower overall dietary energy concentration. Our recommendations would be to formulate the close-up diet at approximately 0.64 to 0.66 Mcal/lb of NEL if the group is a commingled cow/heifer group and approximately 0.61 to 0.63 Mcal/lb of NEL if the group is composed of mature animals and DMI is high. This lower energy diet also can be an acceptable one-group dry cow approach if overall herd management dictates such an approach. Diets formulated in these ranges will help to ensure adequate, but not excessive energy intake within the dynamics of group-feeding and competition among animals.

Diets formulated using a combination of corn silage and straw to form the forage component of the diet typically can have between 5 to 10 lbs of chopped straw, making feeding management a critical component of implementation of bulky, low energy dry cow diets. As described by Drackley (2007), the three key components of this implementation are 1) prevention of sorting, 2) ensuring continuous and non-crowded access to the TMR, and 3) careful monitoring of dry matter content and attention to detail. Most of these diets will contain added water in order to aid with prevention of sorting. A final point relative to these types of diets is that it is important to account for the metabolizable protein requirements of the cow during late pregnancy. These diets typically contain lower amounts of ruminally fermentable carbohydrate than those that have been typically fed for the last ten to fifteen years, and therefore will supply less metabolizable protein from ruminal bacteria. Inclusion of rumen-undegradable protein sources to result in total metabolizable protein supply in the range of 1,100 to 1,200 g/d is critical for early lactation performance and overall success. Furthermore, in anecdotal cases where these diets have been linked with lower milk yield during early lactation, I speculate that energy intake may have been pushed too low, especially during the close-up period.

Environmental Factors and Role in Intake Regulation

In addition to factors related to nutritional management and diet formulation, there are clearly effects of facilities and other environmental factors on DMI, and likely cow to cow variation in DMI in particular. Cook and Nordlund (2004 and updated proceedings papers since) clearly outlined considerations for managing stocking density, pen moves, and other facility considerations for transition cow housing and management. In addition, heat stress abatement and commingling of cows and heifers are other key facility and management factors that affect DMI and transition period outcomes.

Cook and Nordlund (2004 and subsequent) base much of their key recommendations (e.g., 30" of feed bunk space per animal, favoring very short stays in maternity pens, all-in all-out management of prefresh pens) on effects on DMI. Some of these effects may be direct as a result of feed access and others may be mediated by aspects of stress physiology and how they influence the metabolism described in the first part of this paper.

Recently, we (Huzzey and Overton, 2010) described a study in which we evaluated the effects of overstocking (200% vs 100% stocking of feedbunk and stalls) on feeding behavior, aspects of stress physiology, and metabolism of dry cows. Despite marked changes in feeding pattern, average feeding time per animal was nearly identical between the two groups and average pen DMI was actually increased in the overstocked group (~ 33 lbs of DMI vs. 31 lbs DMI). Consistent with other research evaluating stocking density effects on feeding behavior, rates of feed intake were higher in the overstocked group. Despite higher DMI, the overstocked group of cows had higher NEFA and tended to have elevated concentrations of cortisol breakdown metabolites in feces, indicative of a role of stress physiology in cow responses to treatment. In addition to the overall effects on the group, the heifers that were commingled with the older cows clearly were impacted to a greater extent by the increased stocking density. This notion would be consistent with that of Cook and Nordlund (2004), who postulated that the effects of facilities and environment are not equal across all animals, rather they have greater impact on compromised animals or those of lower rank within the groups.

Monitoring Cow to Cow Variation in Dry Matter Intake and Metabolism on Farms

One of the challenges of monitoring opportunities for improved nutritional management and especially those related to grouping management and other nonnutritional factors is that they cause increased variation in DMI and performance, and these are very difficult to impossible to detect in pen averages. We believe that the use of some of the blood-based markers of energy metabolism (e.g., prepartum NEFA; postpartum NEFA and beta-hydroxybutyrate; BHB) provide us with opportunities to assess energy issues in transition cows. Data from a large commercial farm study that we conducted (Ospina et al., 2010) indicated that herds with more than 15% of cows over 0.3 mM NEFA prepartum, 0.7 mM NEFA postpartum, or 12 mg/dL of BHB) were at risk for higher disease, poorer reproductive performance, and in particular decreased milk yield (Table 1). Variation in plasma NEFA may be a good proxy for variation in DMI within both prefresh and fresh groups.

Table 1. Herd-level impacts of elevated prepartum and postpartum NEFA and postpartum BHB in commercial dairy farms (Ospina et al., 2010)

Metabolite level	Herd alarm	Herd-level impact
Prepartum NEFA (14 to 2 d precalving) > 0.3 mM	> 15%	- 1.2% 21-d pregnancy rate + 1.4% disease incidence - 529 lbs ME305 milk
Postpartum NEFA (3 to 14 d postcalving) > 0.6 (heifers) – 0.7 (cows) mM	> 15%	- 1.3% 21-d pregnancy rate + 1.3% disease incidence Heifers: - 640 lbs ME305 milk Cows: -1,272 lbs ME 305 milk
Postpartum BHB (3 to 14 d postcalving) > 10 (cows) – 12 (heifers) mg/dL	> 15% > 20%*	- 1.3% 21-d pregnancy rate + 1.3% disease incidence *Heifers: - 1,179 lbs ME305 milk Cows: -732 lbs ME 305 milk

15% of 15 animals sampled= 2 to 3 animals over threshold; 90% confidence interval that it sample represents herd prevalence

Table 2 describes three possible outcomes and potential interpretations for a herd to consider after NEFA and/or BHB evaluation in prefresh and fresh groups. Whenever NEFA are elevated in prefresh cows, it is generally a good signal that either energy intake as a whole is inadequate or facility/management issues exist and are causing significant cow to cow variation in DMI and hence metabolite concentrations. Independent of postpartum analyte values, we associate elevated precalving NEFA with negative disease, reproductive, and production outcomes (Table 1). The most likely metabolite pattern for a herd that is overfeeding energy either far-off or close-up is low NEFA values precalving but high NEFA and/or BHB values postcalving. Herds and consultants should remember, however, that a number of factors specific to either nutritional management or facility/grouping management also can elevate postpartum concentrations of NEFA and/or BHB independent of precalving values. Typically, when herds are overfed either far-off or close-up I see quite rapid and marked loss of BCS in the fresh cows as another observation – plasma NEFA testing in the fresh cows can help to confirm this.

Table 2. Interpretation of energy-related metabolites to assess herd-level opportunities

Scenario	Likely cause and possibilities
High prepartum NEFA High postpartum NEFA and/or BHB	Likely starting with low DMI in close-up cows Too low energy in prefresh diet, facility and/or management issues (grouping, stocking density, heat stress?)
High prepartum NEFA Low postpartum NEFA and/or BHB	Low DMI in close-up cows Sampling the survivors in the fresh pen? Is herd outmanaging or putting band-aids on fresh cow issues?
Low prepartum NEFA High postpartum NEFA and/or BHB	Is herd overfeeding energy either far-off or close-up? Diet or facility/management issues specific to maternity/fresh group

Summary and Conclusions

Success in transition cow programs depends upon excellent management in a number of different areas to optimize energy intake and minimize variation in DMI during the far-off and close-up periods. Our understanding of the metabolic regulation underpinning the changes that occur in energy metabolism of cows during the transition period is increasing, and with this understanding has come new potential opportunities for enhancing transition cow health and performance. Controlling energy intake of cows during the prepartum period (both far-off and close-up) is an important factor in nutritional management of transition cows. In addition, management of nonnutritional factors (stocking density, grouping management, environmental control) is critical as a complement to dietary strategies for transition period success. Blood-based analytical strategies to allow herds and their consultants to assess variation in energy status in cows during both the prepartum and postpartum periods are readily available – interestingly, it appears that the major herd-level impact associated with variation in these markers is milk yield and reproduction rather than disease, which challenges the paradigm in which these analytes typically have been used in herd-level assessment.

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Connecting Transition Cow Physiology, Behavior, and Nutrition

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Introduction

In the past, efforts to improve the transition to lactation have focused largely on preventing infections and maximizing energy intake in transition cows, and these have generally been treated as independent issues. However, new models are emerging to explain the development of numerous transition disorders. A combination of insults, including social stress, negative energy balance, heat stress, endotoxin exposure, and oxidative stress may promote inflammation, suppress feed intake, and impair both metabolic and immune function during the transition period. These models suggest that transition cow management must be viewed in a holistic way, with the cow's environment, nutrition, and immune function interacting in many complex ways. Fortunately, a number of practical approaches can be used to improve the overall health of transition cows, which can decrease the cull rate in early lactation and improve both productivity and reproductive success.

The Biology of the Transition Dairy Cow

A number of dramatic changes occur in the dairy cow during the transition period. Dairy cattle, like many other species, often consume less feed in the week prior to parturition (Grummer et al., 2004), and it can take up to a week post-calving before dry matter intake (**DMI**) exceeds what the cow was consuming in late gestation. In the final 24 hours before calving, cows typically separate themselves from other cows to the extent possible, and it is not surprising that DMI is low during this short period. However, the extended period of low DMI experienced by many cows is more difficult to explain and it is far more problematic for the cow as her nutrient requirements rise rapidly at the onset of lactation.

The drive to produce milk is given priority over nearly all other physiological processes during this time, and a number of changes occur to partition nutrients to the mammary gland. Negative energy balance and homeorhetic adaptations during the transition to lactation decrease plasma insulin concentration substantially (Doepel et al., 2002) and also decrease the responsiveness of adipose tissue to insulin (Bell and Bauman, 1997). These adaptations lead to dramatic increases in plasma non-esterified fatty acid (**NEFA**) concentration, and this also leads to greater uptake of fatty acids by the liver. This increase in fatty acid supply to the liver often exceeds the capacity for oxidation, resulting in both ketone body production and storage of triglycerides (Drackley et al., 2001). This process can occur quite rapidly, and cows can develop moderate fatty liver and ketosis in the course of just a few days.

Increased liver glucose production is another adaptation to lactation. Meeting the increased demand for glucose during the transition period is especially challenging, because little glucose is absorbed from the ruminant gastrointestinal tract. Over the course of the first 2 months of lactation, liver glucose production increases by at least 2-fold (Schulze et al., 1991), and most of this change likely occurs within a week after calving. Several studies have found decreased capacity for gluconeogenesis in liver slices from cows with fatty liver (Mills et al., 1986, Veenhuizen et al., 1991), and others have shown that induced fatty liver results in decreased activities of several rate-determining gluconeogenic enzymes (Rukkwamsuk et al., 1999, Murondoti et al., 2004). The ability of a cow to successfully up-regulate gluconeogenesis in early lactation is critical to both avoid metabolic problems (e.g. ketosis) and to maximize peak milk production, and the negative effect of fatty liver on gluconeogenesis is one reason that this condition is of concern.

The large increase in calcium requirements also strains the regulatory mechanisms of the transition cow. Calcium requirements can increase by more than 3-fold on the very first day of lactation, and this drain continues as milk yield increases much more rapidly than DMI (Horst et al., 2005). As a result, cows selected for high milk yield will nearly always experience some decrease in available (ionized) blood calcium during the first week of lactation. Although the adoption of anionic prepartum diets has been quite successful at reducing the incidence of milk fever, subclinical hypocalcemia can occur even with careful management of dietary cation-anion difference (**DCAD**; Moore et al., 2000).

Another key component of transition cow biology is the decrease in immune function throughout the 6-week transition period. Components of both the innate and adaptive immune systems appear to be affected during this period, and have been measured as decreased function of monocytes (Nonnecke et al., 2003), lymphocytes, and neutrophils (Mallard et al., 1998). In contrast, however, monocytes response to stimulation with greater release of inflammatory cytokines such as tumor necrosis factor α (**TNFα**) during this period (Sordillo et al., 1995). It is believed that the general decrease in immune function during the transition period contributes to the high incidence of infectious disorders at this time (i.e. mastitis, metritis), and there is growing interest in the potential effects of inflammation during this period as well.

Physiological Interactions in the Transition Cow

Traditionally, experts on dairy cattle have focused on isolated components of dairy management: nutritionists worked on diets, veterinarians responded to disease outbreaks, and others were called upon to design facilities to maximize cow comfort. What we are learning today is how much nutrition, pathogens, and environmental challenges interact to influence the physiology of the cow.

One such interaction is the effect of energy balance on immune function. Nearly all transition cows experience at least 3 weeks of negative energy balance, a situation in which they require more energy for maintenance and milk production than is consumed from the diet. One response to this nutrient imbalance is rapid mobilization of adipose tissue triglyceride, resulting in elevation of plasma NEFA concentrations by as much as 10-fold (Ingvartsen and Andersen, 2000). Greatly elevated concentrations of NEFA often result in significant conversion of NEFA to ketones (e.g. BHBA) in the liver. Recent work has demonstrated that elevated NEFA concentrations may directly impair neutrophil viability (Scalia et al., 2006) and high BHBA concentrations can decrease neutrophil function (Grinberg et al., 2008). These relationships may help to explain at least some of the decrease in immune function during this time of negative energy balance.

Another common nutrition-related issue discussed above is the subclinical hypocalcemia that occurs in most transition cows. This issue is most commonly discussed in terms of the risk for milk fever; hypocalcemia can cause paresis because of the critical role of calcium in initiating muscle contractions and in transmission of nerve signals. However, calcium is an important signal transducer in many other cell types, including immune cells. It was demonstrated that monocytes from cows experiencing hypocalcemia had low intracellular calcium stores and did not mobilize calcium to the same extent in response to stimulation (Kimura et al., 2006). An inability of monocytes to mobilize intracellular calcium after being stimulated would be expected to dampen functional responses such as cytokine release and cell proliferation. Such findings may provide a physiological basis for the long-observed links between hypocalcemia and mastitis in transition cows (Curtis et al., 1985).

These are examples of findings that are shedding light on why nutritional deficiencies and metabolic disorders can depress immune function and promote infectious disorders in the transition period. In fact, decreased feed intake was observed before calving in cows that ended up with subclinical ketosis or metritis after calving (Huzzey et al., 2007, Goldhawk et al., 2009), suggesting that behavioral changes and nutrient imbalances can precede key transition problems by days, if not weeks. Another line of work is focusing on the other side of this relationship – why biological stressors promote metabolic problems.

Stress, Sources of Stress, and the Consequences

Stress is a term that is widely used but rarely defined in discussions about animal agriculture. For the purposes of this discussion, I will refer to the original definition by Hans Seyle in 1936 of biological stress as "the non-specific response of the body to any demand for change". Note that this definition does not necessarily imply that stress is a negative thing; in fact, some components of the transition to lactation are certainly stressful by this definition. Furthermore, it is worth considering the "non-specific" nature of this definition. For example, the endocrinology of a cow entering lactation directs a number of specific metabolic changes that have collectively been described as an example of homeorhesis (Bauman and Currie, 1980), which are not themselves stress responses because they are programmed changes that accompany the initiation of lactation. Likewise, a cow suffering from *E. coli*-induced mastitis is expected to mount a specific response to the pathogen (i.e. antibody production and targeted phagocytosis) which is not necessarily considered stress. On the other hand, the innate immune system also responds by releasing a number of *non-specific* factors such as prostaglandins and inflammatory cytokines which make the infection a source of systemic stress for the cow. Again, this is not to imply that the stress is necessarily negative, because these non-specific factors can also play a critical role in fighting the infection.

Although stress is difficult to clearly define and impossible to measure directly, it is worth considering because it is one way in which we can understand the intricate links between behavior, nutrition, and physiology. Common stress responses include decreased feed intake and inflammation, both of which have been implicated in most transition disorders. I will discuss social stress, infection, metabolic stress, and heat stress as key sources of stress in the transition cow.

Social Stress. The best-studied source of social stress in transition cows is overcrowding. Competition at the feedbunk has been shown to decrease DMI of multiparous cows in the critical final week of gestation (Proudfoot et al., 2009), in spite of the fact that cows in this stage of production eat less than half as much dry matter as cows at peak lactation. Cows competing for access to feed also spent more time standing, and time spent standing during the transition period has recently been documented as a key risk factor for the diagnosis of claw horn lesions later in lactation (Proudfoot et al., 2010). Finally, feedbunk competition also results in cows consuming fewer and larger meals (Hosseinkhani et al., 2008), which could increase the risk for ruminal acidosis, at least after the transition to a lactation ration. Although few controlled studies have been conducted to evaluate the effects of re-grouping cows, anecdotal evidence suggests that repeated re-grouping of cows can induce similar stress and may likewise suppress feed intake and promote lameness.

Infection. Infectious disorders, as described above, cause both specific and non-specific responses. Among the most important stress responses to infection is inflammation. The host of signaling molecules released by activated immune cells includes inflammatory mediators such as nitric oxide, prostaglandins, and cytokines. While many of these molecules promote local inflammation and increased blood flow to the infected tissue, inflammatory cytokines play a key role in stimulating systemic inflammatory responses, including increased body temperature, increased heart rate, and decreased feed intake (Dantzer and Kelley, 2007). Cytokines are able to alter many physiological systems because nearly all cell types express cytokine receptors. One effect of cytokines is to activate production of acute phase proteins such as haptoglobin and serum amyloid A, primarily produced by the liver. Proteins that participate in the acute phase response are generally found in very low abundance in the bloodstream, but are greatly elevated during systemic activation of the immune system.

It is clear that mammary and uterine infections result in both local and systemic inflammation. Coliform mastitis results in release of endotoxin into the bloodstream and increased plasma concentrations of cytokines and acute phase proteins (Hoeben et al., 2000). Likewise, metritis is associated with an acute phase response in transition cows (Huzzey et al., 2009); in fact, plasma haptoglobin is elevated prior to clinical signs of metritis. These non-specific inflammatory stress responses to infection promote the development of metabolic disorders by suppressing feeding behavior, and they may also directly impair metabolic function by altering gene expression in the liver.

Metabolic Stress. Inflammation has been proposed as a missing link in the pathology of metabolic disorders in transition cows (Drackley, 1999), and recent findings have indeed documented relationships between inflammatory mediators and metabolic disorders. Plasma concentrations of haptoglobin and serum amyloid A were increased in cows that developed fatty liver (Ametaj et al., 2005), and Ohtsuka and colleagues (2001) observed increased serum TNFα activity in cows with moderate to severe fatty liver. A retrospective study of cows on 3 commercial Italian dairies suggested that liver inflammation is associated with a problematic transition to lactation (Bertoni et al., 2008). Cows were classified in quartiles for degree of liver inflammation based on plasma concentrations of acute phase proteins. Those cows with the strongest inflammatory profiles were at 8-fold greater risk for experiencing one or more transition disorders, had lower plasma calcium concentrations, took longer to re-breed, and produced less milk in the first month of lactation (Bertoni et al., 2008). These correlations have driven strong interest in potential mechanisms underlying an inflammation-based pathogenesis of transition cow disorders.

Metabolic stress can be initiated by a variety of factors, including inflammation derived from infection (discussed above), oxidative stress, and translocation of endotoxin from the gut. Oxidative stress in transition cows is likely driven by lipid peroxides, which are produced when intracellular lipids encounter reactive oxygen species (**ROS**) such as hydrogen peroxide. Some ROS are always produced in the liver; however, events occurring in early lactation likely contribute to enhanced ROS production. One adaptation to increasing delivery of NEFA to the liver in early lactation is an increase in the capacity of peroxisomal oxidation (Grum et al., 1996), an alternative pathway for fatty acid oxidation. Enhanced peroxisomal oxidation increases total oxidative capacity of the hepatocyte, but the first step in this pathway produces hydrogen peroxide (Drackley, 1999), and therefore it contributes to ROS production to a greater extent than mitochondrial oxidation. Increased ROS production in early lactation cows, coupled with increased NEFA concentration, increases lipid peroxide formation. This is especially true for cows with excessive adipose tissue stores, likely because plasma NEFA concentrations are elevated to a greater extent in these cows. As a result, both the transition to lactation and high body condition are associated with increased plasma markers of lipid peroxidation (Bernabucci et al., 2005). Lipid peroxides are of concern because, like other ROS, they can damage cellular proteins and DNA and are potent activators of inflammatory pathways, inducing many of the same cellular responses as inflammatory cytokines (Pessayre et al., 2004).

Endotoxin is a component of the cell wall of Gram-negative bacteria, and detection of endotoxin by immune cells initiates a strong inflammatory response. It has long been debated whether acidosis promotes release and translocation of endotoxin from the rumen and into the bloodstream. Khafipour et al. (2009) nicely demonstrated that induction of sub-acute ruminal acidosis increased both ruminal and plasma endotoxin concentrations. This treatment also significantly elevated plasma concentrations of acute-phase proteins, indicating that the elevation was adequate to stimulate inflammation in the liver.

Metabolic inflammation can therefore be derived from at least 3 sources: infection, oxidative stress, and endotoxin translocated from the gut. What are the consequences of such inflammation? In 2 recent studies, inflammatory mediators directly induced metabolic problems. Trevisi and colleagues (2009) orally administered interferon-α (a cytokine) daily during the final 2 weeks of gestation, which caused liver inflammation and release of acute phase proteins. Compared to control cows, treated cows had significantly higher plasma ketone concentrations in the first 2 weeks after calving. Our own lab recently reported that subcutaneous injection of TNFα for 7 days doubled liver triglyceride content in late-lactation dairy cows (Bradford et al., 2009). We also observed changes in mRNA abundance consistent with transcriptionally-mediated increases in fatty acid uptake and esterification and decreased fatty acid oxidation. These results strongly support the hypothesis that inflammation disrupts normal metabolism, because although both of the above treatments were considered low-dose and short-term, they nevertheless promoted ketosis and fatty liver, respectively.

In addition to promoting metabolic disorders by stimulating inflammation, oxidative stress can directly suppress immune function by damaging lipids, proteins, and DNA of immune cells (along with other cell types). Oxidative stress may, in fact, play a key role in the immunosuppression observed in transition cows, a hypothesis that is support by numerous studies demonstrating beneficial effects of supplementing antioxidants in the transition period (Sordillo and Aitken, 2009). On the other hand, it must be cautioned that excessive supply of antioxidants can also cause oxidative stress and may actually impair immune function (Bouwstra et al., 2010).

Heat Stress. Another common stressor for transition cows is excessive heat load. Many operations that have become accustomed to cooling lactating animals, either because of the logic that these cows have the highest heat burden or because of the fact that the benefits of cooling lactating cows are so easy to observe in daily milk weights during heat waves. However, the stress of such environments on dry cows has not received as much attention. Recent work showed that heat stress during the dry period decreased DMI during the week of calving by nearly 50%, decreased neutrophil function after calving, and decreased peak milk production by more than 10 lbs/day (do Amaral et al., 2011). Although the exact mechanisms linking heat stress to these long-term effects remain unclear, what is clear is that there are substantial costs associated with allowing dry cows to experience sustained heat stress.

Cause-and-Effect?

One frustrating aspect of transition cow biology is the continual question of which observations are causes and which are effects. For example, a cow with ketosis nearly always presents with high plasma NEFA and BHBA concentrations, low feed intake, and some degree of fatty liver. One could presume that something caused her to eat poorly, leading to mobilization of NEFA from adipose tissue, accumulation of fat in the liver, and ketone production. However, there is also evidence that NEFA (Allen et al., 2009) and/or BHBA (Rossi et al., 2000) can directly suppress feed intake, or perhaps feed intake was suppressed because of an inflammatory response associated with the liver fat accumulation. These scenarios would suggest that excessive lipolysis could be the root cause of the problem. In many such situations, all of the issues arise almost simultaneously, making it nearly impossible to use time courses to point to a single cause.

Numerous labs are investigating transition cow problems with the goal of identifying the initial insults that lead to disease. However, it is also worthwhile to remember that positive feedback loops are a hallmark of most disease states, including these conditions. For example, in a cow that moves through the transition period successfully, plasma NEFA concentration rises, but those NEFA are largely oxidized in the liver, driving glucose production, which fairly quickly provides negative feedback on lipolysis and the NEFA concentration begins to drop again. In this scenario, a state of relative homeostasis is recovered. However, in a cow that suffers from the fatty liver/ketosis complex, NEFA is elevated to a greater extent, lipids are not completely oxidized in the liver and begin to accumulate, leading to an inhibition of glucose production. The resulting hypoglycemia further stimulates lipolysis and ketogenesis, and somewhere in this progression, feed intake begins to drop as well. This exacerbates the negative energy balance and further decreases glucose production by limiting the supply of glucose precursors, which again results in even greater stimulation of adipose tissue mobilization. This vicious cycle, or positive feedback loop, is what drives the cow into a clinical disorder. With these types of feedback loops operating, it can be quite difficult to identify a true cause of a disorder; perhaps in most cases, the problem arose because of several suboptimal conditions rather than one obvious problem. On the bright side, this reality also means that interventions do not always have to be perfectly targeted at the root cause of a problem to help resolve it.

Practical Implications

These findings suggest a number of focus areas for dairy managers aiming for a holistic management scheme to accommodate the complex nutritional, environmental, and behavioral needs of the transition dairy cow.

Housing. The clear implication of recent findings from the group at the University of British Columbia is that it is a mistake to overcrowd dry cows. During the financial difficulties of the past several years, numerous stories have circulated about farms decreasing stocking rates of lactating cows from 120% to 100% without losing milk in the bulk tank. Perhaps this is reminder about the importance of adequate space (both in free stalls and bunk line), and if anything, the literature suggests that this is even more critical in the dry period. Behavioral responses to overstocking are expected to lead to greater lameness, more negative energy balance, and an increase in all of the transition disorders that are associated with these issues. With the recent findings from the University of Florida, similar negative effects can be expected in cows that are exposed to heat stress through the dry period. Providing adequate space and keeping cows cool should be high priorities in any dry cow management plan.

Another factor worth considering is the grouping of cows. For many years, it was recommended that dry cows be managed in separate far-off and close-up pens to allow for different diets to be fed during these periods. However, with the information now available on one-group dry cow strategies (see below), this is no longer necessary. According to some, the reduced stress of not having to move cows an extra time is reason enough to make the change to a one-group dry cow system. When considering grouping strategies for dry cows, realize that subordinate cows are the most susceptible to social stress; these are the cows who are bullied away from the feedbunk, eat less feed, and spend more time standing when overcrowded. As a result, these cows are the most susceptible to transition disorders if not properly managed. If possible, it is wise to pen close-up heifers separate from dry cows, and subordinate cows (small or simply submissive cows) can be housed with heifers if necessary. Finally, remember that pen movements do not just affect the cow that is moving, but the entire group. As a result, even if a single pen is used to house all dry cows on a farm, the weekly influx of new cows constantly disrupts the social structure in the pen and serves as a potential source of stress. While certainly not practical on all farms, some larger operations are experimenting with “all-in, all-out” management schemes, where a group of dry cows all enter the pen together and will end up in a fresh cow pen together once all have calved. This type of system has the potential to minimize the amount of social stress for transition cows.

Nutrition. The primary goal in transition cow nutrition has been crystallized in the past decade: control body condition. No other factor that we can measure is a better predictor of a disastrous transition period than a BCS of 4 or greater. In fact, most academics who focus on metabolic disorders during this period would now advocate a target BCS of 3 or even less at calving, because the consequences of high BCS have proven to be far more serious than the consequences of low BCS (Garnsworthy and Topps, 1982). Cows suffering from “fat cow syndrome”, despite having more stored energy to help offset negative energy balance, experience greater decreases in DMI than healthy cows, have greater increases in plasma NEFA, and are far more likely to have clinical cases of ketosis and even infectious disorders. In my opinion, this goal is best met by feeding relatively low-energy diets throughout the dry period (Drackley and Janovick Guretzky, 2007), although a wide variety of formulations can potentially be used to accomplish this. The devil, of course, is in the details: preventing excessive sorting, promoting sufficient DMI to meet energy requirements, and balancing for DCAD.

As is the case for social stress, nutritional needs of close-up heifers can be best met by housing them separately. Because these heifers are still growing and because they are less susceptible to fat cow syndrome, it is probably logical to offer them a slightly higher-energy diet than multiparous cows. Likewise, anionic diets that benefit multiparous transition cows have been observed to dramatically decrease DMI of heifers (Moore et al., 2000). Heifers rarely experience severe hypocalcemia anyway, so it is best if they are fed diets without added sources of anions.

Disease Prevention. The immunosuppression that cows experience during the transition period suggests several management strategies that may help to limit disease pressure and associated stress during this time. Clearly, dairies are interested in reducing pathogen loads for all cows. However, if there is an opportunity to improve the cleanliness of certain pens, it would be wise to invest that effort in the fresh pens, since this is where the majority of mastitis and metritis cases occur. Additionally, vaccination protocols should be designed to avoid vaccinating cows during the final 3 weeks of gestation, as the decreased function of the adaptive immune system during this period would limit the effectiveness of vaccines (Mallard et al., 1998) and produce potentially harmful inflammation during a critical time.

Conclusions

Even on farms with relatively low incidence rates of transition cow disorders, suboptimal social settings, environmental conditions, feed intake, metabolic status, or immune function may impair the ability of transition cows to reach their genetic potential for peak milk yield, resulting in significant economic losses over the lactation. While the mechanisms underlying some of these interactions remain elusive, there are some clear messages that stand out from recent research.

- Transition cows need adequate bunk and stall space, and heat stress during this period has long-term negative effects.

- Separating heifers from dry cows and minimizing group changes during the transition period allows for improved nutritional management and decreased social stress.

- Because of the numerous interactions between different physiological systems, improving feed intake after calving, improving metabolic function, or decreasing infections should all have beneficial effects on the other factors and ultimately increase health and productivity.

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Managing Variability in Feed Ingredients and Feed Delivery

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The impact of the feeding program on financial success of the dairy herd will likely increase in the future. Increased feed prices demand more efficient utilization of both forage and supplemental concentrate resources. Additionally, environmental pressures provide incentives to reduce overfeeding of nitrogen and phosphorus to reduce these nutrients leaving the farm. Under these conditions, improved feeding management on the farm results in a win: win scenario where reductions in overfeeding can enable dairy producers to be better stewards of the environment.

Improved feeding management is the result of science and application of these new tools. Research has resulted in the development of nutritional models which enable us to meet the nutrient requirements of the lactating dairy cattle with tremendous accuracy. Historically, most dairy cattle rations have incorporated larger margins of safety to assure that maximum milk yield was obtained. These new models describe the factors influencing milk yield more accurately and enable reductions in the concentration of nutrients in many dairy cattle diets. A recently completed study of Virginia dairy herds adopting the use feed management software found that more accurate feeding resulted in improved whole farm nutrient balance for nitrogen and reductions in the levels of phosphorus in diets by 19%. This study also revealed considerable challenges in the feeding management and a disconnect between the diet formulated by the nutritionists and its implementation by the feeder and subsequent consumption by the cow.

Ultimately, improved economic and nutritional efficiency is achieved when one achieves maximal utilization of nutrients delivered to the farm. Therefore the successful manager must achieve the following:

- Control shrink. Reduce losses of nutrients during harvest of forages, storage, feeding mixing and delivery.
- Maintain quality of the feed between storage and consumption by the cow.
- Accurately define the nutrient composition of ingredients used in the ration.
- Accurately estimate the digestibility of the nutrients consumed by dairy cattle.
- Transmit relevant information to the nutritionist on a timely basis to permit formulation of rations which promote high nutrient and economic efficiency.

- Monitor the mixing and delivery of rations to assure compliance with recommendations of the nutritionist.
- Monitoring animal performance and transmitting information to the nutritionist and management personnel.

This panel will feature three individuals from dairies located in the Southeast, High Plains and Pacific Northwest. Each manager has provided a perspective of their approach to feed management which has proved to be successful for their resources. Contact information and a brief synopsis of their operations follows:

Michael Pedreiro – Dairy Production Systems – High Springs, FL. Michael was raised on a dairy farm in the San Joaquin Valley in California. He has degrees from Modesto Jr. College and Cornell. Michael interned with Aurora Dairy while at Cornell and became Assistant Operations Manager with Aurora before assuming his current position as Executive Vice President and Chief Operating Officer for Dairy Production Systems (DPS) which has facilities in 5 southern states (TX, MS, GA & FL) with over 12,000 lactating dairy cattle. The focus for Michael's presentation will be on routine monitors and the use of owner created software which enables them to evaluate their feeding program and to make timely management decisions. Their operation is unique in that Michael is involved in management of feeding programs on five dairies in geographically different areas of the south. Key components of feed management at DPS are:

- Timely evaluation of forages and supplemental feeds
    - Dry matters on all forages (i.e. - corn silage, rye grass haylage, sorghum silage, coastal haylage) are measured in a microwave oven every Monday, Wednesday, and Friday.
    - Penn State Shaker Box particle analysis and dry matter check is conducted on all milking group TMR's (Fresh, High & Late Lactation) on Wednesday of each week.
    - These results are entered into the DPS feed module software and emailed once/week to the nutritionist and Michael along with daily dry matter intakes and % refusal for each pen.
    - Wet Forage samples are sent to Cumberland Valley Analytical Services Lab every month to be tested for ADF, NDF, NDF 30 hour digestibility, starch and 7 hour starch digestibility, and fermentation acids.
- A feed module spreadsheet developed by DPS management and their nutritionist in 1993 is used to enable them to track the following measures:
    - Dry matter intake by cow groupings
    - % refusal by cow groupings
    - Ingredient usage
    - Ingredient inventory

- Analyzed nutrient composition with expected nutrient composition of all forage and concentrate ingredients
- Pen counts
- Feeder load sheets for accuracy
- Feed costs on a per cwt of milk, per unit of dry matter basis as well as daily feed costs.

Contact Michael @ michaeal.pedreiro@dpsdairy.com

Kyle Averhoff – Royal Dairy – Garden City, KS. Kyle was raised on a 200 cow dairy in Stephenville, TX. He received his B.S. from Tarleton State and a M.S. degree from the University of Florida. Kyle spent three years with Monsanto Dairy Business working with producers in southern California and southwestern Kansas. He joined Royal Dairy as its manager in 2003. He works with 5 partners and key managers to develop and implement key areas of direction and focus for the dairy. Royal Dairy is a western style open lot dairy housing 6,300 milking animals and 7,000 heifers. They ship 13,000,000 lb. of milk monthly and employ 60 people. Currently average production is 74 lb. / cow with 120,000 SCC, and feed efficiency of 1.39. Annualized 21 day preg rate is 24%.

The herd is fed with 2 – 1400 Cu. Ft. vertical mixers. There are three feeder shifts from 4 AM TO 8 PM and 12 trained feeders. The Feed Watch system from Valley Ag Software is used. Feeding management at Royal Dairy is centered on a management philosophy emphasizing inventory and quality control, routine monitoring and hiring, training and retaining excellent people. Subjective evaluation and use of objective measures are used in all areas of feeding management. The biggest challenges at Royal Dairy are:

- Wind and moisture
- Changes in DM% of wet feeds
- Managing feed bunks around pen count changes.
- Improving Milk: Feed ratio.

Key components of inventory management involve weighing and recording all incoming forages and supplements and monitoring utilization through the Feed Watch program. This information is used to predict weekly as well as annual feed utilization. Deviations from expected utilization are cause for timely intervention. Inventories are evaluated weekly and orders made according to usage. Once a month inventories are reconciled between calculated inventories and amount on hand.

Quality control begins with maintaining feed quality by minimizing adverse effects of weather and feed handling to provide ingredients of predictable quality to the cows. Routine monitors involve the following:

- Daily feed area visits by managers in which bunks are scored for consistency of the mix as well as level of refusals.
- Dry matters are estimated for all wet feeds and forages twice weekly.
- Once weekly particle size is evaluated on silages and TMR's.
- Urine pH is evaluated on pre-fresh cows.
- Once monthly forages are sent off for evaluation
- TMR samples are routinely obtained for evaluation.
- Scales on TMR mixers are evaluated periodically.

Key features used from Feed Watch are:

- Inventory received and fed
- Global adjustment of TMR's when changes are detected in DM's of forages and wet byproducts.
- Daily estimates of pen or group dry matter intakes.
- Bunk management involving scheduling and routing of mixer trucks.

Key monthly goals for feed management are:

- Feeder loading accuracy
  - <4% of ingredients loaded beyond 200 lb. of target weight
- Grain Shrink
  - <2.5% / ingredient
  - Bagged ingredient usage reconciles within 1 ton of predicted usage.
- Forage shrink
  - Pit silos
    - As fed shrink of <9%
    - Shrink increases with storage time and moisture appreciation
  - Bags
    - As fed shrink of <8%
    - Greatly impacted by weather.
- Milk: Feed ratio of >1.39.

Contact Kyle at averhoff@ucom.net

Dick Bengen – Ruby Ridge Dairy – Pasco, WA. Dick is the owner and manager of Ruby Ridge Dairy located in south central Washington. The dairy originated in Whatcom County in northwestern Washington in 1967. Increasing urban development and the desire to expand resulted in moving the dairy to its current location in the early 2000's. The dairy houses over 2300 lactating dairy cattle and 2,100 heifers. It consists of 2200 acres of pivot irrigated land of which 1900 is used for production of corn silage, earlage and alfalfa. The first, 5th or 6th cuttings are harvested as haylage with the remainder as hay. Dick emphasizes the need to harvest forage of high quality and consistency. A 500 hp chopper and two 17 ton tractors are used to harvest and pack silage. Silos are capped every day with all spoilage removed. Silos are faced twice daily to provide fresh forage with minimal heating and losses from the silo face.

The move to a new location provided the Bengen's with an opportunity to design a feeding system which focused on insuring precision and accuracy in the ration delivered to all animals on the farm. This facility features a large stationary ration mixing facility with the potential to mix ten different milk cow rations three times daily, two dry cow rations twice daily and six different heifer rations fed once daily. The system can mix rations of varying batch sizes and is easy to operate. Key features of this system are:

- A 14 bay commodity shed with capacity to hold one rail car. There is a conveyor at the bottom of each bay leading to the central mixing facility
- Forages are moved from the bunker silos to the mixing facility using a forage box and yard goat tractor.
- All rations are mixed in the central mixing facility enabling close supervision by management.
- All conveyors for forages and supplemental feeds feature load cells which weigh ration ingredients prior to mixing.
- Mixed rations are delivered by boxes without scales.

Dick notes that this system has enabled them to:

- Reduce feed loading time by 60%
- Improve accuracy of mixed rations when compared to those specified by the nutritionist
- Reduce shrink to less than 2%
- Train employees more readily and successfully. Seven different people are involved in feed mixing and delivery. In most cases employees can be trained within 3 sessions.
- Improve ingredient management in that oldest feed is always fed first.

I would note that it is a challenge to visualize what the Bengen's have accomplished without observing the operation visually. Dick's presentation will feature many digital images of the feeding system.

Notes: