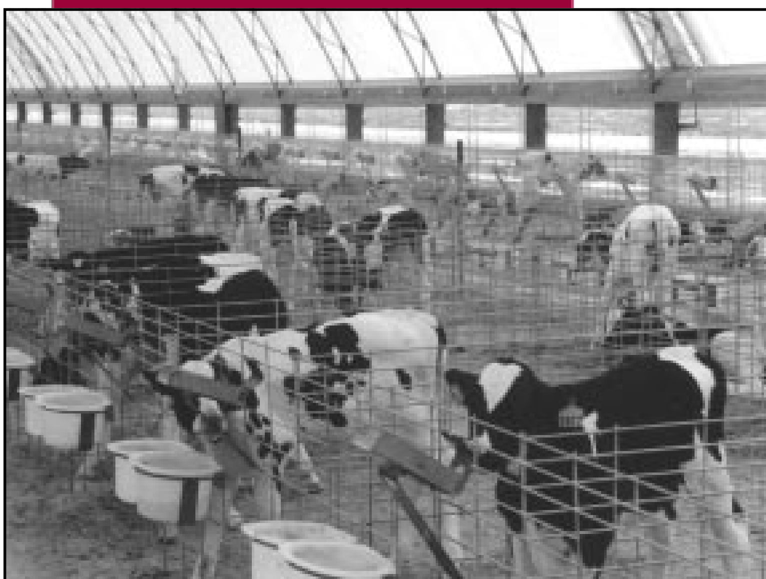
Proceedings of the

5th Western Dairy Management Conference




Las Vegas, Nevada

April 4–6, 2001

TENTATIVE

Western Dairy Management Schedule

Section A

WEDNESDAY

8:00	Welcome
8:10	Milking Parlor Performance
8:50	Benefits of Faster Milking—Shorter Milking Times
9:30	Water Use on Dairies—Amounts, Sizing System
10:10	Break
10:30	Lighting Freestalls for More Milk
11:10	Facilities for Special Needs and Labor Efficiency
11:50	Lunch
1:20	Waste Management Treatment Systems Impact on Nutrition
2:00	Flushing Sand-Laden Manure
2:40	Federal Manure Regulations *(with panel one hour)*
3:40	Break
4:00	Controlling Disease by Stopping it Before it Starts
4:40	Adjourn

THURSDAY

8:00	Getting the Most From Your Dairy Beef
8:40	Importance of Fiber in Lactating Diets
9:20	Environmental Impacts on Dry Matter Intakes
10:00	Break
10:30	Commodity Issues—QC, Shrink, Contamination, Facilities
11:10	Managing the Fresh Cow—Transition Cows
11:50	Lunch
1:30	Factors Influencing on Reproductive Efficiency
2:10	Techniques for Evaluating Reproductive Performance
2:50	Break
3:20	Accelerated Growth of Dairy Heifers
4:00	Cultural Effects on Personnel Performance
4:40	Adjourn

FRIDAY

9:00	Evaluating Nutrition Management Changes
9:40	Financial Benchmarks for Larger Dairies
10:20	Monitoring Herd Peformance—Case Study
11:00	Heat Stress Abatement in Four-Row Freestall Barns
12:00	Adjourn

Section B

WEDNESDAY

8:00	Welcome
8:10	Getting the Most from Your Dairy Beef
8:50	Importance of Fiber in Lactating Diets
9:30	Environmental Impacts on Dry Matter Intakes
10:10	Break
10:30	Commodity Issues—QC, Shrink, Contamination, Facilities
11:10	Managing the Fresh Cow—Transition Cows
11:50	Lunch
1:20	Milking Parlor Performance
2:00	Benefits of Faster Milking—Shorter Milking Times
2:40	Water Use on Dairies—Amounts, Sizing System
3:20	Break
3:40	Lighting Freestalls for More Milk
4:20	Facilities for Special Needs and Labor Efficiency
5:00	Adjourn

THURSDAY

8:00	Factors Influencing on Reproductive Efficiency
8:40	Techniques for Evaluating Reproductive Performance
9:20	Financial Benchmarks for Larger Dairies
10:00	Break
10:20	Evaluating Nutrition Management Changes
11:00	Heat Stress Abatement in Four-Row Freestall Barns
12:00	Lunch
1:30	Monitoring Herd Performance—Case Study
2:10	Cultural Effects on Personnal Performance
2:50	Break
3:20	Controlling Disease By Stopping it Before it Starts
4:00	Adjourn

FRIDAY

9:00	Accelerated Growth of Dairy Heifers
9:40	Waste Management Treatment Systems Impact on Nutrition
10:20	Flushing Sand-Laden Manure
11:00	Federal Manure Regulations *(with panel one hour)*
12:00	Adjourn

2001 Western Dairy Management Conference

Table of Contents

Sponsors

A.L. Gilbert Co.
Ag Bag International, Inc.
Agpro, Inc.
AgStar Financial Services ACA
Alltech, Inc.
Alta Genetics, Inc.
Arm & Hammer® Animal Nutrition
Associated Feed
Beef Checkoff, Beef Board & National Cattlemen's Beef Association
Bou-Matic
Burton-Fellers Sales Inc.
CAL TAG, INC.
Calf-tel by Hampel Corp.
Cargill Foods—Flour Milling
Conewango Products, Corp.
Dairy Biz.com/Moo Milk.com
Dairy Farmers of America
Dairy Health Equipment, Service & Supply Co., Inc.
Dairy Management, Inc.™
Dairy Records Management Systems, DRMS
DAIRYWORKS
DeLaval
DHI–Provo
Diamond V Mills
Ecolab
Elanco Animal Health
Farm Credit of New Mexico
FARME Institute, Inc.
Farnam Companies, Inc.
Feedstuffs
Fort Dodge Animal Health
Foster Farms
Genex Cooperative Inc.
Genske, Mulder & Co., LLP, CPA
Global Parlor Performance Audits
Holstein Association USA
Hubbard Feeds Inc.
I.D. Ology
Intervet
Kirby Mfg. Inc.
LaBudde Group, Inc.
Lester Building Systems
Loveland Industries Inc.
Merial Dairy Marketing
Merrick's, Inc.
Milk-Rite USA, Inc.
Min-Ad, Inc.
Monsanto
Novus International Inc.
Nutritech Solutions, Ltd.
Nutrius
PalmLab Inc.
Paul Mueller Company
Pfizer Animal Health
Pharmacia & Upjohn Animal Health
Pioneer Hi-Bred International, Inc.
Priority One
Purina Mills, Inc.
Ranch-Way Feeds
Roche Vitamins Inc.
Select Sires, Inc.
SoyBest
The Schlueter Co.
United Dairymen of Arizona
Vaca Resources
West Agro, Inc.
Westfalia Surge, Inc.
Zaugg Dairy Nutrition
Zinpro Corporation

Media Sponsors

Agribusiness Publications
Dairy Herd Management
Dairy Profit Weekly
Dairy Today
Hoard's Dairyman
Hoard's West
Midwest DairyBusiness
Northeast DairyBusiness
The Progressive Dairyman
Western DairyBusiness

Milking Parlor Performance

D.V. ARMSTRONG—Department of Animal Sciences, University of Arizona, Tuscon, AZ 85721
Tel: 520-621-1923 Fax: 520-621-9435

M.J. GAMROTH—Department of Animal Sciences, Oregon State University

J.F. SMITH—Animal Sciences & Industry, Kansas State University

Introduction

The size and type of milking parlors on western U.S. dairy farms has changed during the last 10 years. In 1999, performance information was presented on 14 rotary parlors, parallel parlors up to 100 stalls, and herringbone parlors up to 80 stalls at the Western Dairy Management Conference by Smith, et al. This paper on parlor performance will be an update with 61 rotaries and parallels up to 120 stalls. The parlors were evaluated by multiple observations using the time and motion method for determining steady state throughput during the complete milking period. The time required for cleaning the milking system, time between group changes (if the parlor stops or there are no cows in the parlor) and milking the hospital and fresh cow groups are not included. In this way, parlors evaluated in 2000 can be compared with other parlors evaluated since 1960.

Herringbone and Parallel Parlors

Herringbone parlors in the last five years have not increased in size, but parallel parlors have. The 1999 paper at the WDMC (Smith, et al, 1999) reported on herringbones up to 80 stalls and parallels up to 100. Since 1999 there have been a number of parallel parlors with 100-120 stalls built in the western United States. Based upon a limited number of parlors, the one management technique which greatly influences performance of these large parlors is the pre-milking hygiene routine. In the 1999 study Smith reported the use of a pre-dip or full routine of pre-dip or spray, strip, wipe and attach reduced parlor performance by 15-20%. This was not a recommendation of either a minimal or a full routine. The type of dairy housing (free-stall or open corral) management systems, level of mastitis, somatic cell count, and bacteria counts will indicate which pre-milking hygiene routine that needs to be used, not the type of parlor. Table 1 is an update on data through the year 2000 on large herringbone and parallel parlors.

Cows per hour and cows per labor hour is slightly more for the parallel when compared to herringbone parlor up to D-40-44 size. Entry time per cow is slightly less for the 1st cow into the parlor to milking position for parallel parlors, even when the cow has to turn 90?. Walking distance of the operator is less in the parallel parlor. This is especially true of the operator who is doing a preparation routine which requires more than one pass by each animal. Cows per hour is less for both parallel and herringbone when a full pre-milking hygiene is used when compared to the minimal routine (Table 1).

In the large parallel parlor cows per labor hour is highest at D-35 to 40 stalls. Although the data in Table 1 on parallels larger than D-50 is a limited number of observations, the trend is for more cows per hour but the same cows per labor hour.

Rotary Parlors

In the last five years there has been a renewed interest in rotary parlors. The rotary parlor of the late 1990?s has been referred to as the new version. Observation of several changes in design would indicate that the new parlors are largely with the operator on the outside of the platform (external) and the platform contains more stalls which should make them more compatible for easier cow entry and the milk production level of today?s cows which requires a larger platform. Data on rotary parlors reported in 1977 (Bickert and Armstrong) were from 8 to 26 stall parlors. The difference between the set actual entry time per stall as set by the manger-owner and the actual entry time per stall minus the empty stalls and second rotation cows indicated actual performance of parlors was only 61-67% of the manager-owner set entry time per stall. The data reported in this paper is for an average size of 53 stalls (28-120) and now this efficiency averages 80%. The second major design change is that the majority of the rotary platforms installed in the U.S. from 1995 to 2001 are concrete platforms. An interesting observation in platforms in Australia are that where once the majority were steel platforms, the majority today are concrete platforms. Of the 20 parlors presented in this paper, observed in October 1999 and 2000, 19 are concrete and one is steel. Another observation of the present rotary platform design is the addition of more support wheels and improvement in the undercarriage of the platform.

During the past three years the authors of this article have traveled in the U.S., Mexico and Australia to collect data on rotary parlors. Presently, there are 61 parlors in the database. Thirty-seven of these parlors are in the U.S., 4 in

more ⟶

Mexico, and 20 in Australia. Data was collected for complete milkings and in the majority of parlors for repeat milkings and repeat observation at different times of the year. Data collected included: (1) owner-operated set entry time/stall (seconds per stall), (2) actual entry time (seconds per stall), (3) time required to make one complete rotation of the parlor, (4) number of empty stalls per rotation, (5) number of cows which go around a second time (either voluntarily or unvoluntarily) per rotation, (6) stops per rotation for problems at entry, exit, miscellaneous (machine repair, problem cows, routine catch-up time, etc.). Other observations recorded were; (1) direction of rotation, (2) slope of platform (toward the inside or toward the outside), (3) milk production level of herd, (4) milking frequency, (5) platform surface, (6) platform and equipment manufacturers, (7) attachment time of milking units (on some parlors), (8) pre-milking hygiene routine, and (9) number of operators (including personnel in holding pen assisting cows onto the platform). Personnel making group change are not included in milking personnel). Measurements of entry lane included width and length and angle of front of holding pen was recorded.

Data from the parlor was then used to calculate; (1) the owner-operator cows per hour maximum possible parlor performance, (2) actual cows per hour performance, (3) number of actual rotations per hour, (4) cows per labor hour. A parlor performance efficiency rating based upon the theoretical rotation time of the platform divided by actual rotation time of the platform minus the number of stalls which were empty or used by cows making a 2nd rotation.

The database was then evaluated by; (1) country, (2) internal vs. external parlors, (3) pre-milking hygiene routine, and (4) three different groups of parlor size for U.S. parlors. Different widths and lengths of entry lanes where evaluated for their effect on cow entry. Number of stalls for cow exit at different rotation speeds was evaluated. Stall angle on the platform was observed for its effect on cow entry and exit as well as the angle of the front of the holding pen on cow entry. Width of exit lane and placement of foot bath or sort gates was also observed. Finally the influence of the slope of the cow platform (in or out) on leg position was noted. Summary of the data for all parlors is presented in Table 2.

Mexico Parlors

The four parlors in Mexico consisted of one internal rotary with a steel platform and three steel, external platforms. Summary of the data is also in Table 2. Although the number of parlors is small, there are several small differences, which resulted in the efficiency of these Mexican parlors being less than the U.S. or Australian parlors. The set (owner-manager) entrance time was low (8.4 seconds per stall) resulting in more frequent and longer stops for cow exit for the external parlors. The internal parlor also had more frequent stops for cow entry. One external and one internal parlor had efficiency rating of 61% which lowers the average for the four parlors. The steel external platform also had more frequent, longer stops to exit cows with leg problems. This also has been observed in U.S. parlors.

Australian Parlors

The database for the 20 Australian parlors is also presented in Table 2. This data was collected during the last two weeks of October, 1999 and 2000. With seasonal calving being practiced on these dairy farms, the data collection period was during highest milk production with herds averaging 80-110 days in milk. Some late calving heifers were still adjusting to the parlor, which made the parlor atmosphere similar to U.S. parlors.

The Australian dairy industry has had more experience with rotary parlors, as they have a higher percent in use over a longer period of time. Rotary parlors in this data base have been in use from 1 to 12 years. Traditionally, the parlor is in operation for 1-1/2 to 2-1/2 hours a milking. Even with a 1,400 cow dairy the milking time was less than 3 hours. In the majority of parlors, the owner or manager is involved with at least one milking and usually all milkings each day.

The Australian parlors also have a higher efficiency rate by 5% (84% Australia vs. 79% U.S. parlors) which is a measurement of rotation time per stall set by the owner-manager, minus the time the parlor is stopped, plus, 2nd cow rotation and empty stalls. Why? An observation would be the operators with more experience and training on rotary parlor platforms. Although the number of cows going around the second time was high (the period of data collection was at peak milk time), both empty stalls and stops per rotation were less than U.S. parlors. The entry on the platform was quicker for Australian parlors, which had a long entry lane (13-15 ft) that was about 33 inches wide, and with the angle of the fence closest to the parlor at 30-45 degrees than those with a flat 15-20 degree angle and shorter entry lane of 7-8 feet, presently being used in the majority of U.S. rotary installations. Cows per labor hour was 147 compared to 99 for U.S. parlors because of the use of a minimal or no pre-milking hygiene routine in the majority of Australian parlors. All parlors were feeding grain on the platform. Operators said entry on the platform becomes much more aggressive in late lactation or when the availability of feed in the pasture becomes less. In summary, we can learn considerably from the Australian dairy industry on design and management of rotary parlors especially if observations are made when milking conditions are similar to the U.S.

Internal vs. External Rotaries

The data from Table 3 representing the internal operator vs. the external operator shows that the external operated parlor efficiency (81%) is more than the internal parlors (70%). Cows per labor hour are also higher for the external operated parlors. Although missed stalls and cows going around the second time per rotation are less for the internal parlor, total stops per rotation are greater. Rotations per hour for external operated parlors are less than internal operated. Although this data base only represented 5 internal operated parlors, it would indicate that they are less efficient, which may be a factor in why there are less internal operated parlors being built.

Full vs. Minimal Pre-milking Hygiene Routine

Pre-milking hygiene routine, presented in Table 4, was divided into three sub-groups: none, minimal, and full. As would be expected, cows per labor hour is greater for minimal pre-milking hygiene routine when compared to a full routine because the minimal routine requires fewer operators. The 13 minimal routines broke into three categories; 3 strip only, 3 wipe only and 7 wipe and strip. In several parlors where wipe and strip was being used, the speed of the platform was not allowing sufficient time for both of these routines to be done 100% of the time. It would appear that the owner-operator set rotation time per stall must be 12 seconds or greater for both wipe and strip to be completed. On dairy farms which practiced a full pre-milking hygiene routine the average milk production per cow was 73 lbs., compared to 64 lbs. for herds where a minimal routine or no routine was practiced. The difference of 9 lbs. may be partially explained by the improved pre-milking stimulation, which usually occurs with a full milking hygiene, which improves let-down response. In the minimal pre-milking routine herds it is not uncommon to see a partial let-down after the milking unit is attached and then milk flow stops for one to one and half minutes (7-10 stalls) before a second let-down occurs.

Three Sub-groups by Size

An analysis of three sub-groups of the external operated rotary platforms is presented in Table 5. From this data, differences in performance of different parlor sizes can be analyzed. As rotary parlor size increases the owner-operator set entry time per cow is faster. The difference is largely due to large rotary platforms are built for larger herds in use more hours per day, therefore the pressure to milk more cows results in a stall rotation time which is faster. Cows per hour is higher in the larger parlors with more operators being used (a larger percent of the small and large parlors used a full pre-milking hygiene routine) resulting in a lower cows per labor hour. Missed stalls per rotation was lowest in the 48-54 size rotaries. Cows going around the 2nd time was lowest in the smaller (24-44) and medium-sized parlors (48-54). Total stops per rotation was highest in the smaller rotary parlors. Rotation of platform per hour was very close to the same for all parlors sub-groups.

If a dairy owner is considering building a rotary parlor, the number of cows and hours a day it will be used will determine stall entry time to milk the number of cows they desire, but the platform must be large enough to milk the herd now and with future higher milk production. An owner should select a parlor size that allows about an 11 to 12 second entry time with about 9 minutes of unit on-time at 80% efficiency.

Maintenance and life expectancy of the tables was discussed with owner-managers to try and evaluate the life expectancy of the tables. Because a large number of the parlors being sold in the U.S. which are manufactured in Australia, this may give our dairy industry an insight as to what to expect in the future. Table 6 is a summary and projection of maintenance or replacement of major components of rotary platforms from personal communication with dairy farm owners and managers. One message, which was repeated by owner-managers in Australia, was that maintenance and replacement would be influenced by the number of hours of operation. Preventive maintenance and future improvement in components will also influence replacement of components.

Summary

A considerable amount of this performance data is available with existing computer programs without personnel being present. However, the authors of this article chose to personally take the data to help answer questions concerning future decisions in parlor design and management, including the reason for the stops, entry and exit design effect on stops, empty stalls, 2nd cow rotation, parlor size as it affects the operator routine for reattach or adjustment of units, pre-milking hygiene?s effect on operator?s ability to complete his or her duties, etc.

Table 7 is a summary of the performance of the 61 rotary parlors. Table 8 includes the summary of recommendations in rotary parlor design.

more →

Acknowledgements

Thanks to the owners, managers and milking personnel on the dairy farms in Mexico, Australia and the U.S. where the information for this paper was collected. Without the dairy personnel?s assistance this paper would not have been complete.

References

Armstrong, D.F., J.F. Smith and M.J. Gamroth (1994). Milking parlor performance in the United States. In *Dairy Systems for the 21st century.* Proceedings of the 3rd International Dairy Housing Conference 59-69. St. Joseph, MI ASAE.

Bickert, W.G., and D.V. Armstrong (1977). Rotary Milking Parlors. Michigan State University Extension Bulletin, No. 123, E-1047. East Lansing.

Smith, J.F., J.P. Harner III, M.L. Brouch, D.V. Armstrong, M.J. Gamroth and M.J. Meyer (1999). *Relocation and Expansion Planning.* In proceedings of Western Herd Management Conference, Las Vegas, NV pp73-85.

Table 1. Milking parlor performance on dairy farms using herringbone and parallel parlors with different pre-milking hygiene routines for 3X milking.

	Herringbone[c]				Parallel			
	Full[a]		Minimal[b]		Full[a]		Minimal[b]	
Parlor size	Cows /hour	Cows/ labor hr	Cows /hour	Cows/ labor hr	Cows /hour	Cows/ labor hr	Cows /hour	Cows/ labor hr
D-20-24	210	70	185	93	217	72	202	101
D-25-29	230	77	252	84	231	58	227	91
D-30-34	—	—	—	—	270	90	280	93
D-35-39	—	—	390	98	280	112	390	130
D-40-44	392	56	408	102	385	96	491	123
D-45-49	—	—	—	—	396	79	528	106
D-50-54	—	—	—	—	460	92	540	108
D-55-59	—	—	—	—	517	103	—	—
D-60	—	—	—	—	497	99	532	107

[a]pre-dip, strip, wipe, attach
[b]strip and attach or wipe and attach
[c]herringbones are parlors with stalls from 34 to 45 inches on center

Table 2. Rotary milking parlor performance on dairy farms.

	No. of parlors	No. of stalls	Set ent. time	Actual ent. time	Actual cows /hr	%[a] eff.	No. of oper.	Cows/ labor hr.	Milk prod.	Missed stalls p/r	2x cows p/r	Total stops p/r	Cow/ stall hr.	Rota./ hr.
All parlors	61	53	10.8	12.9	298	80	3	114	67	1.5	3.0	4.0	5.6	6.0
U.S. only	37	50	12.0	14.0	281	79	3	99	69	2.0	2.0	5.0	5.5	6.0
Mexico only	4	57	8.4	11.6	321	73	3.6	97	62	1.7	2.3	5.3	5.6	5.7
Australia only	20	58	10.0	11.0	325	84	2	147	63	1.0	5.0	2.0	5.7	6.2

[a]Percent efficiency (is a measurement of rotation time per stall set by the owner-manager divided by the actual rotation time per stall minus the time the parlor is stopped, 2nd cow rotations, and empty stalls.

Table 3. Internal vs. External operator effect on rotary milking parlor performance on dairy farms.

	No. of parlors	No. of stalls	Set ent. time	Actual ent. time	Actual cows /hr	%[a] eff.	No. of oper.	Cows/ labor hr.	Milk prod.	Missed stalls p/r	2x cows p/r	Total stops p/r	Cow/ stall hr.	Rota./ hr.
Internal	5	38	14.0	19.8	193	70	2.5	89	65	.6	.1	5.9	5.2	5.2
External	56	55	10.5	12.3	308	81	2.9	117	67	1.6	3.2	3.8	5.6	6.1

[a]Percent efficiency (is a measurement of rotation time per stall set by the owner-manager divided by the actual rotation time per stall minus the time the parlor is stopped, 2nd cow rotations, and empty stalls.

Table 4. Pre-milking hygiene routine effect on rotary milking parlor performance on dairy farms.

	No. of parlors	No. of stalls	Set ent. time	Actual ent. time	Actual cows /hr	%[d] eff.	No. of oper.	Cows/ labor hr.	Milk prod.	Missed stalls p/r	2x cows p/r	Total stops p/r	Cow/ stall hr.	Rota./ hr.
None[a]	24	57	9.6	11.0	328	82	2.4	114	63	1.2	5.0	2.7	5.8	6.3
Minimal[b]	13	51	10.9	12.4	295	82	2.7	114	66	2.3	2.1	4.2	5.8	6.2
Full[c] Routine	19	53	11.4	13.8	291	79	3.7	85	73	1.8	1.7	4.8	5.3	5.7

[a]none—no pre-milking hygiene
[b]minimal routine—strip and/or white and attach
[c]full routine—pre-dip, strip, white, attach
[d]Percent efficiency (is a measurement of rotation time per stall set by the owner-manager divided by the actual rotation time per stall minus the time the parlor is stopped, 2nd cow rotations, and empty stalls.

Table 5. Sub-groups by size (stall number) rotary milking parlor performance on dairy farms.

	No. of parlors	No. of stalls	Set ent. time	Actual ent. time	Actual cows /hr	%[a] eff.	No. of oper.	Cows/ labor hr.	Milk prod.	Missed stalls p/r	2x cows p/r	Total stops p/r	Cow/ stall hr.	Rota./ hr.
22–24 stalls	14	39	14.1	16.7	211	78	2.4	105	64	2.1	2.2	4.5	5.4	6.1
48–54 stalls	25	50	10.8	12.5	284	83	2.3	130	66	1.2	2.0	3.4	5.7	5.9
60–116 stalls	17	74	7.2	8.22	422	81	4.3	108	71	2.0	5.8	3.8	5.7	6.3

[a]Percent efficiency (is a measurement of rotation time per stall set by the owner-manager divided by the actual rotation time per stall minus the time the parlor is stopped, 2nd cow rotations, and empty stalls.

more →

Table 6. Estimated projection of maintenance or replacement of major components on rotary platforms manufactured in Australia and operated in Australia and United States.

	Australia 4 hrs. daily use	United States 20 hrs. daily use
Drive unit		
minor maintenance	1–2 yearly	5–10 yearly
major replacement	10 years	2 years
Wheel bearing replacement	8 years	1.5 years
no difference between steel/nylon	—	—
Central Swivel (gland)	depends on manufacturer 6 months–5 years	?
Table surface		
Concrete	15 years	?
Steel	depends on manufacturer 5–10 years	?

Table 7. Summary of performance of 61 rotary parlors in Mexico, Australia and United States.

1. Entrance time tends to decrease as parlor gets larger.
2. Rotation time of the platform averages 6.0 per hours (3.8–8.0) and is not influenced by parlor size.
3. Pre-milking hygiene effects cows per labor hour.
   a. All parlors 114 per hour (range 47–206)
   b. Minimal or none 119 (range 64–200)
   c. Full routine 85 (range 47–206)
4. 1.5% of stalls are empty per rotation (range 0–12%)
5. 3.0% of cows go around second time per rotation (range 0–24.5%)
6. Average number of stops per rotation for entry, exit, machine repair, etc. 4.0 (range 0–11)
7. Average parlor efficiency as measured by owner/manager set cow entry time divided by actual cow entry time minus empty stalls and 2nd cow rotation was 80% (range 47–97%)
8. Cows per hour average 298 (range 103–597)
9. Cows per labor hour highest in the parlor size of 48–54 stall groups.
10. Cows per hour highest in the 60–116 stall group.

Table 8. Summary of design observations in 61 rotary parlors in Mexico, Australia and United States

1. Majority of platforms are concrete (51 concrete vs. 10 steel) and slope inward.
2. Milking machine attachment is fastest in large parlors with fast entry time, parlor rotation direction clockwise vs. counterclockwise have little effect.
3. Entry design for best cow entry
   a. 33" wide chute
   b. 14–16' long chute
   c. Shield operator and exit area in entry chute
   d. Angle of front of holding pen 45 degrees and shield area from attachment area.
   e. Holding pen width 36–38' or less
4. Exit area design for best cow exit
   a. 3 stall width for rotation time of 11 seconds per stall or greater
   b. Exit lane 6–10' wide
   c. All cow sort gates and foot baths minimum of 60' from parlor unless sort gate is manually operated
   d. Shield cow exit from cow entry near platform

Why Unit On Time is Important for Your Dairy

DAVID A. REID, DVM—Rocky Ridge Veterinary Services, Hazel Green, Wisconsin 53811
Tel: 608-854-2242 Fax: 608-854-2444

STEVEN STEWART, DVM—University of Minnesota

The dairy industry is rapidly changing. Dairies are becoming larger, more productive, and more intensively managed. High-quality labor may be difficult to attract and retain. The recent low milk prices have presented an all too obvious challenge. Consumers are increasingly demanding higher quality and safer products. Legal somatic cell count levels will likely be reduced in the next few years. These changes require technical advances in milking systems to milk cows efficiently in a manner consistent with highest product quality and animal health.

On most commercial dairies, the parlor is a major capital investment. It is also where the primary income source is harvested, where much of the labor is employed, and where the quality of the product is largely determined. For these reasons, parlor performance and efficiency discussions are common in today's dairy industry. The goal of most dairies is to milk as many high-producing cows during each milking while still allowing time for adequate cleaning of the equipment.

Several studies have shown teat condition and teat sanitation prior to unit attachment are key factors in reducing the new mastitis infection rate. Poor teat skin condition decreases the primary protective mechanism from mastitis. Roughened teat end conditions can cause difficulty in cleaning teat ends effectively. These factors can lead to higher new infection rates.

Many herds in the United States have problems with good "milkability". Cows may be more reluctant to enter the parlor in these herds. In a parlor, poor milkability can be spotted early in the milking process when cows move and step excessively during udder preparation practices. Stepping may also be seen soon after the units are attached and/or near the end of milking, often leading to a significant number of units being kicked off during milking.

Excellent milkability is present when cows have excellent milk flow as soon as the last teat cup is attached to the cow, with a steady, visible increase in flow until peak levels are reached. Peak flow should last 60 to 120 seconds, depending on the production of the cow. With excellent milkability, milk flow will drop off rather quickly after peak milk flow is over. As the end of milking nears, milk flow should suddenly drop to very low levels. If equipment settings are proper, the unit will then be promptly removed. There should be minimal stepping and kicking throughout the entire milking process.

Good milkability requires adequate oxytocin prior to units being attached to cows. However, this creates a major dilemma in the industry. To achieve better performance from a parlor, the goal often becomes focused only on milking more cows. When more cows are milked, there may not be enough time allowed to properly prep cows for effective cleanliness and maximum oxytocin letdown. Unit on time (duration) is a key factor of parlor performance that has been largely ignored until recently.

Unit on time is dependent on the amount of milk and the average claw vacuum under peak milk flow conditions. Adjusting systems to achieve average claw vacuum levels between 12.5 to 12.8 inches under peak milk flow conditions will decrease the unit on time. Adjusting take off settings to remove units promptly upon completion of the milking will also significantly reduce the unit on time.

Research in both Europe and the United States has shown the key factor to reducing teat end hyperkeratosis is unit on time. To appreciate how unit on time contributes to reduced teat end hyperkeratosis, it is important to understand the normal pattern of milk flow from cattle during each milking. Immediately after the unit is attached to properly stimulated cows, milk flow increases rather rapidly until it reaches a peak milk flow rate. This peak flow rate is variable and depends to a great extent on the amount of milk actually given during a milking. After a period of peak milk flow, milk flow drops rather quickly. Depending on how the milking equipment is set, there can be a long period of extremely low flow and relatively higher vacuum exposure of the cows' teats. The longer the period of relatively low flow, the longer high vacuum and increased pulsation cycles will be applied to the teat ends. This will lead to increased hyperkeratosis and a reduction in skin condition teat scores. Adjusting take-offs to remove units sooner will simply shorten the low flow/high vacuum phase at the end of milking. Removing units sooner and at a more appropriate time is important to improve teat end condition and teat end scores. However, earlier removal of units is in opposition to one of the oldest dogmas of the dairy industry: Under-milking the cow (no matter how

more →

slight) will cause new mastitis infections. This dogma in fact is not true, but this perception is very difficult to overcome on some dairies.

An extensive database is being established at the University of Minnesota to monitor parlor performance during normal milkings for selected United States and Canadian herds with automated parlor data collection systems. The information is presented to the dairyman using DairyCOMP305 software for management purposes while the raw data is being sent electronically to the university for more detailed research purposes.

Early trials with a group of these dairies show there is no decrease in milk production when vacuum level and take-off settings are changed. Several of the herds experienced an increase in milk production as adjustments were made to both take-off settings and vacuum levels to decrease unit on time. The herds in one study all showed significant reductions in unit on time as take-off changes and vacuum levels were altered. The herds in the study and many other herds have experienced changes of over one and one-half minutes average unit on time on a per cow basis.

Reducing unit on time will improve teat end condition. Reducing unit on time will also allow time to properly prep cows to ensure the teats are clean, dry and well stimulated when units are attached. Proper udder preparation allows cows to milk quickly, completely and evenly, all of which are key factors to improving milkability in the herd. Improved milkability will improve the attitude of milkers because fewer units will require readjustment or reattachment. Clearly, reducing unit on time offers distinct advantages to any dairy farm.

An example of results that can be achieved on real farms is a dairy milking approximately 800 cows in a double fifteen parlor. The average claw vacuum was maintained at approximately 12.7" under peak milk flow conditions measured between the first and second minute after the units are attached. During a 30-day period, the take-off setting was changed from 1.4 pounds per minute flow rate to 1.8 pounds per minute flow rate. In addition, the delay time was reduced from 2 seconds to 1 second during this same 30-day period. The result of these changes was the average flow rate per minute of unit attachment increased from a base of 5.5 pounds per minute to 6.1 pounds per minute. The average unit on time decreased from 5.1 minutes to 4.8 minutes. The average milk weight on this dairy increased 1.6 pounds per milking during the same 30-day period. These results show unit on time can decrease even in the face of increasing production.

This herd continued to make changes to their take-off settings. In early July of 2000, the take-offs were set at a 2.3 pounds per minute flow rate with a 1 second delay. On this date, 817 cows were milked with an average milk production of 26 pounds. The average flow rate was 7.3 pounds per minute. The average duration for the herd was 3.6 minutes.

This dairy was equipped with a BouMatic 2050 ProVantage parlor controller and software to export data to DairyCOMP305. The exported data allows calculation of flow rates in discrete time intervals in the early stages of a milking. This dairy achieved calculated flow rates of 2.7 pounds per minute in the first 15 seconds. This increased to 6.8 between 15 to 30 seconds and was 7 pounds per minute between 30 to 60 seconds. Peak milk flow rates defined in this software as between the first and second minutes after unit attachment was 9.3 pounds per minute. Fifty-seven percent of the milk was produced in the first two minutes on this dairy.

Another example of the effects of take-off changes and the vacuum level can be seen in a start-up herd milking approximately 460 cows in November 1997. The take-off settings were 1.0 pound per minute with a 1-second delay. The herd was averaging 23 pounds of milk from 462 cows. The average flow rate was 4.5 pounds per minute with an average duration of 5.7 minutes. In April 1998, the herd size was 451 cows and production was 26 pounds per milking. The average on time was 5.3 minutes with an average flow per minute of attachment of 5.0 pounds. In July 1998, the take-off settings had been increased to 1.6 pounds and 1 second. The herd now consisted of 693 animals milking an average of 23 pounds of milk. The average flow rate was 6.5 pounds per minute of unit attachment. The average duration was 3.7 minutes. This dairy is currently milking approximately 750 cows with unit on times between 3.8 and 4.1 minutes on a daily basis. Take-off settings are currently at 2.0 pounds per minute with a 1 second delay and average milk production has been in the mid 20 pound range with 3X milking.

Vacuum level is also an important factor in driving unit on time. I visited a herd in California on June 8, 1998, with 2,405 cows milking 36 pounds on 2X milking. The average unit on time was 7.0 minutes. The average flow per minute was 5.4 pounds. The take-off settings were 1 pound per minute with a 5-second delay. Management made adjustments to the take-off settings and vacuum levels over a 4-week period. On July 12, 1998, the herd had 2,402 cows milking 36 pounds. The average unit on time was now 5.3 minutes with a flow rate of 7 pounds per minute. The take-off settings were 1.2 pounds per minute and 1 second. The vacuum on the system had been raised 2 full inches during the adjustment period. The changes to the vacuum were made in ½ inch increments at approximately 6- to 7-day intervals. Reducing milking times by 1.7 minutes would allow adequate time to properly prep teats at any dairy without sacrificing parlor performance or efficiency.

An 850-cow 3X dairy on the east coast was checked in 1999. The take-off settings were 1.3 pounds per minute and 2 seconds (Note: These are already significantly higher than the equipment manufacturer's factory takeoff default levels of .9 pounds and 12 seconds). The table outlines the setting changes and results.

Number of Cows	Milk Weight	Takeoff Flow	Takeoff Delay	Ave Flow Rate	Ave Duration	Date
864	25	1.3	2 s	4.8 #/min	5.2 min	Jan 99
873	25	1.5	1 s	5.2 #/min	5.0 min	Feb 99
864	26	1.6	1 s	5.4 #/min	4.9 min	Mar 99
1098	31	1.7	1 s	6.7 #/min	4.7 min	Apr 99
1078	29	1.9	1 s	7.2 #/min	4.1 min	Jun 99

Most companies offer end of milk point and delay times. If your system has both end of milk point and delay times, the delay times should be reduced first prior to increasing the end of milk point. Once the end of milk point is above 1 pound per minute with a short delay time, the vacuum level on the system can be increased if necessary to achieve peak milk flow claw vacuums of approximately 12.5 inches. Systems equipped with milk metering systems and interfaces with DairyComp305 allow making fine tuning changes to the take-off settings and vacuum levels while monitoring the results on parlor performance summaries. The goal is to maintain or increase the pounds of milk produced on a per cow basis while increasing the flow rate per minute of unit attachment. This, in turn, will reduce the unit on time.

Unit on time can be easily listed with most automatic milk meter systems. Caution is necessary when interpreting the reported times, as some manufacturers report it as the time from first dump of milk to last dump of milk. We are attempting to standardize the definition of unit on time as being the total time from vacuum on at the claw to vacuum off at the claw. Unit on times can also be checked in DHI herds by monitoring on times either the day before or after testing. An achievable goal is for the first 25 pounds of milk at any milking to take 4.25 minutes or less. Each additional 10 pounds of milk should require 0.75 minutes or less.

I believe the goal for all dairies should be to maximize the amount of milk produced by every cow at every milking. In addition to maximizing milk yield, all milk from the dairy should be of the highest quality possible on every day of the year. Fine-tuning take-off settings and vacuum levels will allow time for excellent premilking udder preparation to achieve clean, dry, stimulated teats before units are attached to minimize unit on time and maximize udder health.

Water System Design Considerations for Modern Dairies

JOSEPH G. MARTIN—Consulting Engineer, 6024 SW 89th Terr., Gainesville, FL 32608 Tel: 352-371-4655

JOSEPH P. HARNER—Biological and Agricultural Engineering, Kansas State University, Manhattan, Kansas

JOHN F. SMITH—Animal Sciences and Industry, Kansas State University, Manhattan, Kansas

Introduction

Site selection for modern dairy production facilities is dependent on numerous criteria. One of these criteria is an adequate water supply. The facility must have the potential to develop or obtain a water supply of sufficient quantity and quality to serve the anticipated present and future production needs (Hoehne et al., 1994). Minimum water requirement for meeting the intake water needs of lactating cows, milk parlor usage and other needs of a functioning dairy seem to range from 40 to 50 gallons per cow per day (gal/cow/dy) (Allen el al., 1974; Bailey et al., 1993; Beede, 1992; MWPS-7, 1997). Water usage can increase to 100 gal/cow/dy if a wash pen is used. The following figures suggest if a wash pen is not used, then 1 acre-foot of water is annually required per 15 cows. Therefore, it is critical adequate water rights be obtained during the initial phase of planning, expanding or remodeling of dairy. Generally, adequate water rights are obtained but due to lack of planning, the water supply cannot be delivered in quantities necessary to meet the dairy demands. Poor planning has also resulted in some dairies not having adequate water supplies to address heat abatement issues.

Water Supply

Groundwater is probably the water source of choice if it is of sufficient quantity and quality (Hoehne et al, 1994). A secondary well provides a back-up in the event of failure of the primary well. If a single well is used, a storage tank with a minimum of a two- to three-day water supply is recommended. Some dairies are purchasing water. Hoehne et al. (1994) state it is their "opinion that water supplied by rural water districts should not be the primary water source for modern dairies." Dairies purchasing water from a rural water district must also have a storage tank to handle outages. These dairies also must work with the rural water district to ensure their system can handle the demands of the dairy facility. Hoehne et al. (1994) recommended surface water supplies have a minimum of two-year storage capacity. Reservoirs must be large enough to store the anticipated water used plus losses due to evaporation, seepage and other inherent losses. Surface water supplies will probably require treatment prior to usage. Minimum treatments would control bacteria and reduce sediment.

Demand vs Usage

There are two water issues to address during the planning of a dairy. The demand is maximum water used during a given time period and is normal measured in gallons per minute (gpm). The water system must be able to meet the maximum amount of water used during a single 1- to 5-minute interval during the day. There will also be seasonal demands. A water supply may be adequate during the winter but insufficient during the summer when heat abatement equipment is utilized. On a modern dairy, the maximum demand generally will occur during the summer when the milk parlor equipment is being cleaned. This is the time period when there is a percentage of the cows drinking water, sprinkler or mister may be on and milk parlor and equipment lines are cleaned.

The second factor to consider is the usage. Usage is the total amount of water used during a day. It is important to consider all present water requirements as well as future water needs. Modern dairies need to consider the drinking water requirements of heifers, dry cows and lactating cows, cleaning of milk parlor, usage at hospital facilities, water requirements of restrooms, truck wash water, etc.

In the housing area approximately 69 percent of the water is used for drinking with the remainder being used for sprinkler systems. However, the minimum demand by the watering troughs for a 1,000-cow dairy is 30 gpm, while the sprinkler demand is 125 gpm assuming all of the cows are cooled simultaneously.

Types of Water Lines

A water line or pipe transfers water between two points, and other factors beyond just the demand and usage must be considered. Equivalent pipe length, pipe diameter, pipe location, and piping losses must be considered. There are three basic types of water lines to consider, however, each water line must be able to supply the demand requirements. These include the main, distribution and branch water lines.

The main line carries the water from the well or storage tank into a dairy complex. Proper sizing of the main pipe is critical because it must be able to deliver the demand

more →

of the entire dairy. Water distribution problems arise when future expansion is planned but the main water line is sized only to meet the current needs. Unless a second water line is going to be installed, the main water line must initially be sized to meet the demands of the final dairy size.

Distribution lines carry water from a main line junction to specific buildings or areas. Examples include to freestall housing area, milk parlor or office complex. It is recommended to size the distribution lines in freestall housing areas based on the demands of the watering and sprinkler systems. Generally, this water line is undersized because adding sprinklers for cow cooling is an after thought and not planned. Therefore in the future when a cooling system is added, even though the initial plan was never to install one, the water lines cannot meet the demands of the sprinkler and watering system. The demand to meet the needs of the sprinkler system is 3 to 4 times greater than the demand of the watering troughs.

The third line type is the branch line which carries water from the distribution line to the end use. Examples include the waterers, sprinklers, plate coolers, wash machine or milk parlor platform. Normally, these water lines are probably adequately sized. The difficulty occurs when a branch line becomes a distribution line. For example, a branch line to a watering trough is tapped into for the sprinkler system. The other difficulty occurs when a branch line needs to be added but installation requires placement of lines under concrete. Often in this scenario, the line is added above ground and then lack of maintenance, draining lines that may freeze, becomes a problem.

Pipe Losses

Water pipes need to be able to supply water to the end usage based on the peak flow rates. The plumbing system must be able to overcome losses incurred as water moves through the pipes. Pressure losses occur due to pipe friction, elevation differences between the pump source and point of use and velocity losses due to water movement. Friction losses are due to water flowing through pipes, fittings and valves. Often friction losses through fittings and valves are based on the equivalent feet of straight pipe (MWPS-30). Table 1 shows different fittings and their equivalent straight pipe length. The water velocity and inside surface roughness affect the friction losses. To reduce excess friction losses, normally the system is designed to limit pipe velocity to 5 fps or less. Water hammering will result when velocities exceed 5 fps. Table 2 shows the flow rate in gpm through various size pipes based on 4, 5 and 7.5 fps flow velocities. It is recommended to use the column showing 4 fps for the main and distribution lines. Branch lines can be sized based on the 5 fps velocities. Table 2b shows the capacity of different size pumps based on the total head at which a pump must operate against. Pipes should be selected based on the following guidelines (MWPS-7): 1. Limit the pressure loss to 5 psi when moving water from the pressure tank to building (this would be the losses in the main and distribution lines); 2. Limit the pressure losses in the branch lines to less than 5 psi; 3. Limit the pressure losses in the main line to less than 1 psi per 100 feet of pipe; and 4. Use a maximum water velocity of 4 fps to prevent water hammering.

Water Usage

Water usage on a dairy will vary significantly amongst dairies. Zuagg (1989) studied five dairies and found water usage varied from 80 to 240 gallons per lactating cow per day. Dairies raising replacement heifers and using calf barns utilized more than 200 gallons per lactating cow per day. Wiersma (Zaugg, 1989) reported water usage on Arizona dairies in 1975 at 91.5 gallons per cow per day. Zuagg (1989) also indicated the Arizona Department of Water Resources adopted 105 gallons per lactating cow per day and 20 gallons per nonlactating cow per day as the maximum water usages for dairies by the end of 2000. Table 3 summarizes the daily water usage on the five dairies in the Zuagg (1989) study. In South Flordia, dairies applying for a consumptive use permit to use 40 gallons per cow per day for drinking and 130 gallons per cow per day for flush water (Bray et. al., 1994).

Drinking Water Requirements

Lactating milk cows will drink from 30 to 50 gallons of water per day. A summary of daily water requirements for different type of dairy cattle is shown in Table 4. Data collected during the study comparing the impact of dietary fiber (Dado and Allen, 1995) indicates a cow will drink about 1.5 gallon of water per trip to a watering trough at a rate 1.3 gpm. They also found a cow will spend about 12 to 16 minutes per day drinking water. Their measured free water intakes were lower than most studies. However using this data, a cow makes about 24 trips per day if she drinks 40 gallons per day and 1.5 gallons per visit. Assuming a 12 foot watering trough and 6 cows present, the minimum water flow rate would be 8 gpm. A group of 100 cows spends approximately 40 hours of time per day at watering troughs. Even though cows spend only about 2½% of their time at the water trough, adequate water space recommendations per cow are to provide 2 feet of tank perimeter or 1 watering space per 15 to 20 cows (MWPS, 1997). Reinemann and Springman (1992) determine the drinking water requirements based on 4.5 to 5 pounds of water per pound of milk. They recommend the peak flow to waterers at 0.5 to 1 gpm per 10 cows. Dairies using a parlor more than 18 hours per day can probably use a 0.5 gpm per 10 cows peak flow rate, whereas dairies using a parlor less than 12 hours per day should use 1 gpm per 10 cows.

Martin (2000) estimates peak flow rate for larger dairies based on 10 gpm times the number of waterers in one group plus 10 gpm on all remaining lactating groups. If the facility houses heifers and dry cows, then peak flow rates for these groups may be based on daily consumption (gallons) divided by 1,440 minutes per day), to estimate the flow rate (gpm).

Wash Pen

The wash pen is a significant user of water on a dairy. Wiersma (1988) indicates 15 to 20 gallons per cow per milking may be used in the wash pen. Zaugg (1991) found on five dairies in Arizona the wash pen used from 19 to 93 gal/cow/day. The average value was 50 gal/cow/day. The water usage in a wash pen can equal the drinking water requirements. However, the demand will be much higher because a group of cows must be washed in a relatively short period of time.

Milk Equipment and Parlors

Many dairies have reduced water usage in the milk parlor by changing udder prep procedures. Dairies using hand operated wash hoses or automatic prep systems will utilize between 1 and 4 gallons per cow per milking. Water usage can be reduced to less than ½ gallon per day when using low water techniques such as single service towels. If cow towels are being used, water usage by the wash machine must be considered. Larger amounts of water are required for spray pens. Ludington and Sobel (1992) reported in a case study hot water usage dropped from 3.4 gallons per cow per day to 0.69 gallons per cow per day when changing from udder washing to dry prepping with pre and post dip.

Factors influencing the water usage in cleaning milking system include pipeline diameter, air injector settling, number of cycles per milking, etc. Automatic clean-in-place systems require from 100 to 300 gallons per milking for large parlors with weigh jars. Milk equipment suppliers should be able to provide an estimate of water requirements for cleaning the type of system being installed.

Water usage for bulk tank cleaning can be estimated by dividing a bulk tank size by 20 (Reinemann and Springman, 1992). The amount of water required is 3 to 5 percent of the tank volume with automatic washing systems. Water utilized in cleaning the milk equipment and bulk tank is not potable but may be stored and reused for flushing the cow platform and holding pens.

Reinemann and Springman (1992) recommends sizing the water requirements of plate coolers based on 1 to 2 pounds of water per pound of milk. Water usage may be less than 1 to 1 if no attempts are made to control water and milk flow. Spencer (1992) also notes water usage with pre cooler may be twice as much as the milk production while obtaining 30 to 50 percent of the cooling requirements.

Fresh or clean water is required when flushing the parlor platform and holding pen. Water can be recycled from the plate cooler to perform this task. Weeks (1992) reported about 7.5 gallons of water per cow were required per day for flushing the milk parlor and holding pen. However, the milk parlor was only used less than 8 hours per day. Some data suggest an adequate flush can be obtained using 1.5 gallons per sqare foot per flush. Assuming 30 cows per milk stanchion per milking, with each stanchion being 40 square feet (2.5 feet by 16 feet—rapid exit space included) along with 15 square feet per cow in the holding pen would result in 2.75 gallons per cow per flush or frequency of milking. Therefore, it is recommended for planning the water requirements for flushing the milk parlor be based on 5 to 7.5 gallons per cow per day. Basing the demand on delivering the water during a 3-minute flush cycle, the water demand can be estimated by multiplying the number of lactating cows by 1 gpm. A 1,000 cow dairy would have a water demand for flushing the platform and holding pen of 1,000 gpm. This demand does not have to be included in the water distribution system if recycled water from the milk equipment room is utilized. Another method to reduce the water demand is to provide a storage tower. In this case the demand can be based on the available time to fill the tank. If 4 hours are available, then the demand reduces from 1,000 to 10 gpm.

Sprinkler Systems

Sprinkler systems are used to wet the cow's back and can be used in the holding pen and along the feed lane. Bray et. al. (1994) reported water usage for low pressure systems ranging from 18.6 to 56 gallons per cow per day. They reported a study by Montoya (1992) found 23 percent of the water was evaporated and 15 percent of the total water applied evaporated from the cow's body. This rate of evaporation equaled about 1.1 gallon per cow per hour.

more ⟶

Bray and Bucklin (1995) recommend applying 0.05 inches per cycle when sprinkling cows. This converts to 0.03 gallons per square foot of wetted area. A cow will have about 12 square feet of wet area based on 2 feet along the feed line and 6 feet for cow length. Sprinkler systems generally operate based on 3 minutes on and then 12 minutes off. This will vary among regions and system design. The demand of the sprinkler system can be estimated by the number of cows being cooled multiplied by 0.1 gpm/cow. The water usage can be estimated by multiplying the number of cows by 0.3 gal/cow/cycle or 1 to 2 gallons per cow per hour. Therefore, if 1,000 cows are being cooled simultaneously, the demand would be 100 gpm and the water usage would be 300 gallons. Table 6 provides a summary of water usage and demand rates for low pressure sprinkler systems based on length of feed line. Pipe size can be reduced by locating the water line serving the sprinkler system in the middle rather than at one end. Plumbing becomes expensive with trying to meet the water demands on long feed lines due to the increase in pipe size necessary to carry the water demand.

Sprinkler systems can be operated either simultaneously or sequenced. A simultaneous system cools all of the cows at once and places the most demand on a system. The system basically comes on for the set time interval and is off until the next cycle occurs. The 1,000 cow example mentioned earlier has a demand of 100 gpm. A sequenced system results in using controllers to sequence the sprinklers on between different pens. For example, using a four-row 1,000 cow freestall, the sprinkler system in each quadrant of the building would come on at different times. This results in significant cost savings because the demand on the water system is reduced from 100 gpm to 25 gpm. The water usage is still 300 gallons but it can be delivered over a 12-minute interval rather than 3 minutes. Additional controllers are required with sequencing systems and management must be available to operate these systems. It is much easier to switch from a simultaneous to sequence system than vice versa. Therefore, initial planning requires careful consideration.

High pressure systems using misters require different types of planning. Bray et.al. (1994) reported high pressure fog ring systems use between 1.5 to 2 gallons per hour with water usage a function of pressure. For planning purposes, dairies can estimate the water demand of high pressure systems based on 0.03 gpm per fan. The system demand is based on the total number of fans being installed with misters multiplied by 0.03 gpm/fan. Assuming 1 fan per 5 cows, the system demand for a 1,000 dairy would equal 6 gpm. However, in many regions a sprinkler system is still needed along the feed line to adequately cool cows.

Dairies in the southwest United States use evaporative cooling under shade or cattle shade coolers. Armstrong and Welchert (1994) reported water usage for these systems from 0.2 to 2 gpm. One fan will serve 13 to 15 cows. The daily water usage with a shade cooler can be estimated by multiplying the number of cows times 0.1 gpm times the minutes per day of operation. The water demand can be estimated by multiplying the total number of shade cooler unit fans by 1.5 gpm. Using the 1,000 cow example and 12 hours of operation per day, the daily water usage would equal 72,000 gallons of water and the demand would be 100 gpm.

Holding pen sprinkler systems should be sized based on providing 0.01 gallons of water per square foot of area (gal/sq.ft.). Table 8 shows the water requirements for different size holding pens and the required flow rate of the water system. The flow rate is based on a cycle of 1 minute on and 6 minutes off. The time the sprinkler nozzles are on may be reduced if the udder of the cow is getting wet.

Summary

Modern dairy facilities will use between 50 to 200 gallons of water per cow per day depending on the operation. Proper planning requires obtaining adequate quantities and qualities of water to meet the present and future water requirements. It is important during the planning phase to consider the water demands of the dairy and design accordingly. When in doubt or uncertain, it is better to err by installing larger pipe so that management changes may be made in the future.

References

Allen, J.B., J.F. Beatty, S.P. Crockett and B.L. Arnold. 1974. An analysis of the water usage and waste treatment at a modern dairy. ASAE Paper No. 74-4038. American Society of Agricultural Engineers. St. Joseph. MI.

Armstrong, D.V. and W.T. Welchert. 1994. Dairy cattle housing to reduce stress in a hot-arid climate. Proceedings of Third International Dairy Housing Conference: Dairy Systems for the 21st Century. American Society of Agricultural Engineers. Pp. 598-604.

Bailey, K., M. Bennett, J. Garrett, D. Hardin, J. Hoehne, J. Spain, B. Steevens and J. Zulovich. 1993. Missouri Dairy Plan - The Missouri System of Dairy Production 500 Cow Plan. Unpublished Extension Manual. Diary Focus Team, Commercial Agriculture Program, University of Missouri Extension, Columbia, MO.

Beede, D.K. 1992. *Water for Dairy Cattle.* Large Dairy Herd Management: Chapter 28. H.H. Van Horn and C.J. Wilcox (eds.). Management Services, American Dairy Association. Champaign, IL.

Dado, R.G., and M.S. Allen. 1995. Intake limitations, feeding behavior, and rumen function of cows challenged with rumen fill from dietary fiber or inert bulk. *Journal of Dairy Science.* 78:118-133.

Bray, D.R., R.A. Bucklin, R. Montoya and R. Giesy. 1994. Means to reduce environmental stress on dairy cows in hot, humid climates. Proceedings of Third International Dairy Housing Conference: Dairy Systems for the 21st Century. American Society of Agricultural Engineers. Pp. 589-597.

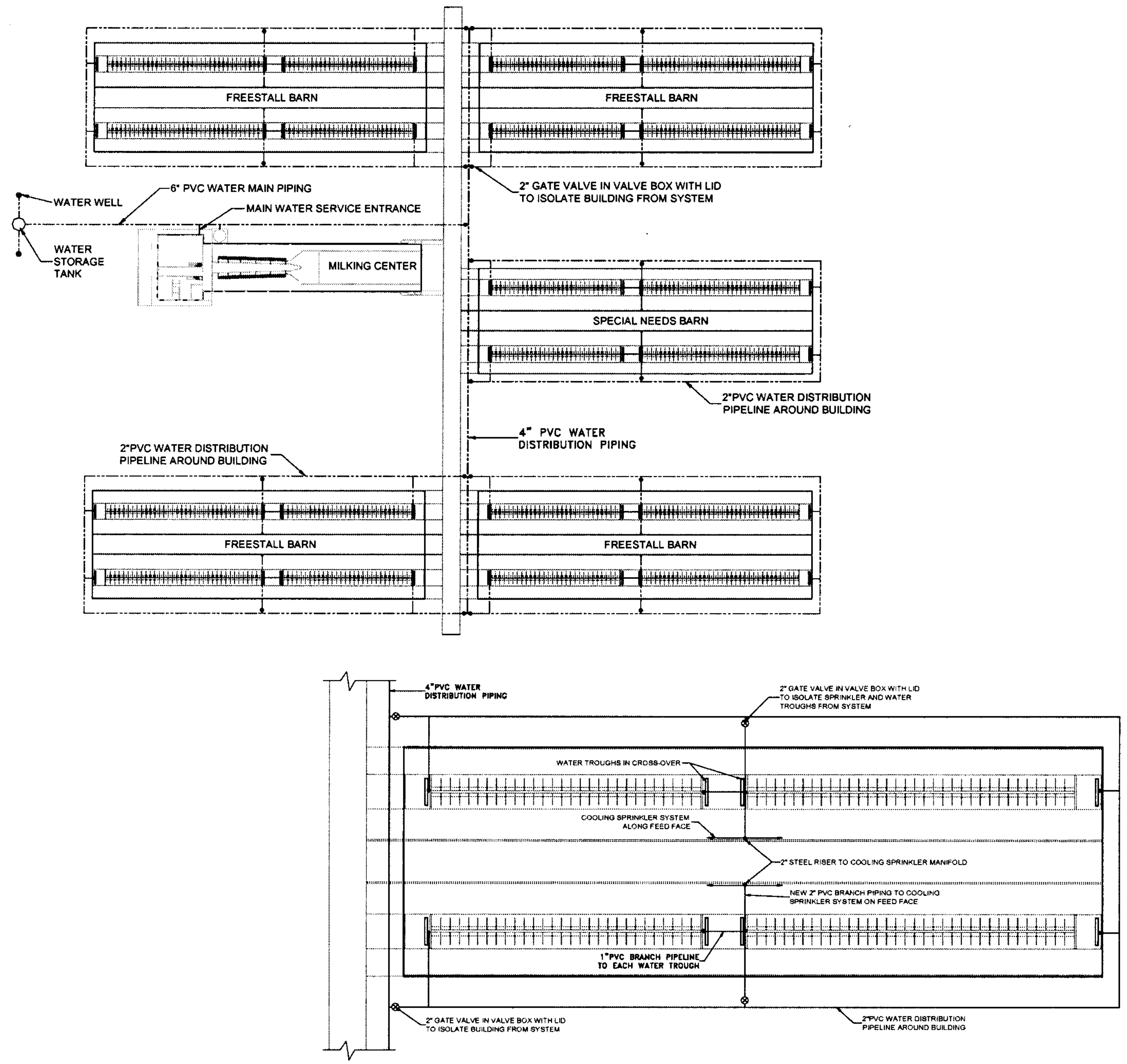
MWPS-7. 1999. *Dairy Housing and Equipment Handbook.* 4th Edition. Midwest Plan Service, Iowa State University, Ames, IA.

MWPS-30. 1999. *Sprinkler Irrigation Systems Handbook.* 1st Edition. Midwest Plan Service, Iowa State University, Ames, IA.

Hoehne, J.A., J.M. Zulovich and C.D. Fulhage. 1994. Proceedings of Third International Dairy Housing Conference: Dairy Systems for the 21st Century. American Society of Agricultural Engineers. Pp. 677-682.

Ludington, D.C. and A.T. Sobel. 1992. Providing hot water economically. NRAES-66. Proceedings from National Milking Center Design Conference. Northeast Regional Agricultural Engineering Service, Cornell University, Ithaca, NY.

Design of a Water System



more →

Reinemann, D.J. and R. Springman. 1992. Water quality, quantity and distribution. NRAES-66. Proceedings from National Milking Center Design Conference. Northeast Regional Agricultural Engineering Service, Cornell University, Ithaca, NY.

Spencer, S.B. 1992. *Milking cooling and storage equipment.* Chap 12. A.J. Bramley, F.H. Dodd, G.A. Mein and J.A. Bramley (eds.) Machine Milking and Lactation. Published by Insight Books.

Weeks, S.A. 1992. Cleaning the milk parlor. NRAES-66. Proceedings from National Milking Center Design Conference. Northeast Regional Agricultural Engineering Service, Cornell University, Ithaca, NY.

Wiersma, F. 1988. Water requirements for an Arizona dairy. Personnel correspondence.

Zaugg, N.L. 1989. Water usage on dairies in the southwestern desert. Unpublished report

Table 1. Effect of friction associated with pipe fittings and valves.

Fitting Type	Pressure loss (psi)	Equivalent pipe length (ft)
90° long sweep elbow	0.05	14
90° standard elbow	0.8	20
45° elbow	0.03	8
Gate valve, wide open	0.02	5
Gate valve, half open	0.41	130
Flow meter	0.14	32

Table 2. Estimated flow rate of various pump capacity operating against different pressure losses.

	Estimated Flow Rate (gpm) Based on Pump Size (hp)					
Pump Size	Average Feet of Head					
(horsepower)	20	40	60	80	100	120
10	1,485	743	495	371	297	248
20	2,970	1,485	990	743	594	495
30	4,455	2,228	1,485	1,114	891	743
40	5,940	2,970	1,980	1,485	1,188	990
50	7,425	3,713	2,475	1,856	1,485	1,238
75	11,138	5,569	3,713	2,784	2,228	1,856
100	14,850	7,425	4,950	3,713	2,970	2,475

Table 2b. Recommended maximum flow rate through pipe using different flow velocity. Water hammering may occur at velocities greater than 5 fps and require special fittings.

Nominal Pipe Diameter (inches)	Flow velocity through pipe (feet per second)		
	4	5	7.5
0.5	2	3	5
0.75	6	7	10
1	10	12	20
1.25	15	20	30
1.5	20	30	40
2	40	50	70
2.5	60	80	120
3	90	110	160
4	160	200	300
6	350	440	660
8	630	780	1,200
10	980	1,200	1,800
12	1,400	1,800	2,600
16	2,500	3,100	4,700
24	5,600	7,000	10,500

Table 4. Estimate of drinking water requirements for different dairy animal types (MWPS, 1999).

Animal Type	Water Usage (gallon/day/head)
Calves (1 to 1.5 gal/100 lbs)	6 to 10
Heifers	10 to 15
Dry Cows	20 to 30
Lactating Cows	25 to 50

Table 5. Estimate of water usage (gallons) and demand (gpm) for low pressure system located along a feed line.

Length of Feed Line (ft)	Water Usage per Cycle(gal)*	Water Demand (gpm)
100	20	7
200	40	13
400	75	25
600	110	38
800	150	50
1,000	190	62

*Based on wetted distance from feed line of 6 ft and 0.05 inches of water/cycle/sq.ft and 3 minute on cycle.

Table 6. Sprinkler nozzle requirements based on holding pen capacity.

Holding Pen Capacity	Typical Pen Size (feet by feet)	Water Required (Gallons/Cycle)	Minimum Flow Rate (gpm)*
80	24 by 50	40	14
100	32 by 48	50	16
120	32 by 56	60	20
160	32 by 75	80	30
200	32 by 96	100	40
300	32 by 144	150	50
400	32 by 192	200	75
500	32 by 240	250	100

*Flow rate based on a 3 minute on cycle with 12 minutes off.
**Assumes nozzles have an 8 foot spray diameter and 0.5 gpm capacity.

more →

Table 3. Summary of daily water usage on five dairies in southwestern United States (Zaugg, 1989).

	Dairy Identification and Milking Frequency				
	A(3X)	B(3X)	C(2X)	D(2X)	E(3X)
Daily Water Usage					
Total Gallons per Lactating Cow*	186	101	95	72	182
Udder Wash per Lactating Cow	93	49	19	24	65
Drinking					
Early Lactation	34	31	30	29	35
Late Lactation	27	28			25
Dry Cow	16	13			17
Close-up		16			17
Calves (hutches or barns)		3	2	2	25**
2-6 months		3	4	4	5
7-15 months					10
16-22 months					11
Cooling					
Shade Evaporative Cooler		15			16
Shade Misters			4.5		
Fence Line Misters			2.5	1.4	
Holding Pen Sprayer		2	2	2.3	
Exit Sprayer	2.1			0.8	
Parlor Evaporative Cooler	1.4	0.5		0.1	5.4
Parlor					
Hot Water	0.8	0.3	0.7	0.8	0.9
Cold Water	5.9	2	1		
Drop Hoses	1.8			2.5	2.1
Wash Hoses	3.3		6		6.5
Vacuum Pump	6.5				5

*Total water usage divided by the number of lactating cows.
*Includes cleaning and sanitizing wire cages, concrete floors and alleys.

Table 7. Estimate of daily water requirements and demand for 1,000 lactating cows.				
	Percent of Lactating Cows	Daily Usage (gal./day)	1,000 Lactating Cows (gal./day)	Minimum well(s) capacity based on 20 hours pumping (gal./min.)
Drinking Water				
Lactating Cows	92	40 gal/cow	36,800	31 gpm
Dry Cows	25	30 gal/cow	7,500	7 gpm
Calves/Heifers	115	15 gal/cow	17,250	15 gpm
Sick/Lame Cows	8	30 gal/cow	2,400	2 gpm
Milk Parlor				
Plate Cooler		1.5 lb water per lb milk	14,400	12 gpm
Wash Water	100	5 gal/cow	5,000	4 gpm
Flush Water	100	25 gal/cow	25,000	21 gpm
Employees	1 FTE/80 cows	50 gal/employee	600	0.5 gpm
Sprinkler System*	4 cycle/hr	1 gal/cy/cow	96,000	80 gpm
Special Needs				
Special Needs Parlor	8	15 gal/cow	1,200	1 gpm
Holding Pen	3x milking	3 gal/cow/milking	9,000	8 gpm
Minimum pumping capacity from the well into a storage tank				185 gpm

*assumes the times are sequenced such that no more than 4 groups are being sprinkled at a time using a 3 minute on and 12 minute off cycle.

Photoperiod Control Improves Production and Profit of Dairy Cows

GEOFFREY E. DAHL—Animal Sciences, University of Illinois, 230 ASL, MC-630 1207 W. Gregory Dr. Urbana, IL 61801
Tel: 217-244-3152 Fax: 217-333-7088 gdahl@uiuc.edu

Environmental factors that potentially depress milk production efficiency are often planned for in dairy housing. For example, cooling to abate heat stress, bunk management to maximize dry matter intake, and bedding choices that improve cow comfort all act to prevent a loss of production. One environmental factor, photoperiod, can be used to effectively improve production efficiency in lactating cows. As with any management approach, there are certain guidelines that require consideration for successful implementation. Combination of long day lighting with other management technologies such as bST and three times a day (3X) milking increase the complexity of effectively implementing the technique.

What is photoperiod? Photoperiod is defined as the duration of light an animal is exposed to within a 24-hour period. Animals use photoperiod to track the length of the day. A long day photoperiod (LDPP) is considered continuous exposure to 16 to 18 hours of light along with a 6- to 8-hour period of darkness. In contrast, a short day photoperiod (SDPP) is usually 8 hours of light and 16 hours of darkness. Poultry producers have used light manipulation for decades to improve growth and egg laying efficiency (22). Data is now available to support application of photoperiod management to dairy cattle in all housing situations (7).

At least nine published research studies (2, 8, 9, 11, 13, 14, 15, 18, 20; summarized in Figure 1) show that milk production is increased in cows exposed to long days relative to those on natural photoperiod. The consistency of the response is striking and averages about 5 lbs/cow/day. Milk production increased in cows regardless of production level, suggesting that the response is fixed rather than yield dependent. In addition, the types of housing, ration and other management factors were variable; further evidence that long days would be effective in any dairy facility. There is no effect of photoperiod on milk lactose, protein, or solids. Slight variance in fat has been observed, with an increase in one experiment and a decrease in another. In general, there is no effect on fat or other components (7). From a milk yield perspective there is overwhelming evidence that extending the duration of light exposure to lactating cows increases milk yield.

Exposure to light suppresses secretion of the hormone melatonin in cows as in other species (7,19). Thus, as the length of photoperiod increases, there is a reduced duration that melatonin is at high concentrations in the blood. The pattern of melatonin influences secretion of other hormones, particularly prolactin (PRL) and insulin-like growth factor-I (IGF-I). We believe that the changes in IGF-I are important to the increase in milk yield observed in cows on long days (8). This is the same hormone thought to mediate the effects of bST (1), but it appears that photoperiod and bST act via slightly different pathways to produce the response. Indeed, long day lighting can be combined with bST for an additive response (13). In addition, cows on LDPP and bST increased dry matter intakes sooner than cows receiving bST under natural photoperiod. With photoperiod, as with bST, we are manipulating the cow's physiology with a signal to increase milk production.

As cows produce more milk after exposure to long days, they will eventually increase dry matter intake (7, 13). The added feed cost, however, is more than covered by the higher milk production. It is important to point out that the intake lags the increase in production; it is not that improved lighting somehow drives the cow to eat more and thus make more milk. This concept is critical in evaluating where and how many lights are placed in a barn. Lights should never be limited to the area over the feedbunk in freestall housing. Rather, the entire barn should be illuminated to an intensity of 15 footcandles (FC). This based on the fact that cows spend a majority of their time lying in stalls versus at the feedbunk (5, 6). To effectively influence the cow's physiology, exposure to light is necessary for at least 16 hours. Thus, placement over the feedbunk alone will not be effective.

It is important to remember that cows need some darkness — it will not be possible to sustain a response if the lights are left on continuously. As stated earlier, animals use the pattern of melatonin to track daylength. In the absence of any darkness, there is no cue for relative daylength, and it appears that cows default to a short day response. This does not mean that continuous lighting will reduce production, only that a long day induced increment will not be sustainable. Likewise, it is not necessary to leave a "night light" on for cows to see the waterer or feed. Cows are able to find both feed and water in the dark. Remember that at least a 6 hour period of darkness is required, and "night lighting" may interfere with that. Low

more ⟶

intensity red lighting (7.5W bulbs at 20- to 30-foot intervals) has been used successfully for observation and movement of cows during dark periods.

One question often asked is "how dark is "dark?" Light intensity is measured in FC or lux (lx), with 1 FC = 10.8 lx. There are limited data available on the lower limit of light that a cow can detect. However, it appears that cows can not detect light at less than 5 FC. It should be noted that cows may experience a shift in their ability to perceive light depending on the difference in intensity of the light relative to dark. Extraneous light sources, therefore, should be limited whenever possible. This includes yard lights, night lights, etc.

Milking cows 3X poses a logistical challenge in maintaining the dark period when milking occurs at 8-hour intervals. Yet, if cows receive adequate dark periods, they will respond, even if milked three times daily. Remember to keep a 6 hour uninterrupted period of darkness between two of the milkings. This may require coordination of milking schedules and darkness in different sections or barns. On one farm, approximately 1000 cows were exposed to 18 hours of light and milked 3X. Milking times were scheduled such that different strings received darkness for 6 hours based on their time spent in the parlor, though the dark period was asynchronous among strings. Cows on long days produced 6.5 pounds per day more milk than a similar group on natural photoperiod. Of interest, when the second group of cows was placed on long days, it was impossible to maintain an uninterrupted dark period, and their response was much less.

Because responses to long days have been observed in cows exposed to fluorescent, metal halide (MH), and high pressure sodium (HPS) lighting, the type of light selected for long day lighting does not matter (7). The choice of lighting type should be made according to efficiency and the mounting height most appropriate to the barn. In freestalls, lights can often be mounted at heights of 14 to 16 feet or higher, thus, MH or HPS are appropriate. These lamps provide the desired intensity with high efficiency and are, therefore, the lowest in operating cost. One caution to the use of HPS is that many people do not respond well to the yellow light output from those lamps. Therefore, worker acceptability should be considered in lamp choices.

To observe a production response in lactating cows, an intensity of 15 FC at 3 feet from the floor of the stall is recommended. Responses have been observed at intensities as low as 10 FC, but the extra 5 FC gives a buffer for dirty lamps, burned out bulbs, etc. Estimation of the number of fixtures required to achieve a 15 FC intensity is straightforward (3, 4). The first equation, (Area) x (FC) x (K), yields the total lumens needed. Area is the square footage of the barn, FC is the desired footcandles of intensity (i.e. 15), and K is a constant for outdoor lighting conditions (versus indoors where wall reflectance would be a factor). An open or curtain sided barn would use a K of "3", whereas an enclosed stanchion style barn would require a K of "2". Once Total Lumens have been determined, simply divide by the lumen output of the lamp in question, to yield the number of fixtures required. Manufacturers provide luminal output information for all lamps. As for spacing, a maximum distance between lamps can be estimated by dividing the recommended mounting height by a factor of 1.5 (3).

It is important to remember that the dispersion of light over an area should be as uniform as possible. Appropriate dispersion can be achieved with correct mounting height and distance. Light meters to test light intensity can be obtained from electrical suppliers or photographic shops; they are usually priced between $75 to $125.

Light meters are simple to operate and portable. Regardless of lighting design recommendations, all lighting systems should be tested with a light meter. Not only will this allow determination of the intensity, but meter readings throughout the facility will confirm that light is evenly distributed between lamps. Problems such as "spot-lighting" and low light corners can then be avoided. Photoperiod can also be used during the dry period and late gestation to improve milk yield in the subsequent lactation. In contrast to lactating cows, recent experiments from our laboratory and Canada indicate that a short day photoperiod is most appropriate for dry cows. Cows on SDPP when dry produced 7 lbs/day more than cows on LDPP when dry (Figure 2; 12). This is consistent with preliminary work by Petitclerc et al. in cows (17) and heifers (16, 17) that showed higher production in animals exposed to SDPP during the dry period (final 60 days of gestation in heifers) relative to those exposed to long days. We suspect that the short days before parturition "resets" the cow's ability to respond to LDPP in the subsequent lactation.

In addition to lactation and the dry period, photoperiod manipulation can affect cows in other ways. Although cows are not considered seasonal breeders, there are some subtle effects of photoperiod on the reproductive axis (10). Exposure to LDPP hastens puberty in heifers. Heifer calves exposed to long days grow faster and have greater secretory tissue growth of the mammary gland (21). In lactating cows, no direct effect of photoperiod has been observed on reproduction, but seasonal effects associated with differences in photoperiod occur. Notably, cows calving in the winter, when days are short, have a longer delay in return to estrous cyclicity relative to cows that calve in summer, when days are long. Thus, extending the photoperiod in cows may hasten the return to estrus during the winter and fall. Certainly no adverse effects of long days on reproduction in cattle have been observed.

Table 1. Milk price sensitivity to photoperiod management for a typical 250 cow free-stall barn.

Milk Price[a]	$14.00	$13.00	$12.00	$11.00	$10.00	$9.00
Milk Response[b]	5	5	5	5	5	5
Milk Income[c]	$0.70	$065	$0.60	$0.55	$0.50	$0.45
Feed[d]	$0.11	$0.11	$0.11	$0.11	$0.11	$0.11
Electricity[e]	$0.04	$0.04	$0.04	$0.04	$0.04	$0.04
Total Cost	$0.15	$0.15	$0.15	$0.15	$0.15	$0.15
Net Profit	$0.55	$0.50	$0.45	$0.40	$0.35	$0.30
Profit/Mo	$4,125.00	$3,750.00	$3,375.00	$3,000.00	$2,625.00	$2,250.00
Annual Profit[f]	$41,250.00	$37,500.00	$33,750.00	$30,000.00	$26,250.00	$22,500.00

[a]Mailbox price per cwt.
[b]Average response per cow each day.
[c]Per cow each day.
[d]Assume 1.8 lb increase in dry matter to support 5 lb increase in milk.
[e]Electricity to power supplemental lighting 8 hr/day.
[f]Assumes response only 10 month each year.

Even in times of low milk prices, photoperiod management profitable. Table 1 presents an example of the milk price sensitivity with adoption of photoperiod management in a typical freestall operation. Although LDPP is profitable on farms of all sizes, certain economies of scale factor in on larger farms and increase the profitability. These include the higher density of freestall barns, greater ability to use natural lighting in curtain-sided barns, and use of higher efficiency lamps to illuminate freestall facilities. Using a cost of $50/cow, in all of the examples in Table1, the payoff time for a completely new lighting system would be less than 6 months. Even at a cost of $75/cow, payoff time is less than a year.

The take home message of this paper is that extending photoperiod in lactating cows is simple to implement, easy to manage, and profitable. More information on the topic can be found at www.ansci.uiuc.edu/photoperiod. This site contains more information on photoperiod, worksheets to assist producers in light design and cost analysis, and other contact information.

References

1. Bauman, D. E. 1999. Bovine somatotropin and lactation: from basic science to commercial application. Domest. Anim. Endocrinol. 17:101-116.
2. Bilodeau, P. P., D. Petitclerc, N. St. Pierre, G. Pelletier, and G. J. St. Laurent. 1989. Effects of photoperiod and pair-feeding on lactation of cows fed corn or barley grain in total mixed rations. J. Dairy Sci. 72:2999-3005.
3. Chastain, J. Lighting in freestall barns. 2000. pp. 115-130 In: Proceedings of the Dairy Housing and Equipment Systems Conference, NRAES-129, Ithaca, NY.
4. Chastain, J. and R. S. Hiatt. 1998. *Supplemental lighting for improved milk production*. Electric Power Research Institute Bulletin, National Food and Energy Council, Columbia, MO.
5. Dado, R. G. and M. S. Allen. 1993. Continuous computer acquisition of feed and water intakes, chewing, reticular motility, and ruminal pH of cattle. J. Dairy Sci. 76:1589-1600.
6. Dado, R. G. and M. S. Allen. 1995. Intake limitations, feeding behavior, and rumen function of cows challenged with rumen fill from dietary fiber or inert bulk. J. Dairy Sci. 78:118-133.

more ⟶

7. Dahl, G. E., B. A. Buchanan and H. A. Tucker. 2000. Photoperiodic effects on dairy cattle: A review. J. Dairy Sci. 83:885-893.
8. Dahl, G. E., T. H. Elsasser, A. V. Capuco, R. A. Erdman, and R. R. Peters. 1997. Effects of long day photoperiod on milk yield and circulating insulin-like growth factor-1. J. Dairy Sci. 80:2784 2789.
9. Evans, N. M., and R. R. Hacker. 1989. Effect of chronobiological manipulation of lactation in the dairy cow. J. Dairy Sci. 72:2921-2927.
10. Hansen, P. J. 1985. Seasonal modulation of puberty and the postpartum anestrus in cattle: a review. Livest. Prod. Sci. 12:309-327.
11. Marcek, J. M. and L. V. Swanson. 1984. Effect of photoperiod on milk production and prolactin of Holstein dairy cows. J. Dairy Sci. 67:2380-2388.
12. Miller, A.R.E., R. A. Erdman, L. W. Douglass, and G. E. Dahl. 2000. Effects of photoperiodic manipulation during the dry period of dairy cows. J. Dairy Sci. 83:962-967.
13. Miller, A.R.E., E. P. Stanisiewski, R. A. Erdman, L. W. Douglass, and G. E. Dahl. 1999. Effects of long daily photoperiod and bovine somatotropin (Trobest(r)) on milk yield in cows. J. Dairy Sci. 82: 1716-1722.
14. Peters, R. R., L. T. Chapin, R. S. Emery, and H. A. Tucker. 1981. Milk yield, feed intake, prolactin, growth hormone, and glucocorticoid response of cows to supplemental light. J. Dairy Sci. 64:1671-1678.
15. Peters, R. R., L. T. Chapin, K. B. Leining, and H. A. Tucker. 1978. Supplemental lighting stimulates growth and lactation in cattle. Science (Washington, DC) 199:911-912.
16. Petitclerc, D., C. M. Vinet, and P. Lacasse. 1989. Peripartum effects of photoperiod and lactose on primiparous Holstein heifers. 41st Ann. Mtg. Eur. Assoc. Anim. Prod. P 86 (Abstr.).
17. Petitclerc, D., C. Vinet, G. Roy, and P. Lacasse. 1998. Prepartum photoperiod and melatonin feeding on milk production and prolactin concentrations of dairy heifers and cows. J. Dairy Sci. 81(Suppl. 1):251 (Abstr.).
18. Phillips, C.J.C., and S. A. Schofield. 1989. The effect of supplementary light on the production and behavior of dairy cows. Anim. Prod. 48:293-303.
19. Rieter, R. J. 1991. Pineal melatonin: cell biology of its synthesis and of its physiological interactions. Endocrine Rev. 12:151-180.
20. Stanisiewski, E. P., R. W. Mellenberger, C. R. Anderson, and H. A. Tucker. 1985. Effect of photoperiod on milk yield and milk fat in commercial dairy herds. J. Dairy Sci. 68:1134-1140.
21. Tucker, H. A., D. Petitclerc, and S. A. Zinn. 1984. The influence of photoperiod on body weight gain, body composition, nutrient intake and hormone secretion. J. Anim. Sci. 59:1610 1620.
22. Tucker, H. A., and R. K. Ringer. 1982. Controlled photoperiodic environments for food animals. Science 216:1381-1386.

Figure 1. Summary of nine studies reporting the effect of long day photoperiod on milk yield in lactating cows.

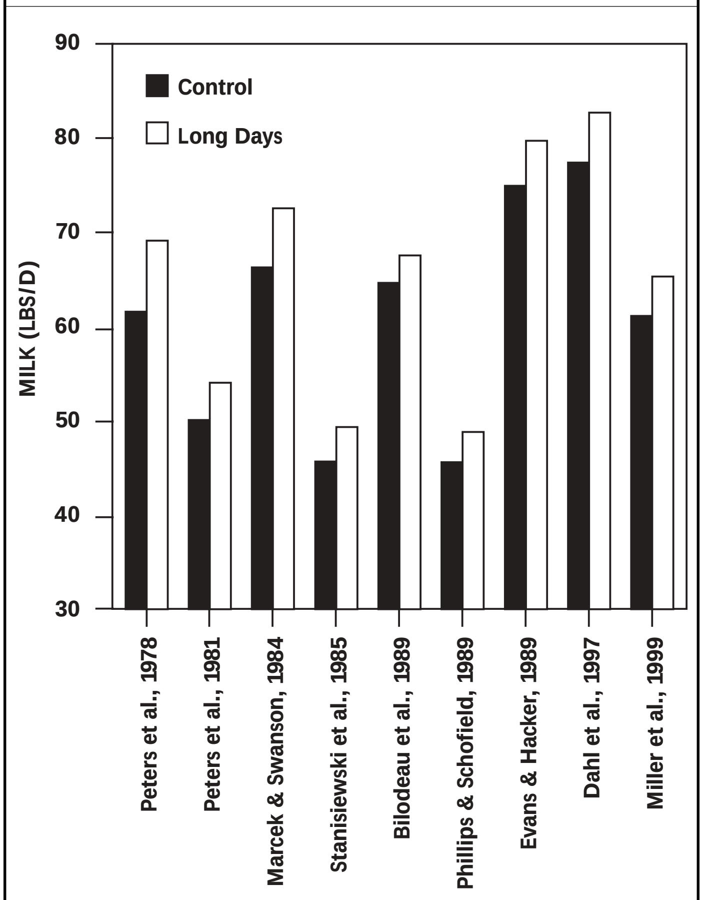
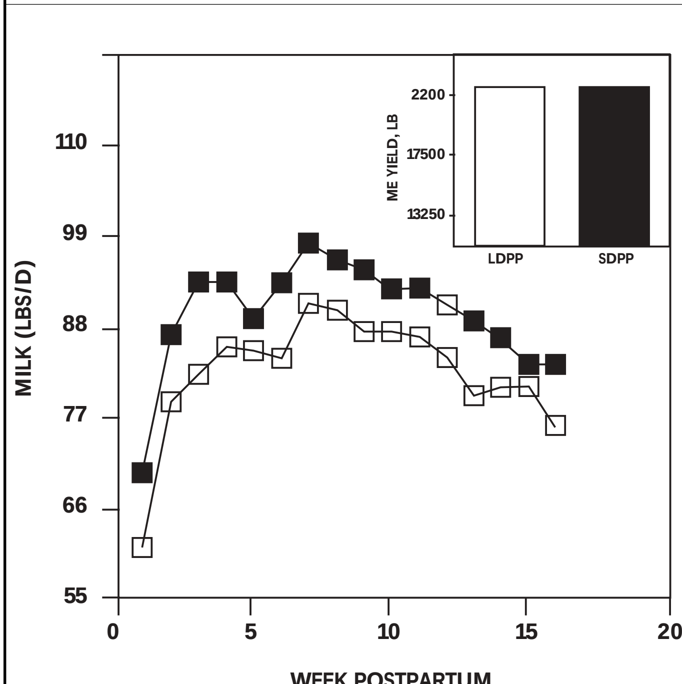


Figure 2. Group means for milk yield (lbs/d) during the subsequent lactation of cows exposed to long-day (LDPP = o, n = 18;) or short-day photoperiods (SDPP = n; n = 16) during the dry period. At calving all cows returned to natural photoperiodic conditions (January to June in Maryland). Each symbol represents the mean yield of the cows in that group for that week of lactation, through the first 16 wk of lactation. The inset depicts the average ME milk for the previous lactation, confirming that the groups were uniform with regard to production potential. Adapted from Dahl et al., 2000.



Recommendations for Special Needs Facilities

J.F. SMITH—Animal Sciences & Industry, 125 Call Hall, Kansas State University, Manhattan, KS 66506
Tel: 785-532-1203 Fax: 785-532-5681 jfsmith@oznet.ksu.edu

J.P. HARNER III—Biological & Agricultural Engineering, Kansas State University

M.J. BROUK—Animal Sciences & Industry, Kansas State University

N. ST-PIERRE—Department of Animal Science, The Ohio State University

S.R. STOKES—Department of Animal science, Texas A&M University

W. J. COLE—Monsanto Dairy Business

J.P. GOFF—National Animal Disease Center

G. BOOMER—Monsanto Dairy Business

G. BETHARD—G & R Dairy Consulting

D.V. ARMSTRONG—Department of Animal Science, University of Arizona

M.J. GAMROTH—Department of Animal Science, Oregon State University

Introduction

Often, when dairy producers are planning to build new dairy facilities a lot of time is spent on selecting and sizing the milking parlor and cow housing. However, often not enough effort is put into designing, selecting, and sizing special needs facilities. There are an overwhelming number of reasons from a cow health and milk production standpoint to have a well-designed special needs facility that will not be a barrier to management. The transition from a pregnant cow to a lactating cow represents the period of greatest challenge to the health and productivity of the dairy cow (Curtis et. al., 1985). The majority of metabolic and infectious disease the cow will experience will occur in the first weeks of lactation. The sudden onset of milk production outpaces the animal's ability to increase intake of nutrients placing the animal in negative balance for such vital nutrients as energy, protein and calcium in early lactation. Cows failing this metabolic challenge can develop milk fever, ketosis and displaced abomasum. The hormonal changes associated with the act of calving have a suppressive effect on the immune system of the animal increasing susceptibility to infectious diseases such as mastitis and Salmonellosis. Negative energy balance and environmental stresses can have an additive effect on immune cells and further suppress the animal's resistance to infection. To reduce disease and improve the productivity of the cow we must design facilities and strategies to maximize feed intake and reduce "stress" on the transition cow. Stress can take many forms but generally results in an increase in cortisol release by the cow, which tends to reduce immune cell function.

This paper discusses the issues associated with special needs facilities. The examples in this paper are based on a 2,400 lactating cow dairy that has chosen to use freestall housing configured in 4-row barns.

Definitions

Before proceeding into the heart of this topic it is important to define some terms. Listed below are definitions used in these proceedings.

Special needs facility — The facility and equipment needed to manage cows and heifers starting with 21 days prior to calving (close-ups) to 16 after calving (fresh cows), sick cows, and high-risk lactating cows. This facility must ensure the safety and well being of employees and minimize the stress on a dairy animal(s) due to additional interactions between the employee and dairy animal.

Close-up — Cows and heifers that are from 4 to 28 days prepartum up to but not including calving.

Maternity — The area provided for cows and heifers to give birth.

Fresh cows and heifers — Cows and heifers from calving to 16 days postpartum.

Transition Period — Twenty-eight days prepartum to 16 days postpartum.

High-risk lactating cows — Cows that produce milk that can be sold but need special attention. Examples would be lame cows, older cows, slow milkers and cows that had just been released from the sick pen.

Mastitis and sick cows — lactating and sick cows that have been treated with antibiotics.

Activities to be Completed in the Special Needs Facilities

A number of activities will need to be carried out in the special needs facilities. Numerous authors have pre-

more →

sented materials discussing restraining and treating cows (Bickert 2000, Bickert 1998, Hardin, et al. 1994, Veenhuizen and Graves, 1994). Table 1 lists these activities and the possible locations they could be carried out in the special needs facility. The decision to use or not to use headlocks needs to be made early in the design process. If headlocks are installed along the feed barrier, many of these activities may be carried out in headlocks. The planning team must determine how all the activities are going to be performed by the management team.

Grouping Strategies and Building Requirements

The size and number of cow groups on a dairy are critical planning factors. Factors affecting the number and types of groups are largely associated with parlor size, maximizing cow comfort, feeding strategies, reproduction and increasing labor efficiency. Lactating cows are allotted to one of seven classifications;

1. Healthy lactating heifers
2. Healthy lactating cows

Table 1. Possible areas activities can be completed in the special needs facilities.

Activity	Lockups	Chute	Palpation Rail	Shipping Area	Parlor / Equipment Room	Maternity	Table
Drenching	X	X					
Injections	X	X	X				
Rectal Temperatures	X	X	X				
Urine pH	X	X					
I.V.'s	X	X					
Sorting	X	X	X				
Palpations	X	X	X				
Insemination	X	X	X				
Postmortem Exams				X			
Hoof Trimming		X					X
Surgery	X	X					
Milk Pasteurization					X		
Pulling Calves						X	
Process Calves						X	
Shipping				X			
Drying Off					X		
Treat Mastitis					X		

3. Fresh cows and heifers with non-sellable milk (0 to 2 days postpartum)
4. Fresh cows with sellable milk (3 to 16 days postpartum)
5. Fresh heifers with sellable milk (3 to 16 days postpartum)
6. Sick cows with non-sellable milk
7. High risk cows with sellable milk.

The cows in classifications 3 to 7 are typically housed in the special needs area along with close-up cows and heifers. Figure 1 illustrates how cows and heifers would move through the special needs area, starting with 21 days prepartum. Some may opt to move heifers into this facility 28 to 35 days prepartum.

Heifers respond favorably when grouped separately from older cows. Heifers have lower dry matter intakes and greater growth requirements as compared to older cattle. In addition, mixing heifers with older cattle increases social pressure resulting in less than optimal heifer performance. Isolating heifers from mature cows immediately following calving is difficult on most dairies due to the small number of cows and heifers that will be 2 days postpartum at any given time. In Figure 1, cows and heifers are co-mingled for 2 days after calving.

Close-up dry cows and springing heifers differ in nutritional requirements. Close-up cows have greater intakes and are more likely to develop milk fever than heifers. Springing heifers may also benefit from a longer transition period than normally allowed for cows. Thus, heifers and dry cows should be separated. Close-up cows should be moved into a close up pen 21 days prior to calving. The diet in this pen typically has greater concentrations of protein and energy as compared to the far off dry cow diet. In addition, the diet should be low in calcium and potassium or contain anionic salts with appropriate amounts of calcium and potassium to prevent milk fever. Milk fever is generally not a problem with heifers but heifers may benefit from receiving the typical transition diet for 5 weeks rather than 3 weeks. Thus, feeding a diet with higher levels of protein and energy without anionic salts for 5 weeks prior to freshening would be beneficial for heifers. Allowance in the special needs facilities must be made during the initial planning process if heifers are to be housed 28 to 35 days prepartum rather than 21 days.

Immediately (24 to 48 hours) prior to calving close-up cows and heifers would be moved into a maternity pen with a bedded pack. Following calving, cows and heifers may be co-mingled or kept separate until the milk can be sold. This is the only area in the special needs area where cows and heifers may be housed together. If the facilities allow, keeping the cows and heifers separated during this period is recommended. Cows and heifers would be segregated when they move out of the fresh non-sellable pen into the fresh pens. Cows and heifers would be housed in the fresh pens for 14 days where rectal temperatures, dry matter intakes and general appearance can be monitored on a daily basis.

Other pens for mature cows and heifers in the special needs area would be a sick pen used to house cows treated with antibiotics and a high risk pen for lame cows and slow milkers producing sellable milk. An additional pen would also be supplied as a holding area for cows to be culled, dried off, or moved to another group of cows. Generally, this is a dry lot pen, which is conveniently located near the shipping area.

Space near the maternity area is needed to process and house calves after calving. Calf housing should be provided for the number of calves that will be born in a 24-hour period or sized according to the calf grower pick-up arrangements.

Table 2 provides recommended groups, group sizes and typical housing requirements for cows, heifers and calves. It is important to realize these group sizes have been increased to account for fluctuations in calvings and cow and heifer numbers. If these pens are only sized for static or average numbers, there will be a considerable amount of time where the special needs facilities are over stocked.

Selection of Cow Housing

In a freestall dairy, cows and heifers in the special needs facilities are housed in either freestalls or loose housing. There are advantages and disadvantages to the two different housing systems. Loose housing maximizes cow comfort but requires additional space, bedding material, and labor to maintain a sanitary environment. This is particularly true when organic bedding is used. Freestalls reduce the labor cost of maintaining the resting area. Stalls may intimidate certain groups of cows and, therefore, should not be used. Some of the housing options that can be used for different groups of cows are listed in Table 2.

The data in Figure 2 is similar to recommended group sizes published by Stone (2000). Kammel et al, (2000) presented case studies of how dairy producers managed special needs facilities. The information in these case studies is similar to the information presented in Table 2.

Transition Cow Cooling

Heat stress in the transition cow may impair health, decrease milk yield, and lengthen time to peak milk

more →

Table 2. Recommended Groups and Facilities for Cows Housed in the Special Needs Area in a 2,880 Cow Dairy (2,400 lactating cows).

Group	Average Time in Facility	% of Lactating Herd	# of Cows	Housing System
Close-up cows	21 days	6%	144	Freestalls or loose housing
Close-up heifers	21 days	3%	72	Freestalls or loose housing
Maternity cows	3 days	.33%	8	Loose housing
Maternity heifers	3 days	.33%	8	Loose housing
Maternity overflow	3 days	.33%	8	Loose housing
Fresh cows & heifers, non-sellable milk	2 days	1%	24	Freestalls or loose housing
Fresh cows	14 days	3.5%	84	Freestalls
Fresh heifers	14 days	1.5%	36	Freestalls
Mastitis & sick cows, non-sellable milk	N/A	2%	48	Freestalls or loose housing
High risk sellable milk	N/A	2-6%	48-144	Freestalls or loose housing
Cull and dry cows	N/A	1.5%	40	Loose housing
Calf housing	24 hours		12	Hutches or small pens

production and peak feed intake. Transition cows are particularly susceptible to infectious diseases and metabolic disorders. Cost estimates of impaired health in the fresh cow range from $145 per case of clinical ketosis to $340 per case for displaced abomasum (Hoard's Dairyman, 1996). Perhaps the biggest challenge in managing the fresh cow is to get her on feed the first few weeks postpartum. Aggressive postpartum appetites minimize the time spent in negative energy balance and are necessary to support high levels of milk production.

Research reports that prepartum cooling consistently decreases rectal temperature, lowers respiration rate, and increases calf birth weight. While milk production responses have been somewhat variable, these variations may be explained by differences in duration and extent of prepartum cooling across trials. Wiersma and Armstrong (1988) reported higher peak milk production (up to 5%) in cows cooled prepartum compared to those not cooled prepartum (88.4 versus 84.2 pounds milk per cow per day for cooled and control cows, respectively). Collier et al. (1981, 1982) also reported trends for higher milk production due to prepartum cooling (either as shades or evaporative cooling systems). Field trials have demonstrated increased peak milk yield and earlier days to peak production in fresh cows cooled with evaporative cooling compared to non-cooled cows (Stokes and Pope, 1997). Likewise, cooled cows showed greater lactation persistency compared to non-cooled control cows.

The endocrine system is perhaps more sensitive to moderate heat stress during the dry period than during lactation. Prepartum heat stress affects growth of maternal tissues (mammary gland, placental, or fetal tissue), influences postpartum mammary function (Collier et al., 1982), decreases calf birth weight (as much as 10%), reduces immunoglobulin content, and lowers nutrient (fat, protein, and lactose) concentration in colostrum. Calves born during the summer suck their dams less vigorously and may have impaired absorption efficiency caused by heat stress. This lowered absorption efficiency, coupled with the lowered content of colostrum, may increase the incidence of health complications and mortality in calves born during the summer and early fall.

Heat stress in cows prior to breeding and during the implantation phase may influence fertility. Wolfenson et al. (1988) reported an increase in both conception rate (59 vs 17%) and 90-day pregnancy rate (44 vs 14%) of cooled cows compared to non-cooled cows. Additionally, estrous behavior lasted longer in cooled (16 hours) than non-cooled (11.5 hours) cows having low body condition scores (average 2.6). Others have demonstrated a 15% decrease in services per conception and a reduction in the number of cows culled for reproductive failure (19 vs 7.7%) in response to prepartum cooling (Wiersma and Armstrong, 1988). Dunlap and Vincent (1971) reported heifers exposed to heat stress the first 72 hours after artificial insemination did not conceive at all.

Postpartum production benefits of cooling dry cows may be dependent on the length of the cooling period. Initial research in this area involved shade as the cooling method. While adequate shade is recommended for the far off dry cow (first 4 to 6 weeks of the dry period), recent work suggests that more extensive cooling systems may be justified for close-up dry cows. Much of the immune and endocrine responses reported with transition cows may be applicable to other immune-compromised groups, such as high-risk, mastitis, and sick pens.

Cooling should be provided for all cows housed in the special needs area. Low-pressure sprinklers or soakers should be placed on the feed lines. Mechanical ventilation or fans should be provided both on the feed lines and the housing area. The sprinklers should provide .03 gallons of water per square foot of wetted area per cycle. A common cycle would be 3 minutes on and 12 off. Typically 6 to 8 feet is wetted behind the feed lines (J. Harner et al., 1999). Fans should be placed on the feed lines and the cow housing areas to provide 800 to 1000 cfm per cow. Typically, a single row of fans over the feed lines and a single row of fans over the freestalls will accomplish the desired airflow. Thirty-six inch fans should be spaced a maximum of every 30 feet and 48-inch fans should be spaced every 40 feet. Fans over loose housing should be placed in banks with fans 10 feet on center with the banks of fans being spaced according to the diameter of the fans being used (J. Harner et al., 1999 and M. Brouk et al., 1999).

Dairy Layout

One of the issues with special needs facilities is where these facilities will be located on the dairy. They will either be located near the milking parlor or at the back of the dairy. Locating these facilities near the milking parlor reduces walking distance to and from the milking parlor. It also allows employees who work in close proximity to the parlor to observe close-up cows. The advantage of locating these facilities at the back of the dairy allow for easy movement of far off dry cows, beef cows and cows that have been dried off to and from the special needs facilities. Locating these facilities away from the main parlor may necessitate the need for a hospital parlor. If the dairy has two main parlors in a head to head configuration, the special needs facilities can be split into two barns directly behind the parlors. Figure 2 includes a drawing of a 2,400 lactating cow dairy with special needs facilities incorporated. You will notice that the special needs facility require the space equivalent to three pens of healthy lactating cows. Figures 3 and 4 include detailed drawings of the freestall buildings that would include the special needs facility.

Special Needs Facilities

Economic Impact

Generally, special needs facilities require additional capital investments by the dairy producer. These investments must be recovered in the form of additional milk sales from reduced culling, better health, etc. Unfortunately, the economic impact of special needs facilities is very case specific and generalization can be dangerous. Our objective, here, is to estimate the approximate magnitude of the additional investments required, of the additional expenses incurred, and of the additional milk production required to cover such costs.

The following points are important for understanding our analysis:

1. Cash-flow issues are not considered. Thus, we assume that the dairy has access to additional capital and that additional cash reserves are in place to ensure cash coverage in the short and medium term.
2. All capitalization projects are assumed to be financed at an annual rate of 8% for 10 years. We make no differentiation on the source of such capital. Thus, any additional equity capital has an implicit 8% annual rate of return built into it.
3. Because cash-flow issues are not considered, it makes no difference from a profitability standpoint whether the annual capital cost is in the form of interest or depreciation. The depreciation used for tax purpose could be different depending on prior fiscal decisions, current tax liabilities, future tax expectations, and changes in tax laws. Tax implications could change cost figures significantly.
4. Repairs and maintenance as an annual cost percentage of initial capital cost was set at 2 percent for buildings and 5% for equipment.

more →

The additional capital investment assumed for each component of the special needs facilities are reported in Table 3 along with a percentage of the milking herd for which they should be designed. Depending on the specific conditions of a herd, there are two views that can be taken with regard to these investments. The first one is that with the exception of the free-stalls for close-up cows and heifers and the hospital parlor (if constructed), facilities would have to be secured for the different classes of cows whether these animals are housed separately from the milking herd or not. For example, mastitic and sick cows would require 48 stalls in the freestall barns if special facilities were not built. An alternate view looks at all special needs facilities as a single investment project. With this view, all special needs facilities are considered as additional investments. In this document, we will report results for both ends of this spectrum. Thus, additional capital for special needs facilities would range between $288,000 and $1,056,400 in a 2,400 milking cow dairy, or an additional $120 to $440 of capital investment per milking cow.

The costs of capital (building and equipment) expenses are reported in Table 3 both on a total annual basis and on a per cow per year basis. At the low end, facilities for close-up cows and close-up heifers incur an additional capital cost of $18 per milking cow per year. At the high end, these costs would amount to $66 per cow per year, including the cost of a small double-10 parlor to milk an average of 48 mastitic and sick cows and 24 cows with non-sellable milk. Table 3 also presents the bedding cost expected from these specialized facilities. These costs are based on bedding cost of $50/stall per year, and $0.75 per cow per day on a bedded pack. Total bedding costs in the special needs facilities amount to $17 per cow per year. This figure overestimate the real net cost because it assumes that any alternatives to dedicated special needs facilities would incur no bedding cost.

Total expenses for the special needs facilities are estimated at $23 per cow per year at the low end, and $83.25 per cow per year at the very high end.

Special needs facilities may result in additional operating costs or savings depending on the conditions. The efficiency of cleaning animal facilities may or may not be improved. Parlor efficiency would likely improve if a small parlor were built to handle cows with non-sellable milk. Assuming that additional cows with sellable milk can be milked through the large herd parlor(s). The dairy could theoretically milk an additional 100 to 200 cows through the large parlor without any additional fixed costs and little additional labor cost.

Assuming gross milk revenues of $12/cwt and net marginal revenues (Income minus variable costs) of $6/cwt, special needs facilities require, at the minimum, an additional 383 pounds of milk/cow per year to break-even or roughly 1 pound of milk/cow per day. Using the high estimate for costs, special needs facilities require an additional 2,770 pounds of milk/cow per year, or roughly 7.5 pounds/cow per day. Because, in general, a great proportion of the capital and bedding cost would be incurred regardless of whether separate special needs facilities are built, we think that a figure equivalent to 2 pounds of milk cow per day is a good benchmark for the situation where a small parlor is not included. Because large parlors are more capital and labor efficient than small parlors, new facilities should be designed where all cows are milked in one large milking center. The large milking parlor would be used to milk the 9 groups of healthy lactating cows and high risk sellable cows 3x per day in 6.5 hours per shift, allowing 1.5 hours per shift to milk sick cows, fresh cows non-sellable and to clean the parlor facilities. During the initial planning, allowances should be made to construct a hospital parlor in the future. This way, a dairy can increase by 5 to 10% the number of cows with sellable milk being milked in the large dairy parlor in the future. Milking 3X herd size should be able to increase 10 to 15%.

Risk Management and Biosecurity

The special needs area provides a dairy an opportunity to manage risk through disease control measures (Wells, 2000). Manageable risks include disease (both animal and human), financial loss, marketability of milk and animals and potential liability. Animals housed in these facilities are particularly vulnerable to contracting new infections. This is especially true for fresh cows, which have suppressed immunity around the time of calving. The newborn calf is at risk to contract Johne's disease (*Mycobacterium paratuberculosis*). Cleanliness and daily maintenance of the calving area and the special needs facilities are critical. This area also provides an excellent opportunity to reduce the risk of antibiotic contamination of milk, as treated animals can be effectively isolated away from the lactating herd.

It is important to identify potential risks and develop a prioritized list and appropriate control measures. The manager needs to gather information and advice from the herd veterinarian and others to properly assess the exposure to these various diseases and develop a plan. Some of the pathogens generally regarded as high risk for dairy

Table 3. Additional capital investments for each component of the special needs facilities for 2,400 lactating cow dairy.								
		Capital Expense[1]			Bedding Expenses[2]		Total Expenses[3]	
% of Herd	Category	Add. Capital	$/year	$/cow/year	$/year	$/cow/year	$/year	$/cow/year
	Close-up cows and close-up heifers							
10	240 stalls @ $1200	$288,000	$43,200	$18.00	$12,000	$5.00	$55,200	$23.00
1	Calving area (120 × 40) @ $10/ft²	48,000	7,200	3.00	6,500	2.70	13,700	5.70
1	Fresh cows — non sellable milk pen 24 stalls @ $1200	28,800	4,320	1.80	1,200	0.50	5,520	2.30
5	Fresh cows — sellable milk pens 120 stalls @ $1200	144,000	21,600	9.00	6,000	2.50	27,600	11.50
2	Mastitis and sick cows, non-sellable 48 stalls @ $1200	57,600	8,640	3.60	2,400	1.00	11,040	4.60
6	High-risk, sellable milk pen 144 stalls @ $1200	172,800	25,920	10.80	7,200	3.00	33,120	13.80
3	Hospital parlor Double shell-building Equipment	 80,000 140,000	 12,000 21,000	 5.00 8.75	 — —	 — —	 12,000 21,000	 5.00 8.75
1.5	Beef and calves shipping area 90 sq. ft/cow × $10/ft²	32,400	4,860	2.00	5,000	2.10	9,860	4.10
	Treatment area 2500 sq. ft.: $25,000 Equipment: $25,000	50,000	7,500	3.10	—	—	7,500	3.10
	Calves area 800 ft²: $8,000 Equipment: $1,800	9,800	1,470	0.60	1,200	0.50	2,670	1.10
	Office 200 ft² @ $25/ft²	5,000	750	0.30	—	—	750	0.30
	Total	$1,056,400	$158,460	$65.95	$41,500	$17.30	$199.960	$83.25

[1]Capital expenses are based on 8% interest rate over 10 years and include depreciation, interest, taxes and insurance.
[2]Bedding expenses are based on $50 per/stall/year or $0.75 per cow/day on bedded pack.
[3]Total expenses are the sum of capital and bedding expanses.

herds include *Staphylcoccus aureus*, *Mycobacterium paratuberculosis* (Johne's disease), bovine viral diarrhea (BVD) and *Salmonella* species. In addition diseases such as mycoplasma, foot warts, *Chlamydia* and other pathogens for which there is not an effective vaccine could jeopardize individual cows as well as herd health. The highest risk for introduction of new disease into the herd comes from purchased cattle. Therefore, an effective program of pre-screening and isolation of new arrivals is an important key element of an effective biosecurity program. A location for accepting, processing and quarantining new arrivals should be located at least one-half mile from the closest animal facility. An additional risk exists with movement of animals in multiple site operations. Consideration should also be given to cattle movement, people movement, vehicles and equipment, feedstuffs, birds, rodents and wild ruminants, water and manure management.

An effective biosecurity program needs a written document. It must be clearly communicated to employees,

more →

consultants and visitors. Dairies should have appropriate signage to alert and remind people of the dairy's policies. The biosecurity plan should include a drawing depicting the traffic flow plan for all activities on the dairy. Access to the special needs facilities should be limited to only those personnel that are necessary to carry out the daily activities. This minimizes the transfer in or out of organic material or contaminated equipment that could spread infectious disease. Veterinarians, hoof trimmers, service persons, sales people and any other visitors to the dairy need to have easy access and a defined area where they are to perform their service to the dairy. This minimizes unnecessary traffic around the dairy. The capability to disinfect equipment should be provided in close proximity to working areas. Professional, delivery and service activities as well as sales personnel need to be aware of the dairy's policy on disease containment. Equipment and vehicles should be clean and/or disinfected. Clothing should also be clean and footwear should be of the type that can easily be disinfected. In some cases, on-site disposable coveralls and shoe covers may be provided.

Vehicles entering the dairy to deliver new arrivals should be afforded an entry point that allows bypass of the majority of the dairy and easy access to the isolation/quarantine area. Vehicles arriving to remove dead or cull animals should have a designated location where easy loading is available and away from the special needs area. This area could also double as a location where the herd veterinarian could perform post mortem examinations on dead animals. A provision for cleaning and disinfection should be considered. After removal of the carcass and rinsing of the area, a final disinfection should occur. Examples of disinfectant solutions include chlorhexidine diacetate (Nolvasan®-S), sodium hypochlorite (bleach), quaternary ammonium chloride (Spectrosol®) and quaternary ammoniums with bis-n-tributylin oxide (Roccal®-D Plus).

REFERENCES

Bickert, W.G. 2000. Restraint and treatment facilities and equipment. NRAES-129: Proceedings of Dairy Housing and Equipment Systems: Managing and Planning for Profitability. Northeast Regional Agricultural Engineering Service. Ithica, NY.

Bickert, W.G. 1998. Sorting, handling and restraining lactating cows for treatment and other purposes. Proceedings of Fourth International Dairy Housing Conference. American Society of Agricultural Engineers, St. Joseph. MI.

Brouk, M.J., J.F. Smith, and J.P. Harner, III. 2000. Freestall barn design and cooling systems. Heart of America Dairy Management Conference, St. Joseph, MO. pp. 87-94.

Collier, R.J., R.M. Eley, A.K. Sharma, R.M. Pereira, and D.E. Buffington. 1981. Shade management in subtropical environment for milk yield and composition in Holstein and Jersey cows. J. Dairy Sci. 62:844.

Collier, R.J., S.G. Doelger, H.H. Head, W.W. Thatcher, and C.J. Wilcox. 1982. Effect of heat stress during pregnancy on maternal hormone concentrations, calf birth weight, and postpartum milk yield of Holstein cows. J. Anim. Sci. 54:309.

Curtis, C.R., H.N. Erb, C.J. Sniffen, R.D. Smith, and D.S. Kronfeld. 1985. Path analysis of dry period nutrition, postpartum metabolic and reproductive disorders, and mastitis in Holstein Cows. J. Dairy Sci. 68:2347-2360.

Hardin, D.K., R.F. Randle and J.M. Zulovich. 1994. Creating a palpation workstation to enhance reproductive herd health. Proceedings of Third International Dairy Housing Conference: Dairy Systems for the 21s Century. American Society of Agricultural Engineers. St. Joseph. MI.

Harner, J.P. III, J.P. Murphy, M.J. Brouk, and J.F. Smith. 2000. Fan selection and maintenance. Heart of America Dairy Management Conference, St. Joseph, MO. pp.32-36.

Harner, J.P. III, J.F. Smith, M. Brouk, and J.P. Murphy. 1999. Sprinkler systems for cooling dairy cows at a feed line. MF-2401. Cooperative Extension Service Publication. Manhattan, Kans.: Kansas State University.

Kammel, D.W. and K.A. Janni. 2000. Facility design for the transition cow. NRAES-129: Proceedings of Dairy Housing and Equipment Systems: Managing and Planning for Profitability. Northeast Regional Agricultural Engineering Service. Ithica, NY.

Kammel, D.W., S.L. Gunderson, T. Rehbein, and R.A. Thompson. 2000. Transition cow facilities: case studies. NRAES-129: Proceedings of Dairy Housing and Equipment Systems: Managing and Planning for Profitability. Northeast Regional Agricultural Engineering Service. Ithica, NY.

Moore, R.B., J.W. Fuquay, and W.J. Drapala. 1992. Effects of late gestation heat stress on postpartum milk production and reproduction in dairy cattle. J. Dairy Sci. 75:1877-1882.

Nocek, J.E. 1997. Feeding management of the postpartum cow. *In: Mid-South Ruminant Nutrition Conference Proceedings*, ed. E.R. Jordan. pp. 54-61.

Stokes, S.R. and J. Pope. 1997. The response to Korral Kool Systems on dairy cow performance in Central Texas. *In: Balanced Dairying*, ed. E.R. Jordan. Vol. 20, No. 4.

Stone, B. 2000. Defining and managing special cows. NRAES-129: Proceedings of Dairy Housing and Equipment Systems: Managing and Planning for Profitability. Northeast Regional Agricultural Engineering Service. Ithica, NY.

Veenhuizen, M.A. and R.E. Graves 1994. Handling and treatment facilities for large dairies. Proceedings of Third International Dairy Housing Conference: Dairy Systems for the 21s Century. American Society of Agricultural Engineers. St. Joseph. MI.

Wells, S.J. 2000. Biosecurity on Dairy Operations: Hazards and Risks. J. Dairy Sci. 83:2380-2386.

Wolfenson, D., I. Flamenbaum, and A. Berman. 1988. Hyperthermia and body energy store effects on estrous behavior, conception rate, and corpus luteum function in dairy cows. J. Dairy Sci. 71:3497-3504.

Wiersma, F. and D.V. Armstrong. 1988. Evaporative cooling dry cows for improved performance. Am. Soc. Ag. Eng. Int. Mtg. #88-4053.

Figure 1. Timeline to move close up and fresh cows through the special needs area.

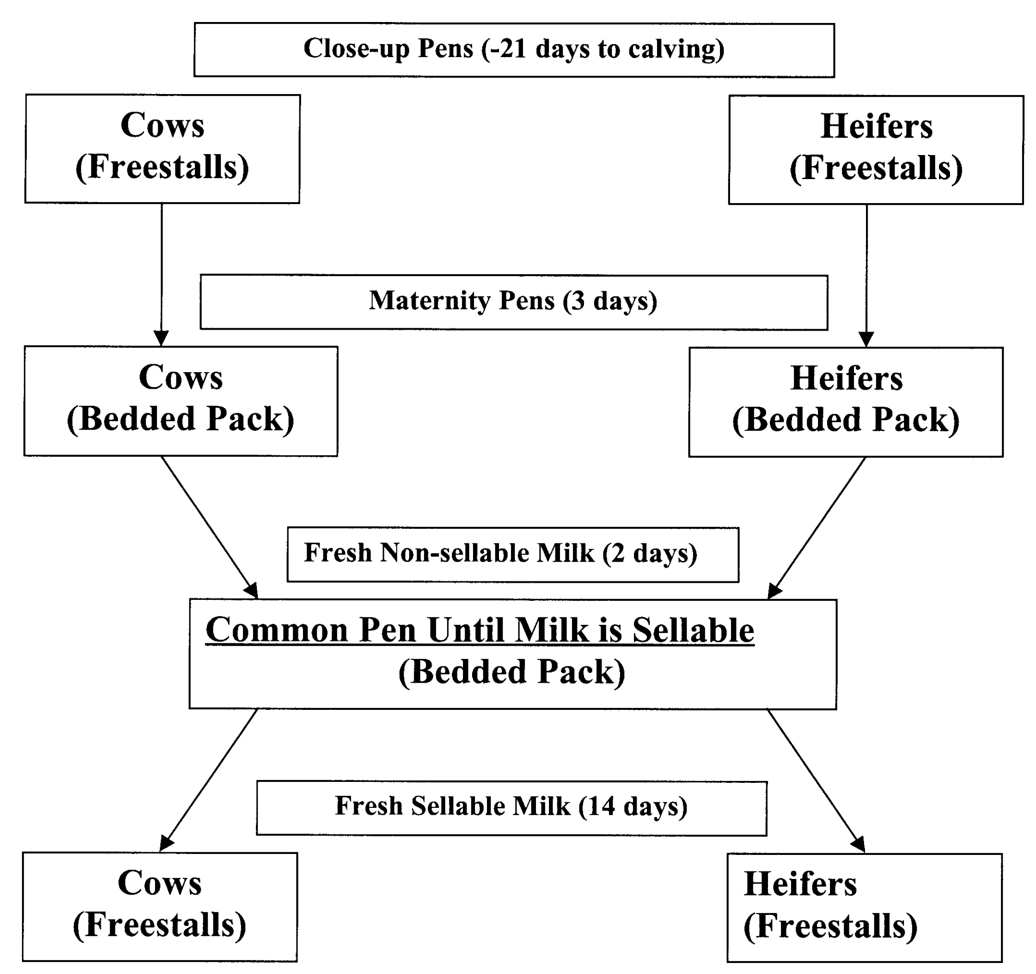
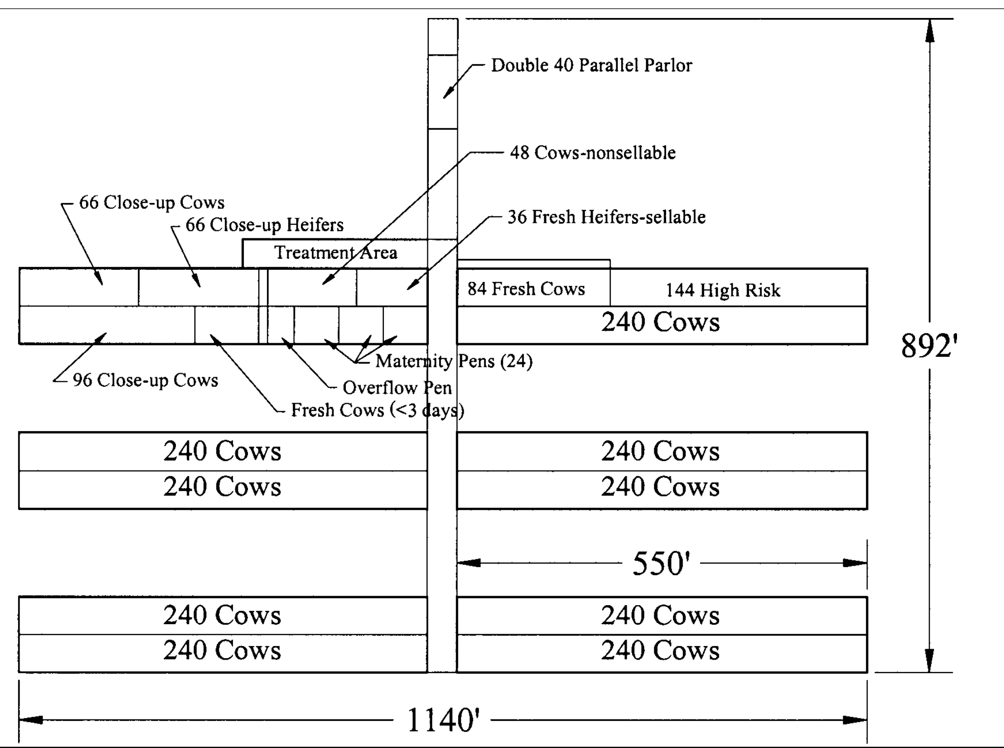


Figure 2. Layout for 2,400 Lactating Cow Dairy Facility Including Special Needs Facilities.



more →

Figure 3. Special Needs Facilities for Close-up, Maternity, and Non-sellable Cows

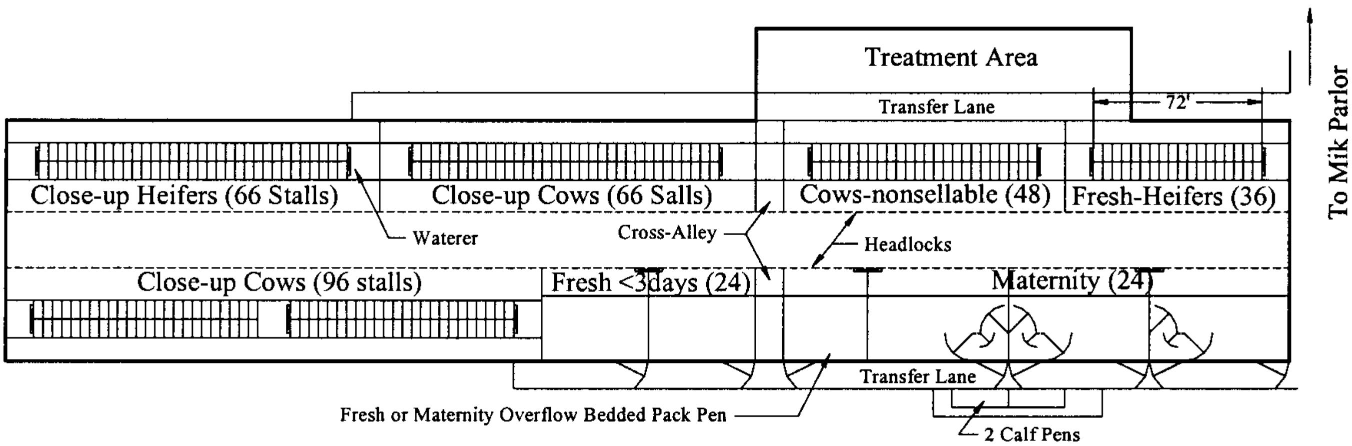
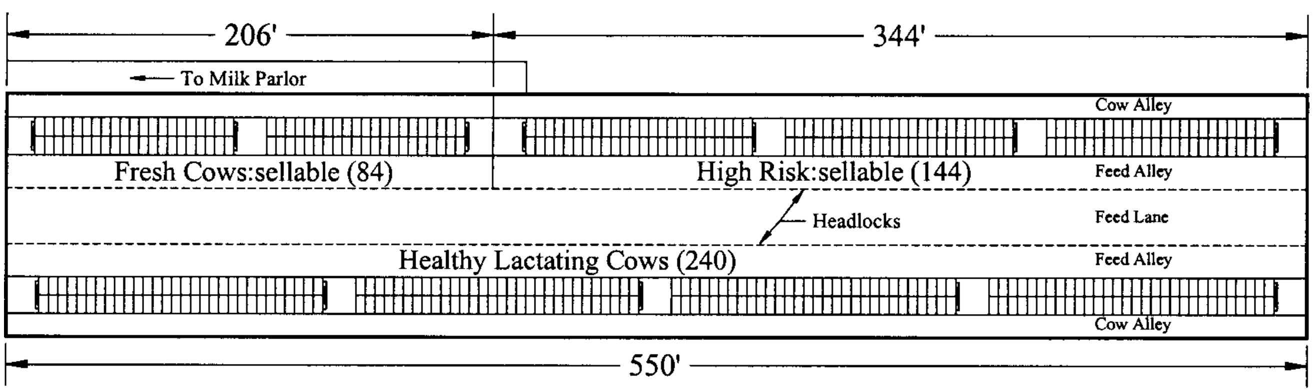


Figure 4. Special Needs Facilities for Fresh and High Risk Sellable Cows



Manure Quality Principles Applied to Lagoon Sludge: The Dairy's Forgotten Liability

BRENT W. AUVERMANN—Agricultural Engineering, Texas A&M University System
6500 Amarillo Blvd., West Amarillo, TX 79106
Tel: 806-359-5401 Fax: 806-358-9718 b-auvermann@tamu.edu

Introduction

Specialists in livestock waste management often remark how strangely amusing it is that the tough waste management rules pushed by environmental advocacy groups and agencies end up encouraging and accelerating the growth and concentration of confined animal feeding operations (CAFOs). Many of the advocacy groups, tacitly or otherwise, make clear their desire to see CAFOs revert to the small, family-owned, independent producers as the model for long-term sustainability. However, their pet policies — for example, the recent effort by the Environmental Protection Agency (EPA) to remove the 24-hour-storm exemption for permitted discharges, to require that lagoons be covered and to advocate phosphorus-based nutrient management plans — actually seem to drive the trend in the opposite direction. Under many circumstances only the largest, corporate entities can afford to implement the strict structural, management and monitoring schemes that the environmental groups demand. As a result, the small producers liquidate, not proliferate.

Perhaps such an explanation seems utterly simplistic. Obviously, more forces drive the growth trend than merely the rapid increase in regulatory pressure. Still, the regulatory trend anticipates a time when advanced treat-and-release systems for managing manure are the norm, and lagoons are but a quaint relic of an earlier, less sophisticated day. Unfortunately, the strict no-discharge policies of the past 30 years have given the animal-feeding industry little incentive to develop the advanced systems needed to sustain confined animal production in the absence of lagoons. We are making good headway, but we have yet to develop systems that are effective, widely applicable and economically feasible.

Producers of confined livestock and poultry need to be reminded of the underlying lesson in all of this: choices made principally to satisfy short-term objectives invariably return to cause long-term problems. In the case of the more aggressive environmental advocacy groups, the short-term goal was to eliminate lagoons as a treatment and storage option in a zero-discharge framework, and the result has been an acute growth in the very large-scale operations that such groups condemn as ecological disasters-in-waiting. Producers, as well as their land-grant advisors and private consultants, have often focused on short-term disposal options like nitrogen-based nutrient planning, relying on volatilization of ammonia and nitrogen oxides from liquid manure-handling systems to reduce drastically their annual land-area requirements for beneficial use of manure and wastewater. Among the unintended results of that short-term focus have been:

1. A buildup in soil phosphorus pools;
2. Localized enrichment in atmospheric ammonia (and, in some areas, an accompanying increase in secondary fine particulate matter, or $PM_{2.5}$; see Watson et al., 1998);
3. Unrealistically small land-application areas for long-term disposal of manure and wastewater; and
4. Accumulation of lagoon sediments.

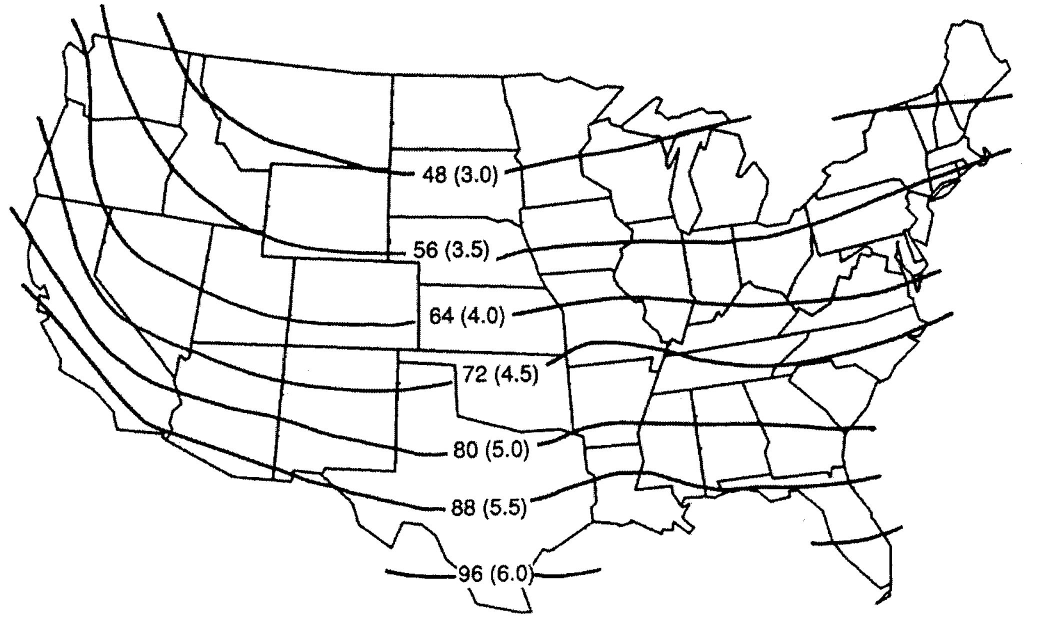
All four phenomena are closely related because of a single axiom known as the Principle of Conservation of Mass: what goes in must either be discharged or stored. As discharge and disposal restrictions to air and soil have been added to the traditional effluent limitations, we have come to recognize that storage capacities are finite. As these storage pools reach their capacities due to short-term planning, the likelihood of discharges can only increase. Sustainability, on the other hand, demands a more long-term view in which storage pools are used to detain manure components rather than to sequester them (as in lagoon sediments), assimilate them (as in soil phosphorus pools) or waste them (as in ammonia volatilization).

Why is Lagoon Sludge Important?

The buildup of sludge in anaerobic lagoons is not a new phenomenon. Lagoon design standards published by the American Society of Agricultural Engineers (ASAE, 1995), the Natural Resources Conservation Service and other organizations have long provided for a sludge-accumulation layer in the design process because it is a technical necessity for efficient anaerobic treatment. Accounting for sludge buildup is vital to efficient lagoon operation because unchecked accumulation of sediments eventually encroaches on a crucial lagoon layer, the minimum treatment volume (MTV). The MTV is the minimum volume of free lagoon liquid required to permit complete digestion of volatile solids (VS) and is typically determined by referring to a figure such as Figure 1.

more →

Figure 1. Recommended volatile solids loading rates for anaerobic lagoons in the United States (excerpted from ASAE, 1995).



A lagoon in which sludge accumulation has encroached on the MTV will often turn sour because the products of incomplete anaerobic digestion are tremendously odorous and offensive. (These intermediate compounds may also be toxic to plants.) A well designed, well maintained and conscientiously operated anaerobic lagoon system will provide an effluent that is rich in stable nutrients and only minimally odorous.

Lagoon Sludge and Principles of Manure Quality

If providing stable, relatively odor-free effluent for land application were the only critical objective of operating a lagoon system, it would be justification enough for attentive sludge management. As environmental regulations become increasingly strict, they reduce the number of permissible discharge pathways for manure constituents. Under those constraints, however, managing sludge takes on a new dimension of importance. The advent of phosphorus-based nutrient planning, which usually increases acreage requirements over the traditional nitrogen-based management plans, has forced many livestock producers either to purchase or lease new land-application fields or to market their manure to off-site users. Where acquisition of additional land is not feasible or is prohibitively expensive, this dynamic has highlighted the importance of producing manure of high quality and value. The further the manure has to be hauled for beneficial use, the higher its quality must be to justify the hauling expenses.

As authors and extension specialists have frequently noted over the past decade, the nutrient content of manure products is usually out of balance with respect to crop nutrient requirements. For grain crops and forages, the N:P ratio of the crop requirement may exceed the N:P ratio of manure by a factor between 3 and 6. That is particularly true of lagoon sludge because (a) phosphorus compounds are relatively insoluble and therefore accumulate in sediments and (b) ammonia nitrogen is continually lost from an anaerobic lagoon, effectively stripping it from lagoon solids.

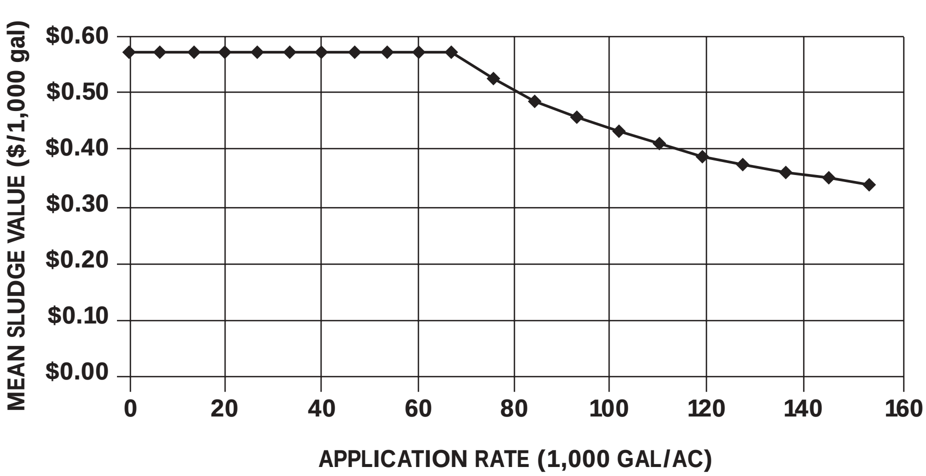
Sweeten et al. (1980) studied the buildup, composition and cost of removal of lagoon sediments on two dairies and a cattle feedyard in Texas and Tennessee. They determined that sludge accumulation from a free-stall dairy averaged 5.9 m^3 hd^{-1} yr^{-1} (1,560 gal hd^{-1} yr^{-1}). When removed via an open-impeller pump into an irrigation ditch for land application, the sludge contained about 5.5% solids. The solid fraction of the sludge contained 62% volatile (digestible) solids (VS), 0.7% nitrogen (N) and 0.6% phosphorus (expressed as P_2O_5). Extrapolated to a modern, 1000-cow dairy, the sludge accumulation rate estimated by Sweeten et al. (1980) corresponds to nearly 5,000 lb yr^{-1} of N and 4,300 lb yr^{-1} of P_2O_5, or 5 lb N hd^{-1} yr^{-1} and 4.3 lb P_2O_5 hd^{-1} yr^{-1}. Lindemann et al. (1985) estimated that the total fertilizer value of sludge removed from dairy lagoons in Erath County, Texas, would offset only 30 to 50% of clean-out costs.

Because it depends on soil type and cropping regime as well as manure composition, manure quality for land application is a relative attribute, not an absolute one. In other words, manure quality for a particular use depends on (a) how well matched the nutrient ratios in the manure are to the nutrient ratios required by the crop based on a soil test and (b) how much water and ash are contained in the manure. Thus, the historical method of computing manure value — computing the inorganic fertilizer equivalents of the manure nutrients and adding them all up — fails to recognize the concept of the "limiting nutrient," which can be defined as follows:

The limiting nutrient for land application of manure and/or effluent is defined as the crop-essential nutrient that results in the lowest recommended application rate during a particular year when all soil-test requirements, availability fractions and regulatory restrictions have been considered.

Note that this definition of the limiting nutrient includes provisions pertaining to, for example, soil-test phosphorus thresholds (e. g., "regulatory restrictions"), cropping regimes and soil types (e. g. "soil-test requirements"). To illustrate, suppose that the lagoon sediments analyzed by Sweeten et al. (1980) are to be applied to a field where irrigated corn will be grown with a yield goal of 220 bushels per acre (bu ac^{-1}). The soil test, which reflects the character of many alkaline soils of the western United States, calls for 200 pounds per acre (lb ac^{-1}) N, 75 lb ac^{-1} P_2O_5 and no potassium (K, often expressed as K_2O). Assuming that 50% of the N and P_2O_5 in the sludge is available during the first year, an application rate of 67,000 gallons per acre (gal ac^{-1}), or 2.5 inches, will satisfy the soil-test phosphorus requirement; however, that application rate will provide only 88 lb ac^{-1} or 44% of the soil-test nitrogen requirement. Below the 67,000 gal ac^{-1} application rate, both N and P contribute to the sludge's value as a replacement for inorganic fertilizer. Above the 67,000 gal ac^{-1} rate, however, because the P requirement has been met, any additional sludge applied can be credited only to the crop's N requirement. At this point, the phosphorus in the sludge adds no additional value. (In a conventional fertility program, no additional phosphorus would have been applied once the 75 lb ac^{-1} P_2O_5 recommendation had been met.) Figure 2 shows how the average fertility value of the lagoon sludge changes with application rate as the soil-test requirements are met.

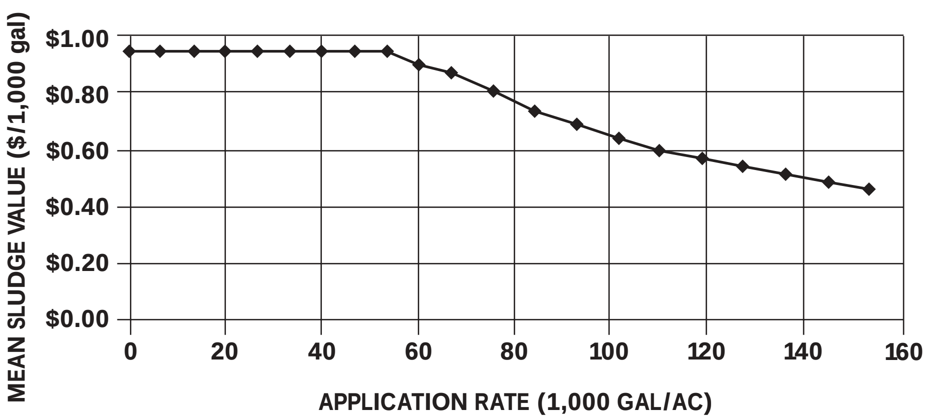
Figure 2. Average value of dairy lagoon sludge ($1,000 gal) as a function of application rate, computed on the basis of inorganic fertilizer equivalence. Note how the average sludge value begins to drop once the soil-test requirement for the limiting nutrient (in this case, phosphorus) has been met. Figures assume that inorganic fertilizers cost $200/ton (82-0-0) and $250/ton (10-34-0) for anhydrous ammonia and liquid superphosphate, respectively.



Many of the highly leached soils of the eastern United States would have a potassium requirement for corn production, which immediately adds value to the lagoon sludge. Sweeten et al. (1980) did not publish the potassium content of the lagoon sediments, but it is reasonable to assume that their K_2O content would have been about 0.75% of the total solids. Assuming a soil-test K requirement of 150 lb ac^{-1} K_2O, potassium is the limiting nutrient whose economic threshold is reached at an application rate of 53,500 gal ac^{-1}. Even though the potassium limit is reached at an application rate well below that of the phosphorus limit, the marginal value of the sludge's potassium content increases the maximum manure value (i. e., $ per 1,000 gallons) by 70%, from $0.57 to $0.97 per 1,000 gallons. As before, the marginal value of phosphorus in the sludge vanishes at application rates above 67,000 gal ac^{-1}.

more →

Figure 3. Average value of dairy lagoon sludge ($1,000 gal) as a function of application rate, computed on the basis of inorganic fertilizer equivalence. In this case, with a soil-test potassium (K) requirement, the average sludge value first decreases as the K requirement is met, then more steeply after the phosphorus requirement is met. Figures assume that inorganic fertilizers cost $200/ton (82-0-0), $250/ton (10-34-0) and $175/ton (0-0-60) for anhydrous ammonia, liquid superphosphate and potash, respectively.



As Figures 2 and 3 have shown, manure value is closely tied to nutrient content, nutrient ratios, soil-test fertilizer requirements and the fluctuating prices of inorganic fertilizers. As such, manure quality depends on too many external factors (cropping regime, natural gas prices, soil types) to be considered an absolute (or intrinsic) characteristic. Furthermore, to this point we have not considered the two major components of lagoon sludge that reduce its economic value: water and ash.

Water and Ash: The Manure Contaminants

Manure quality goes far beyond nutrient content, especially in the context of liquid or semi-solid manure. Water and ash both reduce manure value because of the high cost of transporting them to the field as compared to their agronomic value when they are applied. In most cases, the amount of water applied to the field in the form of lagoon sludge (e. g., 2.5 inches in the example above) is quite small compared to the amount of water required annually to meet the yield goal. Moreover, ash, which is the functional equivalent of adding mineral soil to the manure, would not ordinarily be applied to crops by any reasonable farmer. Still, both water and ash contribute significantly to the weight of the sludge bulk, and with hauling costs and application rates typically based on tonnage, water and ash reduce the value of the manure tremendously.

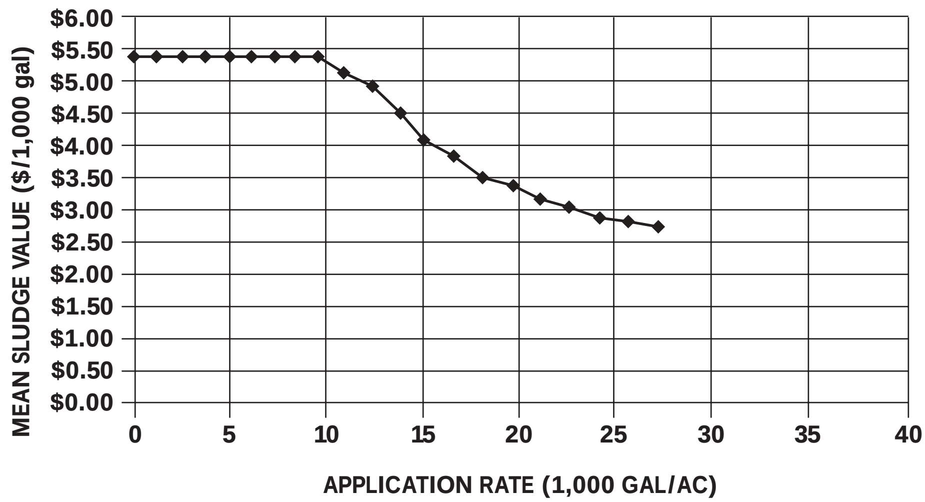
To illustrate the negative value of water, assume that we are able to harvest the same amount of sludge dry matter as above, but that we harvest it at 75% moisture instead of 96%. Figure 4 shows that the maximum value of the sludge or manure increases from $0.97 to $5.37 per 1,000 gallons — a staggering 450% increase in value achieved simply by reducing the water content from 96% to 75%.

In addition, the threshold application rate has been reduced from 53,500 to 9,600 gal ac^{-1}, which potentially reduces the number of trips across the field by a tank wagon. Where compaction is a concern, the lower moisture content indirectly increases the manure value by reducing fuel costs and decreasing compaction or added tillage requirements. Incidentally, a moisture content of 75% is well within the typical range for fresh manure, so these manure values closely approximate the potential value of manure handled mechanically rather than hydraulically.

A comparison of Figures 3 and 4 indirectly shows how the potential value of manure is drastically reduced through the use of hydraulic manure handling. Interestingly, the free-stall dairy studied by Sweeten et al. (1980) was equipped with a two-chamber settling basin. Under optimum conditions of design and management, settling basins can reduce total solids loading to the lagoon by up to 60% (Moore, 1989), but few settling basins actually achieve that separation efficiency. Mechanical separators like inclined screens and hydrocyclones typically remove 20 to 25% of the solids.

Ash is another manure contaminant, reducing manure quality. In the example represented by Figure 3, however, decreasing the ash content from 38% to 25% (dry basis) does not change the sludge value in $ per 1,000 gallons; it only reduces the hauling costs. The decrease in value associated with high ash content is most significant in the context of dry products like as-collected or composted manure.

Figure 4. Average value of dairy lagoon sludge ($1,000 gal) as a function of application rate, computed on the basis of inorganic fertilizer equivalence. The sludge represented here is the same as in Figure 3, but has been dried from the original 96% moisture to the 75% moisture that is typical of freshly excreted manure.



Summary

Hydraulic manure handling is popular in the dairy industry because of its relatively low management costs, its ease of automation and its potential to reduce odors associated with residual manure in the barns and on feed aprons. A properly designed and operated flush system maintains clean feed alleys and, with recycling systems, need not use tremendous amounts of expensive fresh water. Still, because solids separation is an inefficient process, most of the manure solids generated in the feed alleys and the milking parlor ends up in the bottom of the lagoon. That will be increasingly true as the trend from open-lot to free-stall production persists. According to figures published by Sweeten et al. (1980) and others, sediments accumulating in an anaerobic lagoon can induce periodic dredging costs ranging from $5 to 10 or more per head per year of accumulation. For a 1,000-head dairy whose lagoon system is designed with 10 years of sludge capacity, dredging costs could exceed $50,000 per dredging event. The extremely low economic value of lagoon sediments virtually ensures that they will be preferentially applied to land owned by or immediately adjacent to the dairy. Adding water to manure is, as a practical matter, an irreversible process, and in light of water's negative effect on manure value, manure quality considerations as applied to lagoon sediments argue against hydraulic manure handling for the long-term sustainability of the industry.

References

ASAE. 1995. Design of anaerobic lagoons for animal waste management. In: Standards of the American Society of Agricultural Engineers, Engineering Practice EP403.1.

Lindemann, E. R., J. M. Sweeten and J. P. Burt. 1985. Sludge removal from dairy lagoons. Proceedings of the Fifth International Symposium on Agricultural Wastes, December 16-17, Chicago, IL.

Moore, J. 1989. Dairy manure solid separation. Proceedings of the Dairy Manure Management Symposium NRAES-31, February 22-24, Syracuse, NY.

Sweeten, J. M., L. M. Safley and S. W. Melvin. 1980. Sludge removal from lagoons and holding ponds: case studies. In: Livestock Waste: A Renewable Resource. American Society of Agricultural Engineers, St. Joseph, MI. Pp. 204-210.

Watson, J. G., E. M. Fujita, J. C. Chow, B. Kielinska, L. W. Richards, W. Neff and D. Dietrich. 1998. Northern Front Range air quality study: final report. Submitted to the Cooperative Institute for Research in the Atmosphere, Colorado State University, Ft. Collins, CO.

Handling Sand-Laden Manure

J.P. HARNER and J.P. MURPHY, Extension Engineers—Livestock and Grain Systems, Biological and Agricultural Engineering, 233 Seaton Hall, Kansas State University, Manhattan, KS 66506
Tel: 785-532-5813 Fax: 785-532-6944 jharner@falcon.bae.ksu.edu

Issues Associated With Handling Sand-Laden Manure

Sand-laden manure may be handled using a scrape or flush system. The handling systems should allow for the sand and solids to separate from the effluent. The abrasiveness of sand may create problems when mechanically handling sand-laden manure. Manure weighs about 60 pounds/cubic foot (lbs/cf) whereas sand has a density of 120 lbs/cf. Sand-laden manure will have an approximate density of 72 lbs/cf if 20% of the manure is sand. A portion of the sand will settle rapidly in a flush system by changing the velocity of the water. Since sand is heavier, it will not remain in suspension as long as manure and settles. However, a some sand and inert material will remain in suspension with any type of system. Many problems associated with handling sand-laden manure can be avoided if the sand and manure solids are stored in a different structure from the effluent.

Scrape Versus Flush

The benefits from flushing include labor reduction with automated systems, limited scraping requirements, lower operating cost, drier floors, potential reduction in odor and cleaner facilities. An optional method of handling manure may be necessary in colder weather. The disadvantages include the water requirements per cow and the initial fixed cost. Scraping may be required if the flush system is improperly designed. The ideal flush system requires no handling (scraping or restacking) of the manure until it is land applied. Flushing does not eliminate the need to apply the manure and effluent to land at environmentally acceptable levels.

Figure 1 shows there are different nutrient contents in the lagoons and solid basins when comparing scrape and flush systems on dairies using sand. If the manure has to be transported away from the immediate vicinity of the storage structures, then a scrape system may be preferred since there are more nutrients per unit volume in the solids. Dairies using recycled flush water for flushing will land in close proximity to the lagoons for irrigation purposes.

Design Parameters

Daily water requirements for flushing is a function of the width, length, bedding material, and slope of the alley. Alleys sloping 2 to 4 percent will use less flush water per day compared to those at 1-percent slope (Table 1). With composted manure bedding, at a slope of 1 percent, a minimum flush volume is 14,400 gallons per 12 feet gutter for flushing lengths of 800 feet. Design data for freestall alleys less than 150 feet suggest 100 gallons per foot of gutter width is adequate. Longer lengths require more water with a suggested maximum release of 175 gal/ft of gutter width. A study of six dairies found flush water requirements ranging from 240 to 620 gallons per cow per day (gal/cow/dy). Another design procedure suggests selecting the larger of two volumes — either 52 gal/cow/flush or 1.35 gal/square foot (sq.ft.) of alley per flush. Observations with sand-laden manure (SLM) suggest a high velocity flush system can clean alleys with less with than 1 gal/sq.ft. whereas, low velocity system may require more than 4 gal/sq.ft.

The cleanliness of an alley depends on the energy available in flush water. Present design procedures suggest the flushing wave should be 150 feet in length, 3 inches deep and moving at a velocity of 5 feet per second (fps). How these recommendations change when sand is added to the manure stream is not fully understood. Buildings longer than 450 feet require a flush wave equal at least ⅓ of the total length. If the length is less than 150 feet, then the design procedure is based on a 10 second (sec) contact time. The amount of time the flush water moves past a given selection of the alley is known as contact time. Many dairies bedding with sand are using contact times of 10 minutes or longer when flush velocities are 3 fps or less. Observations reveal many alleys are still scraped at least once per day even with the longer contact times. Other dairies using velocities of more than 7 fps are using contact times of less than 1 minute.

System Components

Properly designed flush systems use a flush device to release a volume of water at a known discharge rate and length of time. This achieves the designed flow velocity, contact time, and depth of water in the gutter to obtain adequate cleaning.

Two basic flush systems discussed in this paper are referred to high and low velocity systems. For purposes of this paper, a high velocity flush (HVF) system uses wave velocities greater than 5 fps with 7.5 fps being preferred. Low velocity flush (LVF) systems have wave velocities of

more →

less than 5 fps, generally around 3 fps. HVF systems store flush water in a tank or tower at the upper end of the area being flushed. A low horsepower (hp) pump is used to transfer water from the lagoon to the storage tank. Flushing tanks are 4 to 12 foot deep with a large discharge openings. Towers have depths of 20 feet or more and discharge through 12 to 24 inch diameter pipe. LVF systems are often pump flushing systems and use the lagoon for storing the flush water. A large hp pump transfers water to the upper end when flushing is desired. No additional storage is required in a flush pump system. Storage towers may be used with LVPS, however, piping losses often reduce the flow velocity.

Table 1 provides a summary of flush volume and discharge (release) rate required to meet the recommended design requirements for flushing a 12-foot alley at different slopes and lengths. The valve open time is equal to the required volume of water divided by the release rate. With high velocity units, the release rate varies from a minimum of 10 seconds to more than 60 seconds for longer buildings. Release rates can vary from 1,000 gpm to over 15,000 gpm if properly designed. Flush water pumping or low velocity systems are often limited by the pump capacity and the water release rate is from 1 to 15 minutes. Most pumping systems have a release rate of less than 3,000 gpm with 1,500 gpm being common.

Flush water is commonly released using "pop-up" or recessed valves which are controlled manually or automatically. Automated valves are pneumatically operated. Discharge rate from a value is influenced by the hydraulic characteristics from the pipeline to the valve and the initial head pressure. Common design procedures connect multiple tanks to a valve from both sides to maintain a higher head pressure and thus increase the discharge rate. The increase in discharge rate with multiple tanks requires increasing the pipe size. Many use a pump system with recessed values. Other release methods include a hinged plate, open pipe and gated pipe. Pumping losses can be reduced by using larger diameter pipes from the storage structure to the valve. For example, a 16 inch diameter pipe has 75 percent more cross-sectional area than a 12-inch pipe even though the diameter is only 33 percent larger.

The channel for controlling the flushing water is normally the freestall alley or holding pen. Flushing dairy facilities is different than swine facilities. Flushing channels in swine buildings range in width from 8 to 12 feet with secondary channel dividers located 3 to 4 foot on center. These secondary channels provide directional control of the flush water as it moves the length of the building. Channels for dairy facilities range from 8 feet to 14 feet in a freestall and up to 40 feet wide in a holding pen. Secondary channel dividers are not used because of vehicle and animal traffic.

Some scraping or manual cleaning may be needed because of amount of manure deposited along the curb to provide adequate cleaning of the alleys or channels on dairies. Alley may have ¾ to 1 inch crown in the center to direct water along the curbs in a tail to tail freestall facility. The crown will interfere with scraping, therefore, it is recommended to use level alleys or pens across the alley width with tail to tail stalls. Dairies with head to head stalls may pour the alleys with a ½ to 1-inch slope from the outside of alley to the freestall curb. This increases the depth of the flush wave along the curb and may improve sand removal.

Flush water is collected at the lower end of a building in a gutter or alley. The water flows towards a mechanical separator or gravity-settling basin. The separation allows the solids to accumulate in a basin and the liquid to drain to a lagoon.

Solid Separation

Mechanical solid separators may be inclined screen, press roller, or screw press. The inclined screen allows the liquid to pass through the screen and the solids remaining on the surface are transferred to a storage area. The inclined screen require daily cleaning to avoid solids flowing in lagoon. The press roller has the flushed material passing through a pair of rollers with the water draining away. The pressing action is designed to produce a drier material. The third mechanical separator is the screw press which uses more pressure to separate liquids and solids. A study at Mississippi State University found inclined screens removed very little of the sand from the flush water since the screen openings were larger than the diameter of the sand particles. Sand will cause additional wear on the mechanical solid separators. The abrasiveness of sand on the pumps and screens in a mechanical systems decreases the equipment life and increases maintenance cost. These increased maintenance costs may be reduced using gravity systems.

Gravity systems use a settling basin to settle out the solids and drain off the liquids. Earthen trenches or concrete basins are commonly used. The earthened trenches require a backhoe or excavation for cleaning. With gravity settling basins, the sand normally separates at the upper end of the basin. A large portion of the sand can be recovered from a gravity solids separating basin since much of it settles out near the discharge pipe. This is the location where there is the first major change in velocity of the flush wave. Generally, the sand is stacked and allowed to dry prior to reuse.

High Velocity Flush Systems

A high velocity flush system was installed in a 420-foot long freestall building with a 2% slope. The alleys were sloped 1 inch toward the freestall curb from the outside wall. The four-row barn had 168 freestalls per row. The feed alley was 14 feet wide and the cow alley was 12 feet wide. The flush system consisted of open-top flush tanks which are 10 feet in diameter and 38 feet tall. The flushing system uses a 6- to 7-foot section of 16 inch pipe exiting the tank at a right angle. The 16-inch pipe has a 45 degree sloped inlet inside the tank. Another 6 to 7 foot section of 12-inch pipe, which includes a 12-inch manual gate value, is then used to carry the water to the flush alleys. Figure 2 provides a schematic of the tank. The pipe outlet directs the water along the freestall curb. Table 2 presents the results of a study with the valve opened 90 degrees. There was a reduction in velocity from 11.5 fps to 6.7 fps as the head reduced from over 30 feet to less than 10 feet. The depth of wave also reduced about 50 percent as the initial head reduced. Based on the number of freestalls and flushing three times per day, the water usage was 48 gal/stall/flush or 140 gal/day/stall. The water usage based on a 8,500 gpm discharge rate and a 30-second flush is equal to 0.84 gal/sq. ft., giving a flow rate of 700 gpm and a water usage of 350 gal/ft width of gutter. The flush system removed the sand and manure from the alleys based on visual inspections. Flushing three times per day eliminated the need to scrape the freestall alleys. Scraping was required when flushing was reduced to twice a day.

A high velocity flush system was installed in the milk parlor using a 25 foot tall and 9 foot diameter tank. The tank was elevated such that a 12 inch entrance pipe was located about 6 ft above the milk parlor floor. The release rate in the milk parlor was 4,700 gpm with a flow velocity of 5.6 fps. The water flowed through approximately 30 feet of 12 inch pipe prior to the pipe outlet. Flushing rate could be increased by modifying where the flush water enters the transfer pipe and using long sweep elbows. Based on a 30 second flush three times per day in the milk parlor, the water usage in the milk parlor was 39 gallons per cow per day.

Guillotine Gate Flush Tank

Flush velocities have been obtained from four freestall buildings using a manual guillotine or scissor gate flush system. Two of the barns released the flush at a 90° angle to the alleys. The release was parallel to the long axis of the alleys in the other barns. The tanks were 4 feet deep with length and width dimensions of 12 feet by 16 feet. The approximate tank capacities were 5,000 gallons. The tank capacity equaled approximately 2 gallons per square ft of alley. The flush water exited the tank through an orifice measuring 8 in by 96 in at full opening. The flush velocities in the guillotine tanks were 6 to 9 fps. The tanks with the flush water exiting at right angle to the alley had a flush velocity 5 to 6 fps or about 2 fps slower than the other tanks. Energy was lost in changing the direction of the water. These design suggestions can be applied to flush alleys less than 250 feet long.

Other Considerations with High Velocity Systems

Based on visual inspection of alleys with sand bedded freestalls, the minimum flush velocity should be 5 fps with 7.5 to10 fps being preferred. Current recommendations on release rates with 400 ft alleys are adequate based on field studies. The water depth at the freestall curb should be a minimum of 3 inches with 4 inches preferred. The energy of the flush water needs to be directed along the freestall curb rather than in the center of the alley with sand bedded freestalls. This enables the flushing system to remove sand away from the curbs and minimizes scraping sand away from the curbs.

Sand Traps

Dairies using sand bedded freestalls should have a sand trap or sand separator between the freestall and the solid separating system. Gravity and mechanical separation are two basic methods for settling out the sand from the manure stream prior to solids separation. The flush tank release rate must be compatible at the upper and lower end of the alleys. If a HFVS is used, then the water channels, sand traps, or gravity solid settling basins at the lower end of the freestalls must be designed to handle the higher velocities. Any significant change in the velocity of the flush wave due to restrictions, wider channels, elbows, etc will result in some sand settling from the stream.

Gravity basins depend on the ability of the system to slow the flush velocity to 1 to 2 fps. At these velocities, the organic matter appears to remain suspended with the liquid and will discharge from the sand trap with minimal settling. Figure 3 shows the results of sampling a gravity system using a sand trap, solid basin and lagoon. This data shows that less than 3% of the solid material in the sand trap is organic material. The moisture content was 29% with 69% of the remainder being ash (sand) and 2% being organic material.

Many dairies are using sand lanes to transfer water from a freestall to a lagoon. Table 6 show data collected from two dairies based on a very limited field study in

more ⟶

California. Grabs samples at various locations and times were taken and then composited prior to lab analysis. It was estimated about 40 percent of the sand in flush wave was deposited in the sand lane at Dairy 2. Less than 3% of the sand was deposit at Dairy 1. The initial concentration of inert material (sand) was much higher at Dairy 1 than Dairy 2. Table 6 does not account for the sand which was scraped into the sand lane. At both dairies, most of the settling occurs in the first 3 minutes of the flush process. This data tends to support comments by dairy producers than alleys flush better when cleaner water is used.

Design parameters for gravity sand traps have not been fully determined. Some data suggest the flush water has to be slowed to less than 1.5 fps to allow the sand to settle out before the effluent and manure is transferred to the mechanical or gravity separators. Velocities in the sand lanes on four western dairies were measured. The velocity on all of the dairies was 2 to 3 fps. Design data suggest the velocities could be reduced to 1 to 1.5 fps to settle additional sand without settling organic matter. Using Manning's equation, a 1.5 fps velocity may be obtained with a sand lane sloping at 0.25 percent and 12 feet wide with a release rate of 2,000 gpm. The key principle to remember is to change or slow down the velocity of the flush.

A mechanical separator has been developed by Wedel and Bicket (1996, 1998) and is marketed by McLanahan[2]. The separator has the ability to remove or recycle 90% or more of the sand from the waste stream. The sand is much cleaner than from a gravity separator since it is washed. The mechanical separator works better with coarse sand than fine sand. Burcham et al. (1997) found an inclined screen was not effective in separating the sand from the waste stream. The screen openings were larger than the sand particles. Sand also had a tendency to settle out up stream of the inclined separator as the flush wave velocity was reduced. Mechanical separators must be part of the total system and not a bottleneck. Bottlenecks within a sand system tend to result in settling sand at undesirable places.

Comments Related to Low Velocity Systems

Many flushing systems utilize purchased components using pop-up valves or plates and underground piping. However, it is questionable whether an adequate release rate of the water can be obtained with long freestall buildings based on current engineering recommendations when piping losses are considered. Dairies are utilizing these low velocity systems by increasing the contact (flushing) time. However, observation also reveals they are scraping alleys at least once per day. Normally, the scraping process is part of the freestall maintenance routine.

The challenge is to minimize the energy lost in moving the flush water through the pipes. Table 3 shows the estimated flow rate through a 12 inch PVC pipe with a friction coefficient of 0.02. As the equivalent pipe length is increased, the flow rate is reduced unless more head pressure is utilized. This may be accomplished by using a taller tower or larger pump. Table 4 shows the equivalent length of pipe for different fittings. For example in a four row barn, there may be 100 feet of pipe, 3 elbows, and 3 tees. In this case the water would have to flow through the equivalent of 315 feet of pipe. Therefore, the flow velocity is reduced by 35% by just moving the water through the fittings. If pop up valves are used, it is better to use 16 inch or larger pipe and not reduce the pipe size until at the valve.

Table 5 shows the theoretical flow rate for different pump sizes operating at 50 percent efficiency against various pressure losses. The pressure losses not only have to include the friction losses through the pipe but also the vertical lift of the water. Pumping water from the lower end to the upper end of a 1,000 foot free stall building on a 2% slope requires a minimum vertical left of 20 feet. Realistically it may be closer to 40 feet when vertical length from the lagoon is considered.

General Guidelines for Sand-laden Manure

There are some general guidelines to remember when working with sand:

1. Sand-laden manure will not stack or pile up like manure mixed with organic material such as straw or paper. It tends to spread and move away particularly in wet weather. Naturally, sand-laden manure does not appear stack more than 12 to 18 inches deep. Therefore, before it can be handled, you have to contain it.
2. Based on experience, observations and comments by dairy producers, the longer it is contained in a storage structure other than a lagoon, the easier it is to handle. It is recognized that weather does impact the handling characteristics.
3. It is easier to handle sand-laden manure if it is contained in a structure other than the lagoon or holding pond. Difficulties in retrieving and handling occur once the sand moves into a liquid storage area such as a lagoon or holding pond.
4. Utilize the forces of nature as much as possible. Begin the waste handling system design by taking as much advantage of gravity as possible. Only use pumps and

[2]Mention of trade names does not imply endorsement of the product nor criticism of similar products not mentioned by the authors or Kansas State University.

augers as a last resort in moving the manure stream from the end of the freestalls to the holding structures.

5. Do not judge the effectiveness of a system designed to handle sand by what is seen on the surface. Generally, the top surface will be a slurry and initially emptying a solids storage basin takes time. Once the slurry is removed, the rest of the material in the structure will be at less than 80 percent moisture.
6. Flushing systems work better when the energy created by the water depth or head pressure in the flush water tower (and pumps) is used to move manure and sand rather than flush water through the pipes and elbows. A certain amount of energy is lost for every foot of pipe the flush water has to move through. When flushing sand, it is better to purchase more storage towers and move them closer to the alleys than to buy pipes and elbows. If the piping system is desired, then use a larger pipe for the manifold system and do not reduce down to the pop up valve size until after the last elbow or tee joint.
7. Recycling sand for bedding in the near future will require mechanically separating and washing sand, if clean sand and biosecurity are primary concerns. Some producers are experimenting with stock piling gravity separated sand. Most are partially blending the dirty sand with clean sand. The stocked piled period ranges from 1 to 6 months prior to reuse. If a dairy is expanding, the gravity separated sand may be used in construction projects. The run off from the sand pile should be contained and transferred to the lagoon. In a recycled flush water system, the additional drainage area may be beneficial in providing some extra flush water.

Summary

Flushing can be a viable alternative to scraping of dairy manure. Existing facilities can be constructed for the addition of flushing systems at a latter date even if scraping is planned for in the immediate future. This requires placing the buildings at 2 to 3 percent slope. It is recommended to slope the alleys ¾ to1-inch towards the curbs. If a minimal amount of scraping is desired, the flush velocities need to be a minimum of 5 fps with 7.5 fps preferred. Sand will settle from the waste stream by reducing the wave velocity to less than 2 fps. A 6 to 8 foot difference in elevation between the lower end of the flushed areas and the lagoon freeboard will be necessary for inclusion of separation equipment and transfer collection gutters. Inclusion of flushing systems in existing buildings has to be determined on an individual bases. An adequate water supply for fresh water flushing of the milk parlor and holding pen must also be available.

References

Anon (1995). MWPS-7 Dairy Freestall Housing and Equipment. Midwest Plan Service. Ames, IA.

Bickert, W.G. and A.W. Wedel. 1998. Manure management systems using sand-manure separation. Proceedings of 4th International Dairy Housing Conference. ASAE. St Joseph, MI.

Burcham, T.N., S.K. Gill and R.B. Moore. 1997. Comparison of dairy manure separation technologies. Paper No. 97-4050. American Society for Agricultural Engineers, St. Joseph, MI.

Fulhage, C.D. 1998. Design of a gated pipe water release device for flushing dairies. Proceedings of 4th International Dairy Housing Conference. ASAE. St Joseph, MI.

Fulhage, C.D. and J.A. Hoenhe. 1998. Performance of a screen separator for flushed dairy manure. Proceedings of 4th International Dairy Housing Conference. ASAE. St Joseph, MI.

Fulhage, C.D. and J.G. Martin. 1994. Dairy waste flushing. Proceedings of Third International Dairy Housing Conference: Dairy Systems for the 21st Century. American Society for Agricultural Engineers, St. Joseph, MI.

Fulhage, C.D. and D. Pfost. 1993. Basic requirements for flushing dairies. Publication No. WQ-314. Extension Publications, University of Missouri, Columbia, MO.

Fulhage, C.D. and W.R. Bock. 1977. Flushing warm confinement calf housing in southwest Missouri. Paper No. 77-4560. American Society of Agricultural Engineering. St. Joseph. Michigan.

Harner, J.P., T.S. Strahm and D. Key. 1999. Nutrient analysis of sand-laden manure. Report of Progress — in print. Kansas State University Agricultural Experiment Station. Kansas State University. Manhattan, KS.

Harner, J.P., J.P. Murphy and J.F. Smith. 1998. Tower tank valve flush systems for dairy facilities. Paper No. MC98-4562. American Society for Agricultural Engineers, St. Joseph, MI.

Harner, J.P., and J.P. Murphy. 1997. Flushing manure systems for dairy facilities. Report of Progress 792. Kansas State University Agricultural Experiment Station. Kansas State University. Manhattan, KS.

Harner, J.P., J.P. Murphy and D.V. Key. 1997. Manure storage structures for small Kansas dairies. Proceedings of the Fifth International Symposium: Livestock Environment V. American Society for Agricultural Engineers, St. Joseph, MI.

Hermanson, R.E. 1982. Flush cleaning dairy facilities. Extension Bulletin 1031, Washington State University. Pullman, WA.

Hermanson, R.E. 1985. Flush cleaning dairy barns — case studies. Agricultural Waste Utilization and Management. ASAE Publication 13-85.

Loudon, T.L., J.G. Gerrish and W.G. Bickert. 1982. Flushing systems in Michigan confinement dairy barns. Paper No. 82-4527. American Society of Agricultural Engineers, St. Joseph, MI.

Maarfi, M.A., J.I.Sewell and B.L. Bledsoe. 1977. Hydraulic modeling of dairy flush systems. Paper No. 77-4562. American Society for Agricultural Engineers, St. Joseph, MI.

Moore, J. 1989. Flushing freestall alleys. Dairy Manure Management Symposium .Handbook NRAES-31. Northeast Regional Agricultural Engineering Service.

more →

Stowell.R.R., and A.McKenney. 1998. Solids content analysis of dairy farm flush water in storage and at critical points of the waste stream. Paper No. 98-4120. American Society for Agricultural Engineers, St. Joseph, MI.

Wedel, A.W. and W.G. Bickert. 1998. Performance characteristics of a sand-manure separator. Proceedings of 4th International Dairy Housing Conference. ASAE. St Joseph, MI.

Wedel, A.W. and W.G. Bickert. 1996. Separating sand from sand-laden manure: factors affecting the process. Paper No. 96-4016. American Society for Agricultural Engineers, St. Joseph, MI.

Wedel, A.W. and W.G. Bickert. 1994. Handling and storage systems for sand-laden manure from free stall barns. Proceedings of Third International Dairy Housing Conference: Dairy Systems for the 21st Century. American Society for Agricultural Engineers, St. Joseph, MI.

Table1. Volume of flush water (gal) required for gutters 12 feet wide based on gutter length and slope.

Gutter Length (ft)	Gutter Slope (%) 0.5	1	2	3	4
150 ft or less	4,700	2,700	1,550	1,150	1,300
200	6,300	3,600	2,100	1,500	1,500
300	9,400	5,400	3,100	2,250	2,250
400	12,550	7,200	4,150	3,000	3,000
500	15,700	9,000	5,200	3,800	3,800
600	18,800	10,800	6,200	4,500	4,500
800	25,100	14,400	8,300	6,000	6,000
1000	31,340	18,000	10,400	7,500	7,500
Discharge Rate (gpm)	28,200	16,200	9,300	6,800	7,700

Table 2. Characteristics of flushing system with valve 90 degrees open

Initial Head (ft)	No. of Rep	Velocity (fps)	Flow Rate[1] (gpm)	Flow Depth (in)	Contact Time[2] (sec)
>30	3	11.5	9,740	3.6	11.2
26–30	3	10.8	8,630	3.6	11.9
21–25	2	9.4	7,760	3.0	13.4
16–20	3	8.3	7,390	3.3	15.4
11–15	3	7.6	5,940	3.0	16.3
6–10	3	6.7	5,010	2.5	20.0

[1] Average flow rate based on from opening to closing of valve.
[2] Estimated based on released rate, flow depth, velocity.

Table 3. Estimated flow rate (gpm) through a 12 inch PVC pipe with a friction coefficient of 0.02 for varying pipe lengths and water pressures.

Equivalent Pipe Length (ft)	Average Feet of Water Pressure					
	10	15	20	25	30	40
100	5,200	6,320	7,300	8,200	8,900	10,300
200	4,000	4,900	5,700	6,300	6,900	8,000
300	3,400	4,100	4,800	5,300	5,900	6,800
400	3,000	3,700	4,200	4,700	5,200	6,000
500	2,700	3,300	3,800	4,300	4,700	5,400
750	2,200	2,700	3,200	3,500	3,900	4,500
1000	2,000	2,400	2,800	3,100	3,400	3,900

Table 4. Equivalent feet of pipe for different fittings and valves for 12-inch diameter PVC pipe.

Fitting or Valve Opening	Equivalent Pipe Length (ft)
Gate Valve fully opened	7 ft
Gate valve ½ opened	30 ft
Gate valve ¼ opened	200 ft
90° Elbow	35 ft
90° Long Sweep Elbow	20 ft
Tee w/ Straight through Flow	20 ft
Tee w/ vertical Flow	70 ft

Table 5. Estimated flow rate (gpm) for different pumps sizes and water pressures.

Pump (hp)	Average Feet of Head					
	20	40	60	80	100	120
10	1,485	743	495	371	297	248
20	2,970	1,485	990	743	594	495
30	4,455	2,228	1,485	1,114	891	743
40	5,940	2,970	1,980	1,485	1,188	990
50	7,425	3,713	2,475	1,856	1,485	1,238
75	11,138	5,569	3,713	2,784	2,228	1,856
100	14,850	7,425	4,950	3,713	2,970	2,475

more →

Table 6. Concentration (ppm) of inert material (sand) in the flush wave at different times and locations of wave entering and exiting a sand lane and of the initial recycled flush water. Data does not include the amount of sand scraped from the alleys prior to flushing.*

Location and Time of Sample	Dairy 1	Dairy 2
Water at pop-up valve	5,500	1,800
30 sec after flush wave reached end of freestall alley	14,000	27,400
210 sec after flush wave reached end of freestall alley	6,500	8,000
390 sec after flush wave reached end of freestall alley	6,100	3,500
30 sec after flush wave exited the sand lane	13,400	18,200
210 sec after flush wave exited the sand lane	6,100	6,200
390 sec after flush wave exited the sand lane	6,300	3,100
Estimate of sand deposited in lane during 390 seconds**	3%	40%

*Data based on a limited field study in which grab samples were obtained while flushing on two western dairies.
**Based on estimated weight difference between beginning and end of the sand lanes during time period and using release rates of 1,300 gpm release rate at dairy 2 and 2,000 gpm at dairy 1.

Figure 1.

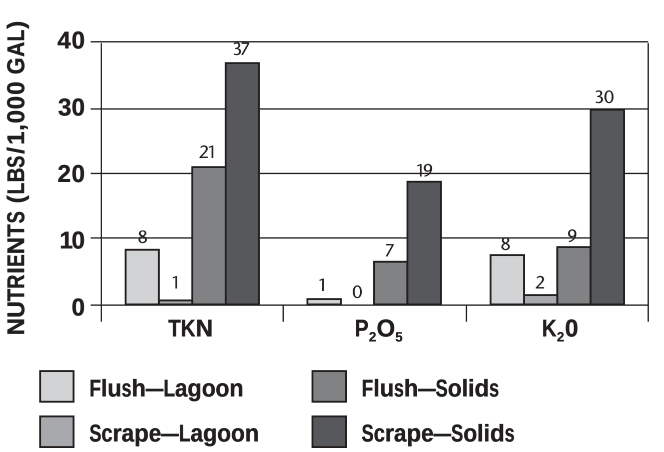


Figure 3.

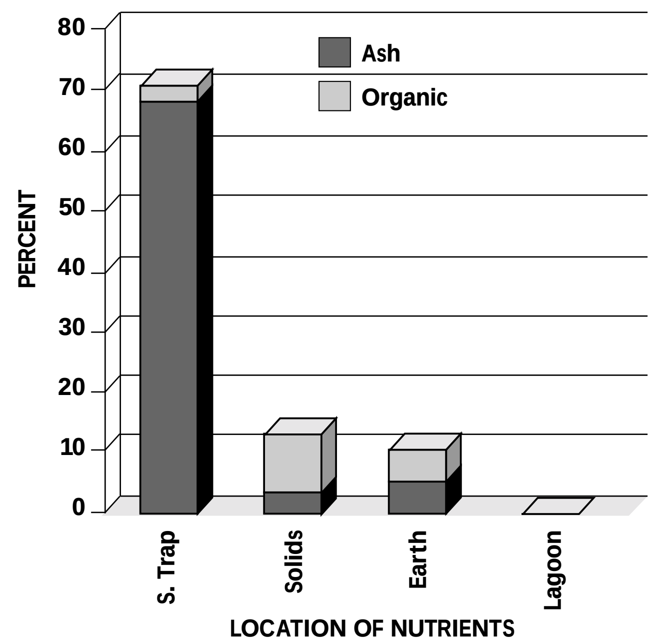
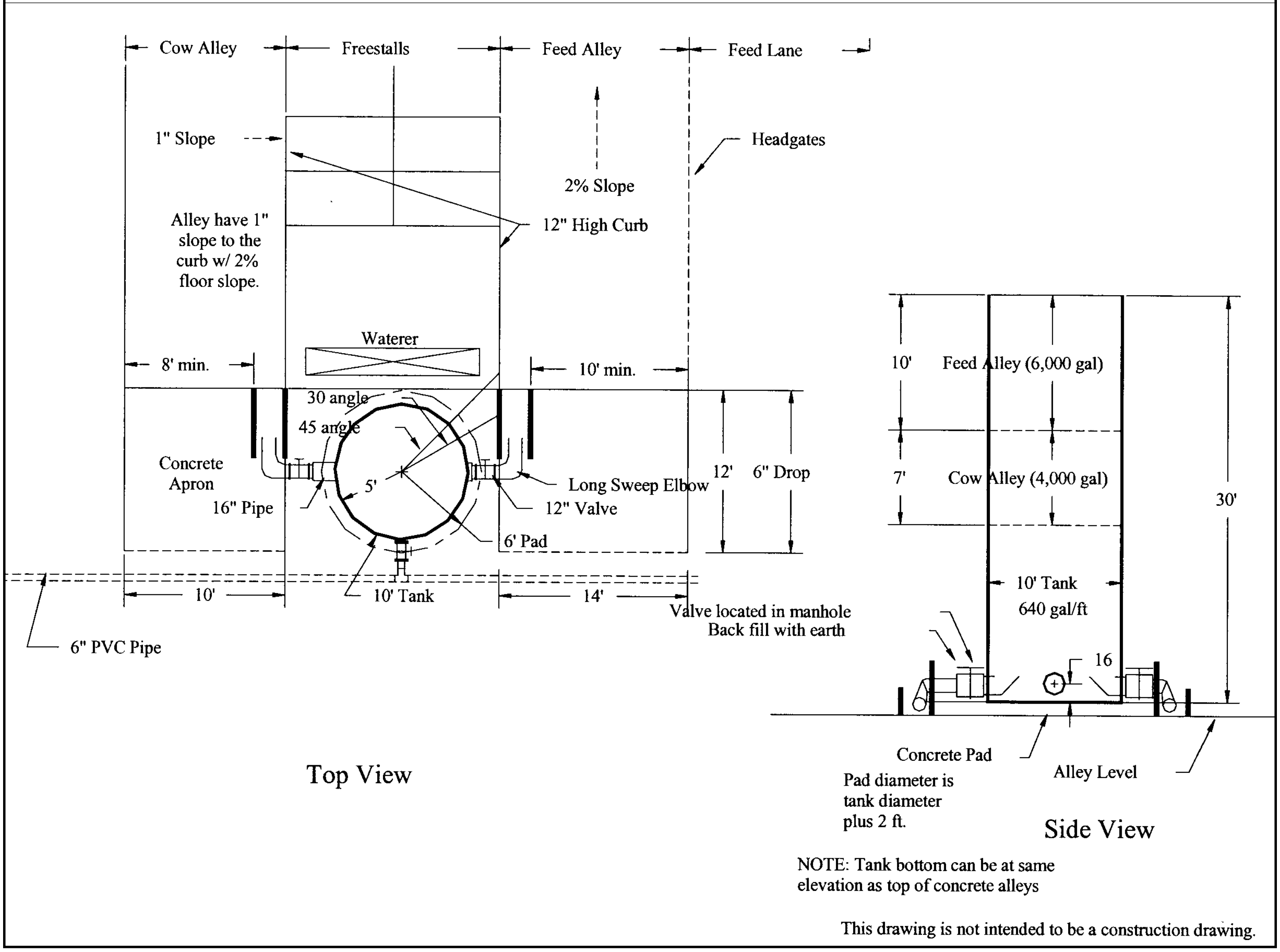


Figure 2.



Cow Alley
Freestalls
Feed Alley
Feed Lane
1" Slope
Headgates
2% Slope
Alley have 1" slope to the curb w/ 2% floor slope.
12" High Curb
Waterer
8' min.
10' min.
30 angle
45 angle
Concrete Apron
5'
Long Sweep Elbow
12'
6" Drop
16" Pipe
12" Valve
6' Pad
10'
10' Tank
14'
Valve located in manhole
Back fill with earth
6" PVC Pipe
Top View
10'
Feed Alley (6,000 gal)
7'
Cow Alley (4,000 gal)
30'
10' Tank
640 gal/ft
16
Concrete Pad
Pad diameter is tank diameter plus 2 ft.
Alley Level
Side View
NOTE: Tank bottom can be at same elevation as top of concrete alleys
This drawing is not intended to be a construction drawing.

Navigating Manure Regulations—California, Idaho and Texas Dairy Producers

DEANNE MEYER–Livestock Waste Management Specialist, One Shields Ave., University of California, Davis, CA 95616
Tel: 530-752-9391 Fax: 530-752-0175 dmeyer@ucdavis.edu

The information superhighway has arrived and right now, you're right in the middle of a 105 car pile-up. Where do you turn for reliable information? At the Federal level, policy is changing. The methodology for doing business as an animal operation will be vastly different within the next two years. A producer recently said to me "the reason I'm involved in so many committees and groups is that I want to keep the dots connected". In order to connect the dots it is imperative that a minimum amount of time is invested to attempt to navigate the mine field associated with environmental compliance issues. Many people don't realize how important it is to be involved and understand how policy is created.

Herd owners of large dairies manage people and information. The critical impact on a dairy is how owners and managers allocate time. Where is information obtained? How do people receive information? Who is viewed as a reliable source of information? Where does a person turn to find the correct information? The answers to these questions may make or break a facility in the area of environmental compliance.

For some producers connecting the dots requires keeping an eye on the Federal government. For other producers, this means watching the Federal government and their State Capitol. And then we have the ever growing group of people that need to watch the Federal and State levels, but must get involved at the local level in development of County policy.

The objectives of this session are to provide a brief insight into the regulatory process at the Federal level and encourage producers to take time and become involved in establishing policy at Federal, State and local levels.

What jurisdiction does the US EPA have over dairy facilities?

NPDES permit: The US EPA can require a discharge permit for industries. This is the National Pollutant Discharge Elimination System Permit (NPDES). The rules of the permit are found in Effluent Limitation Guidelines (ELG). Enforcement actions as a result of violations are based on the ELG. Many industries are obligated to obtain NPDES permits. The permit spells out what is allowed to be discharged (volume and chemical composition). For the dairy and livestock industries, the NPDES permit has associated Effluent Limitation Guidelines (ELG) that firmly PROHIBIT discharge from permitted facilities. The ELG is the regulatory tool used to enforce NPDES permits. Concentrated Animal Feeding Operations (CAFO) are identified as point sources by the Federal Clean Water Act. As a point source, such facilities are required to obtain NPDES permits and comply with associated ELG.

The criteria for determining a CAFO are defined in Appendix B to Part 122.3 of the Clean Water Act. An animal feeding operation is a concentrated animal feeding operation for purposes "...if either of the following criteria are met.

700 mature dairy cattle (whether milked or dry cows); or

200 mature dairy cattle (whether milked or dry cows) and either one of the following conditions are met: pollutants are discharged into navigable waters through a man-made ditch, flushing system or other similar manmade device; or pollutants are discharged directly into waters of the United States which originate outside of and pass over, across, or through the facility or otherwise come into direct contact with the animals confined in the operation." This is followed by the statement "Provided, however, that no animal feeding operation is a concentrated animal feeding operation as defined above if such animal feeding operation discharges only in the event of a 25 year, 24-hour storm event."

The US EPA functions through 10 regional offices. Most State Regulatory Agencies that have enforcement responsibilities for the Clean Water Act oversee NPDES permits. In a few States the Regional EPA office is responsible for issuing the NPDES permit. A State Compendium report is available through *http://www.epa.gov/owm/stcpfin.pdf* . This document continues to be updated and may serve as an excellent starting point for individuals unfamiliar with their State's program.

The permit requires that the facility NOT discharge, except during a 25 year, 24-hour storm event. Land application of manure, resulting in runoff to surface waters, has resulted in prosecution. The findings set precedence that the land application component of manure management was linked to the point source operation (the CAFO) and associated discharges therefore VIOLATED the NPDES permit.

Environmental groups have focused attention on CAFO. Additionally, bills were introduced in the US Senate

more ⟶

(Harkin, 1997), and the US House of Representatives (Miller in 1998 and 1999) to amend the Clean Water Act and modify the requirements for the NPDES Permit. The Miller bill submitted to the House of Representatives has a few points that are worth noting (Table 1). During this process, groups and government agencies asked US EPA how many CAFO are in compliance with existing regulations? Unfortunately, there was insufficient information for the regulatory community to respond. The US EPA developed a Strategy to improve compliance of CAFO. The Strategy was released in March 1998. It was quietly rescinded and resurfaced in September 1998 as a Joint Unified Animal Feeding Operation Strategy with the USDA Natural Resources Conservation Service (NRCS). There were 11 listening sessions held throughout the United States. More than 2,100 comment letters were received by the January 19, 1999, deadline. On March 3, 1999, the Final AFO Strategy was released.

During the last 20 months, the Strategy has served as a roadmap for where US EPA may travel with respect to the NPDES permit. Comprehensive Nutrient Management Plans (CNMP) were introduced as a management tool to assist in tracking nutrients through a facility (managed, stored, and utilized in a proper fashion). In one respect, the Strategy identified CNMP as a great opportunity for all animal facility managers to assist in managing their facilities. A CNMP as presented in the Strategy would in fact be a tremendous amount of documentation. Utilization of the information in a CNMP would require management skills and should improve the efficiency and reduce the liability at CAFO. It was identified that less than 5% of the facilities would be required to do CNMP. The CNMP would be voluntary for most of the operations in the United States. See Table 1 for a comparison of the Strategy and Miller's bill.

In July 2000 US EPA published an outreach document to announce that draft Effluent Limitation Guidelines would be released by mid-December. On December 15, 2000, Carol Browner, Secretary of US EPA signed the draft Effluent Limitation Guidelines. A prepublication copy can be found at *http://www.epa.gov/owm/afos/proposedrule.html*. The final proposed rule appeared in the Federal Register on January 12, 2001. You can access it through the Federal Register by going to their website *http://www.gpo.ucop.edu/search/fedfld.html* and selecting 2001, and entering national pollutant discharge as the word or phrase. Select after in the issue date box and type in 1/11/01 in the box to the right of the issue date. In the Sections box, click proposed rules. Click run search. It will print a list of results. The particular item you are interested in is National Pollutant Discharge Elimination System Permit Regulation proposed rule dated January 12, 2001. There are 4 files that combine to make this document. Three of the files are 50 pages and the last file is 37 pages. It's a much more concise version due to the size font used in the Federal Register. The important part of the document is near the end beginning on page 3135 of the Federal Register version. From there you can open a PDF file to print. It's not a brief document. There is a 120 day comment period. There will be no listening sessions and there are no formal presentations planned by US EPA on this draft document.

Table 1 attempts to compare differences between Miller's proposed bill, the AFO Strategy, NRCS CNMP guidance, and the draft ELG. Keep in mind that the current Federal requirement (the NPDES permit) requires that dairy operators that are defined as point source not discharge to surface waters of the United States. It does not have detailed requirements to prohibit discharge, nor does it have detailed requirements for monitoring and reporting. All of the proposed alternatives require extensive amounts of record keeping.

It is imperative that livestock producers provide comment on this document. It is a bit lengthy. The pre-proposed rule document was over 900 pages long. If you actually single space the document and eliminate the footnote indicating it's a pre-document, it's markedly shorted (around 300 pages). There is an excellent table of contents and lots of appendix material. Producers should be encouraged to work in small or medium sized groups to provide thoughtful comment on the content of the draft ELG.

TMDL: The ELG review and revision (technology-based effluent limits) is just one part of the Clean Water Act. The Total Maximum Daily Loading (TMDL) component in the Clean Water Act will require attention in some parts of the United States. This is a quantitative water quality-based approach to pollution control. A TMDL defines how much of a pollutant a water body can tolerate on a daily basis and still meet the relevant water quality standards. The total of all the sources of the pollutant in the watershed must not exceed the TMDL. Areas that have impaired water bodies are obligated to prepare TMDL to identify standards for the daily loading of specific nutrients. This section of the Clean Water Act was not enforced for years. Rulings of lawsuits have resulted in the US EPA being responsible for development of TMDL when States fail to develop TMDL for impaired water bodies. US EPA is under court order in many States to produce TMDLs. Environmental groups continue to file additional complaints.

Much about TMDL requirements is unclear, confusing, and unpredictable. US EPA spells out how the States should prepare the list of impaired water bodies and prioritize the water bodies on the list. Once prioritized, States are obligated to establish TMDL for the priority water bodies. Levels should be set "at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety that takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." Most States do not have policies or regulations guiding TMDL development. Additionally, State regulatory agencies do not typically have staff or funding for program development, enforcement, and review. It should not be ignored that many States lack sufficient data to adequately determine if water bodies are impaired or not. There is a large variation in how individuals or groups define polluted water bodies. Regulatory staff have tremendous flexibility and opportunity in the absence of Federal or State policy clearly defining methodology for TMDL development.

The US EPA has issued guidance documents that further clarify TMDL. These are guidance documents and lack the force of regulation. Their purpose is to assist states with program implementation prior to issuing formal regulations.

For many parts of the United States, phosphorus is a critical nutrient. The development and implementation of standards will require monitoring for individual land owners and groups of individuals within a water shed. Violations of standards are subject to fines and potentially jail time. If your area is going through the TMDL process, you will want to be involved. It is critical to understand what the responsibilities of the regulatory agencies are and what you can do to best manage your animals and land.

Coastal Zone Act Reauthorization Amendments: The Coastal Zone Act was amended in 1990. The basic objective of the amendment was to require coastal states to develop and have approved a non-point source plan. Coastal states include all states within 10 miles of high tide and states that contribute to waters that have coastal outlets. The coastal zone consists of states bordering the Pacific, Atlantic, and Gulf of Mexico, those bordering the Great Lakes and states with rivers that go to any of these water bodies. Most of the United States falls under Coastal Zone Act jurisdiction. The US EPA issued a guidance document to present management measures for agricultural sources. This included erosion and sediment control, facility wastewater and runoff from confined animal facility (facilities were identified down to 20 cows), nutrient management, pesticide management, grazing management, and irrigation water management. Non-agricultural sources identified were forestry, urban areas, marinas and recreational boating, hydromodification (channelization and channel modification, dams, streambank and shoreline erosion), and wetlands, riparian areas, and vegetated treatment systems.

The timeline for implementation of the Coastal Zone Act Reauthorization amendments was for states to develop technical advisory committees to address the management measures and then submit a state plan to US EPA and the National Oceanic and Air Administration for coastal non-point plan. Originally, states were scheduled to begin implementation by January 1996, and be completed by January 1999.

Clean Air Act: The Clean Air Act was passed in 1954. It established ambient air quality standards for six compounds. When the ambient standards are exceeded in a local air basin, the state is required to develop and implement plans to reduce concentrations of the compound. In the absence of the state developing a plan, or if the plan is not deemed acceptable to citizens or groups, law suits can be filed. The end result is that US EPA is obligated to develop a federal implementation plan to reduce emissions of the compound.

Once compounds exceed the maximum standards, the regulatory agency will conduct an inventory process. Typically, they identify the categories and associated activity factors (how many are in this category) that contribute to the emissions. Then they determine the emission rate for each category. Lastly, they multiply the activity factor by the emissions rate to estimate the total emissions for each category. The numbers are summed over all categories and the total emissions are estimated. Each category can determine its contribution to emissions by dividing its rate by the total rate. In air sheds where there are considerable numbers of dairy animals, the dairy may well have the highest contribution to ammonia emissions.

Although the process for the regulatory agency to follow is straight forward, there are some potential areas for problems (mis-calculations) to occur. It is important to be sure that someone knowledgeable with livestock is involved in estimating emissions. At a minimum, producers need to be involved in the review process after calculations are made. You need to be sure that the numbers make sense. A common mistake is for data to be obtained from an Ag Commissioner's office. There's nothing wrong with the data as long as you understand what they mean. If the Ag Commissioner has data for numbers of bulls and this

more →

number includes bull calves sold, one should use caution before applying the number directly to an emission rate. Depending on the destination of the bull calves, they may not be contributing to air emissions (sold out of county for veal, feedlot, etc.). You don't need to be an air chemist to study population numbers and identify if they make sense for your geographic area. You can't expect the staff from the regulatory agency to fully understand the subtle differences in how data are collected and what they mean. You have the ability to take control of your destiny and get involved in the emissions calculations.

The two compounds of interest to dairy operators are particulate matter of less than 10 microns in aerodynamic diameter (PM_{10}) and ozone. Both compounds are associated with human health problems. The PM_{10} is from primary sources (dust particles in the atmosphere) and secondary sources. Dust from animal and farming activities can add to the PM_{10}. Ammonia emitted from decomposition of manure (the crude protein that doesn't end up in milk is excreted and can be volatilized into the atmosphere as ammonia) can react with oxides of nitrogen in the atmosphere (exhaust from gas engines) and form ammonium nitrate. This particle is less than 10 microns in aerodynamic diameter.

The other compounds of interest are reactive organic compounds. These are carbon based compounds that are reactive and serve as catalysts in the formation of ozone. Elevated ozone in the air we breath (not the hole in the upper atmosphere) is undesirable. It a component in smog and is the compound measured in most air sheds that is used to determine the air quality index. The same academic exercise is accomplished for reactive organic compound formation that is done for ammonia emissions. Unfortunately, the data to estimate emissions are sketchy at best. If you live in an air shed where reactive organic compound emissions are being estimated, be sure you speak with someone that is familiar with the scientific data so you are best informed.

The other air issue (other than odor) is methane. It is not associated with the Clean Air Act. However, it does make the radar screen when folks discuss global warming. The biological fact of manure decomposition is that methane will be formed when manure is in an anaerobic system. Standard retention ponds without aeration technology result in anaerobic conditions and methane generation. The larger the herd, the higher the potential for methane generation. Also, the greater the target if the regulatory agency needs to reduce methane emissions.

As an emitter, life may not be all bad. There are some good things that can come from conserving nitrogen (reducing ammonia volatilization). The more nitrogen that is conserved in the system, the better the nitrogen to phosphorus ratio for land application. Many parts of the United States are in areas where phosphorus standards will be applied for land applied nutrients. As a result, standard manure management will result in the need to increase use of commercial fertilizer to meet plant nitrogen requirements. With nitrogen conservation, it is possible to reduce the reliance on commercial fertilizer. Commonly used technologies may need to be revisited and evaluated for additional criteria to consider environmental ramifications.

In the category of "here we go again," the methane emissions may not be a bad thing either. There are plenty of companies willing to turn manure into electricity. Given the electrical problems associated with this winter, it is a given more producers will look to additional technologies. There are simple and complex systems. Be wise in making decisions if you chose to collect methane and generate electricity. Gather information. Understand your options. Understand your obligations. Critically evaluate the additional resources needed to adequately operate the system. Read beyond the testimonials. Do your homework ahead of time. Check to see if you can get someone else to pay for the system. Electric companies will want to increase electric output. To build additional plants will require a need to offset additional methane emissions. Maybe an electric provider will pay for part or all of the technology.

State or local regulations

Each of the states and territories in the United States has the potential for additional requirements. And, counties have the opportunity to have even more stringent requirements. Ask any California dairy producer about the California Environmental Quality Act (CEQA). If there is not immediate reaction, the odds are fairly good that the individual has not gone through a county permitting process in the last few years to either expand their current dairy or relocate. Like many of the previously mentioned regulations, enforcement of CEQA on agriculture and animal facilities has been almost non-existent during its first 25+ years. More recent attention from environmental groups has resulted in stronger enforcement of CEQA. The end result is a much extended and highly public process associated with obtaining a permit. Once the permit is issued, the groups then file suit against the issuing agency for not adequately addressing CEQA. Many producers have been in the land of unknown territory as they try to get permitted. Other producers, who have expanded their facilities and neglected to update use permits may end up in the same place.

What do you do when you find yourself in an unknown area? First, get information. Be sure it is from a reliable source. There are numerous consultants and companies willing to sell their services to fix your problem. Interview them to determine if they have the qualifications you are looking for. Be sure your team has someone knowledgeable in environmental law (or whatever the law of concern is) and be sure they have a minimum understanding of how dairies operate.

Conclusions

Knowledge is gold! Yes, it takes time away from the animals and from making other decisions. Consider this time an investment in your future. As we have all learned from Alice In Wonderland, if you don't know where you want to go, any road will take you there. Be decisive. Know what you need. Realize that if you call different individuals with different regulatory responsibilities you may well get correct and conflicting information. Do your best to identify what puts you at risk for contaminating the environment and then make sound management decisions to minimize your risk.

There will be more emphasis on environmental compliance. There will be a bit more equity in the existence of regulations with the additional proposed Federal regulations. Dairy producers of the year 2020 will be keen managers of information and personnel. Start preparing now for your future. Be sure when you purchase equipment or expand your herd that you consider the ramifications on manure management and its associated record keeping requirements.

In an era of being bombarded by information on all sides, be sure you know who provides reliable and sound information. Work with your County Agent or Dairy Advisor. These individuals have direct links to others in the Land Grant College system. They can get reliable information for you and potentially assist in conducting research. Research scientists at the Land Grant College are also potential resources for assisting in research projects. Work with your trade associations. They provide information and lobby when necessary. This may be an important avenue to consider. Read trade magazines. Be sure that when you read articles you understand the differences between products and technologies that have been tested and testimonials. Be highly skeptical and critical of claims to reduce manure problems, odors... It can be done. Buyer beware! Remember that the internet is a place to find information. You need to be informed enough about a subject to decipher if what you read off the internet is valuable information or just a bunch of words.

Your future as a dairy producer will depend on how you address and manage numerous issues. Environmental stewardship is just one of the many "new" subjects that producers will need to address to continue to be successful in the dairy industry. Animal health and welfare issues and food safety issues are equally as important.

References:

USDA NRCS websites of interest:

NRCS website with links to CNMP guidance, interdepartmental site for Clean Water Action Plan, public comment letters on the AFO Strategy, text of the final Unified National Strategy for Animal Feeding Operations (in English and Spanish). *http://www.nhq.nrcs.usda.gov/PROGRAMS/ahcwpd/AFO.html*

USDA Agricultural Waste Management Field Handbook *http://www.ftw.nrcs.usda.gov/awmfh.html*

USDA NRCS National Planning Procedures Handbook (NPPH). *http://policy.nrcs.usda.gov/scripts/lpsiis.dll/EDS/RTFList.html*

USDA NRCS Conservation Planning Course *http://www.ncg.nrcs.usda.gov/start.htm*

USDA NRCS Core4 Conservation Practices Training Guide *http://www.nhq.nrcs.usda.gov/BCS/agro/CORE4.PDF*

USDA NRCS Agronomy Technical Notes. *http://www.ncg.nrcs.usda.gov/tech_notes.html*

USDA NRCS National Agronomy Manual establishes policy for agronomy activities and provides technical procedures for uniform implementation of agronomy tools and applications. Release due fall 2000.

General Manual Technical Guides *http://policy.nrcs.usda.gov/national/gm/title450/part401/index.htm*

Nutrient Management homepage *http://www.nhq.nrcs.usda.gov/BCS/nutri/manage.html#nm*

US EPA websites

Home page for TMDL *http://www.epa.gov/OWOW/tmdl/*

There are four factsheets available on the TMDL process. *http://www.epa.gov/OWOW/tmdl/cleanfs4.html* (Type in 1 through 4)

Compendium of state programs *http://www.epa.gov/owm/stcpfin.pdf*

Additional websites:

To access the Federal Register *http://www.gpo.ucop.edu/cgi-bin/gpogate*

Copeland, C. and J. Zinn. 1998. Congressional Research Service Report for Congress. Animal waste management and the environment: background for current issues. The Committee for the National Institute for the Environment, Washington, D.C. Updated May 12. *http://www.cnie.org/nle/ag-48.html*

National Resources Defense Council, Inc. 1998. Reports America's animal factories how states fail to prevent pollution from livestock waste. *http://www.nrdc.org/water/pollution/factor/aafinx.asp*

US EPA. 1997. Animal waste disposal issues. EPA office of Inspector General #7100142. *http://www.epa.gov/oigearth/hogexsm.htm* April 21.

Public Law 80-845. 1948. Water Pollution Control Act. 80th Congress. June 30, 1948.

more →

Table 1. Comparison of proposed legislation, the AFO Strategy and draft ELG.

Parameter	H.R. 684 Miller	Unified National AFO Strategy	NRCS CNMP guidance	US EPA draft ELG
CAFO definition	350 mature animals	Identified effluent limitation guidelines (ELG) would be reviewed and revised.	N/A	2-tier structure 350 milk cows; 3-tier unchanged from current definition.
Permit required	Required for CAFO within performance standards.	If a facility is defined as a CAFO. Public access to Notice of Intent, CNMP and associated reports.	N/A	NPDES for CAFO. Permit Nutrient Plan (PNP) required.
Documents required	Yes	CNMP (Feed management, manure handling and storage, land application of manure, land management, record keeping, other utilization options.)	Identifies management and conservation actions that will be followed to meet clearly defined soil and water conservation goals. Documentation of management and implementation activities associated with CNMP.	Notice of Intent (to seek coverage for NPDES permit), and Notice Plan Development (to identify PNP is being developed) must be submitted to regulatory agency and will be made publicly available (WEB and in office). PNP will be available to public upon request. Identification of nearest water body.
Monitoring requirements	Excessive application of nutrients identified as a discharge.	Record keeping to identify amount and destination of manure. Soil and manure testing should be incorporated into the record keeping system.	Documentation required: number and type of each category of animals present; estimated manure and wastewater volume produced; manure storage type, volume and duration (how they function and limitations); existing transfer equipment; operation and maintenance activities that address collection, storage, treatment and transfer of manure and wastewater; nutrient content and volume of manure.	Maintain records for 5 yr. Visual monitoring: daily- drinking water lines; weekly- stormwater diversion and collection devices; also monitor: seepage, erosion, vegetation, animal access, decreased freeboard, rain gauges, irrigation equipment. Depth marker in ponds to determine liquid level. Mortality management.
Feed management	N/A	Identified component of CNMP.	Can be an effective tool to address excess nutrient production. A professional animal nutritionist should be consulted.	Not discussed.

Additional websites:

Public Law 84-159. 1955. An act to provide research and technical assistance relating to air pollution control. 84th Congress. July 14, 1955.

Public Law 92-500. 1972. Federal Water Pollution Control Act Amendments of 1972 (Clean Water Act). 92nd Congress. October 18, 1972.

Public Law 93-205. 1973. Endangered Species Act of 1973. 93rd Congress. December 28, 1973.

Public Law 100-4. 1987. Amendments to Federal Water Pollution Control Act (Water Quality Act of 1987). 100th Congress. February 4, 1987).

Public Law 101-508. 1990. Subtitle C. Amendments to Coastal Zone Management Act of 1972. 101st Congress. November 5, 1990.

Table 1, continued

Parameter	H.R. 684 Miller	Unified National AFO Strategy	NRCS CNMP guidance	US EPA draft ELG
Manure handling and storage	Design for liquid storage structures must be identified and approved. Prohibit use of unlined containment structures or the use of other structures that pose significant risk of pollution to surface or ground water. Eliminate within 10 years, open-air lagoons for the storage of animal waste.	Divert clean water, prevent leakage, provide adequate storage, minimize atmospheric deposition when treatments are used; appropriately handle mortality.	Provide adequate collection, storage, and/or treatmentof manure to allow for application during favorable weather conditions and at times compatible with crop management. Additional considerations include air quality, pathogens.	Identify manure collection, handling, storage and treatment practices; record amount of manure generated annually, amount of manure transported offsite, repairs to manure storage and treatment facilities, estimates of wastewater generated, rainfall events (duration, quantity, overflow if catastrophic or chronic); method used to estimate nitrogen losses; record.
Land application limitations	Application of animal manures based on nitrogen and phosphorus to not exceed the reasonably anticipated agronomic nutrient uptake of the vegetative cover growing. USDA NRCS shall establish maximum permitted levels for other nutrients, minerals metals, or other substances found... that would pose a significant threat of pollution to surface or ground water.	Balance nutrients applied with those that are already present in the soil and that are applied from other sources (commercial fertilizer, biosolids, manure). Prevent over-application of nutrients beyond the capacity of the soil and planned crops to assimilate nutrients and prevent pollution. Soils and manure should be tested to determine nutrient content.	Meet NRCS Nutrient Management policy contained in NRCS General Manual Title 190, Part 402; Nutrient Management Code 590; Irrigation water management Code 449 (restrict land application based on phosphorus). Nutrient budgets developed with nitrogen, phosphorus, and potassium to include all nutrient sources. Test soil, manure, organic by-products; document form, source, amount, timing and method of application and equipment calibration.	Identify crop rotation and yield goals, field condition as determined by phosphorus index, soil test phosphorus, or phosphorus threshold, number of acres to receive manure, application rate (and pounds of nitrogen, phosphorus, and potassium). Record maintenance of berms and diversions, test methods used for nutrient analysis. Setback application 100' from surface water, tile line intake structure, sink hole, or agricultural well head.
Method of application	Aerial spraying–establish minimum distances (to prohibit spraying) from residences and environmentally sensitive locations.	Calibrate equipment to ensure application rate is desirable.	Must be consistent with NRCS Field Office Technical Guide.	Annual calibration of application equipment (solid and liquid). Identification of rate limiting parameter (nitrogen, phosphorus or potassium). Applicator must attend USDA sanctioned training.
Application timing	Prohibited on ice, snow, frozen soil, saturated soil.	Apply manure to prevent it from entering streams, other water bodies, or environmentally sensitive areas.		Record date of manure application, weather conditions at time of application and for 24 hr before and after and results from manure and soil sampling.
Waste agreements	Written agreement to include terms and conditions necessary to ensure waste is applied acceptably.		Notation should be available to describe manure sources and destinations.	Must sample manure sources and provide nitrogen, phosphorus, and potassium content to receiver.

more →

Table 1, continued

Parameter	H.R. 684 Miller	Unified National AFO Strategy	NRCS CNMP guidance	US EPA draft ELG
Emergency (contingency) plans	Mandatory		Address spills and catastrophic events.	Must have on file at facility as part of PNP.
Agency to approve plan	Administrator (USDA NRCS ?)		NRCS to approve plans.	Illegal discharge or insufficient documentation violates NPDES permit.
Penalties	Animal owner liable under §309 Clean Water Act.	The ultimate responsibility for developing and implementing CNMPs resides with the CAFO owner and/or operator.	Will be done for producers participating in NRCS programs and voluntary for producers seeking assistance.	Subject to civil and criminal enforcement actions depending on violation.
Address air quality, odor, nuisance issues	Eliminate atmospheric deposition of nutrients, minimize odors and pests.		Air quality impacts of associated conservation practices should be considered.	Discussed at length in text prior to proposed rule. Not mentioned in the proposed rule.
Other	Significantly reduce liquid content of wastes; promote technologies and production practices that minimize the need for largescale storage of animal waste. Remove and dispose of animal waste within 180 days after facility ceases production.	Certified specialists to develop plans. Consideration for contribution to total maximum daily loading rate (TMDL). Increase inspections and compliance assistance. Eliminate agricultural stormwater exemption for land receiving manure nutrients.		Emphasis on no discharge to surface waters (directly or via hydrologic connection). No specification in proposed rule that NRCS will need to approve plan. Name of state approved specialist that prepared or approved the PNP, or record and documentation of training and certification for owners or operator writing their own PNP.

Abbreviations: Concentrated Animal Feeding Operation (CAFO), Comprehensive Nutrient Management Plan (CNMP), Permit Nutrient Plan (PNP), Total Maximum Daily Loading (TMDL), United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS),

Miller, G. 1998. H.R. 3232 & 1999 H.R. 684. Farm Sustainability and Animal Feedlot Enforcement Act introduced in the House of Representatives February 12 (105th Congress) and February 10th (106th Congress).
USDA-US EPA. 1999. Unified National Strategy for Animal Feeding Operations. *http://www.epa.gov/owm/finafost.htm* March 9.
USDA NRCS. 2000. Comprehensive nutrient management plan technical guidance. *http://www.nhq.nrcs.usda.gov/PROGRAMS/ahcwpd/ahCNMP.html* December 1.
US EPA. 2001. 40 CFR Parts 122 and 412. National Pollutant Discharge Elimination System Permit Regulation and Effluent Limitations Guuidelines and Standards for Concentrated Animal Feeding Operations. Proposed Rule January 12. Will be available through *Http://www.epa.gov/owm/afos/rule.htm*.

Stopping Disease Before It Takes Hold

FRANKLYN GARRY—Integrated Livestock Management, Colorado State University
Department of Clinical Sciences, Fort Collins, CO 80523-1620
Tel: (970) 491-0371 Fax: (970) 491-1275 fgarry@lamar.colostate.edu

The Spectrum of Dairy Cattle Health Problems

Over the last several decades, changes in management, nutrition and genetics of our dairy cow population have led to a shift in the type of diseases perceived to be important. We increasingly recognize the importance of suboptimal performance that occurs without overt disease signs, the occurrence of metabolic and production related diseases and a variety of management problems that limit performance but are not directly related to specifically diagnosed diseases. Examples of these types of problems include rumen acidosis, ketosis and fatty liver disease, laminitis, hypocalcemia/milk fever, displaced abomasums, and reproductive inefficiency.

Enough emphasis has been placed on this variety of problems that it is easy to perceive that infectious disease is proportionally less of a problem now than it was in times gone by. Recent information from the National Animal Health Monitoring System Dairy '96 Study demonstrates, however, that infectious diseases still represent a tremendous area of concern. This study estimates that clinical mastitis occurs in 13.4% of all dairy cows, respiratory problems in 2.5%, lameness in 10.5%, and diarrhea in 3.4%. In dairy calves, scours, diarrhea and respiratory problems are responsible for 85% of all calf deaths.

These estimates of average disease incidence provide only one side of the infectious disease picture. Infectious disease remains an extremely important concern in any livestock operation. Even more troublesome than ongoing disease losses can be the development of explosive new infectious problems. Despite the lower profile infectious diseases may have assumed in some discussions of herd health and productivity, infectious agents are still as important as ever and perhaps even more problematic as animal density and herd size increase.

Clearly, the spectrum of dairy cattle health issues is very broad, both in terms of the types of disease problems, and the management required to deal with these problems. These issues range from non-infectious to infectious diseases, from nutritional management to vaccination strategies, from antibiotic residue concerns to food safety issues. It is evident to anyone involved in dairy production that health problems are central to many of the management decisions that need to be made on a daily basis.

How Do We Deal With Dairy Cattle Health?

Ongoing scientific advancements influence our perception of disease and our methods of dealing with these problems. For some, increased knowledge about the impacts of nutrition and animal management as primary determinants of livestock health has led them to ignore many infectious disease issues. It has been easy to assume that vaccine improvements make infections ever more preventable, and antibiotic improvements make these diseases ever more treatable. With advances in computer technology and animal monitoring techniques, we have increased our ability to evaluate indices of herd performance and productivity. Thus we look at reproductive performance, milk production, sick pen days, milk somatic cell count, etc. to evaluate the herd.

Sooner or later, however, almost every dairy faces a real crisis in animal health. This might occur as a sudden increase in an infectious disease, a rapidly fatal disease of unknown cause, or recognition that a certain problem has been increasing over a prolonged time and is now rampant in the herd. When this occurs, several truisms become apparent:

1. Even with the best possible management, disease is a fact of life.
2. We can manage animals as a herd, but disease ultimately manifests in individual animals.
3. In a complex system, something goes wrong eventually.

While there are many ways we could respond to these observations, I believe the best approach is the one least frequently employed. Keeping in mind the many different disease challenges we need to consider, plus the many different factors that can promote disease, plus the many different methods we might use to manage disease problems, there is no set of management practices that could fit all situations. Clearly there is need to fit management to each individual dairy. This requires a balance between generic best management practices and monitoring for the circumstances and disease problems of the dairy. Specifically this requires attention to prompt and thorough diagnosis on a routine and systematic basis.

Disease Management

The following discussion will focus on infectious disease management. As noted above, this is only one group of diseases that would concern dairy operations,

more →

and similar management issues could be addressed for diseases that relate to nutritional factors, toxicities, or housing and facilities. Many disease problems are influenced by combinations of these factors, but the purpose of this discussion is to demonstrate the importance of balancing management and monitoring, rather than outline the causation of multiple diseases.

There are numerous infectious diseases of concern to dairy operations that do not respond well to management focused primarily on vaccination plus treatment. For example, we recognize viral diseases that can circumvent vaccine protection, diseases that respond poorly to treatment, and endemic or chronic diseases with carrier animals that perpetuate the disease in a herd. These include brucellosis, tuberculosis, Johne's disease, salmonellosis, bovine leukosis, mastitis due to Streptococcus, Staphylococcus and Mycoplasma, anaplasmosis, hairy heel warts, ringworm, Pasteurella pneumonia, Haemophilus, BVD, IBR, PI^3 and BRSV.

Infectious disease control is one area where veterinary consultation and management input are virtually indispensable. A look at the findings from the NAHMS Dairy '96 Study puts in perspective the opportunities for improvement in this disease control area. Depending on herd size, between 45% to 80% of dairies brought cattle onto their operation within the year preceding the study. Of the new additions, fewer than 25% were quarantined and even fewer were adequately tested for infectious diseases. These statistics alone emphasize the high risk of infectious disease introduction in most dairies. Between 20% to 50% of dairies fail to require common vaccinations before introducing new cattle into their herd. Thirty to eighty percent of dairies fail to require milk somatic cell counts and 60% to 90% of dairies request no milk culture before introducing new herd replacements.

A biosecurity program must be individually tailored to the herd and its specific concerns and goals. An important first step in the development of a biosecurity program is identification of those diseases that concern a specific dairy operation. Quarantine can help to limit the introduction of infectious agents that induce acute disease, but quarantine alone is an insufficient measure for the prevention of entry of most of the important infectious diseases. Other biosecurity measures will vary with the mode of disease transmission, the duration of infectious agent shedding, the presence of asymptomatic carriers, and the reliability of screening tests for the disease. Quarantine will not work to prevent the introduction of diseases with chronic asymptomatic carrier states such as Johne's disease, BVD, IBR, salmonellosis, BLV and contagious mastitis.

For some diseases, the best method of protection is testing prior to purchase. Screening tests can be very useful for avoiding brucellosis, tuberculosis, contagious mastitis, BVD and BLV. For Johne's disease, screening tests alone are inadequate and knowledge of the Johne's disease status of the herd of origin is probably more important.

Screening tests for Salmonella can be useful but most Salmonella infections are caused by feed, environmental contamination or spread by other species. Risk of disease transmission from other species has been generally considered low but should not be forgotten when considering herd management strategies. Tuberculosis and brucellosis can be spread by deer or other cervids; sarcosporidiosis, hydatid disease and rabies can be spread from dogs; and toxoplasmosis and rabies are commonly spread by cats. The Dairy '96 Study shows that 90% of operations have contact between cattle and cats, 78% of operations have contact with dogs, approximately 50% have contact with deer or other cervids, and 20% or less have contact with beef cattle, horses or poultry. The study also demonstrated that 60% or fewer of dairies prevented access to grain or concentrate storage units by dogs, cats, birds and rodents.

Infectious problems can be spread by contact with infected body fluids. More than 50% of operations that dehorned heifers with spoons, gouges, saws or other surgical methods neither washed nor disinfected between animals; 65% to 75% of operations did not change needles or disinfect needles between animals when administering vaccines by injection. Approximately 75% of operations used the same rectal sleeve for more than one cow when performing rectal palpation. Only 18% of operations separated sick cows to prevent nose to nose contact with other cows and heifers.

Some infectious diseases are spread from dams to newborns and the time of separation of the calf from the cow can have an impact on the transmission of these diseases. Only 13% of operations separated newborn calves from the dams within one hour of birth. Twenty-five percent of operations separated the calves beyond 12 hours after birth. Fifteen percent of operations allowed calves to stay with their dams more than 24 hours. Thirty percent of operations failed to wash teats and udders before colostrum was collected for administration to the calves. Approximately 55% of operations used the calving area as a hospital area for sick cows. Fecal contamination is a common means for spread of many enteric infections. Approximately 33% of operations used equipment for manure handling that was also used to handle feed for heifers less than 12 months of age.

A well designed biosecurity program can have a very significant impact in reducing the risk of infectious spread. The program should be designed for the needs of each individual operation. Consideration should be given to entry of new animals, quarantine of new animals, prepurchase vaccination and testing or screening for disease, knowledge of the herd of origin for new purchases, minimization of feed and environmental contamination, disinfection of instruments, minimized contact between sick and healthy cattle or dams and calves, minimized fecal contamination, fly and other insect control programs, and minimized contact with other species.

Monitoring Disease — The Importance of Accurate Diagnosis

So how do we determine the diseases of importance on an operation? While there are certain management practices that generically help reduce the risk of spread of multiple disease problems, others are very focused on specific diseases. Virtually all of the management items discussed above require that good diagnostic tools are used, or at least that the diagnostic tools used are well understood and employed properly, even when they are not particularly accurate. Additionally, there are unexpected disease problems that occur even when management against disease is well implemented. Unfortunately, it is often the unexpected problems that can cause the greatest losses, exactly because they are unanticipated and therefore unmanaged until they are well advanced.

The most important tool for adapting management to a changing set of disease concerns is prompt and accurate diagnosis. The best opportunities for disease monitoring are typically overlooked. It seems that many producers and veterinarians assume that they have a good feel for the diseases that occur on a specific operation. Alternatively, they assume they can use a good guess on the nature of a disease and manage around the problem. Perhaps they feel that the set of likely problems is limited enough that they don't really need to know the cause of a specific disease. Or perhaps it seems reasonable to apply some 'shotgun' treatment and prevention practices with the assumption that a broad enough approach is likely to be successful regardless of the specific problem at hand.

There is a saying that "You can't manage what you don't measure". While this is not completely true, it is certainly true that the more closely you can identify and measure a problem, the better equipped you are to manage it.

For whatever reason, very few producers or veterinarians take advantage of the array of diagnostic techniques available. When diagnostic methods are employed, they are often used sparingly in bits and pieces, and rarely with a well thought out approach. In other words, it is common that we deal with dairy disease issues without thorough information about the nature and extent of disease problems. Often a dairy will have good information about overall herd production parameters, but fail to get routine disease information about individual sick animals. Some of this information is easily acquired and often quite reasonably priced, especially when compared with the value of the information for making herd decisions.

A dead animal is usually viewed as a waste product, one that brings the burden of disposal. The value of the dead animal is routinely overlooked. It is true that dead animals are a loss to the operation, but they also provide an invaluable opportunity to evaluate an aspect of the herd. Post mortem examination (necropsy examination) is one of the most underutilized tools in dairy herd monitoring and management. It is important to investigate death losses systematically and to record trends observed over time.

The signs of many cattle diseases are remarkably similar and physical examination of sick animals can often fail to provide an accurate diagnosis. For many treatment scenarios this is not a major problem, because some diseases respond to similar treatments, and because treatment regimens can be modified to improve recovery, in many cases without a final definitive diagnosis. On the other hand, the most effective and cost beneficial strategies both for prevention and treatment will be devised on the basis of accurate diagnosis and disease identification. Therefore, routine examination of dead animals on an operation provides one of the best opportunities to evaluate treatment and prevention.

Necropsy examination on a routine and systematic basis, preferably on every dead animal, provides a tremendous advantage in the face of an emerging disease outbreak. Many of the procedures performed on samples submitted to a diagnostic laboratory require time. Waiting to conduct necropsies and submit samples until it has become really clear that a major disease problem is underway is a very poor plan. Typically, by the time you are obliged to submit necropsy samples, substantial losses have already occurred, and more will continue to occur before a reasonable answer is available. These losses are compounded by the waste of poorly directed treatment measures and other costly interventions.

A typical example follows to emphasize these points. A lactating dairy cow dies within 24 hours of getting sick with apparent respiratory disease. Because of the sudden onset and rapid death, and because only one cow was

more →

affected, the operator shrugs it off. Several years ago respiratory syncitial virus infection had occurred in some animals. Consulting with the veterinarian, the owner becomes convinced this cow was likely an aberrant case of the same infection. Two days later another cow dies, followed by several more cows over the succeeding week and a half. Several different treatments are tried, but none with good success, leading the owner and veterinarian to believe more strongly in the original diagnosis, because they don't expect antibiotics to affect the outcome of this viral disease. Unfortunately the disease problem appears to be escalating, and when six cows are dead, and several others surviving but left as respiratory cripples, three new cases appear on the same day. One of these dies, and the other two are euthanized. Necropsy of all three reveals severe bacterial pneumonia, and culture and sensitivity of the organism reveals the best antibiotic to use. However, three more cows are lost while these results are pending. After changing the treatment approach to treat at the first signs of respiratory illness with the right drugs, no further losses occur, and all affected cows respond well to the treatment.

Not all disease problems are as quickly resolved as this case. The point of this illustration was to stimulate the following questions. How many sick animals and how much money would have been saved if the first dead cow had been subjected to necropsy? How many cows do you have to lose before you initiate a good diagnostic workup? How long do you wait before realizing that a problem may be different from what you first expected? How much more money would have been lost if the owner above had instituted a radical change in vaccination programs with an assumed diagnosis that was wrong?

The best diagnostic necropsy is one performed on a recently dead animal. Sometimes it is important to euthanize an animal for necropsy because the diagnostic value exceeds the likelihood that the animal will respond favorably to treatment. In such cases, it is important to carefully select an animal that has the same disease signs, is recently affected by the disease, and thus closely fits the disease scenario you are trying to combat.

Summary

Cattle health problems are very important concerns for dairy producers, playing a central role in many aspects of dairy management. Dairy cattle diseases have many different causes and manifestations. Depending on the circumstances of each dairy operation the problems that face producers will have some similarities, but usually differ greatly from farm to farm. The best approach to managing ongoing disease problems, and heading off new disease threats before they become major problems, is a combination of (1) management practices targeted to control the diseases of importance on the operation, plus (2) ongoing diagnosis and monitoring of disease problems, necessary for modifying the management program. Necropsy and diagnostic sample submission are key elements of a disease monitoring program.

Getting the Most From Your Dairy Beef

G.C. SMITH—Department of Animal Sciences, Colorado State University, Fort Collins, CO 80523
Tel: 970-491-5226 Fax: 970-491-0278 gsmith@ceres.agsci.colostate.edu

D.L. ROEBER—Colorado State University
K.E BELK—Colorado State University
J.A. SCANGA—Colorado State University
T.G. FIELD—Colorado State University
J.D. TATUM—Colorado State University
D.S. HALE—Texas A&M University
W.R. HENNING—Pennsylvania State University
G.L. COWMAN—National Cattlemen's Beef Association

Most dairy producers have focused their management expertise on production of milk, not meat, and their food quality and safety efforts on milk products. Dairymen receive 4% (vs. 16% for cow/calf producers) of their gross revenue from sale of salvage cattle and 96% from sale of fluid milk (Roeber *et al.*, 2000a), justifying their emphasis on milk production and their nonchalance about the value of salvage cattle. There are, however, financial incentives for dairymen willing to become well-informed on the use of meat from market cows and bulls and to promote value by managing their herds to minimize quality shortcomings and defects, by monitoring the health and condition of market cows and bulls, and by marketing salvage cattle in a timely manner (National Cattlemen's Beef Association, 2000).

Contrary to the popularly held belief of most producers, not all of the beef from market cows and bulls is used in the production of commodity ground beef. In fact, beef from market cows and bulls is widely used in the retail and food service sectors in a variety of product forms. Roeber *et al.* (2000a) interviewed packers during the 1999 National Market Cow And Bull Beef Quality Audit and reported that 43.6% of cow and bull beef was sold as 100% Visual Lean (for use in restructured beef roasts) or as primals/ subprimals (for sale as steaks/roasts in supermarkets and food-service operations), leaving 56.4% for use in ground beef and sausage products.

Since 1994, National Cattlemen's Beef Association's Beef Quality Assurance Advisory Board has commissioned five studies: (a) Two kinds of annual audits to identify incidence of injection-site lesions in muscles of the round of dairy and beef cows and bulls; (b) A study to identify uses of meat from dairy and beef, market cow and bull carcasses; and (c) Two studies to identify quality concerns through conduction of national audits of market cows and bulls, their carcasses and their edible and inedible offal (Smith *et al.*, 1999a). These studies were parts of the activities of the NCBA, BQA Advisory Board and were intended to educate producers regarding means for improving the quality and value of market (sometimes called "non-fed," "cull" or "salvage") cows and bulls generated by beef and dairy cattle operations.

National audits have been conducted annually since 1994 to determine the incidence of injection-site lesions in muscles of the round from market cows and bulls; results of the first five of those national audits (Smith *et al.*, 1999b) are presented in Table 1. Information gathered from these audits was the basis for national and state BQA programs designed to increase producer awareness about injection-site lesion problems. From 1994 through 1996, efforts of national and state BQA programs, to encourage producers and veterinarians to choose subcutaneous (rather than intramuscular) routes of administration and alternate body-location sites for injection (in front of the shoulder rather than in the rump or hindquarter), were succeeding (Smith *et al.*, 1999b). Incidence of injection-site lesions was 28.9% in 1994, 23.0% in 1995 and 19.3% in 1996. But, when the incidence dramatically increased — to 40.9% in 1997 — and then, just as abruptly decreased — to 23.9% in 1998 — in a two-year period of study, members of the NCBA, BQA Advisory Board decided that the methodology, by which the audits of muscles from the rounds of market cows and bulls were being conducted, needed to be improved. As a result, it was decided that, for producer awareness and education purposes, the injection-site lesion incidence should be determined more accurately (by carefully slicing whole muscles from end to end) and more definitively (by cattle types—dairy vs. beef).

Beginning in 1998, a national "slice audit" was performed by identifying dairy and beef cows at packing plants across the United States, following the carcasses through fabricating/boning and carefully checking — from end-to-end, from the topline between the hooks and pins down to the hock, in the outside, and eye of, round muscles (*biceps femoris* and *semitendinosus*) — for injection-site lesions (Smith *et al.*, 1999b). Results of the first slice audit (Table 2) revealed that an astonishing percentage of those muscles had visible tissue damage sufficient to cause loss of weight and value (because such lesions must be dissected out and discarded, to remove damaged and greatly toughened muscle). It was also determined that there were substantive differences between rounds from

more ⟶

beef vs. dairy cattle in the incidence and location of the injection-site lesions. In round muscles from beef cows, the incidence of injection-site lesions was 28.7% and most of the lesions were found in the uppermost quadrants of the muscle (38.0% of all lesions were found at the top of the muscle, Quadrant 4 (Q4) — near the backbone — with 36.1%, 19.4% and 6.5% located in quadrants 3, 2 and 1 (Q3, Q2 and Q1), respectively, where Q1 is the Quadrant at the bottom of the muscle — near the hock). In rounds from dairy cows, the incidence of injection-site lesions was twice as high — at 57.5% — and the lesions occurred in Q4, Q3, Q2 and Q1 quadrants of the muscle at incidences of 18.3%, 36.2%, 29.5% and 16.1%, respectively, suggesting that sites preferred by producers and/or veterinarians for administering injections to dairy cows are much lower on the leg (on the standing animal) than are those for beef cows (Smith *et al*., 1999b).

National "slice audits" performed in 1998, 1999 and 2000 (Table 2) reveal meaningful decreases in total incidences of injection-site lesions, over that time period, in round muscles from both beef cows (28.7%, 25.7% and 20.0%, respectively) and dairy cows (57.5%, 51.0% and 34.5%, respectively) suggesting that education efforts of BQA programs are succeeding (Smith *et al*., 1999b; Roeber *et al*., 2000b). Interestingly, proportions of injection-site lesions occurring in the upper-half (Quadrants 3 plus 4) of the round muscles decreased, between 1998 and 2000, from 74.1%, to 52.2% (beef cattle) and from 54.5%, to 33.1% in dairy cattle suggesting that the lower-half (Quadrants 1 plus 2) of the round muscles is becoming a more popular site (25.9%, to 47.8% in beef cattle; 45.6%, to 66.9% in dairy cattle) for administering intramuscular injections (Table 2).

The primary function of activities of the NCBA, BQA Advisory Board is to develop information for use in educational programs of national and state BQA programs. One educational opportunity involves helping cattle producers become more knowledgeable about the uses — as foods — of the muscles from market cows and bulls, and especially about changes in management practices that might improve the quality and value of those muscles (Smith *et al*., 1999a). Unfortunately, far too many producers think of market cows and bulls as "junk," to be discarded at whatever price is offered, because they believe, incorrectly, that the only use for their meat is as a source of raw materials for sausage or inexpensive hamburger meat. Because ground beef sold in supermarkets is so much leaner (85% to 96% lean is now common) now than it was a decade ago (70% to 80% lean was then the norm) a much greater proportion of today's highest quality (and highest priced) retail ground beef is comprised of cow/bull meat. In addition, many subprimal cuts from market cows and bulls are now sold in the same manner (to be merchandized as steaks and roasts) as are subprimal cuts from grain-finished steers and heifers (Smith *et al*., 1999a).

Industry nomenclature for kinds/qualities of market cows and bulls and their carcasses is not used consistently and is not based on any standardized criteria; new, effective official USDA grades are badly needed for price determination and market reporting for these cattle and carcasses (Roeber *et al*., 2000a). Smith *et al*. (1999a) reported results of an interview of management personnel of one of the nation's largest harvesters/fabricators of market cows and bulls, in which that company's grading system was characterized. The classes used by that packer to describe market cow and bull carcasses are:

1. *"White Cows" or "High Quality Cows"* — these carcasses have a significant covering of white fat (many of these are from fleshy Holstein cows and some are from beef cows that have been grouped and fed high-concentrate diets for about 20 to 60 days prior to harvest), good body conformation and high muscle quality (color and marbling).
2. *"Boners and Breakers"* — these are relatively lean carcasses with some marbling and good body conformation.
3. *"Cutters and Canners"* — these are lean carcasses with little or no marbling and with poor to very poor body conformation.
4. *"Bulls"* — these are bull carcasses that usually have little fat cover but good body conformation.
5. *"Bologna Bulls"* — these are bull carcasses that have basically no fat cover (the entire boneless carcass will yield meat that is approximately 92% lean) and for which conformation is not an issue (Smith *et al*., 1999a).

Of the total daily U.S. cattle slaughter, 15 to 25% (depending on season) of beef production will be from market cow and bull carcasses (Smith *et al*., 1999a). Of the national market cow and bull slaughter, about 0.5% are "Bologna Bulls," approximately 9% are "Bulls" and about 1% are "White Cows" while the remaining 88 to 89% of market cows and bulls are classified by packers using names like "Commercial," "Breaker" (or "Breaking Utility"), "Boner" (or "Boning Utility"), "Cutter" (or "Top Cutter," "Cutter" and "Low Cutter") and "Canner" (or "Canner," "Low Canner" and "Shelly Canner") or using names and numbers (e.g., "Boning Utility 2," "Canner 3," etc.).

Some carcasses (usually those of highest quality) from market cows are fabricated into primal and subprimal cuts in the same way as are carcasses from grain-finished steers and heifers (Smith *et al.*, 1999a; Roeber *et al.*, 2000a). After fabrication, the primals are usually boned; some of the subprimal cuts are trimmed, vacuum packaged and boxed, while others are placed in combo-bins for use as raw materials for sausage, restructured beef, or ground beef production. Trimmings from market cow and bull carcasses are often labeled by primal cut of origin for the production of primal-specific products, such as ground sirloin, ground round or ground chuck, which are sold throughout the U.S. in restaurants and supermarkets. In addition to boxed subprimal cuts and beef trimmings, a third type of product that is widely manufactured from market cow and bull carcasses is "100% Visual Lean." 100% Visual Lean can be derived from any whole-muscle subprimal that can be trimmed such that no fat or connective tissue seams remain anywhere on or in the cut.

Boxed subprimal cuts from high-quality market cow and bull carcasses are sold to certain supermarket and food-service operators. The middle meats (tenderloins, striploins/shortloins, ribeyes, top sirloins, etc.) are sometimes sold to retail meat markets, but are most commonly sold to steak-cutting companies that sell them as steaks to family restaurants, airlines, commissaries, or other food-service operators (Smith *et al.*, 1999a; Roeber *et al.*, 2000a). Other cuts, such as tri-tips, skirt steaks, briskets, etc., may be sold to further-processors who produce pre-cooked entrÈes, marinated fajita meat, or corned beef, as well as other products. Almost all of the 100% Visual Lean is sold to further-processors who produce restructured beef products that are sold in roast beef sandwiches.

All primals and subprimals from Bologna Bulls are fabricated into beef trimmings with the exception of the whole tenderloin (sold as a boxed subprimal) and the round cuts and necks which are sold as 100% Visual Lean. Subprimal cuts from White Cows are generally too fat for production of 100% Visual Lean and therefore are either marketed as boxed subprimals or converted to beef trimmings. From White Cows, almost all major cuts are sold as boxed subprimals and the minor cuts such as shanks and short plates (navels) are converted to beef trimmings. Depending on market conditions, the chucks and sirloins (including knuckles) from White Cows may also be sold as beef trimmings.

The following two tables (Table 3 and Table 4) contain information (Smith *et al.*, 1999a) demonstrating how primals and subprimals from carcasses of the three most common classes of market cows and bulls (Bologna Bulls and White Cows are not included) are fabricated and marketed. The proportion of the subprimal cuts from market cow and bull carcasses that is sold as boxed beef is quite substantial. As was reported also by Roeber *et al.* (2000a), slightly more than half of the meat from market cows and bulls is marketed as ground beef (commodity, very-high lean content or primal-cut origin specific) and the remainder (about 44%) is sold as boxed subprimals or restructured beef.

The National Non-Fed Beef Quality Audit — 1994 and the National Market Cow And Bull Beef Quality Audit — 1999 each consisted of three Phases: Phase I was Face-To-Face Interviews with industry leaders to identify and quantify "quality defects"; Phase II consisted of a national audit, in packing plants, to quantify "quality defects" in the holding pens, on the slaughter floor and in the cooler, and; Phase III was a workshop at which researchers, industry leaders, packers, processors, restaurateurs and cattle producers identified strategies to reduce the incidence of product-quality shortcomings, correct non-conformities and improve the quality, consistency and competitiveness of beef from market cows and bulls (National Cattlemen's Beef Association, 1994, 2000).

Quality losses for each market cow or bull equivalent were determined in both the National Non-Fed Beef Quality Audit — 1994 and the National Market Cow And Bull Beef Quality Audit — 1999; results are presented in Table 5. Ranked in order of monetary loss, the five most important quality defects in 1994 were excess external fat, inadequate muscling, condemnations (cattle, carcasses, carcasses passed for cooking), hide value loss (brands) and condemnations (edible offal items) while those in 1999 were inadequate muscling, excess external fat, trim loss (arthritic joints), yellow external fat and condemnations (edible offal items). Two new quality defects (trim loss from birdshot/buckshot and handling/testing for antibiotic residues) appeared in the 1999 Audit. Comparison of results of the 1994 and 1999 Audits suggests that producers made progress in reducing incidence or severity of seven quality defects; those were condemnations (cattle, carcasses, carcasses passed for cooking), disabled cattle (additional handling), hide value loss (brands), trim loss (bruises), trim loss (compliance with "Zero Tolerance"), excess external fat and light-weight carcasses. Producers lost ground on condemnations (edible offal items), hide value loss (scratches, cuts, insect damage), trim loss (arthritic joints), trim loss (injection-site lesions), yellow external fat, dark-cutting muscle, and inadequate muscling (National Cattlemen's Beef Association, 1994, 2000).

The total cost of value losses from data of the National Market Cow And Bull Beef Quality Audit — 1999 was $68.82 ($1.08 less than for 1994), not just for those with one or more quality defects but for every market cow or bull harvested in that year. Of the $68.82 lost, cattle

more →

producers could recover: (a) $13.82 by *managing*, to minimize defects and quality deficiencies, (b) $27.50 by *monitoring* health and condition, and (c) $27.50 by *marketing* in a timely manner (National Cattlemen's Beef Association, 2000).

Strategies for improving quality, competitiveness and value of market cows and bulls, their carcasses, their cuts and their byproducts, identified in the National Non-Fed Beef Quality Audit — 1994 Strategy Workshop were:

1. Minimize condemnations by monitoring herd health and marketing non-fed cattle with physical disorders in a timely manner.
2. Effect end-product improvements by monitoring and managing non-fed cattle and by marketing them before they become too fat or too lean, too light or too heavy, thinly muscled or emaciated.
3. Decrease hide damage by coordinating management and parasite-control practices and by developing new methods for permanent ownership identification of non-fed cattle.
4. Reduce bruises by dehorning, by correcting deficiencies in facilities, transportation and equipment, and by improving handling.
5. Encourage competitiveness by implementing non-fed cattle marketing practices that assure producer accountability.
6. Assure equity in salvage-value by requesting improved consistency of interpretation and application of federal meat inspection criteria among non-fed cattle slaughter establishments.
7. Improve beef safety by encouraging practices which reduce bacterial contamination of carcasses.
8. Prevent residues and injection-site lesions in non-fed cattle by ensuring responsible administration and withdrawal of all animal-health products.
9. Enhance price discovery by encouraging development of effective live and carcass grade standards for non-fed cattle.
10. Encourage on-farm euthanasia of disabled cattle and those with advanced bovine ocular neoplasia (National Cattlemen's Beef Association, 1994).

Participants in the Strategy Workshop for the National Market Cow And Bull Beef Quality Audit—1999 developed four "Directives" for improving the quality and value of market cows and bulls; those were:

A) *Recognize And Maximize The Value Of Your Market Cows And Bulls*,
B) *Be Pro-Active To Ensure The Safety And Integrity Of Your Product*,
C) *Use Appropriate Management And Handling Practices To Prevent Quality Defects*, and
D) *Closely Monitor Herd Health And Market Cull Cattle Timely And Appropriately*. In addition to identifying the four Directives, participants in the Strategy Workshop developed a Quality Assurance Marketing Code of Ethics for use by cattlemen, dairymen and packers when they market and harvest cows and bulls (National Cattlemen's Beef Association, 2000):

I will only participate in marketing cattle that:

- Do not pose a known public health threat
- Have cleared proper withdrawal times
- Do not have a terminal condition (advanced lymphosarcoma, septicemia, etc.)
- Are not disabled
- Are not severely emaciated
- Do not have uterine/vaginal prolapses with visible fetal membrane
- Do not have advanced eye lesions
- Do not have advanced lumpy jaw

Furthermore, I will:

Do everything possible to humanely gather, handle and transport cattle in accordance with accepted animal husbandry practices.

Finally, I will:

Humanely euthanize cattle when necessary to prevent suffering and to protect public health (National Cattlemen's Beef Association, 2000).

Improving the quality and value of market cows and bulls is an attainable goal. Based on results of the National Market Cow And Bull Beef Quality Audit — 1999: 99.8% of market cows and bulls show no evidence of prolapse, *99.7%* are free of birdshot/buckshot, *99%* show no evidence of lumpy jaw, *97%* have a body condition score of 3 or higher, *96%* have clear eyes, *96%* are without abscesses, *90%* are free of excessive hide contamination, and *85%* are sound or have only minor structural problems. To improve further the quality/value of market cows and bulls, success will come not by doing 1 thing 100% better; it will come by doing 100 things 1% better (Roeber *et al.*, 2000a).

Schnell *et al.* (1997) fed cull cows, of Dairy, Brahman-crossbred, British and Continental European breeding, a high-concentrate diet for 0, 14, 28, 42 or 56 days; cows were then harvested and carcass traits and steak palatability characteristics were determined. Live and carcass weights, average daily gain and dressing percentage increased through 28 days of feeding; fat color became whiter but marbling was not affected by feeding. Steak tenderness was higher for cows fed 56 days than for cows fed 0 or 14 days; Continental European cow carcasses yielded more fat-free lean and less fat while Dairy cow carcasses generally provided the most tender beef, across all slaughter periods. In general, sensory tenderness and yields of cow carcass components were increased, without requiring excessive trimming of fat, by feeding cull beef and dairy cows for periods up to 56 days.

The economics of feeding cull cows was also considered in the Schnell *et al*. (1997) study. Feeding cows for 56 days cost $93.80 per head (feed only) and increased live weight enough to improve value by $142.38; value of the ribeye subprimal cuts increased $2.06 per carcass due to higher weight and $6.20 per carcass because fat on those cuts was then white rather than yellow. Value for feeding a cull cow for 56 days was $52.58 (net, after feed cost) for weight gain plus $8.26 for improved quality and weight of ribeye subprimal cuts; so, the net improvement in value for feeding cull cows was $60.84 per head.

Summary and Conclusions

Contrary to the popularly held belief by most producers, not all of the meat from market dairy cows and bulls winds up as commodity ground beef. Instead, beef from market dairy cows and bulls appears in the consumer marketplace in many forms: (a) as entrÈe items (e.g., some loins and ribs are sold as steaks or roasts in family restaurants); (b) as high-value entrÈe items (e.g., some tenderloin steaks are presented in first class service meals on airline flights); (c) as the primary alternative to ground beef in fast-food operations (e.g., as sliced beef in sandwiches at quick-service restaurants); (d) as a snack food (e.g., as beef jerky); (e) as a quick-to-fix form of supermarket beef (e.g., as fajitas); (f) as extra-lean ground beef (e.g., 90%-, 93%-, 95%- or 96%-lean ground beef); (g) as ground sirloin, ground loin, ground chuck or ground round in modified atmosphere packages at major supermarkets, or; (h) as main menu items in buffet meals at gambling establishments in Nevada and New Jersey (e.g., as roast beef, shish kabobs or grilled steaks).

Knowing that the beef from market cows is more than just raw material for commodity ground beef (containing 20 to 30% fat), it is imperative that dairy producers manage and handle such livestock with care and caution. As a case in point, dairy producers presently damage more than one-third of all outside round muscles by creating injection-site lesions that cause extensive trimming and processing losses as well as quality and toughness defects at the fabrication level. In addition, poor handling and stressful movement to harvest can cause problems with muscle appearance (especially color), bruising and microbial contamination problems with the carcass and beef from market cows and bulls. Results of the National Non-Fed Beef Quality Audit — 1994 and of the National Market Cow And Bull Beef Quality Audit — 1999 provide a roadmap for identifying a course of action to be followed by dairy producers who care about the quality of the beef they generate. Included in the Final Report of the National Market Cow And Bull Beef Quality Audit — 1999 are Directives, A Quality Assurance Marketing Code of Ethics and the Audit's Message — to promote value in market cows and bulls, producers should *manage* their cow herds to minimize quality shortcomings and defects, *monitor* the health and condition of market cows and bulls, and *market* cows and bulls, in a timely manner.

References

National Cattlemen's Beef Association. 1994. Executive Summary of the National Non-Fed Beef Quality Audit. Improving the Consistency and Competitiveness of Non-Fed Beef and the Salvage Value of Cull Cows and Bulls & Opportunities for Prevention, Profit and Product Quality. National Cattlemen's Beef Association, Englewood, CO. pp. 1-13.

National Cattlemen's Beef Association. 2000. Executive Summary of the 1999 National Market Cow and Bull Quality Audit. Improving the Consistency and Competitiveness of Market Cow and Bull Beef & Increasing the Value of Market Cows and Bulls, National Cattlemen's Beef Association, Englewood, CO. pp. 1-15.

Roeber, D.L., K.E. Belk, G.C. Smith, J.D. Tatum, T.G. Field, J.A. Scanga, C.D. Smith, P.D. Mies, H.A. Foster, T.K. Kennedy, B.R. Moore and S.G. Hodge. 2000a. Improving The Consistency And Competitiveness Of Market Cow And Bull Beef; And, Improving The Value Of Market Cows And Bulls. The Final Report of the National Market Cow and Bull Beef Quality Audit-1999 to the National Cattlemen's Beef Association. Meat Science Program, Department of Animal Sciences, Colorado State University, Fort Collins, CO. pp. 1-200.

Roeber, D.L., G.C. Smith, J.A. Scanga, R.C. Cannell, E.R. Behrends, K.E. Belk, J.D. Tatum and J.N. Sofos. 2000b. Beef Quality Assurance Audits: Incidence Of Injection-Site Damage In Top Sirloin Butts And In Muscles Of The Round-October 1999 through September 2000. Final Report to the National Cattlemen's Beef Association. Meat Science Program, Department of Animal Sciences, Colorado State University, Fort Collins, CO. pp. 1-30.

Schnell, T.D., K.E. Belk, J.D. Tatum, R.K. Miller and G.C. Smith. 1997. Performance, carcass, and palatability traits for cull cows fed high-energy concentrate diets for 0, 14, 28, 42 or 56 days. Journal of Animal Science 75:1195-1202.

Smith, G.C., R.C. Cannell, K.E. Belk, J.D. Tatum, D.S. Hale, W.R. Henning and G.L. Cowman. 1999a. Careful with that market cow!! The next time you see her may be at your favorite restaurant. Proc. 1999 Dairy Tech Forum (Madison, WI) pp. 1-8.

Smith, G.C., R.C. Cannell, K.E. Belk, J.D. Tatum, J.N. Sofos and G.R. Schmidt. 1999b. Beef Quality Assurance Audits: Incidence Of Injection-Site Damage In Top Sirloin Butts And In Muscles Of The Round-March Through September 1999. Final Report to the National Cattlemen's Beef Association. Meat Science Program, Department of Animal Sciences, Colorado State University, Fort Collins, CO. pp. 1-25.

more ⟶

Table 1. Incidence of injection-site lesions in muscles of the round from market cow and bull carcasses (1994 through 1998).

Audit	Incidence of Lesions	Average Trim per Lesion	Active Fluid-Filled Lesions (of Total Lesions)
1994	28.9%	9.2 oz	7.5%
1995	23.0%	11.9 oz	11.5%
1996	19.3%	11.3 oz	8.3%
1997	40.9%	6.2 oz	3.9%
1998	23.9%	4.9 oz	0.7%

SOURCE: Smith *et al.* (1999b)

Table 2. Incidence of injection-site lesions in muscles of the round from market dairy and beef cows (slice audits, 1998, 1999 and 2000).

	Beef Cows			Dairy Cows		
	1998	1999	2000	1998	1999	2000
Total Incidence	28.7%	25.7%	20.0%	57.5%	51.0%	34.5%
Proportionate Incidence In:						
Quadrant 4	38.0%	53.3%	38.4%	18.3%	8.4%	8.8%
Quadrant 3	36.1%	30.7%	13.8%	36.2%	24.2%	24.3%
Quadrant 2	19.4%	13.8%	32.0%	29.5%	40.1%	47.3%
Quadrant 1	6.5%	2.3%	15.8%	16.1%	27.3%	19.6%
Incidence In Back Of Leg:	26.9% (mostly Q3)	15.3% (mostly Q3)	26.6% (mostly Q2)	36.8% (mostly Q2 and Q3)	49.5% (mostly Q2)	33.6% (mostly Q2)

SOURCE: Smith *et al.* (1999b) and Roeber *et al.* (2000b)

Table 3. Form in which major subprimal cuts (from chuck, rib, loin and round) are marketed from three classes of market cow and bull carcasses.

		Form In Which Fabricated Cuts Are Sold (% Sold As)		
Subprimal Cut	Carcass Class	Boxed Subprimals[a]	100% Visual Lean	Beef Trimmings
Boneless Inside Round	Boner-Breaker	50%	50%	
	Cutter-Canner		100%	
	Bull		100%	
Boneless Gooseneck Round	Boner-Breaker		100%	
	Cutter-Canner		100%	
	Bull		100%	
Boneless Eye of Round	Boner-Breaker		100%	
	Cutter-Canner		100%	
	Bull		100%	
Boneless Knuckle	Boner-Breaker			100%[b]
	Cutter-Canner			100%[b]
	Bull			100%[b]
Boneless Striploin or Bone-in Shortloin	Boner-Breaker	100%[c]		
	Cutter-Canner		100%	
	Bull		100%	
Boneless Tenderloin	Boner-Breaker	100%		
	Cutter-Canner	100%		
	Bull	100%		
Boneless Top Sirloin Butt	Boner-Breaker	67%		33%[b]
	Cutter-Canner			100%[b]
	Bull			100%[b]
Boneless Tri-Tip (Bottom Sirloin)	Boner-Breaker	100%		
	Cutter-Canner			100%[b]
	Bull			100%[b]
Sirloin Flap Meat	Boner-Breaker	100%		
	Cutter-Canner	100%		
	Bull			100%[b]
Boneless Ribeye Roll	Boner-Breaker	100%		
	Cutter-Canner	33%	67%	
	Bull	50%	50%	
Boneless Chuck 2pc, Blade and Clod	Boner-Breaker	10%		90%
	Cutter-Canner			100%
	Bull			100%
Boneless Chuck Flap	Boner-Breaker	100%		
	Cutter-Canner	100%		
	Bull		100%	
Boneless Chuck Tender	Boner-Breaker		100%	
	Cutter-Canner		100%	
	Bull		100%	

[a] When less than 100% of a subprimal within a class is marketed as boxed subprimals, it is typically the best pieces (best in conformation, marbling, color, etc.) that are boxed, and the remaining pieces are marketed as 100% Visual Lean or as beef trimmings.
[b] Knuckles, top sirloin butts, flap meat and tri-tips that are sold as beef trimmings are labeled as "sirloin trimmings" for the production of ground sirloin.
[c] Unless the fat is extremely yellow, in which case it would be sold as 100% Visual Lean.

Source: Smith *et al.*, 1999a

more →

Table 4. Form in which minor subprimal cuts (from thin cuts) are marketed from three classes of market cow and bull carcasses.

		Form In Which Fabricated Cuts Are Sold (% Sold As)		
Subprimal Cut	Carcass Class	Boxed Subprimals[a]	100% Visual Lean	Beef Trimmings
Boneless Brisket	Boner-Breaker	80%	20%	
	Cutter-Canner		100%	
	Bull		100%	
Boneless Front and Hind Shanks	Boner-Breaker			100%
	Cutter-Canner			100%
	Bull			100%
Flank Steak	Boner-Breaker	100%		
	Cutter-Canner	100%		
	Bull	100%		
Inside and Outside Skirts	Boner-Breaker	100%		
	Cutter-Canner	100%		
	Bull	100%		
Boneless Navel	Boner-Breaker			100%
	Cutter-Canner			100%
	Bull			100%
Boneless Neck Meat	Boner-Breaker		100%	
	Cutter-Canner		100%	
	Bull		100%	
Bone-in Backribs	Boner-Breaker	100%		
	Cutter-Canner	100%		
	Bull			100%[a]
Bone-in Shortribs	Boner-Breaker	100%		
	Cutter-Canner	100%		
	Bull			100%[a]

[a] Backribs and shortribs from bull carcasses are boned and sold as beef trimmings.

Source: Smith *et al.*, 1990a

Table 5. Quality losses for each market cow or bull harvested in the U.S.A. in 1994 and 1999 using data and estimates from the national non-fed beef quality audit — 1994 (NNFBQA — 1994) and the national market cow and bull beef quality audit (NMCBBQA — 1999).

	NNFBQA — 1994	NMCBBQA — 1999
Condemnations (cattle, carcasses, carcasses passed for cooking)	$12.02	$4.14
Condemnations (edible offal items)	3.99	4.49
Disabled cattle (additional handling)	0.78	0.56
Hide value loss (brands)	4.56	3.10
Hide value loss (scratches, cuts, insect damage)	2.36	3.17
Trim loss (arthritic joints)	2.13	9.72
Trim loss (bruises)	3.91	2.24
Trim loss (compliance with “Zero Tolerance”)	1.87	0.46
Trim loss (birdshot/buckshot)	—	0.52
Trim loss (injection-site lesions)	0.66	1.46
Yellow external fat	2.27	6.48
Dark-cutting muscle	0.06	1.41
Inadequate muscling	14.43	18.70
Excess external fat	17.74	10.17
Light-weight carcasses	3.12	1.28
Antibiotic residue (handling/testing)	—	0.92
Total	$69.90	$68.82

Source: National Cattlemen’s Beef Association (1994, 2000).

Formulating Lactating Cow Diets for Carbohydrates

MIKE ALLEN—Department of Animal Science, Michigan State University, 2265G Anthony Hall
Tel: 517-432-1386 Fax: 517-432-0147 allenm@pilot.msu.edu

Take Home Messages

- The goal of formulating diets for carbohydrates is to provide low fill, highly fermentable diets that result in consistent ruminal fermentation over time.
- Forage fiber content of diets limit feed intake of high producing cows.
- Rapidly fermented starch sources can decrease feed intake and efficiency of microbial protein production.
- Forages with highly digestible NDF with a high ruminal turnover rate are most valuable for high producing cows.
- Consideration of carbohydrate digestion characteristics when formulating diets is important to maximize energy intake and microbial protein production.

Introduction

One of the most challenging aspects of diet formulation for lactating cows is balancing for carbohydrates. Adequate effective fiber must be provided to stimulate chewing and secretion of salivary buffers. However, effective fiber is more filling than other nutritional components of the diet and the filling effect of the diet often limits energy intake of high producing cows. Therefore, diets for high producing cows should be balanced to provide adequate effective fiber with the least filling effect. A balance must also be attained for ruminal carbohydrate fermentation. Carbohydrate fermentation in the rumen is desirable to provide fuels for microbial growth and production of microbial protein, yet the fermentability of the diet must be limited to prevent excessive production of fermentation acids. Inadequate effective fiber or excessive fermentability of the diet can decrease ruminal pH, feed intake, diet digestibility, and microbial protein production. This is a major problem on many dairy farms that results in poor health, and reduces milk yield and farm profitability. On the other hand, diets with excessive effective fiber that are more filling and diets that are poorly fermentable can also result in lower milk yield and profitability because of reduced energy intake and microbial yield. Both situations can be thought of as lost opportunity for maximization of farm profits. Understanding the complex factors that interact to determine energy intake and microbial protein production in the rumen can pay off generously by allowing increased milk yield and reduced diet costs. The goal of formulating diets for carbohydrates is to provide low fill, highly fermentable diets that result in consistent ruminal fermentation over time. This paper addresses how to attain this goal on your farm by discussing how carbohydrates affect feed intake, ruminal pH and microbial protein production.

Dietary Carbohydrates

The main carbohydrates in diets for dairy cattle are those in the neutral-detergent fiber (NDF) fraction (cellulose and hemicellulose) and starch. The starch content of dairy cattle diets is inversely related to the NDF content and concentrations of both are typically in the range of ~25 to 35% of dietary DM for lactating cows. Other common carbohydrates include pectin and sugars, both with concentrations that are typically less than ~5% of dietary DM. The highly digestible carbohydrates including starch, sugars, and pectin are often referred to collectively as non-fiber carbohydrates (NFC). Because NFC is obtained by subtracting the measured fractions NDF, crude protein, fat and ash from 100%, it is subject to many errors. It is also a misnomer because it doesn't include all non-fiber carbohydrates (the protein fraction is overestimated when non-protein nitrogen is present) and because it includes soluble fiber (pectin, gums). In addition, when fermented feeds are included in the diet, NFC includes fermentation products such as lactic acid, acetic acid, and ethanol.

Long fiber particles (effective fiber, mostly from forage) are needed in the diet to maximize production at least three different ways:

1) Stimulation of chewing which results in the secretion of salivary buffers
2) Formation of a rumen mat that entraps small particles, increasing their ruminal digestibility
3) Providing a consistent source of fuels to the microbes in the rumen which functions to provide a steady supply of fuels to the liver and mammary gland over time

Some sources of fiber are very effective at stimulating chewing and mat formation in the rumen (long and coarsely chopped forages) while others are not (most high fiber byproducts). Also, sources of fiber vary greatly in NDF digestibility and retention time in the rumen. All three of these functions mentioned above are important to maximize milk yield and the most valuable sources of fiber are

more ⟶

those that are effective at stimulating chewing and formation of the rumen mat, and highly digestible with a rapid rumen turnover (less filling).

Starch is an inexpensive source of energy that can be fermented by microbes in the rumen to produce microbial protein and volatile fatty acids (VFA) used as fuels by the cow. Starch that passes from the rumen can be also digested in the small intestine or fermented in the large intestine, also providing fuel, but not microbial protein, to the cow. A large fraction of the fuels produced (propionate, lactate) are used by the liver to produce glucose, which the mammary gland needs to produce lactose, the major determinant of milk yield; 100 pounds of milk contains nearly 5 pounds of lactose. Ruminal digestibility of starch can range from less than 40% to greater than 90% depending on the type of grain (barley, corn, sorghum), conservation method (dry, high moisture), and processing (ground, rolled, steam flaked). Alteration of rate and site of starch digestion is important for optimal diet formulation as discussed below.

Pectin is normally found in low concentrations in most feeds consumed by dairy cows (<2 to 3%) but several feeds contain higher concentrations such as citrus pulp (~15%), beet pulp (~15 to 20%), and alfalfa (3 to 10%). Pectin is of interest because it is highly fermentable and whole tract digestibility is high but it can help moderate fermentation in the rumen. This is because, unlike fermentation of starch, rate of fermentation of pectin slows as ruminal pH decreases. This might help attenuate the rapid decline in ruminal pH following a meal and keep ruminal pH within a narrower desirable range. Sugars are highly fermentable and completely digested. Like pectin, the sugar content of most feeds is low but there are exceptions such as fresh forages, molasses, whey, citrus pulp, and candy waste.

Concentrations and characteristics (physical and fermentation) of these different types of carbohydrate vary greatly in diets of lactating cows and this variation can have dramatic effects on feed intake, ruminal pH, digestibility and microbial protein production. One of the greatest opportunities to increase milk yield and profitability is to understand how dietary carbohydrates can be manipulated to maximize energy intake and microbial yield.

Regulation of Intake

Feed intake is a function of meal size and meal frequency. The brain receives many different signals that affect satiety and hunger. British researcher, Dr. Mike Forbes, recently proposed that animals eat the amount of a particular diet that minimizes the total discomfort produced by signals from various receptors in the body to the brain. Distension in the rumen causes discomfort and can reduce feed intake but high producing animals might tolerate a greater degree of discomfort from physical fill to offset discomfort from hunger. Manipulating diets to increase meal size and increase frequency of meals, can lead to greater feed intake. An understanding of the basic mechanisms regulating intake is invaluable for diet formulation to maximize milk yield. Although regulation of feed intake is very complex, two primary mechanisms regulating DMI that are related to dietary carbohydrates are:

- Filling effect of diets
- Ruminal fermentability of diets

Ruminal fill can limit intake of high producing cows and other cows fed high forage diets. There are receptors in the rumen wall that signal the brain when the rumen is stretched. The rumen doesn't have to be full for ruminal fill to limit intake. Diets with a greater filling effect limit meal size but hunger occurs sooner and the number of meals consumed per day might partially or completely compensate for the decreased meal size. When a group of cows is offered a diet, feed intake of the highest producing cows are most limited by ruminal fill and these cows present the greatest opportunity to increase energy intake by manipulation of dietary carbohydrates. When the filling effect of the diet is decreased, problems can occur with slug feeding because low-fill diets can be consumed rapidly. This is a common problem when cows compete for feed bunk space in over-crowded facilities and requires diets that are either more filling or less fermentable to prevent ruminal acidosis.

Rapid fermentation of ingested feed during a meal produces VFA that can cause satiety. Although acetate is produced in the greatest quantity, propionate has a greater effect on limiting intake. When dietary NDF is held constant, increasing the fermentability of the diet by substituting a rapidly fermentable starch source such as rolled barley for a starch source with more moderate rate of fermentation such as corn meal will likely reduce meal size, and possibly decrease daily DMI. The degree to which fermentation acids limit DMI depends upon many factors, some of which are currently being investigated.

Filling Effect of Diets

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
- Forage type (legumes, perennial grasses, annual grasses)
- NDF digestibility (within a forage family)

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 ~ 5 to 9 lb/d when diet NDF content was increased from 25 to 35% by substituting forages for concentrates. 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. 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. 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 (NFFS) for concentrate feeds has shown little effect on DMI in studies reported in the literature. NFFS include byproduct feeds with significant concentrations of NDF such as soyhulls, beet pulp, cottonseeds, corn gluten feed, and distiller's grains. Fiber in NFFS 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. 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 FNDF for high producing cows.

The extent of lignification of NDF is a useful way to estimate the filling effects of forage NDF. To calculate lignification of NDF, divide the lignin content as a percent of DM by the NDF content as a percent of DM and multiply by 100. Data from the upper Midwest United States indicates that the lignin content of alfalfa NDF ranges from ~11 to 20% and the lignin content of corn silage NDF ranges from ~3 to 9% when measured as acid-detergent sulfuric acid lignin. Forages with low lignified NDF are especially valuable and should be targeted to the highest producing cows to allow them to consume more feed and attain higher milk yield. This is true even if the forage has low protein content or high NDF content, both of which can be compensated for by diet formulation. Forages with greater lignification of NDF should be targeted to animals whose DMI is not limited by ruminal fill such as cows in late lactation, dry cows (except those close to calving), and heifers.

Besides forage maturity, the extent to which NDF is lignified is also greatly affected by growing conditions such as light, heat, and water stress. Lignification of NDF is not related to NDF or protein content for either alfalfa or corn silage. Because alfalfa is priced in some markets based upon NDF or protein content or RFV, and not on the lignification of NDF, this presents an opportunity to purchase a valuable diet ingredient (effective, digestible NDF) inexpensively.

Ruminal Fermentability of Diets

The fermentability of diets depends on digestion and passage characteristics of individual feed ingredients and interactions among them. Starch is generally fermented faster than NDF, but passes from the rumen more quickly. Although NFC is often used as a proxy for the fermentability of diets, it is poorly related to fermentability because fermentability of both starch and NDF vary greatly by source.

Factors affecting ruminal fermentability of fiber include extent of lignification, rate of fermentation, and ruminal retention time. As discussed above, rate of fermentation is dependent on intrinsic characteristics of the feed and on ruminal pH over time. Rate of passage is related to particle size and fermentation characteristics that affect buoyancy in the rumen over time. Retention time of forage NDF ranges from 24 to over 40 hours for lactating cows

more ⟶

depending on the amount of feed intake, diet characteristics and source of NDF.

Ruminal fermentation of starch is affected by particle size, gelatinization of starch, and amount and solubility of endosperm proteins. Dry rolling and grinding decrease particle size of grains, which increases surface area of the grain available to microbes and therefore, rate of fermentation. Steam rolling or flaking increase surface area and also gelatinize starch, which increase accessibility by microbes and rate of fermentation. Endosperm proteins surround starch granules and inhibit accessibility to starch by ruminal microbes. Different grain types such as wheat, barley, corn, and sorghum have major differences in amount and solubility of endosperm proteins that dramatically affect rate of fermentation. Wheat and barley have low concentrations and greater solubility of endosperm proteins, resulting in greater rates of fermentation than corn or sorghum. There is also great variation in amount and solubility of endosperm proteins among corn hybrids. Some hybrids have floury endosperm with soluble proteins and are more readily digested, and others have more vitreous endosperm with insoluble proteins and are more resistant to digestion. High moisture fermentation results in proteolysis and an increase in the solubility of endosperm proteins, increasing rate of starch digestion.

As previously discussed, ruminal starch fermentation ranges from less than 40% to greater than 90% depending upon source. Ruminal fermentability depends upon rate of digestion and rate of passage from the rumen, which depend upon intrinsic characteristics of individual feeds, other diet components, and on characteristics of the animals fed. For instance, rate of starch digestion for a particular feed depends on the population of starch digesting microbes in the rumen. Rate of starch fermentation can increase dramatically when the fermentable starch content of the diet is increased. Rate of passage is affected by the size and density of particles but also by the filtering effects of the rumen mat and by level of intake. The major limitation to fermentation rate of sugars is accessibility by rumen microbes. Although sugars from whey or molasses are fermented very quickly and completely, sugars in fresh forages are less accessible and probably fermented more slowly but completely because of the long retention time of forage particles in the rumen.

Fermentation of organic matter (OM) in the rumen results in the production of fermentation acids. The primary acids produced are acetic, propionic and butyric but other acids are produced as well. Lactic acid is also produced, but its rate of utilization by microbes is usually sufficient to keep concentrations low. If a diet suddenly becomes more fermentable, lactic acid concentrations can increase and ruminal pH can drop rapidly because lactic acid is a much stronger acid than the VFA. This happens when abrupt changes occur in the diet such as when a much more fermentable starch source is substituted for one that is less fermentable, or when heavy rains result in more moisture and less forage DM and NDF added when total mixed rations (TMRs) are mixed. When cows have clinical ruminal acidosis it is because of elevated lactic acid concentrations. Increasing consistency in all aspects of your feeding program, paying particular attention to mixing and to variation in forage DM and NDF content will help prevent lactic acidosis. Lactic acid is not usually factor in sub-clinical acidosis that results in lower energy intake and poor microbial efficiency. This happens when production of VFA exceeds the buffering capacity of the rumen contents, resulting in a decline in ruminal pH.

The optimal ruminal pH to maximize milk yield and efficiency of milk production is unknown. It probably varies for different cows and feeding conditions. However, we do know that fiber digestion decreases as pH is reduced from ~ pH 6 to pH 5.5 and below. This is because growth of fiber-digesting microbes becomes inhibited as pH declines. We also know that once populations of fiber digesting microbes are reduced, it can take many days to restore their numbers. On the other hand, the starch-digesting microbes have shorter doubling times and their populations can increase quickly. The implication of slower fiber digestion in the rumen is that fiber becomes more filling and feed intake might decrease. Fermentation acids are also absorbed from the rumen more quickly as pH declines and this might result in smaller meal size. While this might benefit cows "on the edge" of ruminal acidosis, it might result in lower DMI for others. The average ruminal pH throughout a day is much less meaningful than the fraction of time ruminal pH is below a threshold value such as pH 5.7. Therefore, feeding management decisions should be made to minimize variation not only from day-to-day but also within a day. Factors affecting variation in ruminal pH throughout a day include those that affect the number and size of meals discussed above, and the fermentability of diets.

The production rate of fermentation acids depends upon the amount of OM fermented per unit time and the efficiency at which microbes utilize this OM for growth. When large amounts of highly fermentable OM are provided to ruminal microbes quickly, they sometimes uncouple growth from fermentation. This is called energy spilling and is undesirable for two reasons. The first is that less microbial protein will be produced per lb of OM fermented. The second is that much more acid will be produced per lb of OM fermented, which adds to the acid load in the rumen that must be neutralized or buffered. Efficiency of microbial protein production is decreased as starch digestion in the animal increases, which is dependent upon amount and fermentability of starch in the diet.

Consistency of Ruminal Fermentation

There are many benefits to a high level of ruminal fermentation that is consistent over time. This can be attained by feeding highly fermentable, effective NDF and starch with moderate rate of fermentation with a moderate to slow passage rate from the rumen. It is also important to feed ad libitum, and avoid over-crowding to decrease slug feeding. Starch sources that ferment rapidly result in a more variable fermentation over time with a much greater production of fermentation acids immediately following a meal than prior to the meal. Less variation in fermentation acid production over time translates to greater minimum ruminal pH and allows more fermentable diets to be fed. A consistent supply of available carbohydrate in the rumen will increase efficiency of microbial protein production, reducing the need for expensive sources of bypass protein. This will ensure consistent production and absorption of VFA into the blood which will help increase feed intake and possibly result in less insulin release, and therefore greater partitioning of energy to milk.

Diet Formulation for High Producing Cows

Ultimately, the usefulness of the information presented above is dependent upon how it is used to formulate diets. Although the type and characteristics of carbohydrate must be considered when formulating diets for all cows, it is especially important when formulating diets for cows with high daily milk yield because ruminal fill limits DMI of these cows to the greatest extent. Forage NDF (FNDF) content should be used as the primary basis for diet formulation because it best represents the filling effects of diets and is the primary source of effective fiber in diets. Diets should be formulated based on concentration of FNDF, and not amount consumed per day, because diet characteristics affect DMI and carbohydrates must be balanced for optimal effective fiber and fermentability of carbohydrate. Balanced is the key word; when diets are formulated for an amount of FNDF or effective NDF (which might be a percentage of body weight), the assumption is made that there is a requirement that must be met that is independent of the rest of the diet. Unfortunately, that concept doesn't incorporate much of what we know about factors affecting energy intake and microbial protein production.

The optimum concentration of FNDF that will maximize energy intake of lactating cows ranges from ~ 17 to 28% of DM. The figure below illustrates how several primary factors affect the optimal FNDF content of the diet.

Optimal Diet Forage NDF Concentration, % of diet DM

17% ———————————————— 28%

Highly fermentable starch and sugar sources >

< NFFS

Fast ruminal clearance rate of FNDF >

High NDF forages >

High daily variation in diet composition >

Limited feed bunk space >

No total mixed ration, grain fed infrequently >

Finely chopped forages >

< Added fat

< Added buffers

Because intake may be limited by physical fill as the FNDF content of the ration increases, and FNDF is generally less digestible than other feed components, the goal to increase energy intake should be to formulate diets with lower FNDF concentrations while preventing excessive production of fermentation acids. The concentration of FNDF within this range is dependent on the cow or group of cows, the feeds available, and the feeding system used. The minimum FNDF content would be optimal in relative few situations because of one or more limiting factor(s). Beginning at the minimum FNDF content, several factors will require a higher optimal FNDF content to maximize energy intake and microbial protein production.

Recommendations

- Starch sources with high ruminal digestibility can result in excess fermentation acid production, decreasing efficiency of microbial protein production, ruminal pH and fiber digestion. High propionate production from highly fermentable diets can also limit DMI. These sources include rolled barley and wheat, ground high moisture corn, steam-flaked corn, finely rolled corn silage, bakery waste, and sugar sources such as molasses, whey, and citrus pulp. Adjust site of starch digestion by altering the ruminal degradability of starch. This is easily done by substituting starch

more →

sources, with lower ruminal degradability, for those with higher ruminal degradability. It is important to use starch sources with high whole tract digestibility to maximize energy intake. Finely ground dry corn is generally less fermentable than barley, low-density steam-flaked corn, or ground high moisture corn and can be used to manipulate site of starch digestion because it has high whole tract digestibility. Coarsely rolled corn or sorghum is less desirable because whole tract digestibility is lower for these starch sources. Substitution of a less fermentable starch source such as dry ground corn for high moisture corn can increase DMI when it is limited by propionate production and increase microbial efficiency.

- Concentrations of very rapidly degraded carbohydrates (sugars and starch sources such as wheat and barley) should be limited in the diet. Rapid fermentation of carbohydrates can reduce efficiency of microbial protein production and limit meal size. Adequate ruminally degraded protein should be provided to maximize microbial efficiency.
- Avoid rolling corn silage too finely. Adjust the rollers so that the cobs and most of the grain is in the middle sieve of the Penn State Particle Size Separator. Rolling corn silage too finely can result in excessive ruminal starch fermentation.
- Diet fermentability can also be adjusted by substituting NFFS such as beet pulp or soyhulls for starch in the diet. This might be a reasonable alternative to altering site of starch digestion depending upon the relative prices of the NFFS to starch sources. Rate of fermentation of NDF from NFFS is generally slower than that of starch and sugars and less propionate is produced. Also, rate of fermentation of NDF from NFFS will decline as pH decreases. This has the benefit of limiting the decline in ruminal pH following meals but it might reduce digestibility of the NFFS. Because effectiveness of NFFS are generally very low and because they are generally highly fermented, they are not filling like forage NDF and have little effect on DMI when substituted for grains. Addition of NFFS can result in large reductions in optimal FNDF of diets. While this is desirable to minimize the filling effect of diets, it might not maximize energy intake because of possible rapid passage from the rumen, which results in decreased digestibility.
- Avoid feeding starch sources that are poorly fermented such as dry corn silage, or coarsely rolled corn or sorghum to high producing cows. Diets that are poorly fermented decrease microbial yield and fuels for the production of glucose and milk lactose. In addition, decreased production of fermentation acids results in greater DMI until it is limited by ruminal fill. This often results in increased passage rate from the rumen, decreasing digestibility and feed efficiency.
- Another alternative for limiting diet fermentability is to increase the diet FNDF content. However, unless the FNDF digests and passes from the rumen quickly, this approach will increase the filling effect of the diet and reduce DMI when limited by ruminal fill (see next).
- Feeding forages with highly fermentable NDF with high ruminal NDF turnover will require higher FNDF in the diet but will allow greater energy intake and provide a more consistent source of energy to the cow throughout the day. Forages with high ruminal NDF turnover include alfalfa with low lignification of NDF (< 16% for Mid-Western data), corn silage with low lignification of NDF (< 6% for Mid-Western data). Brown midrib corn silage has been shown to have high rates of clearance from the rumen that allows higher DMI when fill limitations exist. In one recent experiment, response in milk yield to brown midrib corn silage was much higher for high producing cows, presumably with DMI limited by ruminal fill, than for lower producing cows.
- NDF content of forages influences the fermentability and the optimal FNDF concentration of the diet. Forages such as grasses or mature alfalfa with high NDF contents require much more grain or NFFS to formulate diets optimally. Because supplements are generally more fermentable than forages, FNDF concentrations must be higher but this might lower DMI. However, immature alfalfa or corn silage with low NDF contents (< 36%) requires very high forage in the diet. Because forages have lower energy density than most grains and NFFS, energy density of the diet is lower for diets containing high concentrations of low NDF forages. Unless the forage has high NDF digestibility, energy intake might be restricted, limiting milk yield.
- Variation in DM and (or) NDF of forages will cause great variation in ration FNDF and fermentability. Cows consuming low FNDF diets are not able to deal with this variation. If ration FNDF content decreases and fermentability increases, ruminal acidosis might occur. However, if forage NDF or DM content increases and is undetected and uncorrected, energy intake will be somewhat reduced and this is not a great problem to animal health. Therefore, when variation is ex-

pected, higher diet FNDF levels must be fed to lower the risk of acidosis.

- All efforts should be made to reduce variation when forages are harvested (or purchased) and stored. Identify individual lots of forage and have them tested. Variation in forage DM and quality is often a problem for silage. Bunker silos have less daily variation than uprights or bags because the silo is filled in layers that tend to be mixed when removed from the silo. In contrast, abrupt shifts in DM and NDF can occur when removing silage from upright silos or silage bags. Silage DM concentration should be tested routinely. Frequency of testing depends upon the amount of variation and the type of silo. Silage DM in upright silos should be tested twice weekly and when changes are noticed, while silage in bunker silos can be tested less frequently. Mixing loads of silage from wet and dry parts of the bunker face when removed from the silo can help reduce variation, particularly after a substantial rainfall.
- Restrict the concentration of individual ingredients with variable quality or DM. Variation in ingredients that comprise a large fraction of the diet can have a great effect on FNDF and fermentation characteristics of the entire diet. Variation in forages or other feeds can be accommodated if they have relatively little effect on the total diet.
- Sorting can cause variation in diets consumed throughout the day. If sorting is a problem, it can be reduced by more uniform chopping of forages, processing corn silage, avoiding dry rations, and feeding more than one time per day.
- Feeding TMRs will allow lower FNDF concentrations. TMRs have a great advantage because rapidly fermented carbohydrates are consumed along with effective fiber that limits size of meals and the decline in pH following meals. Concentrates can be fed separately but they should be fed four or more times per day and rapidly degraded starch sources should be limited.
- Provide adequate particle length in diets. Reduction in particle length starts when forages are chopped. Further reduction occurs when corn silage is processed and when forages are ensiled in bags by augers during filling. Particle size is also reduced when diets are mixed in many TMR mixers. A constant mixing time should used that is sufficient to adequately mix TMRs while avoiding excessive particle length reduction. Finally, particles are reduced still further when eaten by the cow. Effective fiber is needed to form a rumen mat to selectively retain small particles in the rumen and to stimulate rumination. While there is little to be gained in effectiveness of NDF by having particle length beyond a certain point, particle size in TMRs consumed by cows is sometimes inadequate. The Penn State Particle Size Separator, available from NASCO, is useful to monitor changes in particle size from mechanical treatment and to ensure adequate particle length in TMRs. Less than 40% of the TMR should be recovered in the bottom box following sieving to provide adequate article length. When more than 10 to 15% of the TMR is recovered on the top sieve, the TMR will be more subject to sorting. This leaves over 45% on the middle sieve, which provides most of the effective NDF in the diet. Diets containing silages that are chopped too finely can benefit by including 2 to 3 pounds of long-chopped hay in the diet to improve the effectiveness of NDF.
- Addition of buffers to the diet can increase the buffering capacity of rumen fluid and help attenuate the reduction in pH following a meal. However, they will not have a great effect on optimal FNDF concentration in the diet.
- Diets with added fat require somewhat less FNDF because fat isn't fermented in the rumen to acids. Although fat can be included in diets to increase energy intake beyond what can be attained by diet formulation for carbohydrates, some fat sources have been shown to reduce DMI and might not improve energy intake. In addition, highly fermentable diets containing added fat with polyunsaturated fatty acids might be more prone to reduction in milk fat by production of trans fatty acids in the rumen.
- Grouping cows by milk yield will help increase energy intake because diets can be more closely formulated to meet their needs. High producing cows should be fed low fill diets to maximize energy intake. However, lower producing cows can be offered diets with higher FNDF content which provides the benefit of more consistent supply of fuels throughout the day. A more consistent supply of nutrients might help partition more fuels to milk and help prevent excessive body condition. Wide variation in DMI and milk yield of cows within groups makes it difficult to optimize FNDF concentration for all cows in the group.

more →

Conclusions

The different factors discussed above are important to formulate diets to maximize energy intake and microbial protein production. The complex interactions among these factors prevent accurate prediction of optimal FNDF concentration for cows or groups of cows. Diets should be formulated by evaluating cow response to dietary changes and adjusting the diet based this response. Lower FNDF contents will generally allow higher energy intake and higher milk yield. Exceptions are when FNDF is highly fermentable, which will allow higher FNDF contents and higher energy intakes, and when passage rates of NFFS in low FNDF diets are excessive and digestibility is reduced. Diets with low optimal FNDF content will have starch sources that have moderate ruminal fermentation, forage particles that are sufficiently long, moderate to low forage NDF content, be fed as a TMR, and have little daily variation. Diets with high optimal FNDF contents will limit energy intake of high producing cows. They will generally have rapidly fermented starch sources, finely chopped forages, no NFFS, limited feed bunk space, infrequent grain feeding, and high daily variation. The information presented here can be used to develop a strategy to maximize energy intake and microbial protein production and should be refined with experience.

Facility and Climate Effects on Dry Matter Intake of Dairy Cattle

MICHAEL J. BROUK—Department of Animal Sciences and Industry, Kansas State University
124 Call Hall Manhattan, KS 66506-1600 Tel: 785-532-1207 Fax: 785-532-681 mbrouk@oznet.ksu.edu

JOHN F. SMITH—Department of Animal Sciences and Industry, Kansas State University
JOSEPH P. HARNER, III—Department of Agricultural and Biological Enginering, Kansas State University

Introduction

Performance of dairy cattle may be enhanced or hindered by environmental factors affecting feed intake. Feed intake is the single most critical factor of dairy production. As production levels increase, intake becomes a greater barrier to performance of dairy cattle. The environment of the modern dairy cow includes both physical facilities and climate. Physical factors associated with confinement facilities may have a greater influence on cow performance than climatic factors. Since confinement facilities generally last 20 years or more, design choices have long-term effects upon the dairy operation. Design of freestalls, feed barriers, housing pens, building, holding pens, and milking parlor combine to create the physical environment to which cattle are exposed. Physical facilities should provide adequate access to feed and water, easy access to a comfortable lounging area and provide a comfortable environment that provides adequate protection from the elements of nature. In addition, consideration of management factors related to the interaction of cow and environment should be considered. Correct design and management of facilities can create an environment that enhances the intake and performance of dairy cattle. Climate dictates what type of facilities is required for maximum production. The use of a cooling system or protection from winter conditions is determined by the location of the dairy. Since climate conditions vary widely, different facilities are required in different areas of the world. Choices made in facility design may reduce or increase the effects of climate.

On a day-to-day basis, the two most important numbers any dairy producer should know is the milk production and dry matter intake of each pen of cattle on the dairy. Roseler et al. (1997) utilized data from many studies conducted in four different regions of the United States to develop an equation to explain dry matter intake of dairy cattle. They concluded that milk yield explained 45% of the variability in observed dry matter intake of the cows studied (Figure 1). They also concluded that climate accounted for 10% and feed and management 22% of the variability in intake. Feed and management represented all the variability not explained by the other variables. This data clearly demonstrates that cows need to eat more to produce additional milk. Designing and managing facilities to increase milk production will increase feed intake. The goal of the system should be to provide adequate cow comfort which includes (1) adequate access to feed and water (2) a clean and dry bed which is comfortable and correctly sized and constructed and (3) based on climate appropriate facility modifications to enhance production potential.

Access to Feed and Water

One of the critical decisions that producers make is the type of freestall barn they build. The most common types are either 4- or 6-row barns and many times the cost per stall is used to determine which barn should be built. Data found in Table 1 represents the typical dimensions of the barns and Table 2 demonstrates the effects of overcrowding upon per cow space for feed and water. Grant (1998) suggested that feed bunk space of less than 8 in/cow reduced intake and bunk space of 8 to 20 in/cow resulted in mixed results. Even at a 100% stocking rate, the 6-row barn only offers 18 in/cow feed line space. When over crowding occurs this is significantly reduced. Four-row barns, even when stocked at 140% of the stalls, still provide more than 18 in/cow of bunk space. In addition, when water is only provided at the crossovers, water space per cow is reduced by 40% in the 6-row barn as compared to 4-row barns. Much of the current debate over the effect of 4- and 6-row barns upon intake is likely related to presence or absence of management factors which either reduce on increase the limitations of access to feed and water in 6-row barns.

Recommendations concerning access to water vary greatly. Current recommendations suggest a range of 1.2 to 3.6 linear inches per cow (Smith et al. 1999). In the Midwest, the typical rule is one waterer or 2 linear feet of space for every 10 to 20 cows. In the Southwest, the recommendation is 3.6 linear inches of space for every cow in the pen. Typically, water is provided at each crossover in 4- and 6-row freestall barns and generally a 4- and 6-row freestall have the same number of crossovers. Thus, water

more ⟶

access in a 6-row barn is reduced by 37.5% as compared to a 4-row barn (Table 1). When overcrowding is considered (Table 2) water access is greatly reduced and the magnitude of reduction is greater in 6-row barns. Milk is 87% water and water intake is critical for peak dry matter intake. When building 6-row barns or overcrowding either 4-row or 6-row barns it is important to consider the amount of water space available. In warmer climates, it is necessary to modify building plans to provide 3.6 linear inches of waterer space per cow.

If construction costs are going to drive the decision between a 4- or 6-row freestall barn, overcrowding must be considered. Typically, 4-row barns are overcrowded 10 to 15% on the basis of the number of freestalls in the pen. Due to the limitations of bunk space, many times the 6-row barn is stocked at 100% of the number of freestalls. Thus, comparing the two buildings based on a per cow housed rather than a per stall basis would be more accurate. This will make the 4-row more cost comparable to the 6-row and maintain greater access to feed and water.

Feed Barrier Design

The use of self-locking stanchions as a feed barrier is currently a debated subject in the dairy industry. Data reported in the literature is limited and conclusions differ. Shipka and Arave (1995) reported that cows restrained in self-locking stanchions for a four-hour period had similar milk production and dry matter intake as those not restrained. Arave et al. (1996a) observed similar results in another study, however a second study showed similar intake but 6.4 lb/cow/d decrease in milk production when cows were restrained daily for a four-hour period (9 AM to 1 PM) during the summer. Increases in cortisol levels were also noted during the summer but not in the spring (Arave et al., 1996b) indicating increased stress during the summer as compared to the spring. Another report (Bolinger et al., 1997) found that locking cattle for 4 hours during the spring months did not affect milk production or feed intake. All of these studies compared restraining cows for four hours to no restraint and all animals were housed in pens equipped with headlocks. The studies did not compare a neck rail barrier to self-locking stanchions nor address the effects of training upon headlock acceptance. However, some have drawn the conclusion that self-locking stanchions reduce milk production and only the neck rail barrier should be used. The data indicates that cows should not be restrained for periods of four hours during the summer heat. The argument could be made that four hours of continuous restraint time is excessive and much shorter times (one hour or less) should be adequate for most procedures. These studies clearly indicate that mismanagement of the self-locking stanchions, not the stanchions resulted in decreased milk production in one of three studies with no affect upon intake in all studies.

Another study (Batchelder, 2000) compared lockups to neck rails in a 4-row barn under normal and crowded (130% of stalls) conditions. Results of the short-term study showed a 3 to 5% decrease in dry matter intake when headlocks were used. No differences in milk production or body condition score were observed. It was also noted that overcrowding reduced the percentage of cows eating after milking as compared to no overcrowding. In this study, use of headlocks reduced feed intake but did not affect milk production.

The correct feed barrier slope is also important. Hansen and Pallesen (1994) reported that sloping the feed barrier 20° away from the cow increased feed availability because the cows could reach 14 cm further than when the barrier was not sloped. They also noted that when feed was placed within the cow's reach much less pressure was exerted against the feed barrier indicating greater cow comfort. However, the study did not indicate that intake was increased only that accessibility was increased. Pushing feed up more frequently could achieve the same affect. One disadvantage of sloping the feed barrier is that feeding equipment is more likely to come in contact with the barrier which may result in significant damage to both.

The feeding surface should be smooth to prevent damage to the cow's tongue. When eating, the side of the tongue, which is much more easily injured, often contacts the manger surface. The use of plastics, tile, coatings, etc. will provide a smooth durable surface reducing the risk of tongue injury.

Correct design of the feeding area will allow the cow more comfortable access to feed. Figures 2 and 3 demonstrate the typical design for post and rail as well as headlock systems. It is important to lower the cow standing surface relative to the feed table and to provide the correct throat height. Incorrectly designed feeding areas may limit feed intake and, thus, milk production.

Freestall Design and Surfaces

Freestall Design

Cows must have stalls that are correctly sized. As early as 1954 researchers demonstrated increases in milk production when larger cows were allowed access to increased stall sizes. Today, construction costs often encourage producers to reduce stall length and width. This may reduce cow comfort and production. Cows will use freestalls that are designed correctly and maintained. If cows refuse to utilize stalls, it is likely related to design or management of the freestall area. Table 3 provides data for correctly sizing the stall. In addition, the stall should be sloped front to back and a comfortable surface provided.

Freestall Surface Materials

Sand is the bedding of choice in many areas. It provides a comfortable cushion that forms to the body of the animal. In addition, its very low organic matter content reduces mastitis risk. Sand is readily available and economical in many cases. Disadvantages may include the cost of sand and/or the issues with handling sand-laden manure and separating the waste stream. Since 25 to 50 pounds of sand are consumed per stall per day, it should be separated from manure solids to reduce the solid load on the manure management system. In arid climates, manure solids are composted and utilized for bedding. Producers choosing not to deal with sand or composted manure bedding, often choose from a variety of commercial freestall surface materials. Sonck, et al. (1999) observed that when given a choice, cows prefer some materials (Figure 4). Occupancy percent ranged from over 50 to under 20%. Researchers suggested that the increase in occupancy rate was likely influenced by the compressibility of the covering. Cows selected freestall covers that compressed to a greater degree over those with minimal compressibility. Cows need a stall surface that conforms to the contours of the cow. Sand and materials that compress will likely provide greater comfort as demonstrated by cow preference.

Enhancing Production Potential Environmental Temperature

Mature dairy cattle generally have a thermal neutral zone of 41 to 68°F. This may vary somewhat for individual cows and conditions. Within this range, it is generally assumed that impacts upon intake are minimal. However, temperatures below or above this range alter intakes.

Effects of Heat Stress

Heat stress reduces intake, milk production, health and reproduction of dairy cows. Spain et al. (1998) showed that lactating cows under heat stress decreased intake 6 to 16% as compared to thermal neutral conditions. Holter et al. (1997) reported heat stress depressed intake of cows more than heifers. Other studies have reported similar results. In addition to a reduction in feed intake, there is also a 30 to 50% reduction in the efficiency of energy utilization for milk production (McDowell et al. 1969). The cow environment can be modified to reduce the effects of heat stress by providing for adequate ventilation and effective cow cooling measures.

Ventilation

Maintaining adequate air quality can be easily accomplished by taking advantage of natural ventilation techniques. Armstrong et al. (1999) reported that a 4/12 pitch roof with an open ridge resulted in lower afternoon cow respiration rate increases as compared to reduced roof pitch or covering the ridge. They also observed that eave heights of 14 feet resulted in lower increases in cow respiration rates as compared to shorter eave heights. Designing freestall barns that allow for maximum natural airflow during the summer will reduce the effects of heat stress. Open sidewalls, open roof ridges, correct sidewall heights and the absence of buildings or natural features that reduce airflow increase natural airflow. During the winter months, it is necessary to allow adequate ventilation to maintain air quality while providing adequate protection from cold stress.

Another ventilation consideration is the width of the barn. Six-row barns are typically wider that 4-row barns. This additional width reduces natural ventilation. Chastain (2000) indicated that summer ventilation rates were reduced 37% in 6-row barns as compared to 4-row barns. In hot and humid climates, barn choice may increase heat stress resulting in lower feed intake and milk production.

Cow Cooling

During periods of heat stress, it is necessary to reduce cow stress by increasing airflow and installing sprinkler systems. The critical areas to cool are the milking parlor, holding pen and housing area. First, these areas should provide adequate shade. Barns built with a north-south orientation allow morning and afternoon sun to enter the stalls and feeding areas and may not adequately protect the cows. Second, as temperatures increase, cows depend upon evaporative cooling to maintain core temperature. The use of sprinkler and fan systems to effectively wet and dry the cows will increase heat loss.

The holding pen should be cooled with fans and sprinkler systems and an exit lane sprinkler system may be beneficial in hot climates. Holding pen time should not exceed one hour. Fans should move 1,000 cfm per cow. Most 30- and 36-inch fans will move between 10,000 and 12,000 cfm per fan. If one fan is installed per 10 cows or 150 ft^2, adequate ventilation will be provided. If the holding pen is less than 24 feet wide with 8 to 10 feet sidewall openings, fans may be installed on 6 to 8 foot centers along the sidewalls. For holding pens wider than 24 feet, fans are mounted perpendicular to the cow flow. Fans are spaced 6 to 8 feet apart and in rows spaced either 20 to 30 feet apart (36-inch fans) or 30 to 40 feet apart (48-

more →

inch fan) (Harner et al, 1999). In addition to the fans, a sprinkling system should deliver .03 gallon water per foot^2 of area. Cycle times are generally set at 2 minutes on and 12 minutes off.

Freestall housing heat abatement measures should include feedline sprinklers and fans to increase air movement. Sprinkling systems should deliver water similar to the holding pen system except it should only wet the area occupied while the animal is at the feed bunk. The hair coat of the cow should become wet and then be allowed to dry prior to the beginning of the next wetting cycle. Fans may be installed to provide additional airflow that will increase evaporation rate (Harner et al. 1999).

Cold Stress

Dairy cows can withstand a significant amount of cold stress as compared to other animals. Factors affecting the ability of the cow to withstand cold temperatures include housing, pen condition, age, stage of lactation, nutrition, thermal acclimation, hairy coat and behavior (Armstrong and Hillman, 1998). Feed intake increases when ambient temperature drops below the lower critical temperature of the animal. Protection from wind and moisture will reduce the lower critical temperature and minimize the effects of cold stress. When feed intake is no longer adequate to maintain both body temperature and milk production, milk production will likely decrease.

Supplemental Lighting

Lactating Cows

Supplemental lighting has been shown to increase milk production and feed intake in several studies. Peters (1981) reported a 6% increase in milk production and feed intake when cows were exposed to a 16L:8D photoperiod as compared to natural photoperiods during the fall and winter months. Median light intensities were 462 lx and 555 lx for supplemental and natural photoperiods respectively. Chastain et al. (1997) reported a 5% increase in feed intake when proper ventilation and lighting were provided and Miller et al. (1999) reported a 3.5% increase without bST and 8.9% with bST when photoperiod was increased from 9.5 to 14 hours to 18 hours. Increasing the photoperiod to 16 to 18 hours increased feed intake. Dahl et al. (1998) reported that 24 hours of supplemental lighting did not result in additional milk production over 16 hours of light. Studies utilized different light intensities in different areas of the housing area. More research is needed to determine the correct light intensity to increase intake. In modern freestall barns, the intensity varies greatly based on the location within the pen. Thus, additional research is needed to determine the intensity required for different locations within pens.

Another issue with lighting in freestall barns is milking frequency. Herds milked 3X cannot provide 8 hours of continuous darkness. This is especially true in large freestall barns housing several milking groups. In these situations, the lights may remain on at all times to provide lighting for moving cattle to and from the milking parlor. The continuous darkness requirement of lactating cows may be 6 hours (Dahl, 2000). Thus, setting milking schedules to accommodate 6 hours of continuous darkness is recommended. The use of low intensity red lights may be necessary in large barns to allow movement of animals without disruption of the dark period of other groups.

Dry Cows

Dry cows benefit from a different photoperiod than lactating cows. Recent research (Dahl, 2000) showed dry cows exposed to short days (8L:16D) produced more ($P<.05$) milk in the next lactation than those exposed to long days (16L:8D). Petitclerc et al. (1998) reported a similar observation. Based on the results of these studies, dry cows should be exposed to short days and then exposed to long days post-calving.

Lot Condition

Mud can have a significant negative impact upon dry matter intake. Fox and Tylutki (1998) suggested that every inch of mud reduced DMI of dairy cattle 2.5%. Based on this assumption, feed intake of cattle in 12 inches of mud would be 30% less than those without mud. Based on our current knowledge of the impact of prepartum intake upon subsequent lactation performance. Dry cattle housed in muddy conditions may be at greatest risk. However, significant production losses may also occur in lactating cattle.

Summary

Environmental factors that affect feed intake can be divided into physical and climatic affects. On modern dairies, the physical factors may be more of a concern than the climate. Modern facilities provide the cow with protection from the natural elements. However, the same facilities that protect the cow from the climate may enhance or hinder dry matter intake. Facilities should provide adequate access to feed and water, comfortable resting area and adequate protection from the natural elements. Critical areas of facility design related to feed intake include the access to feed and water, stall design and surface, supplemental lighting, ventilation and cow cooling. The total system should function to enhance cow comfort and intake. It is important to remember that choices made during construction of a facility will affect the performance of animals for the facility life, which is generally 20 to 30 years. Producers, bankers and consultants too often view the additional cost of cow comfort from the standpoint of initial investment rather than long-term benefit.

References

Arave, C.W., D. Bolinger, M.P. Shipka and J.L. Albright. 1996a. Effect of extended lock-up of lactating cows on milk production, feed intake and behavior. J. Anim. Sci. 74(Suppl. 1):43.

Arave, C.W., M.L. Sipka, J. Morrow-Tesch and J.L. Albright. 1996b. Changes in serum cortisol following extended lock up time of lactating cows. J. Dairy Sci. 79(Suppl. 1):191.

Armstrong, D.V. 1994. Heat stress interaction with shade and cooling. J. Dairy Sci. 77:2044-2050.

Armstrong, D.V. and P.E. Hillman. 1998. Effect of cold stress on dairy cattle performance. In: Proc. Colorado Nutrition Conference, Greeley, CO.

Armstrong, D.V., P.E. Hillman, M.J. Meyer, J.F. Smith, S.R. Stokes and J.P. Harner III. 1999. Heat stress management in freestall barns in the western U.S. In: Proc. of the 1999 Western Dairy Management Conference. pp 87-95.

Batchelder, T.L. 2000. The impact of head gates and overcrowding on production and behavior patterns of lactating dairy cows. In: Proc. of the 2000 Dairy Housing and Equipment Systems: Managing and planning for profitability. NRAES publication 129. pp 325-330.

Bolinger, D.J., J.L. Albright, J. Morrow-Tesch, S.J. Kenyon, M.D. Cunningham. 1997. The effects of restraint using self-locking stanchions on dairy cows in relation to behavior, feed intake, physiological parameters, health and milk yield. J. Dairy Sci. 80:2411-2417.

Chastain, J.P. 2000. Designing and managing natural ventilation systems. In: Proc. of the 2000 Dairy Housing and Equipment Systems: Managing and planning for profitability. NRAES publication 129. pp 147-163.

Chastain, J., L. Jacoboson. J. Beehler and J. Martens. 1997. Improved lighting and ventilation systems for dairy facilities: its effects on herd health and milk production. In: Proc. Fifth Int. Livestock Housing Conference. pp 827-835.

Dairy Freestall Housing and Equipment. 1997. Midwest Plan Service, Iowa State University, Ames, IA.

Dahl, G.E. 2000. Photoperiod management of dairy cows. In: Proc. of the 2000 Dairy Housing and Equipment Systems: Managing and planning for profitability. NRAES publication 129. pp 131-136.

Dahl, G.E., J.P. Chastain and R.R. Peters. 1998. Manipulation of photoperiod to increase milk production in cattle: biological, economical and practical considerations. In: Proc. Fourth Int. Dairy Housing Conf. ASAE, St. Joseph, MI. pp 259-265.

Fox, D.G. and T.P. Tylutki. 1998. Accounting for the effects of environment on the nutrient requirements of dairy cattle. J. Dairy Sci. 81:3085-3095.

Grant, R. 1998. Taking advantage of cow behavior. In: Proceedings of the second Midwest Dairy Management Conference Kansas City, MO. pp 97-106.

Graves, R.E. 1998. Guideline for planning dairy freestall barns. Publication NRAES-76 Northeast Regional Agricultural Engineering Service, Ithaca, NY.

Hansen, K. and C.N. Pallesen. 1998. Dairy cow pressure on self-locking feed barriers. In: Proceedings of the fourth international dairy housing conference. ASAE, St. Louis, MO, pp 312-319.

Harner, J.P. III, J.F. Smith, M. Brouk, and J.P. Murphy. 1999. Sprinkler systems or cooling dairy cows at a feed line. Publication MF2401 Kansas State University, Manhattan, KS.

Holter, J.B., J.W. West, M.L. McGillard, and A.N. Pell. 1996. Predicating ad libitum dry matter intake and yields of Jersey cows. J. Dairy Sci. 79:912-921.

McDowell, R.E., E.G. Moody, P.J. Van Soest, R.P. Lehman and G.L. Ford. 1969. Effect of heat stress on energy and water utilization of lactating dairy cows. J. Dairy Sci. 52:188.

Meyer, M.J., J.F. Smith, J.P. Harner, J.E. Shirley, E.C. Titgemeyer and M.J. Brouk. 1999. Performance of lactating dairy cattle in three different cooling systems. Presented at the July 18-21 ASAE Annual International Meeting, Paper No. 994009. ASAE, 2950 Niles Road, St. Joseph, MI.

Miller, A.R.E., E.P. Stanisiewski, R.A. Erdman, L.W. Douglas and G.E. Dahl. 1999. Effects of long daily photoperiod and bovine somatotropin (Trobest(r)) on milk yield in cows. J. Dairy Sci. 82:1716-1722.

Peters, R.R. 1981. Milk yield, feed intake, prolactin, growth hormone and glucocorticoid response of cows to supplemental light. J. Dairy Sci. 64:1671-1678.

Petitclerc, D., C. Vinet, G. Roy and P. Lacasse. 1998. Prepartum photoperiod and melatonin feeding on milk production and prolactin concentrations of dairy heifers and cows. J. Dairy Sci. 81(Suppl. 1):251. Roseler, D.K., D.G. Fox, L.E. Chase, A.N. Pell and W.C. Stone. 1997. Development and evaluation of equations for prediction of feed intake for lactating Holstein dairy cows. J. Dairy Sci. 80:878-893.

Shipka, M.P. and C. W. Arave. 1995. Influence of extended manger lock-up on cow behavior and production factors in dairy cattle management. J. Anim. Sci. 73(Suppl. 1):310.

Smith, J.F., J.P. Harner, M.J. Brouk, D.V. Armstrong, M.J. Gamroth, M.J. Meyer, G. Boomer, G. Bethard, D. Putnam. 2000. Relocation and expansion planning for dairy producers. Publication MF2424 Kansas State University, Manhattan, KS.

Sonck, B., J. Daelemans and J. Langenakens. 1999. Preference test for free stall surface material for dairy cows. Presented at the July 18-21 Emerging Technologies for the 21st Century, Paper No. 994011. ASAE, 2950 Niles Road, St. Joseph, MI.

Spain, J.N., D.E. Spiers and B.L Snyder. 1998. The effects of strategically cooling dairy cows on milk production. J. Anim. Sci. 76(Suppl. 1):103.

more →

Table 1. Average pen dimensions, stalls, cows and allotted space per animal.

					Per Cow		
Barn Style	Pen Width (ft)	Pen Length (ft)	Stall Per Pen	Cows Per Pen	Area (ft^2)	Feedline Space (linear in)	Water Space (linear in)
4-Row	39	240	100	100	94	29	3.6
6-Row	47	240	160	160	71	18	2.25
2-Row	39	240	100	100	94	29	3.6
3-Row	47	240	160	160	71	18	2.25

Adapted from Smith, J.F. et al., 1999.

Table 2. Effect of stocking rate on space per cow for area, feed and water in 4- and 6-row barns.

Stocking Rate (%)	Area (ft^2/cow)		Feedline Space (linear in/cow)		Water Space (linear in/cow)	
	4-Row	6-Row	4-Row	6-Row	4-Row	6-Row
100	94	71	29	18	3.6	2.25
110	85.5	64.5	26	16	3.27	2.05
120	78.3	59.2	24	15	3.0	1.88
130	72.3	54.6	22	14	2.77	1.73
140	67.1	50.7	21	13	2.57	1.61

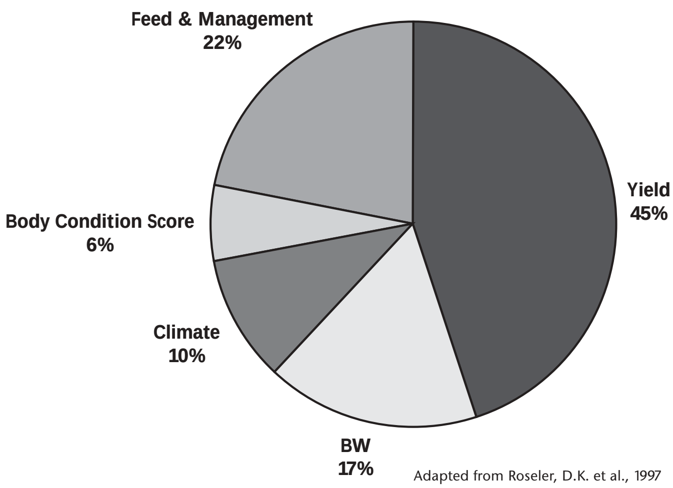
Table 3. Freestall dimensions for cows of varying body weight.

Body Weight (lb)	Free Stall Width (in)	Side Lunge (in)	Forward Lunge[a] (in)	Neck Rail Height Above Stall Bed (in)	Neck Rail and Brisket Board Bed, Distance from Alley Side of Curb (in)
800–1,200	42 to 44	78	90 to 96	37	62
1,200–1,500	44 to 48	84	96 to 102	40	66
Over 1,500	48 to 52	90	102 to 108	42	71

[a]An additional 12-18 inches in stall length is required to allow the cow to thrust her head forward during the lunge process.

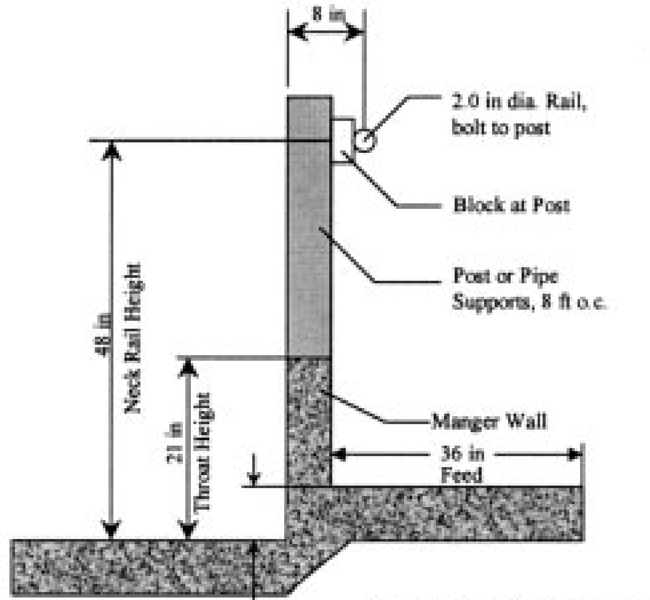
Adapted from Dairy Freestall Housing and Equipment, 1997.

Figure 1. Description of factors that affect DMI in lactating dairy cows and the amount of variability explained by each factor.



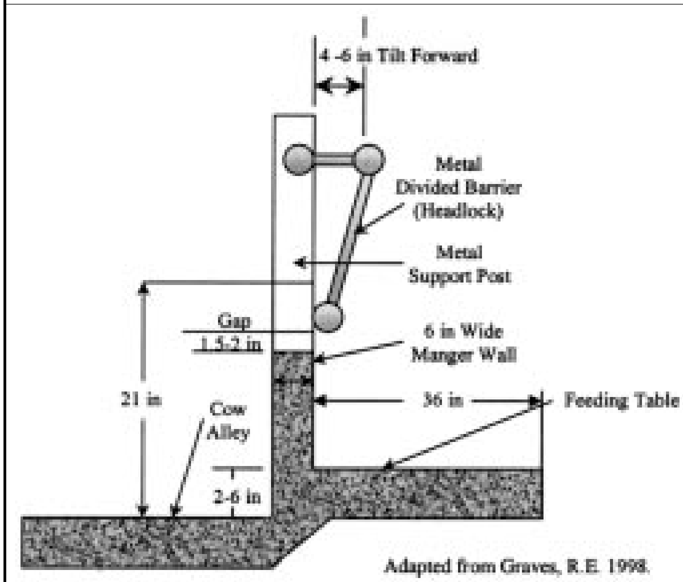
Adapted from Roseler, D.K. et al., 1997

Figure 2. Post and Rail Feeding Fence for Cows.



Adapted from Graves, R.E. 1998.

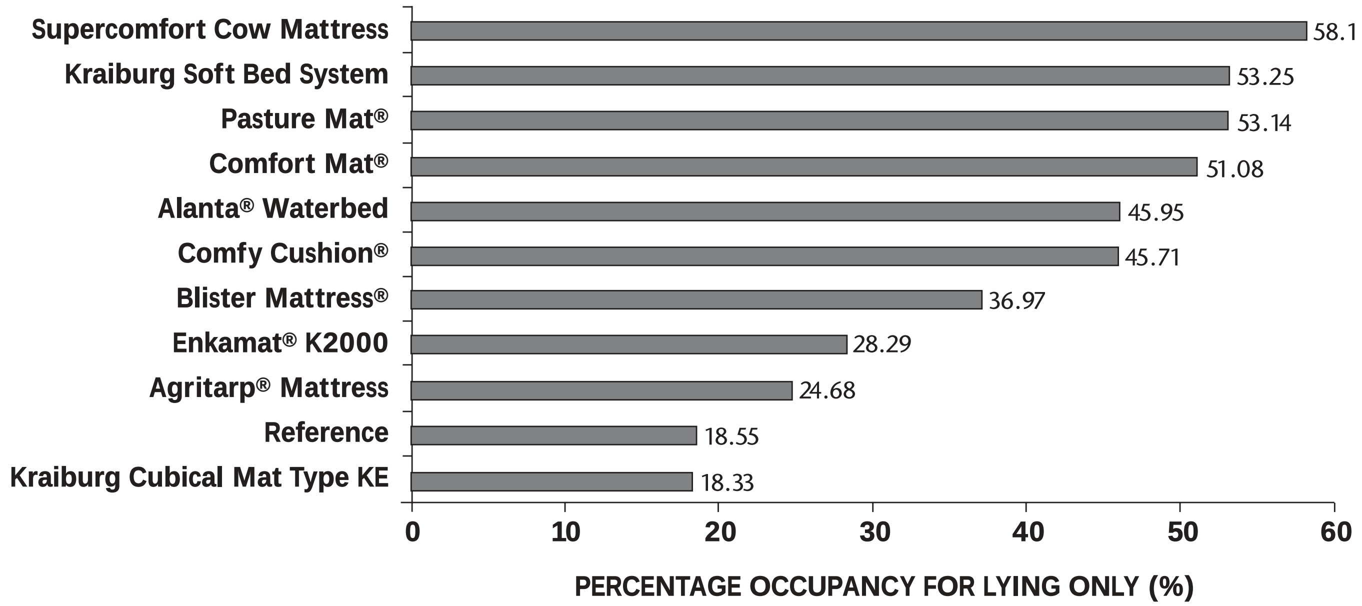
Figure 3. Divided Feed Barrier (Headlock)



Adapted from Graves, R.E. 1998.

more →

Figure 4. Classification of the 11 freestall surface materials, based on the average percentage occupancy for lying only (%).



Adapted from Sonch, B. et al., 1999.

Supercomfort Cow Mattress of R. De Cleene (Belgium) consists of a soft and elastic supporting layer of rubber tiles (30 mm thick) made from small rubber crumbs, combined with a top water-tight layer (6 mm thick) of polypropylene and a PVC back (weight: 3.8 kg/m^2). The latter is the same top layer as the Blister Mattress.

Kraiburg Soft Bed System of Gummiwerk Kraiburg Elastik GmbH (Germany) is a mattress consisting of a rubber mat with a hammered finish (a thickness of 8 mm and a weight of 9.5 kg/m^2) as nonporous top layer. The mat is combined with a 25 mm polyurethane foam underlay (weight: 3.5 kg/m^2). An all-round insulation strip prevents dirt from penetrating the foam.

Pasture Mat® type CS of Pasture BV (The Netherlands) is made by filling rubber crumbs (4-7 mm in size) in twelve independent cells of a bag (57 mm thick and 26 kg/m^2 weight), made from polypropylene and nylon. The independent cells are covered with a non-woven polypropylene top sheet of 3.5 mm thick and 1.9 kg/m^2 weight.

Comfort Mat® of Alfa Laval Agri Belgium: is a soft rubber mat with a thickness of 20 mm and a weight of 4 kg/m^2.

Alanta® Waterbed of Dunlop-Enerka (The Netherlands): is an individual double-sided rubber mat (Styrene-butadiene rubber) filled with water. Thickness of the mat is 9 mm unfilled and 50 mm filled with 50 liters of water. The weight of the unfilled mat amounts to 10 kg/m^2.

Comfy Cushion® mattress of Mac Farm Systems (Belgium) is made by stuffing rubber crumbs in independent cells of a bag of 70 mm thick, made of polypropylene. The weight of this underlayer amounts to 28 kg/m^2. Two tubes spaced 16 cm apart are fastened onto a polypropylene sheet forming an element. Elements are linked to each other by placing them alternately facing up and facing down. The tubes are covered with a white woven polyester sheet with a thickness of 1 mm and a weight of 0.5 kg/m^2.

Blister Mattress® of Brouwers Stalinrichtingen BV (The Netherlands) is made from a combination of a soft supporting layer (20 mm thick) and a top water-tight layer (6 mm thick) of polypropylene and a PVC back (weight: 3.8 kg/m^2).

Enkamat® K2000 of Vape BV (The Netherlands) is a compact mat consisting of 5 thin layers: a wear resistant top layer, an impermeable coating, a reinforcement textile, a second impermeable coating and a polyamide curling underlay.

AgriTarp® Mattress of Agriprom Stalmatten BV (The Netherlands) is made by stuffing rubber crumbs in independent tubular cells of a bag of 60 mm thick, made of polypropylene. The weight of this underlayer amounts to 28 kg/m^2. The tubes are covered by a non-woven polypropylene top sheet of 1 mm thickness and a weight of 0.8 kg/m^2.

Reference: a concrete floor littered with sawdust.

Kraiburg Cubicle Mat Type KE of Gummiwerk Kraiburg Elastik GmbH (Germany) is a classic rubber mat with a hammered finish (18 mm thick and 20 kg/m^2 weight).

Quality Control in Your Commodity Program

MIKE GAMROTH—Department of Animal Sciences, 112 Withycombe Hall, Oregon State University, Corvallis, OR 97331
Tel: 541-737-3316 Fax: 541-737-4174 mike.gamroth@orst.edu

Buying and feeding commodity feeds is an effective way to cut costs on today's dairy farms. Surveys show even small producers can benefit from the cost savings of handling and mixing grains and byproducts on the dairy. However, this cost saving technique places the responsibility of feed quality control squarely on the dairy manager's shoulders.

This presentation will review some of the basics of commodity feeding and then talk about some emerging issues in controlling quality of feeds on the dairy.

To be successful when feeding commodities the dairy manager needs a reliable source of the basic commodities in the dairy ration. A dependable broker can assure a regular supply of feeds at a fair price. A broker can also help by locating commodities of consistent quality. While forward contracting at harvest can help lower the overall annual cost of a commodity, a broker or commodity feeder doing his or her own buying is not going to beat the market often. The savings comes in getting good quality feeds at a wholesale price. Locking in the price can help a manager better determine the cost of production for a period. This will help with wiser cash management, culling decisions, forward pricing of milk, and so on.

There are a wide range in types and sizes of commodity storage and receiving facilities. Commodity feeders find the following characteristics most successful in a commodity storage barn:

- 14' x 30' floor level bins sloped outward so rain or snow melt doesn't flow into the storage bays.
- Floors are poured after walls so seams go down to the base material, not across to the adjacent bay. This makes cleaning bays easier between loads.
- The apron at the open ends of the bins slopes away from storage again to prevent rainfall from entering the storage and to help in cleaning the slab.
- The barn will have two more bins than you need for your regular feeds. This allows you to rotate feeds, clean bins between loads, and pre-mix the commodities if desired.
- Bagged mineral/supplement storage that is adjacent to the barn, but not in an expensive commodity bin. A shed roof with a dry floor is adequate for palleted sacked feeds.
- More commodity barns may include a bin for dry rolling or processing grain and many now include a small dump chute with an elevator and distribution leg for unloading truck deliveries into the appropriate bins.

Besides the cost of building a commodity barn, surveys have determined some of the ongoing costs of farm mixing commodities. Obviously, cost will vary farm to farm, but surveys show the labor involved in taking delivery of feeds, loading them into the appropriate bins, loading and mixing feeds will add about $2 per ton of mixed feeds over the prorata cost of feed ingredients. In addition, feed spillage, refusal, and other feed disappearance (shrink) will add another $2 per ton of finished feed. Don't ignore or underestimate shrink as a cost. By controlling spillage and feed refusal, a manager can save some costs.

Commodity feeding also places some other responsibilities on the dairy manager when compared to buying mixed feeds from a processor. It pays a dairy manager to have truck scales on the farm or nearby available 24 hours per day. Loads arrive with no weigh tickets and it becomes your only way of knowing the delivery amount. Deliveries can also be delayed through weather or breakdowns so managers must plan their supply in advance. There are also seasonal shortages like during the holidays at the end of the year and when feeds like beet pulp are out of stock.

Commodity feeders are unanimous in reporting the need for qualified assistance in planning feed needs and sources and in formulating rations for most efficient production. Training and experience seem to be equally important. A broker may help with market planning, but a good nutrition consultant is where feed and ration planning starts. Your consultant can help you monitor feed quality and how it relates to animal performance and health as well. However, the day to day quality control falls on the dairy manager.

Assuring Feed Quality

There are many aspects of feed quality. Most can be controlled by the dairy manager, but take regular attention.

For high dry matter intake, feed palatability is a primary concern. Buying fresh commodities that are free of weather damage and foreign materials is essential. Be sure to monitor characteristics of pre-farm processing quality along with over all quality. For example, your nutrition consultant can help evaluate the bushel weight or flake thickness on steam flaked grain. The quality of steam flaking has direct relationship to energy digestibility and ultimately to milk production.

more →

All feeds vary in nutrient content. Growing conditions, varieties, harvesting, and other handling all affect the actual feed value of commodities. The California chapter of the American Registry of Professional Animal Scientists (ARPAS) commissioned a study of the variability of some common California by-product feeds. The study reported some interesting facts important to dairy managers and nutrition consultants. Most major nutrient components have small to moderate variation within a feed. However, the variation is greater in high moisture feeds. For example, in the survey almond hulls ranged from 24 to 32% acid detergent nitrogen (ADF) but some were as high as 35% and as low as 19%. The National Research Council (NRC) reports an average 28% ADF content. Protein variation tended to be smaller. The analyses from one laboratory for crude protein in canola meal ranged from 39 to 41% and averaged 40%.

The study also looked at mineral content and found them much more variable. Molasses samples ranged from 123 to 277 parts per million (ppm) iron and 4 to 77 ppm of zinc. Wheat mill run samples varied from 2 to 153 ppm in copper content. Many of the samples were near the average, but it shows the by-products can make formulating the mineral component of the ration more difficult. The authors of the paper caution that while some of the variations seem quite large, it is impossible to predict how these variations influence actual production. Dairy managers seem successful in using by-product to support high production in spite of variable nutrient content.

Another important quality control concern is the source of minerals in a vitamin/mineral pre-mix delivered to the farm. Certainly, a mineral product can be formulated to contain the levels of minerals needed to balance your ration. However, mineral availability to the animal depends on the chemical source of the mineral. For example, oxides of minerals tend to be less available than sulfates of the same minerals. Organic mineral compounds are also usually more absorbable and stable in mixes. You need to talk with your mineral supplier about quality of mineral mixes as well as just the content of minerals. A good rule of thumb: If your mineral mix costs less than the quotes from other mineral mix suppliers, you better check its quality.

Contamination of Commodities

What seems to be a new concern is contamination of feed commodities by spoilage or disease-causing bacteria. Actually, bacterial contamination surveys of feed ingredients have been done for about thirty years. Larger studies with more than 100 samples tested have shown 3 to 30% commodity samples positive for Salmonella bacteria. Salmonella can cause human and animal disease so it's a concern for livestock producers and public health officials.

Since some of the contamination studies only looked at high protein feeds and none had serotyped the bacteria or determined its resistance to antibiotics, Oregon State University scientists decided to look at feed contamination on Oregon dairies. The study, completed in the summer of 2000, sampled 50 feed piles over a six-week period on 12 different dairy farms. We found 42% of samples were contaminated with Salmonella. The contamination occurred on all feeds, even whole cottonseed and pelleted feeds. It was surprising to find bacteria on very dry, low nutrient content feeds like grass seed screenings.

Also surprising was the tendency for the contamination rate to increase over time. When the same piles were sampled over a two week period, the contamination rate went up to 60%. It appears some of the Salmonella contamination is occurring on the farm and that relatively low levels can increase even during a short feed-out period.

It was also alarming to learn that of the Salmonella found in the feeds 62% of the isolates were resistant to ampicillin, but only 10% to tetracyline. We expected some resistance to tetracycline due to low level feeding of antibiotics in calves and heifers. However, the number of isolates resistant to tetracycline was relatively low compared to less commonly used dairy antibiotics and to some drugs not used in animal medicine. It appears some of the contamination is also coming from off the farm. More research will be done to identify more clearly the source of this feed contamination and whether it is contributing to disease on the farm.

We have talked about the characteristics of commodity feeding storage and purchase that will keep your cows healthy, eating well, and producing lots of milk, but don't forget to monitor the cost/nutrient in your feeds. Knowing the quality and nutrient content is important and so is the cost per pound of energy, protein, fiber, and minerals. Nothing can replace testing feeds. Successful managers test ingredients monthly and the total mixed ration once a month.

What Can You Do?

A good quality assurance program for your feed commodities should include:

Monitor for visible contaminants — Inspect loads of feed at delivery for junk, visible mold or spoilage, and heat or processing damage.

Monitor for consistency — If feeds are processed prior to delivery, check the quality of processing and the overall quality of ingredients used. Again this is best done right at delivery of the product. Record weights and delivery times. Watch your farm processing, too. Mix grains, small ingredients, silages, then hay to keep fiber length. Watch group intakes daily and at each push up to get early warnings of problems. Just like you want your feed ingredients of consistent quality, the cow wants her meal of consistent quality. Make feed changes rare and when you have to, do it gradually.

Use clean equipment — Never allow employees to move manure or dead animals with feed equipment and then feed cows. Even bedding or general yard cleanup in feed equipment requires a thorough cleaning before using equipment to handle feed ingredients.

Be aware of unseen contaminants — Mold, toxins, and bacteria can contaminate feed without tipping you off. You will need to test suspicious feed sources occasionally. Develop a list of testing laboratories in your area now.

Rotate stocks — To maintain freshness and to reduce the growth of mold or bacteria, always practice the first feed in, first feed out rule. This may take an extra bin or two to take delivery of replacement feeds while older stocks are used up.

Clean bins between use — Remove all the old feed and dust between loads. Pressure washing with adequate drying time is best to maintain feed quality. Clean the feed barn of dust and cobwebs occasionally.

Control rodents and birds — Rats, mice, and birds are likely one way feeds get contaminated. Do your best to keep their numbers and access to feed low. Don't forget to beware of other animals, like barn cats. Have you ever seen cats using your feed as a litter box?

Managing the Transition/Fresh Cow

JESSE P. GOFF—USDA, Agricultural Research Service National Animal Disease Center, Ames, IA 50010-0070
Tel: 515-663-7547 Fax: 663-7458 jgoff@nadc.ars.usda.gov

Three basic physiologic functions must be maintained during the periparturient period, before and after calving, if disease is to be avoided. These are:

A. Meeting the energy demands of lactation. This will involve adaptation of the rumen — a rumen that is unadapted cannot handle high energy feeds in early lactation without risk of rumen acidosis. It also involves enhancing total feed (and therefore energy) intake.
B. Maintenance of normal blood calcium levels; Note that I am not only talking about preventing milk fever but attempting to normalize blood calcium.
C. Reducing the degree of immunosuppression that occurs around calving. In virtually all species examined the maternal immune system is depressed. To some degree this is caused by the hormone changes associated with calving. However stress and poor nutrition will increase the degree and length of time the animals are immune suppressed. If we focus on the first 2 goals and improve energy and calcium status of the animal the immune system will also benefit. In addition data now suggest that retained placenta may be a disease caused by reduced immune cell function.

Meeting the energy demands of lactation.

Ketosis is diagnosed whenever there are elevated levels of ketones in the blood, urine, or milk of a cow. The disease is always characterized by a decline in blood glucose as well. In lactation, the amount of energy required for maintenance of body tissues and milk production exceeds the amount of energy the cow can obtain from her diet, especially in early lactation when dry matter intake is still low. As a result, the cow must utilize body fat as a source of energy. Every good cow will utilize body reserves in early lactation to help her make milk. However, there is a limit to the amount of fatty acid that can be handled and used for energy by the liver (and to some extent the other tissues of the body). When this limit is reached, the fats are no longer burned for energy but begin to accumulate within the liver cells as triglyceride. Some of the fatty acids are converted to ketones. The appearance of these ketones in the blood, milk, and urine is diagnostic of ketosis. As fat accumulates in the liver it reduces liver function — and a major function of the liver in the dairy cow is to produce glucose.

Recent work (Grummer, 1993) demonstrates the importance of feed intake at calving on the etiology of the fatty liver-ketosis syndrome. On average, dry matter intake decreases by 20 to 30% 1 or 2 days before calving, and does not recover until 1 to 2 days after calving (Bertics et al., 1992, Marquardt et al., 1977). Interestingly, liver biopsies showed that liver triglycerides were increased 3-fold by the day of calving. Triglyceride buildup in the liver is a much earlier phenomena than previously assumed. Even more interesting; when cows were fitted with rumen fistulas and dry matter intake was not allowed to drop around the time of calving by forcing feed into the rumen, liver lipids and triglycerides increased only a small amount. Similar results were also achieved by daily drenching of cows with propylene glycol (1 L/d) during the week before and after calving (Studer, et al., 1993).

The conclusion is that energy intake must not be compromised during the days around calving. Any factor restricting feed intake around calving (such as milk fever or retained placenta) increases fat accumulation in the liver and affecting the energy deficit of the cow increasing the risk of fatty liver-ketosis.

Strategies for prevention of Negative Energy Balance and Ketosis

Control body condition of cows.

Cows should calve with a body condition score (BCS) of 3.25 to 3.75. Cows with BCS of 3.25 will eat better than cows with BCS of 3.75. However a 3.75 BCS cow that is well managed could potentially produce more milk.

What can you do with those fat heifers or dry cows that are overweight?

With very careful management it is possible to place these animals on a poorly digestible diet (straw plus trace minerals and a little soymeal to get NE_L between 0.9 and 1.1 Mcal/kg and about 11% crude protein) at dry off to drop body condition scores, then place cows on the herd close-up ration for the 2 to 3 wks before calving. The idea is to create a hungry cow that will go ahead and eat well once she calves. This strategy requires accurate due dates! Trying to reduce weight in the last 3 weeks of pregnancy will mobilize body fat and nearly guarantee fatty liver development! This strategy will reduce frame growth in the heifers.

Adapting the rumen to handle high energy diets.

Two factors protect the mid-lactation cow from rumen acidosis.

more →

- The microbes in her rumen are acclimated to high starch diets allowing bacterial species that breakdown lactic acid to grow. It appears to take about 3 weeks (34) to build up a rumen population of bugs capable of handling starches — hence a common recommendation to bring cows onto a close-up ration 3 weeks before calving.
- The rumen wall of the mid-lactation cow has long wide papillae projecting into the rumen fluid. This increases the surface area of the rumen wall and allows for more rapid transfer of the volatile fatty acids produced during fermentation of feedstuffs into the blood for transport to the liver and other tissues. One study suggested that as much as 50% of the absorptive area may be lost during the first 7 weeks of the dry period (Dirksen et al., 1985). And in this study it took nearly 5 weeks of exposure to high grain diets to restore rumen papillae length. Recommendation: Our own observations suggest that American cows do not suffer such a large decline in rumen papillae length — probably because our far off dry cow rations tend to incorporate at least some starch (corn silage) so rumen papillae length does not decline as much so 3 weeks in the close-up pen should be adequate for cows. However, heifers do seem to benefit (socially and from a nutritional standpoint) from a longer period of time (5 weeks) on the close-up ration. Cows carrying twins should also enter the close-up pen 5 weeks before expected calving date. They need the extra calories and they usually calve 2 weeks early! Remember too that the standard deviation for calving date is + or — 9 days ; thus, to ensure that 95% of cows in a herd will be on a pre-fresh ration for at least 2 weeks before freshening means that cows in the herd should be started on pre-fresh rations 23 days before their due date.

Strategies to Increase Total Calorie Intake in the Fresh Cow.

High Starch Rations in the Close-up Pen.

The majority of studies that have compared the effects of low starch close-up rations (high forage) with high starch close-up rations have concluded that the number of calories consumed both pre-fresh and post-fresh is increased, largely because dry matter intake is increased. The amount of body fat mobilized (as assessed by monitoring blood NEFA and liver fat accumulation) is also generally decreased, a reflection of the improved energy status of the cow. Starches are converted to propionate in the rumen of the cow. Propionate is the major precursor for making glucose in the liver. Most of the structural carbohydrates in forages are going to be converted to acetate — good for milk fat support but the cow cannot use acetate to make glucose.

How high can we push the NFC (roughly equivalent to the starch content in most cases) in the pre-calving and post-calving diet?

Most nutrition guidelines would suggest that NFC for close-up rations be kept between 33 and 38% of the ration. A recent study by Minor et al., 1998 utilized close-up rations that were 43.8% NFC as compared to a close-up ration of just 23.5% NFC. Dry matter intake pre-calving was elevated from 10.2 kg /d to 13 kg /d by increasing the starch content of the ration. The cows fed the high NFC rations pre- and post-calving had about a 5 pound increase in milk production/day as well. Because the animals were adapted to the higher starch pre-calving the cows could be safely moved to a post-calving ration that was 46.5% NFC without suffering rumen acidosis and laminitis. In contrast changing from a pre-fresh ration that was 23.5% NFC to a post-calving ration that was 41.7% NFC resulted in greater laminitis. This points out that the changes in energy content must not be drastic. Cows can handle high starch rations but it takes time to step them up to the hotter rations.

Increasing starch concentration of the pre-calving ration is not likely to cause rumen acidosis in the pre-calving cow because of the overall low intakes of the dry cow. However, putting more starch in generally means you have reduced the fiber (NDF) content of the ration and this is where the problem lies as it can increase the susceptibility of the herd to displacement of the abomasum. The key is to feed a forage that supplies adequate effective fiber (ie. particles that are greater than 1.5 inches long that help form a mat on top of the rumen fluids), and is not so long or so unpalatable that it is sorted out by the cows. This often means chopping the forages going into the TMR and adjusting moisture content (a good target is 55 to 60% dry matter) so sorting is less likely. In some cases the addition of good clean straw can supply good effective fiber while allowing room in the ration for the added starch in both the pre-calving and post-calving rations. Alfalfa haylages, by and large very palatable, may not supply enough effective fiber to form a good rumen mat and it is this mat which is critical to prevention of left displaced abomasum. Corn silage chopped with less than ½ inch theoretical length of cut also does not contribute greatly to formation of the rumen mat.

Safe and Standard Recommendation

Close-up rations should contain from 35 to 38% NFC

The total NDF should be a minimum of 33% and preferably at least 26% forage NDF. The immediate post-calving ration can then safely be increased to 40 to 42% NFC. Keep NDF of the fresh cow diet above 27% and forage NDF at least 21% of the ration.

"Cutting edge" Recommendation

Close-up rations should contain from 38 to 42% NFC

The total NDF should be a minimum of 30% and preferably maintain at least 26% forage NDF. The immediate post-calving ration can then be increased to 44% NFC. Again, keep NDF of the fresh cow diet above 27% and forage NDF at least 21% of the ration.

It is absolutely essential that forages be eaten and not sorted from this type of diet strategy in both the close-up and fresh cow pens! It may be necessary to add chopped straw or grass hay to these rations to ensure adequate effective fiber.

Strategy — Add Fat to pre-fresh and post-fresh rations to "spare the body's glucose"

The idea behind this strategy is that muscle and other body tissues can burn diet fat for energy instead of blood glucose. Unfortunately, most studies find no benefit and perhaps some increase in non-esterified fatty acid content of blood when fat (both rumen protected or unprotected have been examined) is added to the close-up diet (Skaar et al., 1989). Studies done with cows in early lactation also are not encouraging as the added fat generally has the effect of reducing feed intake in early lactation (Salfer et al. 1995). Once animals are eating well, adding limited amounts of fat to the ration generally increases milk production and improves body condition. Recommendation — do not use supplemental fats until after 2 to 3 weeks into lactation.

Strategy — Increasing dietary protein in transition and fresh cow rations.

The fresh cow loses significant amounts (60 to 80 pounds) of muscle in the first weeks of lactation. She is primarily using the amino acids in her muscle to produce glucose. This strategy suggests that by feeding a high protein ration before calving we can build-up muscle reserves that the cow can draw on in early lactation to help her make glucose. Several studies were done suggesting less ketosis and less loss of body condition when dietary protein of the close-up ration was increased to 16 to 17% crude protein with 38 to 44% of the protein being rumen bypass protein (Van Saun, et al., 1993, Holtenius et al, 1993, Vandehaar et al., 1999). Some of these studies were complicated by changes in energy along with protein in the "high protein diet" treatments. Unfortunately a review of the recent literature does not support increasing diet protein (either as rumen bypass or even as essential amino acids) in pre-fresh rations as a means of improving health or milk production. Most studies suggest there is no gain made by increasing diet crude protein or rumen undegradable protein in close-up rations and a few studies suggest that high protein diets are even detrimental to the cows (Putnam et al., 1999, Greenfield et al., 2000).

So how much protein do we feed the close-up cows?

Santos and colleagues (2000) did a nice study to try to answer this question. They fed 2 levels of dietary protein, 12.7 or 14.7%, to heifers and cows for the three weeks prior to calving. These diets were 36 and 40% rumen undegradable protein respectively. Increasing protein in the close-up diet had no effect on milk production, blood glucose, post-partum body condition score, colostrum immunoglobulin content, or days to first corpus luteum formation in the cows. However, heifers responded to the higher dietary protein in the close-up pen with greater milk production (6.6 lbs/d on average). However blood glucose, post-partum body condition score, colostrum immunoglobulin content, and days to first corpus luteum formation were not improved by the high protein diet.

Recommendation: Cows need 12 to 13% protein close-up rations.

Heifers need 15% crude protein close-up rations. Mix of heifers and cows in the close-up pen? Feed 15% crude protein. Most diets fed pre-partum will have plenty of rumen undegradable protein to meet the metabolizable protein needs of the close-up cows and heifers so it is not a major concern to use bypass protein. In fact, animal sources of bypass protein (blood or fish meal) may reduce feed intake of the dry cow.

How much protein should be in "fresh cow rations".

When only one ration is fed to lactating cows that ration is generally formulated based on the higher intakes of cows at mid-lactation and rations containing around 16.5 to 17% protein will meet the protein requirements for milk production. However, studies demonstrate time and again that the low dry matter intake of the fresh cow will dictate that the amount of protein leaving the body as milk will exceed the amount she will obtain from a 17% protein diet. So, in addition to using body muscle to meet energy needs in early lactation she must also use body muscle to meet the protein needs of milk production.

more →

If you are willing to formulate a special diet for fresh cows (first 2 weeks of lactation), should the protein content of that ration be increased? Some early studies which attempted to improve protein balance in the fresh cow by increasing diet protein utilizing soymeal and alfalfa as sources of protein failed to improve protein balance. Unfortunately the protein in these feedstuffs is mostly rumen degradable. The rumen bugs have only a limited capacity to utilize the ammonia freed up during rumen digestion. Once that is exceeded the rest of the rumen degradable protein is wasted and useless to the cow. A few recent studies have suggested that adding rumen undegradable protein or adding certain essential rumen bypass amino acids to the fresh cow ration could benefit the cow and result in higher milk production (Blauwiekel et al., 1997, Khorasani et al., 1996, Armentano et al., 1993, Volden H. 1999, Iwanska et al., 1999, Garcia-Bojalil et al., 1998, McCormick et al., 1999).

However not all studies show a response. In a well done study by Palmquist and Weiss, (1994) blood meal was added to provide a good source of rumen bypass protein to fresh cows with no benefit. However, in this study adding blood meal reduced feed intake. It is therefore critical that the rumen bypass or amino acid supplements not reduce feed intake.

Safe Recommendation

Fresh cow pen rations should have 17 to 18% crude protein with 10.5% of the ration being rumen degradable protein and the rest bypass protein.

Cutting edge recommendation

Increase diet protein in the fresh cow pen to 18 to 19%.

Limit rumen degradable protein to 10.5% of the ration. The rest should be rumen undegradable protein (ie. trying to formulate a 40 to 45% bypass protein ration!) Try to utilize a palatable source of rumen bypass protein such as expellers soybean meal. Animal protein may be utilized, but the amount must be limited because of poor palatability. If available, this may be an opportune time to utilize bypass amino acids in the ration. Generally, in corn based rations, lysine is the amino acid limiting milk production while methionine is more of a problem in barley based rations.

What is the problem with feeding excess protein?

There are certainly environmental issues associated with feeding excess nitrogen to the cow. But it can also be detrimental to the cow in that excess nitrogen absorbed from the diet must be excreted from the body by coupling 2 nitrogen atoms to a carbon atom to form urea. Unfortunately that carbon comes from a carbohydrate source, ie. the cow is burning up glucose to get rid of nitrogen. While not a huge energy cost overall it should be avoided when possible. For example a dry cow getting 17% crude protein when she only needs 12% crude protein will have to consume approximately ¾ pound extra feed to supply the energy needed to get rid of that extra nitrogen.

Strategy — add Niacin

Thought to reduce mobilization of body fat to reduce non-esterified fatty acid in blood and reduce the fat load to the liver. May also stimulate feed intake. Feed at 6 to 12 g/cow/day, at $.06 to .12 cents a day. Research on this is equivocal.

Recommendation

Probably a good investment only if cows are overconditioned and you anticipate fatty liver.

Strategy — Calcium or sodium propionate and propylene glycol added to the ration.

The idea is to provide the cow with propionate (propylene glycol will be metabolized to glucose also) which can be readily converted to glucose by the liver. Oral administration of propionate salts or propylene glycol is unquestionably an effective means of treating ketosis. Sodium propionate should not be used in pre-fresh rations because it will raise diet DCAD and cause milk fever. Calcium propionate (0.25 lb/day) or propylene glycol (300 ml/day) added to pre-fresh rations will cost around $0.20/ day.

Recommendation

While it has been found useful on some farms, my experience is that the gain in energy content is offset by a reduction in dry matter intake. I cannot advise routine use in pre-fresh rations. In the immediate post-partum period addition of these compounds to the diet seems to hold more promise of improving cow performance. Still they remain expensive feed additives.

The best use of calcium propionate and propylene glycol may be as bolus drenches or pastes administered in the day or two immediately around calving time. Bolus dosing results in rapid increases in blood glucose (and subsequently insulin) which reduces blood non-esterified fatty acid levels in the blood. The price of bolus dosing of these compounds can vary from $1 to $12. This will be discussed more in the section on “Pumping cows”.

Strategy — Add Yeast products and Direct Fed Microbials

Idea is to help improve fiber digestion and improve lactic acid utilization in the rumen. Responses can be variable and each company has its own line of products making assessment difficult. Independent research is still required to make a recommendation on their use. Cost will be between $.03 and $.18/day. New variants on this theme are being researched with some promising results (Dann et al., 2000, Rode et al., 1999).

Recommendation

Try one of those with at least some university research behind it. Use it in both the close-up and fresh cow rations and evaluate whether you are seeing a response on your farm. The response in many herds is good. Others have no response.

Strategy — Add Ionophores (lasalocid, monensin)

Ionophores remain illegal for use in close-up and lactating cow rations in the USA.

These antibiotics promote more propionate production in the rumen which means the cow will have more glucose precursors available to her. Research suggests that lactational ketosis is reduced by addition of 200 to 300 mg/day of ionophores to the diet. The benefit for peri-parturient ketosis reduction is not as great. Cost would run about $.02 to .03/day.

Recommendation

I think the U.S. dairy industry has enough image problems without the public wondering why a banned product is being used by some dairymen so I encourage you not to use it until it is legal.

Strategy — Add Choline

A methyl donor which may help minimize build-up of fats within the liver and perhaps increase mobilization of fats out of the liver to other tissues. Costs about $0.10/day.

Recommendation

Research results are not real favorable and I cannot justify their inclusion in pre-fresh or post-partum rations. Perhaps a rumen protected choline source may prove more effective, though preliminary results that I have seen are not real encouraging.

Strategy — Administer Bovine somatotropin (bST)

This is off-label use of bST and cannot be recommended.

Anecdotal evidence is emerging that cows treated with bST prepartum suffer less ketosis. The theory is that bST stimulates glucose production and increases efficiency of fat utilization. Recommendation: Research support for this is still sketchy and as it is off-label use of bST it cannot be recommended.

Treatment of ketosis

Intravenous glucose should remain the backbone of treatment regimens for ketosis. While one-time treatment is often all that is required to successfully treat lactation ketosis (providing diet is adjusted) repeated treatments are usually necessary to treat peri-parturient ketosis. Glucocorticoids (dexamethasone and isoflupredone acetate) given once can be useful. They may stimulate glucose production within the liver. They also may improve appetite. They also can reduce milk production temporarily which improves the energy balance of the cow. Drawbacks — Dexamethasone tends to suppress the immune system, while repeated or large, off-label doses of isoflupredone acetate can upset electrolyte balance in the cow causing very low blood potassium levels and down cows.

Insulin

A few reports suggest that giving cows insulin at the same time they get IV glucose enhances the therapeutic effect of the glucose (Sakai et al., 1993). Probably not a dramatic improvement over the standard therapy and poses a potential threat to the cow by inducing a low blood glucose coma if the wrong type of insulin is used. Only the short acting insulins should be used and it turns out those products have essentially been removed from the market.

Hypocalcemia and Milk Fever

Two years ago at this meeting I presented a paper on preventing hypocalcemia and milk fever. Briefly, hypocalcemia (low blood calcium, not just milk fever) impairs abomasal contractions leading to more displaced abomasum, prevents the teat sphincter from closing after milking allowing bacteria access to the mammary gland, and the stress of hypocalcemia causes secretion of cortisol which further impairs the immune system of the fresh cow. Milk fever and low blood calcium reduce feed intake, increasing the risk of ketosis in the cow as well. We now believe that hypocalcemia occurs because the dairy cow is in an alkaline blood condition, largely because of the high potassium content of the forages utilized in close-up cow

more →

rations. A second major cause of hypocalcemia is inadequate magnesium absorption from the close-up and fresh cow rations leading to low blood magnesium concentration. We believe that when blood magnesium is marginally low it interferes with the body's ability to regulate blood calcium concentration.

Steps to reduce the impact of hypocalcemia in a herd.

Close-up rations

1. The major culprit causing low blood calcium is high potassium coming into the ration from forages. Sodium is also very bad but generally is not very high in forages. FIND or GROW LOW POTASSIUM FORAGES FOR YOUR CLOSE-UP DRY COWS. Limit potash and manure applications. Rely on corn silage as a major feedstuff for close-up cows. It is palatable, and usually low in potassium. Some byproduct feeds should also be considered. I like to use some beet pulp without molasses. DO NOT TRUST POTASSIUM VALUES DETERMINED BY NEAR INFRARED ANALYSIS. Do a wet chemistry analyses.
2. Bring magnesium content of close-up rations to 0.4% using a combination of magnesium sulfate and magnesium oxide. To check to see if your herd is absorbing adequate magnesium — a blood sample taken from a cow within 12 hours after calving should contain at least 2.0 mg magnesium/dl.
3. Feed 40 g phosphorus/day and bring diet calcium to 1% in the close-up ration.
4. The above steps, provided you succeed in limiting potassium to less than 1.6% of the ration, will nearly eliminate milk fever (blood calcium less than 5 mg/dl which causes cows to lose muscle function) in Holstein herds. To get better control of blood calcium it will be necessary to add anions (chloride and sulfate) to the ration of 2nd lactation or greater cows to help acidify the cow's blood and urine before calving. Traditionally this was done by adding anionic salts such as ammonium chloride, calcium chloride, or magnesium sulfate to the ration. Unfortunately these salts often reduced feed intake in cows causing more problems than it was curing. We believe that chloride is a more effective acidifier than sulfate anions. We also have demonstrated that hydrochloric acid is a more effective acidifying agent than the traditional anionic salts and also appears to be more palatable. Several commercial firms are now producing anion supplements that are based on hydrochloric acid. Liquid hydrochloric acid creates fumes that are toxic and corrosive, making it very unsafe to use on dairies.
5. How do you know how much anion to add?

Bringing the diet cation-anion difference, (sodium + potassium) — (chloride + sulfur), expressed as mEq/kg, to zero is a good place to start. After a few days on that ration, evaluate urine pH of the close-up cows (6 to 8 cows is a good sample size). Samples should be caught cleanly and should be mid-stream collections. Urine pH of Holstein cows in the week before calving should be 6.2 to 6.8. The target for Jerseys is 5.8 to 6.3. If above the target pH then more anion is needed in the ration. If urine pH is below 5.8 you have over-acidified the cows and they will crash unless you reduce the anions in the ration! In my opinion, no one should play with anionic salts unless they are willing to monitor urine pH!

When using traditional anionic salts, calcium can be brought into the ration in the form of calcium chloride and magnesium can be brought in as magnesium sulfate. When using hydrochloric acid as my anion source (which I really prefer, a bias I admit as these type of products are based on my own research), I generally use a small amount of magnesium sulfate (50 to 75 g /day) to get a soluble magnesium source into the ration and then use calcium carbonate and magnesium oxide to reach my targets of 1% calcium and 0.4% magnesium.

Heifers do not need anionic salts. They may perform more poorly as a result of reduced feed intake. Again this is more of a problem when the unpalatable anionic salts are used. Ideally heifers would be fed separately from older cows — they perform better on higher protein diets, without anions, and when housed separately do not have to compete with cows for bunkspace. Heifers do respond to the lower potassium diets with less udder edema. When chloride is utilized as an anion source it has a diuretic effect which can decrease udder edema in some herds. However this may not be true when ammonium chloride salts are used.

Cow "Pumping", drenching and pasting

A number of products are available to boost blood calcium and prevent ketosis in cows. Soluble sources of calcium (calcium chloride and calcium propionate) are used to increase blood calcium for about 6 to 10 hours after dosing. Some products incorporate propylene glycol and propionate as energy sources for the fresh cow. These commercial products are handy, and the thicker pastes available in a caulking gun type delivery tend to be easy to administer and relatively safe in that the cow will not breathe them into her lungs very easily.

With the advent of the esophageal pumping systems many producers are trying to combat the decline in feed intake at calving by administering fluids, calcium, and energy supplements to the cow at calving (and sometimes again 24 hours after calving). These home-made cocktails can be cheap $2 to 4/treatment. Very little research has been done to prove the value of these cocktails administered to the fresh cow. Our own research suggests that herds that are on a good plane of nutrition and well-transitioned do not benefit noticeably from any of these treatments. However they are helpful in herds that are suffering from higher rates of metabolic disease. Best results are obtained when the dose is given at calving and again 24 hours after calving.

A cocktail for fresh cows that is to be delivered by esophageal pump should contain:

- a source of calcium, which we think should be calcium propionate. 1.5 pounds is a good dose for Holsteins.
- A source of energy. Again calcium propionate is a good choice. The 1.5 pound dose supplies a good amount of glucose precursors to the cow. One can also add 0.5 litre (½ quart) propylene glycol or 1 quart of glycerol.
- Electrolytes — 100 to 150 g potassium chloride is a good dose to help restore body fluids lost after calving.
- A source of magnesium. 200 g magnesium sulfate works well in our hands.
- Optional for those farms with downer cow problems diagnosed by vet as low blood phosphorus downers. Give cows 200 g monosodium phosphate.
- Other Options — some people choose to add 2 to 3 pounds of finely ground alfalfa meal to the cocktail to get the rumen going.

Mix all or parts of the above recipe in 3 to 5 gallons warm water and pump into the cow. Be aware that the cocktail should be delivered slowly and INTO THE ESOPHAGUS if you are to avoid drowning cows!!

Maintaining the best immune system possible in the fresh cow

The biggest culprit affecting the immune system are the hormone changes associated with calving and the negative energy and protein balances of cows in early lactation. The energy and protein imbalances are not easily fixed and this is why the first part of this paper has spent so much time discussing ways to improve the status of these two nutrients. Deficiencies of any of the micronutrients will result in immune function loss as well. To that end the following guidelines are utilized by me to prevent the short term deficiencies in vitamins and minerals we sometimes see in dairy cattle.

Feed 2000 IU vitamin E/day for the 2 to 3 weeks before calving and the first 2 weeks of lactation. Feed 0.3 mg/kg Selenium, the legal limit. Add trace minerals in adequate amounts. Farms should get in the routine habit of assessing the adequacy of their trace mineral program by harvesting liver from a cow that has died rapidly due to trauma, lightning , etc., or is going to slaughter, once or twice each year and having the liver sample analyzed for trace mineral content. Liver is the best indicator of the status of copper, zinc and manganese supplementation. Blood is generally unreliable.

Dietary iron greater than 800 mg/kg diet and water iron greater than .5-2 mg/kg is too much. We think this causes oxidative stress in animals and reduces immune cell function.

Recently, we have been able to confirm some earlier studies which suggest that retained placenta is a disease that involves the immune system (Gunnink, 1984). We believe that the fetal tissues comprising the placenta have to be recognized by the mothers white blood cells as foreign and "rejected" by the mother in order to get release of the fetal membranes from the mothers uterus at calving. We find that those cows with reduced immune cell function at calving fail to recognize placental tissue and attack it in our assays and that those cows are the cows that go on to develop a retained placenta.

References

Armentano LE, Swain SM, Ducharme GA. 1993. Lactation response to ruminally protected methionine and lysine at two amounts of ruminally available nitrogen. J Dairy Sci. 1993 Oct;76(10):2963-9. Positive effects on milk protein with rp- Lysine and met.

Bertics, S. J., R. R. Grummer, C. Cadorniga-Valino, D. W. LaCount, E. E. Stoddard. 1992. Effect of prepartum dry matter intake on liver triglyceride concentration and early postpartum lactation. J. Dairy Sci. 75:1914.

Blauwiekel R, Xu S, Harrison JH, Loney KA, Riley RE, Calhoun MC. 1997. Effect of whole cottonseed, gossypol, and ruminally protected lysine supplementation on milk yield and composition. J Dairy Sci. 80(7):1358-65

Dann HM, Drackley JK, McCoy GC, Hutjens MF, Garrett JE. Effects of yeast culture (Saccharomyces cerevisiae) on prepartum intake and postpartum intake and milk production of Jersey cows. J Dairy Sci. 2000 Jan;83(1):123-7.

Dirksen, G. U., H. G. Liebich, and E. Mayer. 1985. Adaptive changes of the ruminal mucosa and their functional and clinical significance. Bovine Pract. 20:116.

Garcia-Bojalil CM, Staples CR, Risco CA, Savio JD, Thatcher WW. 1998. Protein degradability and calcium salts of long-chain fatty acids in the diets of lactating dairy cows: productive responses. J Dairy Sci. 81(5):1374-84.

more →

Greenfield RB, Cecava MJ, Johnson TR, Donkin SS. Impact of dietary protein amount and rumen undegradability on intake, peripartum liver triglyceride, plasma metabolites, and milk production in transition dairy cattle. J Dairy Sci. 2000 Apr;83(4):703-10.

Grummer, R. R. 1993. Etiology of lipid related disorders in periparturient dairy cows. J. Dairy Sci. 76:3882.

Gunnink JW. 1984 Pre-partum leucocytic activity and retained placenta. Vet Q. 6(2):52-4.

Holtenius P, Olsson G, Bjorkman C. 1993. Periparturient concentrations of insulin glucagon and ketone bodies in dairy cows fed two different levels of nutrition and varying concentrate/ roughage ratios. Zentralbl Veterinarmed A. 40(2):118-27.

Iwanska S, Strusinska D, Pysera B. 1999. Effect of rumen protected methionine supplementation on early lactational responses of dairy cows fed a grass silage and cereals diet. Acta Vet Hung. 47(2):191-206.

Khorasani GR, De Boer G, Kennelly JJ. 1996. Response of early lactation cows to ruminally undegradable protein in the diet. J Dairy Sci. 79(3):446-53. Linear increase in milk production with incresing RUP in older cows.

Marquardt, J. P., R. L. Horst, and N. A. Jorgensen. 1977. Effect of parity on dry matter intake at parturition in dairy cattle. J. Dairy Sci. 60:929.

McCormick ME, French DD, Brown TF, Cuomo GJ, Chapa AM, Fernandez JM, Beatty JF, Blouin DC. 1999. Crude protein and rumen undergradable protein effects on reproduction and lactation performance of Holstein cows. J Dairy Sci. 82(12):2697-708. More milk with higher bypass, not just CP

Minor DJ, Trower SL, Strang BD, Shaver RD, Grummer RR. 1998. Effects of nonfiber carbohydrate and niacin on periparturient metabolic status and lactation of dairy cows. J Dairy Sci. 81(1):189-200.

Palmquist DL, Weiss WP. 1994. Blood and hydrolyzed feather meals as sources of undegradable protein in high fat diets for cows in early lactation. J Dairy Sci. 77(6):1630-43.

Putnam DE, Varga GA, Dann HM. 1999. Metabolic and production responses to dietary protein and exogenous somatotropin in late gestation dairy cows. J Dairy Sci. 82(5):982-95

Rode LM, Yang WZ, Beauchemin KA. 1999. Fibrolytic enzyme supplements for dairy cows in early lactation. J Dairy Sci. 82(10):2121-6.

Sakai T, Hayakawa T, Hamakawa M, Ogura K, Kubo S. 1993. Therapeutic effects of simultaneous use of glucose and insulin in ketotic dairy cows. J Dairy Sci. 76(1):109-14.

Salfer JA, Linn JG, Otterby DE, Hansen WP, Johnson DG.1995. Early lactation responses of Holstein cows fed a rumen-inert fat prepartum, postpartum, or both. J Dairy Sci. 78(2):368-77.

Santos, JP et al., Effect of different prepartum dietary levels of protein on dairy cows and heifers. J Dairy Science 2001. IN PRESS

Skaar TC, Grummer RR, Dentine MR, Stauffacher RH. 1989. Seasonal effects of prepartum and postpartum fat and niacin feeding on lactation performance and lipid metabolism. J Dairy Sci. 72(8):2028-38.

Studer, V. A., R. R. Grummer, S. J. Bertics, C. K. Reynolds. 1993. Effect of prepartum propylene glycol administration on periparturient fatty liver in dairy cows. J. Dairy Sci. 76:2931.

Vandehaar MJ, Yousif G, Sharma BK, Herdt TH, Emery RS, Allen MS, Liesman JS. 1999. Effect of energy and protein density of prepartum diets on fat and protein metabolism of dairy cattle in the periparturient period J Dairy Sci. 82(6):1282-95.

van Saun RJ, Idleman SC, Sniffen CJ. 1993. Effect of undegradable protein amount fed prepartum on postpartum production in first lactation Holstein cows. J Dairy Sci. 76(1):236-44.

Volden H. 1999. Effects of level of feeding and ruminally undegraded protein on ruminal bacterial protein synthesis, escape of dietary protein, intestinal amino acid profile, and performance of dairy cows. J Anim Sci. 1999 Jul;77(7):1905-18.

Young, J. W., J. J. Veenhuizen, J. K. Drackley, and T. R. Smith. 1990. New insights into lactation ketosis and fatty liver. Page 60 in 1990 Cornell Nutrition Conference, Ithaca, NY.

Factors Influencing Reproductive Efficiency

W.W. THATCHER—Department of Animal Sciences, IFAS, University of Florida, Gainseville, FL 32611
Tel: 352-392-5590 Fax: 352-392-5595 thatcher@dds.ufl.edu

F. MOREIRA—Department of Animal Sciences, IFAS

J. SANTOS—Veterinary Medicine Teaching and Research Center, University of California-Davis

C.R. STAPLES—Department of Animal Sciences, IFAS

C.A. RISCO—Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida

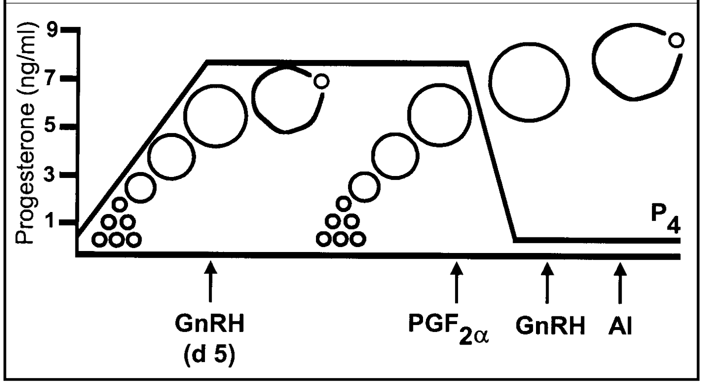
Introduction

The goal of maintaining herd pregnancy rates in current production systems is a challenge due to large herds, confinement systems that are not necessarily conducive to heat detection, cow identification, and the challenge of implementing nutritional management systems that meet individual cow requirements during both the transition and lactation periods that ultimately impact reproductive performance. Under our current production systems, the heat detection rate in high-producing cows is 50% at best. Objectives of this presentation are to examine potential impacts of reproductive technology to increase herd reproductive performance, and to emphasize that use of these new practices has to be founded on an understanding of the technology and its integration with good nutritional management.

Principles and Limitations of Implementing a Timed Insemination Program

At the present time, there are only two drugs available for dairy producers in the USA for use in lactating dairy cows. Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) drugs (e.g., Lutalyse®, Pharmacia Upjohn) can be used effectively to regress the corpus luteum (CL) but are ineffective on CL that are developing on days 1 to 5 of the estrous cycle. The other major drug is the Gonadotrophin Releasing Hormone (GnRH) like drugs (e.g., Cystorelin®, Merial Co.) that release both LH and FSH from the pituitary of the cow. GnRH has the ability to ovulate a mature follicle to form a CL, and induce recruitment of a new follicle. Injection of GnRH recruits development of a new dominant follicle, which will induce the cow to express estrus when $PGF_{2\alpha}$ is injected 7 days later. An additional treatment with GnRH after injection of $PGF_{2\alpha}$ induced a timed ovulation. This procedure is known as the Ovsynch Program because it synchronizes ovulation and permits a timed insemination. Pregnancy rates are normal following a timed insemination (see review by Risco et al., 1998). However, the challenge is to further optimize this system.

Figure 1. Plasma progesterone and follicle dynamics during on Ovsynch program started on day 5 of the estrous cycle.



The Ovsynch protocol is idealized in Figure 1. In this example, concentrations of progesterone are monitored to document presence of a CL (the CL produces progesterone), and an idealized description of follicle development is presented. In this example, the cow is injected with GnRH (Monday, 5:00 PM) on day 5 of the estrous cycle. At this time, the cow has a dominant and healthy follicle that ovulates in response to the GnRH-induced release of LH; furthermore, the increase in FSH induced by the GnRH injection induces recruitment of a new pool of follicles in approximately 2 days (day 7) and one of the follicles is selected to become the dominant follicle. On day 12 of the cycle (7 days after the injection of GnRH), $PGF_{2\alpha}$ is injected (e.g., Monday, 5:00 PM) to regress both the original CL present at day 5 of the cycle and a newly formed CL that was induced by the injection of GnRH on day 5 of the cycle. The decrease in progesterone associated with regression of the CL accelerates growth of the newly recruited dominant follicle and a second injection of GnRH is made 2 days after the injection of $PGF_{2\alpha}$ (e.g., Wednesday, 5:00 PM). The second injection of GnRH induces ovulation 24 to 32 hours later. Knowing that ovulation will occur at this time, the timed insemination is given at approximately 16 hours after the injection of GnRH (e.g., 9:00 AM on Thursday). This permits sufficient time for sperm to develop the capacity to fertilize the egg so that when it ovulates, a fertile population of sperm is present to

more ⟶

carry out fertilization or initiate a pregnancy. This is an idealized scenario and the timing of injections is considered critical to the success of the program. If an interval of less then 7 days is used between GnRH and $PGF_{2\alpha}$ injection, the ability to effectively regress a newly developed CL is reduced. If the second injection of GnRH is delayed to longer than 48 hours or 2 days, then more cows are detected in heat prior to injection of GnRH, cows become asynchronized, and the timing of insemination is not correct. With our present availability of drugs for lactating dairy cows, it is essential that producers not alter the protocol. One commonly asked question is, can cows be inseminated at the time of the GnRH injection or at 24 hours after the injection of GnRH to make the insemination process more convenient? Pregnancy rates will be lowered at the 24 hour insemination, and optimal insemination times appear to be between 12 to 18 hours after the GnRH injection.

Success of the program is dependent on whether lactating dairy cows are cycling as well as stage of the estrous cycle at the time the Ovsynch protocol is initiated in cycling cows. Clearly, if cows in the group are not cycling then it is a given that pregnancy rates of the group will be somewhat less even though the Ovsynch protocol itself may induce some cows to begin to cycle and perhaps conceive. If a cow initiates the program at day 15 of the estrous cycle when a normal second wave follicle is under development. This follicle may or may not ovulate depending upon how mature it is. In many instances the second wave follicle is too small to ovulate and a new CL does not develop. At 2 to 4 days after the injection of GnRH, the cow spontaneously induces regression of the CL by releasing $PGF_{2\alpha}$ from the uterus. Thus, at the time of the $PGF_{2\alpha}$ injection given 7 days after the GnRH injection, the cow has already regressed the CL and may even be in heat. Such cows will be asynchronized in that they will ovulate prematurely and, if we follow the protocol, the insemination is made too late and the cow does not conceive. A second problematic stage of the cycle is in the early phases of the estrous cycle (e.g., day 2). In this scenario, the cow already has been in heat, ovulated and is recruiting a new dominant follicle. This is a small follicle and injection of GnRH on day 2 does not induce a new dominant follicle. As a consequence, at the second GnRH injection, the dominant follicle is considered aged and has expressed dominance for 5 days or longer. Follicles that have periods of dominance longer than 5 days or cows that initiate the Ovsynch program in early stages of the estrous cycle are less fertile. Follicles may ovulate but oocytes are less fertile, or some cows may fail to ovulate their follicle in response to GnRH. We can project what the success rate of the Ovsynch program will be in an idealized situation in which all cows are cycling and are at random stages of the estrous cycle when the program is initiated. Assuming a 20-day estrous cycle, we would expect 5% of the cows to be at each day of the estrous cycle. Thus, for a group of 100 cows, the percent of cows in early stages of the cycle (problematic), early diestrus, late diestrus (problematic) and proestrus have expected pregnancy rates of 20 to 50% at various stages for the reasons described above such that an overall pregnancy rate of 36% is anticipated. However, it is possible to manipulate the estrous cycle of cows such that they are in the ideal stage of the estrous cycle (i.e., days 5 to 10) when the Ovsynch program is initiated. One idealized scenario is to inject all cows twice with $PGF_{2\alpha}$ at an interval of 14 days and to initiate the first GnRH injection of the Ovsynch program on day 12 after the second injection of $PGF_{2\alpha}$. If all cows were cycling, we would expect 90% of the cows to be in the ideal stage of the estrous cycle, between 5 to 10 days, when the Ovsynch program is initiated 12 days after the second injection of $PGF_{2\alpha}$. With this scenario, an expected pregnancy rate to the Ovsynch program is 48%. Such a proposed treatment program prior to implementation of the Ovsynch program is called pre-synchronization with a standard protocol that is practiced in the industry. Effectiveness of such a program will be described later. However, it is imperative that the producer and veterinarian have a thorough understanding of the principles of ovarian manipulation in order to understand how the system functions when they make herd management decisions as to how to implement the program.

Optimization of Reproductive Performance with Pre-Synchronization Prior to the Ovsynch Program and Use of Bovine Somatotropin

A field trial was conducted with the objectives of: determining whether pre-synchronization of lactating cows prior to the initiation of the Ovsynch program would improve pregnancy rates; to verify prior results indicating that bST increased pregnancy rates to the Ovsynch program; to determine whether the possible beneficial effect of bST on pregnancy rates occurred prior to or after timed artificial insemination. Measuring the impact of any therapy or management system on pregnancy rates is a challenge because the experimental response is pregnancy rate in which a considerable number of cows are needed to detect potential differences, and the investigator has to cope with numerous management factors. At least with the Ovsynch program, the management errors associated with heat detection are eliminated and the precise timing of insemination can be controlled tightly. Of concern to dairy producers is whether Bovine Somatotropin (bST®; Posilac®, Monsanto, St. Louis, MO; 500 mg) treatment can be initiated in the ninth week of lactation and be continued without compromising reproductive performance. Our previous research findings indicated that first service pregnancy rates to the Ovsynch protocol were increased when cows received bST treatment at day 63 postpartum concurrently with first injection of GnRH given as part of the Ovsynch program. An additional challenge is to document whether pregnancy rates to the Ovsynch program can be improved with prior implementation of a pre-synchronization program.

Experimental design and treatment of lactating dairy cows:

A total of 543 cows were assigned randomly to the experiment in which half of the cows received the pre-synchronization program. The pre-synchronization program was initiated on a weekly basis such that cows 34 to 40 days postpartum (37±3 days) received an injection of $PGF_{2\alpha}$ (Lutalyse, Pharmacia-Upjohn Co.; 25 mg; i.m.) and this was followed 14 days later (51±3 days) with a second $PGF_{2\alpha}$ injection. In contrast, control cows (no pre-synchronization) did not receive the two injections of $PGF_{2\alpha}$. The rationale for the pre-synchronization program is described above. On day 63±3 days, the first injection of GnRH of the Ovsynch program was initiated, and this was 12 days after the second injection of $PGF_{2\alpha}$ of the pre-synchronization program. The pre-synchronization program will place cows between days 5 to 10 of the cycle at the time of the GnRH injection depending upon what day they expressed estrus after the second injection of $PGF_{2\alpha}$. Days 5 to 10 of the cycle are considered as an optimal time to begin the Ovsynch program as discussed above. On day 7 following the first GnRH injection (70±3 days postpartum), all cows received an injection of $PGF_{2\alpha}$ and the preovulatory injection of GnRH on day 72±3 days postpartum. All cows were time inseminated at day 73±3 days postpartum. A series of blood samples were collected on days 51, 63, 70 72 and 79. Relative comparisons of progesterone concentrations in plasma allow us to determine if cows are cycling (samples on days 51 and 63), stage of the cycle at the beginning of the Ovsynch program (samples on days 63 and 70), whether CL regression was successfully induced (samples on days 70 and 72) and whether cows had a synchronized ovulation (samples on days 72 and 79). All cows were examined by ultrasonography for pregnancy on day 32 after timed insemination and pregnant cows re-examined for pregnancy by rectal palpation on day 74 after timed insemination. This allowed us to characterize fetal losses between 32 and 74 days of pregnancy. All cows diagnosed open at day 32 after the first timed insemination were injected with GnRH and the Ovsynch program repeated with second insemination occurring at 115 days of lactation. The other factors tested in this experiment are the initiation of bST treatment at day 63 (time of the GnRH injection of the Ovsynch program), day 73 (time of artificial insemination as part of the Ovsynch program) or bST-control in which first injection of bST was not given until 147 days of lactation (well after first and second services).

Impact of Anestrous Cows:

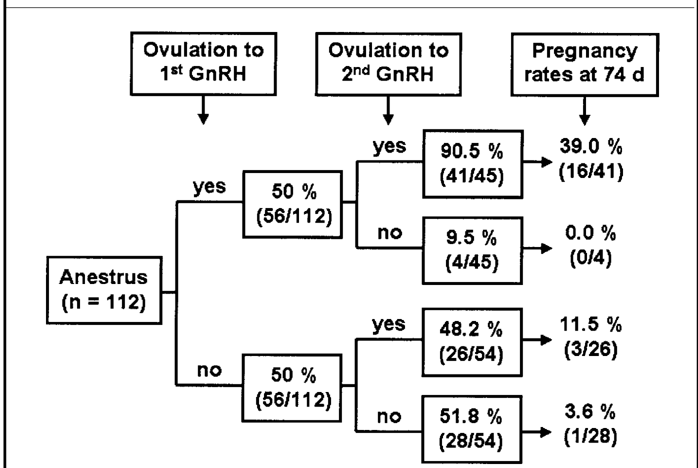
With our ability to measure plasma progesterone in two plasma samples collected 12 days apart (on days 51 and 63 postpartum), it is possible to identify exactly what cows are anestrus when the Ovsynch program is initiated. If cows had progesterone ≤1ng/ml in both samples they were considered to be anestrus. It was important to determine which cows are cycling since pre-synchronization treatment effect would not be evaluated properly in cows that are not cycling. Furthermore, this assessment of anestrous status will allow us to document the frequency of this condition and its impact on reproductive performance of the herd. For the assessment of anestrous status, 499 cows had blood samples collected on both days 51 and 63 postpartum. It is interesting that overall 23.4% of the cows were anestrus or had not started to cycle by 63 days postpartum. Not surprising is the observation that the frequency of anestrus was greater for primiparous or first-calf heifers (35.6%) than multiparous cows (16.9%). The occurrence of anestrus decreased as body condition scores recorded at initiation of the Ovsynch improved. Body condition scores accounted for 7.8% of the variation in occurrence of anestrus. Thus, body condition score is not an absolute predictor of what cows are cycling. Some cows with body condition scores of 3.0 were anestrus. As anticipated, anestrous cows did not perform as well as cyclic cows in terms of pregnancy rates to the first-service Ovsynch protocol. Pregnancy rate at 74 days after insemination was only 22.4% for anestrous cows, which was lower than the 41.7% pregnancy rate at 74 days after insemination for cyclic cows. Postpartum management of lactating dairy cows is of extreme importance and will greatly affect reproductive performance. Efforts to maximize cow health, comfort, and nutritional status following parturition (e.g., enhance dry matter intake) will be reflected later in the lactation in terms of a higher incidence of cycling cows and improved reproductive performance.

In the present experiment, an interesting pattern of ovarian responses (induced ovulation pattern) and preg-

more →

nancy rates for anestrous cows were documented to the Ovsynch protocol (Figure 2). Anestrous cows (n = 112) were classified according to P_4 concentrations. Results indicated that 56 anestrous cows (50.0%) ovulated to the first injection of GnRH of the TAI protocol, as indicated by P_4 concentrations greater than 2.5 ng/ml 7 d later (i.e., LOW-HIGH cows), whereas 56 cows (50.0%) failed to respond to the first GnRH injection and were classified as LOW-LOW. When cows were classified as having either complete or incomplete CL regression based on a 2.0 ng/ml plasma P4 concentration at the time of the second GnRH injection (48 hours after injection of $PGF_{2\alpha}$), only 3.6% (2/55) of LOW-HIGH cows had incomplete CL regression. Neither of the two cows classified as having incomplete CL regression were diagnosed pregnant at 74 days after insemination.

Figure 2. Ovulatory and pregnancy responses of anestrous cows to Ovsynch protocol

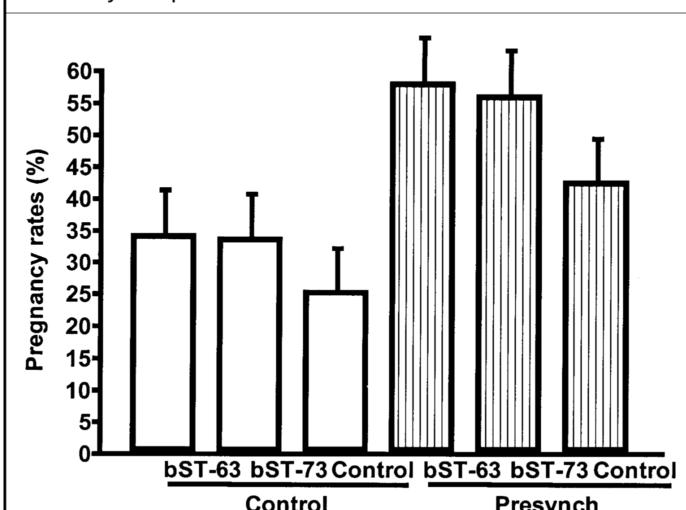


Among LOW-HIGH anestrous cows, which completely regressed their CL upon injection of $PGF_{2\alpha}$ (n = 45), 90.5% were classified as ovulating to the second injection of GnRH in the TAI protocol, whereas ovulation rate to the second GnRH injection for LOW-LOW cows (n = 54) was 48.2% (P<0.01). Pregnancy rates for cows ovulating to the second GnRH were higher (P<0.01) for LOW-HIGH cows than for LOW-LOW cows at 74 days after TAI (39.0%>11.5%). Only 9.5% of LOW-HIGH cows, which had complete CL regression (4/45) failed to ovulate to the second injection of GnRH and none of those cows conceived to the timed insemination. Among LOW-LOW cows, 51.8% (28/54) were classified as having failed to respond to the second GnRH injection. Among the 28 cows not ovulating to the second GnRH injection of the TAI protocol, only one cow conceived to the timed insemination. Overall, the TAI protocol was able to induce cyclicity in 74.5% (82/110) of anestrous cows, based upon the number of anestrous cows which were classified as ovulating to either the first and/or second injection of GnRH. Pregnancy rates for cows that ovulated to both first and second GnRH injections were enhanced compared to pregnancy rates of cows, which ovulated only after the second GnRH injection. Cows ovulating to both GnRH injections would have had a greater exposure to P_4 before insemination. Based on present results, pre-exposure to P_4 may be limited to a period of a few days (i.e., about 5 days of plasma P_4 greater than 1.0 ng/ml) to achieve acceptable pregnancy rates following a timed insemination in anestrous cows. Furthermore, approximately 75% percent of anestrous cows ovulated to at least one of the two GnRH injections of the TAI protocol. Since an ovulation rate of 90.5 % occurred after the second GnRH (if anestrous cows also ovulated to the first GnRH) and pregnancy rate (39.6%) was as high as pregnancy rate of cyclic cows (41.7%), the TAI protocol may stimulate anestrous cows to cycle earlier. The fact that pregnancy rates to the second service for anestrous cows were similar to those obtained for cyclic cows, constitutes further evidence for a beneficial effect of the Ovsynch protocol when used on anestrous cows in response to two GnRH injections over a 9 day period.

Reproductive performance of Cyclic Cows:

Since anestrus had such a highly significant affect on pregnancy rates, reproductive performance was examined only in cyclic cows. First-service pregnancy rates to the Ovsynch protocol were affected by both bST pre-synchronization and bST treatments (Figure 3). Cows initiating bST treatment at 63 or at 73 days postpartum had increased pregnancy rates compared to controls among cows not pre-synchronized and also among cows pre-synchronized. The fact that a similar stimulation in pregnancy rates was

Figure 3. First-service pregnancy rates diagnosed at day 74 after insemination for cyclic cows (n = 375) following the Ovsynch protocol.



observed in cows treated with bST at 63 (day of first GnRH injection) and at 73 days postpartum (day of timed insemination) indicates that bST is probably enhancing embryonic development and survival following insemination and also may be having effects on the reproductive tract. Concentrations of bST are elevated throughout the 14-day period between injections such that bST injection at the time of the second GnRH injection will still induce elevated concentrations of bST 14 days later during the period of embryo development and this is followed by continued bST injections at 14 day intervals.

Increased pregnancy rates at 74 days after insemination were detected when cows were pre-synchronized (Figure 3; vertical bars; 52.3%) compared to cows not pre-synchronized (white bars; 31.1%). An additional comparison is the effect of pre-synchronization in the two groups that did not receive bST in which pre-synchronized cows had a 42.6% pregnancy rate compared to 25.3% for the control group (Figure 3). This difference associated with pre-synchronization (17.3%) approximates the predicted differences (12.0%) discussed above. The reason for increased pregnancy rates to the Ovsynch protocol in cows pre-synchronized was related to the frequency of cows initiating the synchronization protocol at favorable stages of the estrous cycle. As indicated above, it was hypothesized that pregnancy rates to the Ovsynch protocol would be increased if cows received the first GnRH injection between days 5 to 10 of the cycle, and that pre-synchronization would synchronize approximately 90% of the cycling cows such that these cows would be between days 5 and 10 of the cycle when the Ovsynch protocol was initiated. By collecting blood samples at the first injection of GnRH (at day 63) and again when $PGF_{2\alpha}$ was injected (at day 73), we were able to indirectly identify cows that initiated the synchronization program at the early luteal phases of the estrous cycle (e.g., between days 5 to 10 of the cycle). Cows with high plasma progesterone (> 1.0 ng/ml) at both day 63 and day 73 (i.e., HIGH-HIGH cows) probably initiated the Ovsynch protocol at the optimal stage of the estrous cycle. Results from the frequency of cows classified as HIGH-HIGH indicated that approximately 87.4% of pre-synchronized cows were classified as HIGH-HIGH versus only 71.7% of cows not pre-synchronized were HIGH-HIGH cows. Therefore, we were successful in programming the cows to be in the optimal stage of the cycle to begin the Ovsynch program. As a consequence, pre-synchronization increased first-service pregnancy rates by enhancing the rate of synchronized ovulations and this increased the percentage of inseminated cows to respond to bST treatments.

Results from our field experiments indicate for the second time that bST increased first-service pregnancy rates to the Ovsynch protocol. Such an observation impels us to review previous reports of decreased reproductive performance in cows receiving bST and find explanations for such a discrepancy. It has been reported that use of bST may reduce the rate of estrous detection that may reduce reproductive performance of lactating cows. However, when estrous detection was eliminated though the use of the Ovsynch protocol, the inefficiency of heat detection possibly associated with bST may have been eliminated. We surely found no evidence that bST had any detrimental effect on reproductive performance in our studies and dairy producers should not be inhibited to begin a bST program in concert with an Ovsynch program. Indeed, pregnancy rates were increased at first service to timed inseminations as part of an Ovsynch program.

Impact of Body Condition Score on Pregnancy Rates to the Ovsynch Program

There is the perception that pregnancy rates are lower in lactating dairy cows with poor body condition. Retrospective analyses of our field experiments indicate that as body condition score increases pregnancy rate increases to the Ovsynch program. We recently completed an experiment that examined pregnancy rates of the Ovsynch program in cows that had Body Condition Scores (BCS) of <2.5 versus ≥2.5 (Moreira et al., 2000c). Pregnancy rates at days 27 and 45 after insemination were 18.1% and 11.1% for cows with a low BCS (81 cows) versus higher rates of 33.8% and 25.6% for cows with BCS ≥2.5. The proportion of cows conceiving to the first synchronized service was lower for the cows in low body condition, and this was a temporary decrease since rates of cumulative pregnancies during the ensuing 120 days postpartum were similar). This demonstrates the importance of optimizing fertility to the first service. Utilizing the differences in pregnancy rates in cows with body condition scores <2.5 versus ≥2.5, dynamic modeling was used to estimate net revenue per cow per year when considering what percentage of the herd had a low BCS of <2.5. The difference in net revenue was $10.33 per cow per year as to whether 10% versus 30% of the herd had low body condition scores at the time the Ovsynch program was initiated. Thus, it is essential that producers try to nutritionally manage the dynamics of body condition postpartum to optimize fertility rates. Why does a low body condition score result in a lower pregnancy rate to the Ovsynch program? Is the rate of anestrus (non-cycling cows) responsible for the poor pregnancy rates or are pregnancy

more ⟶

rates in cows cycling reduced due to defective eggs and/or the reproductive tract is unable to maintain a pregnancy? The encouraging result presented above in which anestrous cows ovulating twice within a 9 day period to the Ovsynch protocol had a normal pregnancy rate suggests a major constraint in anestrous cows is a failure of ovulation.

Integrated Nutritional and Reproductive Management

Successful management of lactating dairy cows needs to integrate the disciplines of reproduction and nutrition with standard postpartum herd health programs to optimize both milk and reproductive performance. The achievement of high energy intake, to bring cows out of a decreasing negative energy status as early as possible postpartum, is critical for both productivity responses. In the majority of lactating dairy cows, development of dominant follicles on the ovary occurs very early in the postpartum period. However, functional competence of these follicles varies in association with concentrations of IGF-1 in plasma and energy status in which the majority of these follicles emerged after the nadir in energy status. The ability of early dominant follicles to either ovulate, undergo turnover or to form follicular cysts influences length of the postpartum anovulatory period. Both regulation of IGF-1 and preovulatory surges of LH appear to be critical to the efficiency of this process. Subsequent timing of ovarian cycles, measured by formation of CL, also is related to postpartum concentrations of IGF-1 and energy status. It is clear that the anestrous condition impacts reproductive efficiency to timed insemination systems such as Ovsynch and that nutritional programs such as fat feeding may reduce the incidence of anestrus and thus benefit herd reproductive management.

Exciting strategies have developed to integrate nutritional and reproductive management. Fats (concentrated energy sources) can be incorporated into the diet of cows in early postpartum in order to try to minimize the differences between energy intake and energy output. Absorption of total fatty acids by the ruminant is linear up to 1200 g/day, which is about 6% of DMI. Typical nonfat-supplemented diets contain about 2 to 3% fat. Therefore it appears that there is significant room to increase the use of fat in diets without loss of efficiency. Because fat is an energy dense nutrient, it is natural to suppose that supplemental fat would improve energy status of the cow. However, this has not been the result in many cases. Oftentimes energy status is not affected by feeding fat because either DMI is depressed or milk production is increased. Nevertheless, feeding supplemental fat has proven effective in improving reproductive performance of lactating dairy cows. Conception rates were improved by feeding prilled fat or calcium salts of long chain fatty acids.

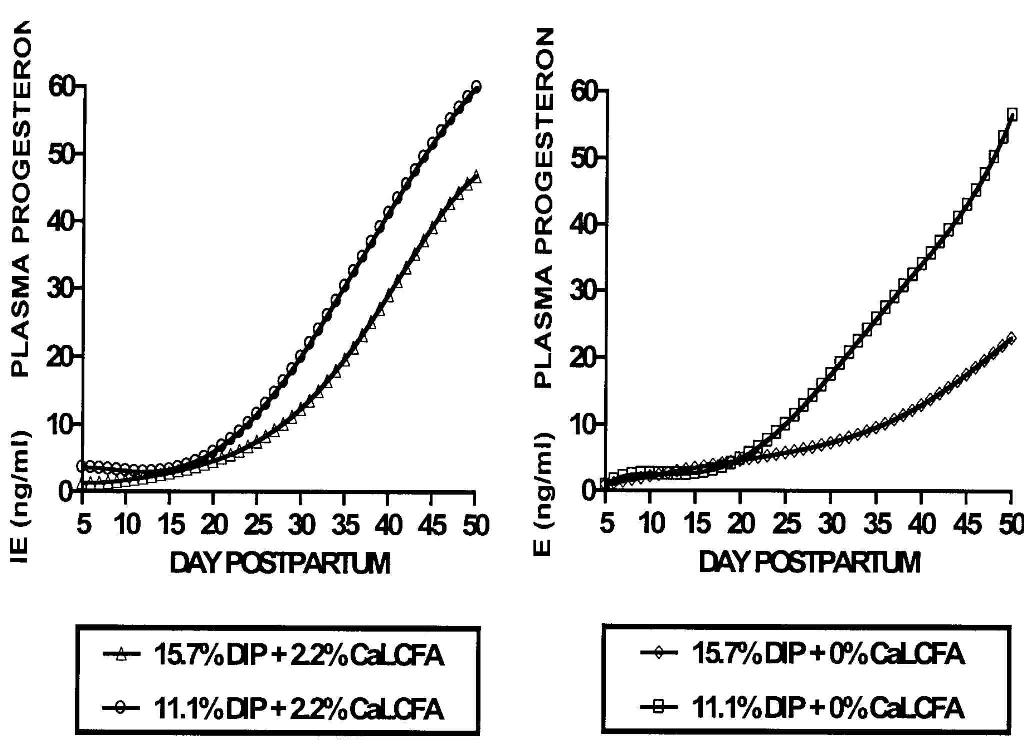
The detrimental effects of feeding a high degaradable intake protein (DIP) diet on reproduction can be alleviated by supplemental fat feeding (CaLCFA). One possibility of how high protein feeding may adversely affect reproductive performance is the increased energy costs to the animal for detoxification of ammonia resulting in a "weakening" of the cow's energy state. This energy cost is likely to push early postpartum cows even further into negative or less positive energy states, thus delaying return to normal ovarian activity. To test the effects of intake of energy and DIP on reproductive performance of lactating dairy cows, 45 cows were assigned at calving to 20% CP diets containing either 15.7% or 11.1% DIP and 0 or 2.2% CaLCFA (Megalac®). Crude protein intake was 1100 g greater than required for milk produced. Treatments continued through 120 days in milk. Cows fed the highly degradable protein diets had greater BUN values (22.0 vs. 17.3 mg%). Based upon progesterone concentrations of blood samples taken three times per week, cows fed the 15.7% DIP diets experienced more days to first luteal phase postpartum than cows fed other diets (39 vs. 25 days). All cows on experiment were synchronized to estrus between days 50 and 57. Cows not cycling prior to synchronization were assigned 50 days to first luteal activity. If cows had not been synchronized, the number of days to first luteal activity likely would have been even greater for cows fed the 15.7% DIP diets. Four out of 10 cows fed 15.7% DIP diet without CaLCFA were anestrus at synchronization compared with only three out of 35 cows fed the other dietary treatments. These prolonged days to restoration of ovarian activity and the anestrus condition were matched with greater loss of body weight and body condition by these cows. Cows fed 15.7% DIP diets lost more body weight and for a longer period of time compared with cows fed 11.1% DIP diets. The absence of CaLCFA resulted in a 10 kg greater loss in BW of cows fed 15.7% DIP diets. In addition, body condition loss was greater and more prolonged by cows fed the CaLCFA-free, 15.7% DIP diet.

The additional energy costs of detoxifying ammonia from highly degradable dietary protein possibly led to a greater reliance on body energy stores for milk production. This resulted in a more severe energy state that delayed ovarian activity. By including CaLCFA in the diet, the energy shortage was somewhat alleviated, allowing cows to rely more on feed energy and less on body reserves for milk production. Days to first estrous was reduced by 6 days when CaLCFA was fed with 15.7% DIP diets. Accumulated progesterone concentrations throughout the postpartum period are depicted in Figure 4. The detrimental effect of 15.7% DIP diets was alleviated markedly by supplementation of CaLCFA, but supplementation of CaLCFA to the 11.1% diet was not stimulatory. Results indicate that dynamics of postpartum ovarian activity can be suppressed indirectly by feeding of high DIP (15.7%), but this adverse effect can be alleviated partially by feeding of CaLCFA. Also of interest was the observation that pregnancy rate by 120 days postpartum was increased from 52.3% to 86.4% when CaLCFA was supplemented and evaluated as a main effect across diets. This study demonstrated the specific benefit of feeding by-pass fat to increase ovarian cycles and reduce the incidence of anestrus in the postpartum period which is a major impediment to herd reproductive efficiency as described above.

Another example of integrated nutritional and reproductive management programs is a study involving 186 cows that evaluated effects of whole cotton seed (WCS) feeding and low doses of bST on reproduction during the postpartum period of lactating dairy cows. Diets were total mixed rations (TMRs) formulated according to the requirements for lactating Holstein cows. Within 24 hours after calving, cows received one of two experimental diets ad libitum. All cows that were on bST treatment received 208 mg (0.5 ml) of bST (Posilac®), Protiva Co., St. Louis, MO) subcutaneously every 2 weeks starting within 7 days of calving. This dose of bST is 50% of the standard commercial dose rate. Since increases in IGF-1 appear to be stimulatory to follicle and ovarian development as described above, we were interested in administering bST at a low dose to evaluate ovarian activity and subsequent fertility. Healthy cows were assigned randomly to one of four treatments (T). Treatments were WCS diet group (15% of DM) with (+WCS +bST; T3) or without (+WCS –bST; T1) bST and no WCS diet groups with (–W CS +bST; T2) or without bST (–W CS -bST; T0). Although early ovarian activity may be associated with subsequent increases in fertility, we feel that it is important not to sustain a long period of progesterone exposure during the period of uterine involution. Consequently, all cows received $PGF_{2\alpha}$ (25 mg im , Lutalyse®), Pharmacia-Upjohn Co., MI) at 30±3 d postpartum to regress any CL and reduce progesterone concentrations. This stimulates turnover of CL and ovarian follicles, permits clearance of uterine contents, and reduces exposure to progesterone that may inhibit uterine defense mechanisms and predispose the uterus to infection. Blood samples were collected three times a week from calving until initiation of the Ovsynch protocol. The Ovsynch protocol was initiated on 65±3 days postpartum, and cows were timed inseminated at day 75. On day 111 postpartum (36 days after insemination) cows were diagnosed for pregnancy by ultrasound examination. If cows were not pregnant the Ovsynch protocol was repeated and second insemination was made at day 121 postpartum. Thus all cows received their first insemination on day 75 postpartum and both inseminations required no heat detection. Following second service, cows were watched for heats for subsequent services.

Feeding WCS diets stimulated ovarian activity based upon a greater accumulation of progesterone during the postpartum period up to 62 days

Figure 4. Regression curves of accumulated plasma progesterone concentrations from lactating Holstein cows fed diets containing 11.1% and 15.7% degradble intake protein and/or 0% and 2.2% CaLCFA.



more ⟶

postpartum when the Ovsynch program was initiated. The increase in accumulated progesterone associated with WCS diets was associated with an earlier occurrence of a progesterone rise following $PGF_{2\alpha}$ injection on day 30 (39.2<43.5 days), and a higher peak progesterone elevation during the rise after $PGF_{2\alpha}$ injection (11.4>9.25 ng/ml). The increase in ovarian activity as measured by accumulated progesterone concentrations may have been associated with higher plasma concentrations of HDL-cholesterol in the WCS treatment group (107.4>83.5 mg/100ml). Cholesterol is essential for the synthesis of progesterone. Although ovarian activity differed significantly between diets with and without WCS, pregnancy rates did not differ following timed inseminations to either the first, second, or accumulative pregnancy rate to first and second service (Table 1). Pregnancy responses demonstrate the advantage of integrating a reproductive management program with nutritional management. Although the diet without WCS was associated with a lower level of ovarian activity, implementation of the Ovsynch protocol stimulated and controlled ovarian activity such that there was no dietary treatment effect on fertility. Indeed the Ovsynch protocol permitted a very precise first service for all cows, and the re-synchronized Ovsynch procedure for cows that did not conceive to first service guaranteed a second service within a 46 day period for all open cows.

Our field experiments with Ovsynch indicate a lower fertility rate in cows identified to be anestrus and in lower BCS. With our ability to guarantee that all cows can be inseminated precisely at a designated time postpartum with the use of Ovsynch , producers can lengthen the voluntary waiting period, since the time of first insemination is controlled more precisely. If all cows are cycling, a normal program of inseminating at detected estrus, assuming a 50% estrus detection rate, would have to be started at day 40 to ensure that mean time of insemination will be day 70 (range 40 to 100 days). However, an Ovsynch program permits all inseminations to be made at 70±3 days if implemented on a weekly basis. Furthermore, an assessment of pregnancy rates for cows that underwent Ovsynch between 76 to 100 days postpartum was greater than cows that received Ovsynch between 50 to 75 days (47% vs. 35%). Thus, it may be an advantage to delay first inseminations until a period of greater fertility, using the Ovsynch program to ensure that there will be no net loss in time to first service by controlling the time of insemination for all cows.

Improved Embryo Survival

Early embryonic losses have been documented in numerous studies in cattle. Factors such as dairy versus beef cattle, fertile versus repeat breeder cows, insemination to spontaneous versus synchronized estrus, season of year relative to heat stress conditions, and other factors such as parity, nutrition and disease contribute to the time of embryonic losses. It is clear that infertile cows (e.g., repeat breeder cows) or groups of animals in which the proportion of infertile cows is high experience appreciable embryonic losses (~30%) by day 7 of pregnancy. In more fertile groups of animals, embryonic losses (~40%) occur gradually between days 8 to 17 of gestation. When the transfer of morphologically normal embryos eliminated fertilization failure and early embryonic losses, 24.4% of recipient cows terminated their pregnancies between day 17 and 24. The rate of late embryonic mortality after day 27 in a fertile group of dairy heifers was estimated to be 10.6% and this agrees with an estimate of 10.5% in lactating dairy cows that were pregnant at 28 days and lost a pregnancy by day 42. Collectively, these reports indicate differential timing of embryonic losses and a failure of different mechanisms to sustain embryo development. Several investigators demonstrated lower progesterone concentrations in plasma of cows that failed to conceive and this was evident as early as day 6 after insemination. Development of the embryo is related to concentrations of progesterone and ability of the conceptus to secrete the antiluteolytic hormone, interferon-ϑ. In fact, exogenous progesterone stimulated embryo development (see review, Thatcher et al., 1994). Studies to supplement progesterone during the luteal phase after insemination (i.e., after day 5) with insertion of intravaginal progesterone releasing

Table 1. Least square means for pregnancy rates at day 45 after timed artificial insemination (TAI) for cows fed diets of 0 or 15% WCS and injected with 0 or 208 mg of bST at 14 days interval.

Treatment	Total cows	1st TAI (%)	2nd TAI (%)	1st and 2nd TAI (%)
0% WCS; no bST	50	37.1	23.6	51.3
15% WCS; no bST	45	33.6	26.4	51.8
0% WCS; +bST	43	27.1	35.8	51.1
15% WCS; +bST	48	27.3	26.2	46.8

devices for 6 to 12 days have had inconsistent effects on pregnancy rates. An alternative strategy to increase progesterone concentrations is to induce an accessory CL by ovulating the dominant follicle at day 5 of the estrous cycle with an injection of hCG (e.g., 3,300 IU, i.m.). The hCG induced CL elevates progesterone concentrations to a greater degree than observed with the use of GnRH.

A study was designed to determine the effects of hCG (3,300 IU i.m.) administered on d 5 after AI on accessory CL formation, plasma progesterone concentration, conception rate, and pregnancy loss in high producing Holstein dairy cows. Following synchronization of estrus (GnRH followed 7 d later by $PGF_{2\alpha}$) and AI at detected estrus, 406 cows were injected with either hCG or saline on d 5 after AI (203/treatment). Blood sampling and ultrasonography of ovaries were conducted once between days 11 and 16 after AI. Pregnancy diagnosis was performed by ultrasonography on d 28 and by rectal palpation on days 45 and 90 after AI. Treatment with hCG on d 5 induced formation of one or more accessory CL in 86.2% of the hCG-treated cows compared with 23.2% in the controls. Differences in progesterone concentrations between hCG and control cows were +6.3 ng/ml for primiparous cows and +3.1 ng/ml for multiparous cows. Accessory CL increased progesterone concentration in hCG-treated cows but not in controls. Treatment with hCG increased conception rates on days 28 (45.8>38.7%), 45 (40.4>36.3%), and 90 (38.4>31.9%) after AI. Pregnancy losses between days 28 and 45, 45 and 90, and 28 and 90 were similar between the two groups. Progesterone concentration and number of CL after AI affected conception rate such that pregnant cows had higher progesterone concentrations and a greater frequency of accessory CL. Body condition score at AI and milk yield affected conception rate, but no interaction between these variables and treatment were observed. However, hCG improved conception rate in cows loosing BCS between AI and day 28 after AI. Treatment with 3,300 IU of hCG on day 5 after AI induces the formation of one or more accessory CL, increases plasma progesterone concentrations, and improves conception rate of high producing dairy cows.

Multiple mechanisms may contribute to the increase in conception rate in response to hCG. Injection of hCG at day 5 after estrus increased progesterone concentrations and induced a three wave follicular cycle. In all hCG-treated heifers, the dominant follicle of the third follicular wave did not reach 9 to 10 mm in size until approximately day 20. Thus the potential estrogenic follicle for hCG treated heifers would not occur until d 20 versus day 14 in control heifers with a two-wave follicular cycle. Therefore, hCG treatment would decrease the estrogenic environment during the period of pregnancy recognition. Injection of hCG on day 7 has increased conception rates in lactating dairy cows with a slight increase in plasma progesterone concentrations. Systems of progesterone delivery are needed that increase substantially both the rate of progesterone rise and absolute luteal phase concentrations of progesterone after insemination. Such systems need to deliver progesterone in an amount equivalent to what the normal CL can produce at various physiological stages.

Selected Readings:

Beam, S.W. and W.R. Butler. 1997. Energy balance, and ovarian follicle development prior to the first ovulation postpartum in dairy cows receiving three levels of dietary fat. Biol. Reprod. 56: 133.

Garcia-Bojalil, C.M., C.R. Staples, C.A. Risco, J.D. Savio and W.W. Thatcher. 1998. Protein degradability and calcium salts of long-chain fatty acids in the diets of lactating dairy cows: reproductive responses. J. Dairy Sci. 81: 1385.

Moreira, F., C. A Risco, M. F. A. Pires, J. D. Ambrose, M. Drost, and W. W. Thatcher. 2000. Use of bovine Somatotropin in lactating dairy cows receiving timed artificial insemination. J. Dairy Sci. 83:1245-1255.

Pursley, J. R., M. R. Kosorok, and M. C. Wiltbank. 1997. Reproductive management of lactating dairy cows using synchronization of ovulation. J. Dairy Sci. 80:301-306.

Risco, C.A., M. Drost, L. Archbald, F. Moreira, R. L. de la Sota, J. Burke and W. W. Thatcher. 1998. Timed artificial insemination in dairy cattle-Part I. Compend. Contin. Educ. Pract. Vet. 20:280-287.

Thatcher, W. W., C. R Staples, G. Danet-Desnoyers, B. Oldick, and E. J.-P. Schmitt. 1994. Embryo health and mortality in sheep and cattle. J. Anim. Sci.72(Suppl. 3):16-30.

Using Pregnancy Rate to Monitor Reproductive Management

DON NILES, DVM—Monsanto Dairy Business, 2027 South Cottonwood, Visialia, CA 93277
Tel: 209-636-3842 don.e.niles@monsanto.com

STEVE EICKER, DVM, MS—Valley Ag Software Paul Rapnicki, DVM, University of Minnesota

STEVEN STEWART, DVM—University of Minnesota

Introduction

Excellent reproductive performance is essential for the success of any dairy operation. Excellent reproductive performance can be summarized as the ability to consistently have the higher producing animals in a herd conceive and maintain pregnancies in a timely, economically justified manner.

Maintaining a consistently high-performing reproductive program requires a substantial investment in management, labor, and other costs such as semen and drugs. Given the importance, costs, and the dynamic nature of these programs, careful monitoring of the current performance is essential. This paper will discuss the use of the measure called "pregnancy rate" to monitor current reproductive performance.

Pregnancy Rate

Many different measurements have been employed to assess reproductive performance. Some commonly used measurements include average days open, first service conception rate, annual services per conception and calving interval. Unfortunately, these measures can fail to detect drops in performance on a timely basis. Ultimately, the question of interest to dairymen is "How many of the cows eligible to become pregnant actually became pregnant in a given time frame?" Since the value is in the pregnancy, a measurement is needed to detect the rate that pregnancies are occurring in eligible cows.

Recently, there has been much talk in the popular press about using pregnancy rate (PR) to assess reproductive performance. Pregnancy rate can be defined as the percentage of cows eligible to become pregnant, in a given time frame, that actually do become pregnant. A logical time frame would be 21 days, the typical length of an estrus cycle.

The pregnancy rate calculation allows an assessment to not only determine how well cows are conceiving but also how quickly they are conceiving. Furthermore, by subdividing the breeding program into twenty-one day intervals, it can determine the effect of any recent changes on the breeding program.

The concept of PR can best be illustrated with some simple examples. Consider a single cow that is turned in with a bull. In the first example shown below, the cow conceives in the first 21-day period with the bull. The pregnancy rate at the end of the 21 days is 100%. In other words, all eligible cows (i.e., the one cow) settled in the first 21-day opportunity. Note that the pregnancy rate is still 100% even if the dairy did not detect the pregnancy until three months later. Because she settled immediately, she was still only "at risk" for getting pregnant for one (the first) cycle, even though she was present all three 21-day periods.

Example #1

Cow ID	First 21 day interval
1	Became Pregnant

Cow ID	First 21 day interval	Second 21 day interval	Third 21 day interval
1	Became Pregnant	Not Eligible	Not Eligible

What if the cow did not become pregnant until the 45th day after exposure to the bull? In this case, the pregnancy rate would be 33% because one cow became pregnant in three cycles at risk.

Example #2

Cow ID	First 21 day interval	Second 21 day interval	Third 21 day interval
1	Open	Open	Became Pregnant

The situation can become a bit more complicated with two cows. Suppose two cows were introduced to the bull at the same time. If one cow settled in the first 21 days and the other settled in the third 21-day period, what would the

more →

pregnancy rate be? It would be 50% because two pregnancies occurred in four "at risk" cycles.

Example #3

Cow ID	First 21 day interval	Second 21 day interval	Third 21 day interval
1	Open	Open	Became Pregnant
2	Became Pregnant	Not Eligible	Not Eligible

This calculation measure can also be used even if all cows are not yet pregnant. Again, in the example, two cows are put with the bull. One cow settles on the first day, while the other is still not pregnant after nine cycles (189 days). In this case, the PR is 10%. One cow became pregnant in 10 total "at risk" periods (1+9).

Example #4

Cow ID	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Cow 1	Preg	Not Elig	Not Elig	Not Elig	Not Elig	Not Elig	Not Elig	Not Elig	Not Elig
Cow 2	Open	Open	Open	Open	Open	Open	Open	Open	Open

Pregnancy rate has often been defined as heat detection rate (HR) multiplied by conception rate (CR). In many instances this will give a reasonable approximation of the actual PR. However, this "shortcut" can at times lead to very misleading results, especially if typical DHIA summary numbers are used. The reasons for this error include the exclusion of culled animals, the exclusion of animals once they enter a bullpen, use of different time frames and different animals in the two parameters, and the possibility of the same animal appearing more than once in a single 21day time interval.

Using this method also leads to the impression that it is necessary to know heat detection rate and conception rate in order to calculate the pregnancy rate. However, note that in the above examples we did not have to know how many times the animals were detected in heat nor the success of any of the individual breedings to calculate an overall pregnancy rate. The examples also illustrate that pregnancy rate calculations can be used whether the reproductive program is 100% artificial insemination, 100% natural service, or some combination of both. Therefore, pregnancy rate provides a method to monitor the rate at which cows become pregnant. However, there are some considerations before use. One consideration is whether the 21 day interval being considered is a:

- 21 day "calendar" window (e.g., January 1st to 21st)
- 21 day increment of days in milk (e.g., 50 to 70 days in milk)
- 21 day increment of days since entering a bull pen

The pregnancy rate concept lends itself well to analysis on a dairy. Table 1 represents a 2,000 cow dairy in central California. The chart calculates the pregnancy rate for each 21-day calendar period for the last year. The column labeled "Pg Elig" shows all the cows eligible to become pregnant in the 21-day period on the same line. In this example, a cow had to be more than 50 DIM (VWP) and open at the beginning of the 21 days to be considered eligible. The column headed "Preg" is the actual number of those eligible cows that did become pregnant during the 21 day period. Finally, the "Pct" column is the pregnancy rate, the percentage of the eligible cows that actually became pregnant during the given time frame.

In this herd, pregnancy rates ranged from 8% between 7/17/00 and 8/7/00 to 20% in the period between 4/24/00 and 5/15/00. By examining the pregnancy rate every 21 days, a dairyman can better understand not only how reproduction is doing now, but also what changes have occurred over time. In the herd used in this example, there is a noticeable downturn in pregnancy rates in both the summer of 1999 and 2000.

In cases where bull pens are properly identified and the movement of cows are properly recorded, further analysis is also possible. Table 2 represents the same herd as Table 1, but only the pens containing bulls are included.

In this case, to be eligible, a cow has to be more than 50 days in milk, not pregnant at the beginning of the 21-day period, and in a bull pen for at least 21 days (1 cycle). This chart, then gives a measure of the success of achieving pregnancies in the bull pens. The performance can be seen to vary considerably, dropping as low as single digits in summers and reaching as high as 38%. This information is valuable to a dairy, as assessments can be made of the overall efficiency of the bull program and as an ongoing monitor of the bull pen management and performance.

Also, if the bull pens are properly identified, accurate assessments can also be made of performance in pens without a bull, i.e. the artificial insemination program

Table 1			
Date	Pg Elig	Preg	Pct
9/6/99	332	36	10
9/27/99	386	49	12
10/18/99	419	67	15
11/8/99	467	96	20
11/29/99	468	71	15
12/20/99	481	92	19
1/10/00	473	90	19
1/31/00	481	83	17
2/21/00	484	66	13
3/13/00	457	66	14
4/3/00	439	72	16
4/24/00	450	91	20
5/15/00	428	72	16
6/5/00	400	40	10
6/26/00	380	41	10
7/17/00	372	30	8
8/7/00	0	0	0
8/28/00	0	0	0
Total	6917	1062	15

Table 2			
Date	Pg Elig	Preg	Pct
9/6/99	166	15	9
9/27/99	154	18	11
10/18/99	144	30	20
11/8/99	137	29	21
11/29/99	123	26	21
12/20/99	140	30	21
1/10/00	132	41	31
1/31/00	156	28	17
2/21/00	143	16	11
3/13/00	119	18	15
4/3/00	77	30	38
4/24/00	150	44	29
5/15/00	229	31	13
6/5/00	191	25	13
6/26/00	240	25	10
7/17/00	205	14	6
Total	2506	420	16

cows. An example pregnancy rate calculation for these cows can be seen in Table 3. This is the same herd as the other examples, except these are now the cows in the AI pens. In this example, to be pregnancy eligible, a cow needs to be 50 days in milk, not pregnant at the beginning of the 21 days, and have remained in the AI pens for the full 21 days. This chart, then, shows the efficiency of the AI breeding and would allow management to evaluate the success of the AI program

In the case of the AI program, the evaluator can go another step in the breeding analysis. Because all breedings are recorded in a typical AI pen, the heat detection rate (HR) can also be measured. The heat detection rate, similar to the PR, shows the percentage of eligible cows actually detected in heat within a given 21 day time frame. This gives management one more powerful tool in evaluating reproductive performance.

The final example, Table 4, is yet another look at the same herd. This chart illustrates how eligible cows can be grouped by a measure other than calendar dates. In this case, the HR and PR are calculated for different groups of cows based on their days in milk at the time of eligibility. The chart shows that 1,341 cows were pregnancy eligible for the 21 day period beginning with their 50th day in milk. Of those cows, 248, or 18% actually became pregnant in the next 21 days in milk. However, since this table includes all cows that have freshened in the past 365 days, this measure has a great deal of momentum and may delay early diagnosis of a change in reproductive performance.

Industry Benchmarks

There are several sources of data available to show typical pregnancy rates in the dairy industry. Graph 1 shows the overall (AI and natural service) pregnancy rate distribution of 80 California herds, representing 100,000 cows. Graph 2 shows the similar data from a Minnesota study. Data was from over 2,200 herds and 250,000 animals. Although the average in both groups is 14 to 16%, many good dairies can consistently maintain pregnancy rates at 20% or more. Once dairy management has the ability to accurately and easily assess pregnancy rates, appropriate interventions can be made to improve reproductive performance long before traditional reproductive parameters would have shown a problem existed.

Further observations can be made by dividing the herd into subgroups. For instance, it is often assumed that bulls will get cows pregnant at a faster rate than artificial insemination. In our experience on commercial dairies, this is not always the case. In most instances the

more →

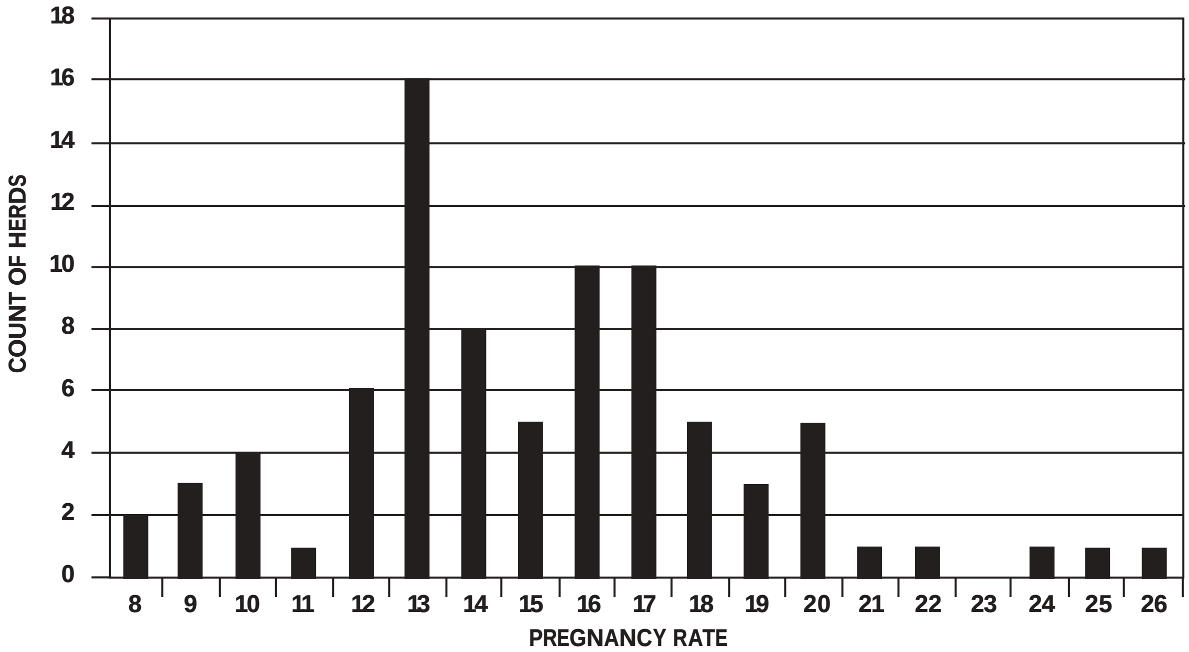
Table 3

Date	Ht Elig	Heat	Pct	Pg Elig	Preg	Pct
9/6/99	175	95	54	175	21	12
9/27/99	226	140	61	226	31	13
10/18/99	262	157	59	262	36	13
11/8/99	326	182	55	325	72	22
11/29/99	311	178	57	311	49	15
12/20/99	318	177	55	317	64	20
1/10/00	305	184	60	303	55	18
1/31/00	331	180	54	330	57	17
2/21/00	349	186	53	346	50	14
3/13/00	353	210	59	346	49	14
4/3/00	293	171	58	289	48	16
4/24/00	226	164	72	223	53	23
5/15/00	206	116	56	205	41	20
6/5/00	212	98	46	210	19	9
6/26/00	144	69	47	142	17	11
7/17/00	154	82	53	153	18	11
8/7/00	146	75	51	0	0	0
8/28/00	116	80	68	0	0	0
Total	4191	2389	57	4163	680	16

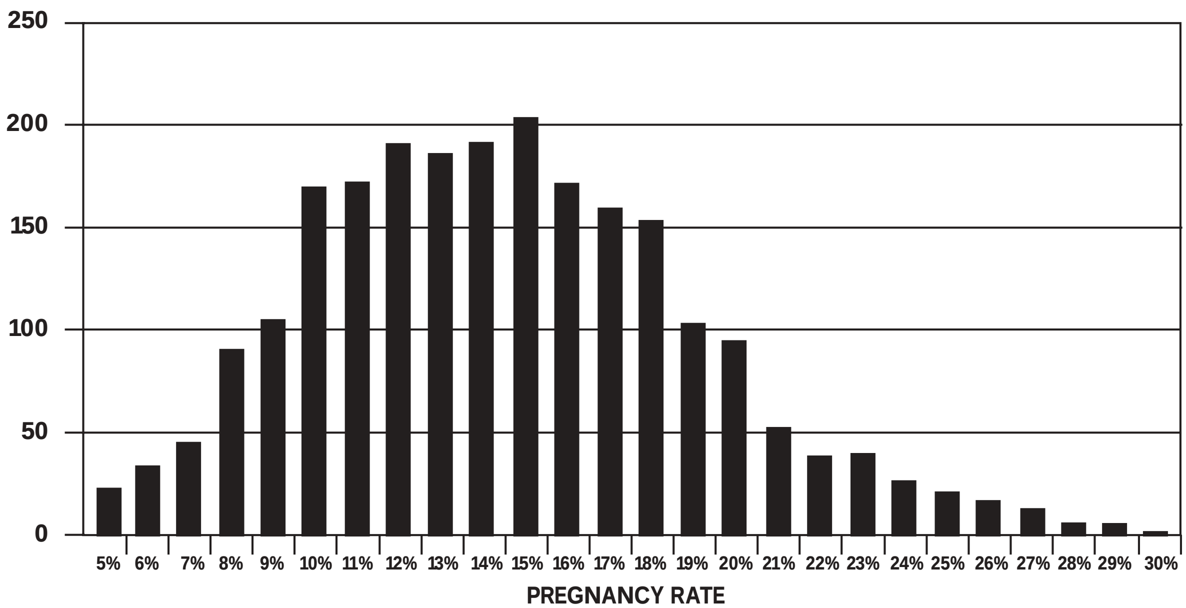
Table 4

DIM	Ht Elig	Heat	Pct	Pg Elig	Preg	Pct
50	1341	727	54	1335	248	18
71	1112	622	55	1108	195	17
92	896	462	51	893	138	15
113	689	369	53	683	101	14
134	390	218	55	385	52	13
155	169	108	63	167	28	16
176	70	38	54	68	9	13
197	20	12	60	19	3	15
218	16	4	25	16	1	6

Graph 1. California Data Set



Graph 2. Minnesota Data Set



Accelerated Growth for Dairy Heifers: I'd Rather Bet on Blackjack

MICHAEL J. VANDEHAAR—Department of Animal Sciences, 226 Anthony Hall, Michigan State University, East Lansing, MI 48824 Tel: 517-355-8489 Fax: 517-432-0190 mikevh@msu.edu

The cost of raising Holstein heifers to first calving at 24 months is about $1,200, which is about 15 to 20% of the total costs for a dairy enterprise consisting of cows and replacement heifers. Many consultants have focused on trying to decrease the cost of raising heifers as a means to increase farm profitability. One way to decrease these costs is "accelerate" the growth and breeding of heifers so they calve earlier; in fact, some suggestions for age at first calving are as early as 20 months. But will accelerated growth result in increased lifetime profitability? To answer this question, we must examine the potential effects of rapid heifer growth on subsequent milk yield.

Level of milk production of a cow is determined by the (1) the ability of the mammary gland to produce milk, (2) the ability of the cow to provide the mammary gland with nutrients, and (3) the ability of the farmer to manage and care for the cow. The ability of the mammary gland to produce milk is largely dependent on its content of milk-secreting cells, which are found in the mammary "parenchymal" tissue. The number of milk-secreting cells is determined by genetics and by the environment during mammary development, especially during the rapid mammary growth that occurs before and during the time of puberty, between 3 and 10 months of age (Sinha and Tucker, 1969). A good heifer rearing program is critical to produce animals at first calving that have well-developed mammary glands capable of producing to the animal's genetic potential and that have good body size and body condition capable of high feed intake and delivery of nutrients to the mammary gland. The goals of this paper are to review the effects of nutrition on mammary development and growth of heifers and to make recommendations for feeding heifers from weaning to calving for maximum lifetime profitability.

The effects of body weight and body condition at calving on subsequent productivity have never been determined definitively in a "cause and effect" study. Most studies examining this relationship have done so using correlations; therefore, our current recommendations must be viewed with a healthy bit of skepticism. So what is the desired body weight? In high-yielding Holstein herds (>22,000 lb milk year), heifers typically conceive at 16 months of age weighing 910 pounds and calve at 25 months weighing at least 1,360 pounds before calving (Hoffman and Funk, 1992). Field correlations suggest optimal body weight is 1,200 to 1,300 pounds after calving and that lighter body weights result in lower milk production (Keown and Everett, 1986; Heinrichs and Hargrove, 1987). Van Amburgh et al. (1998b) found that heifers weighing ~1,260 pounds after first calving produced 700 pounds more milk in the first lactation than those weighing ~1,150 pounds. The potential problem with their data is that prepubertal body weight gain was confounded with calving body weight, and the reason that lighter weight heifers produced less milk might be that they grew too fast before puberty. Postcalving weights above 1,300 pounds for Holstein heifers may decrease milk production, perhaps because heavy heifers may have excess body fat. Animals with excess body fat before calving tend to eat less (Grummer et al., 1995) and probably mobilize more body fat before calving, which is associated with a greater incidence of dystocia, ketosis, and mastitis in the first month after calving (Dyk et al., 1995). Thus, we will assume that optimal body weight after calving is ~1,250 pounds for Holsteins (about 90% of mature body weight for other breeds) and optimal body condition score is 3.0 to 3.5. Optimal withers height is 54 to 56 inches (Hoffman, 1997).

Effect of nutrition on growth, mammary development, and milk yield

To achieve a body weight of 1,250 pounds after calving, heifers must weigh ~1,400 pounds before calving, and they must gain an average of 1.8 lb/day if they are to calve at 24 months. Because daily gains are slower in the first 3 months of life, gains thereafter must approach 2.0 lb/day. If calving at 20 months is desired, then gains at peak growth must approach 2.4 lb/day. High energy diets and rapid gains after breeding have little effect on subsequent milk production if calving occurs at optimal body size (Grummer et al., 1995; Hoffman et al., 1996; Sejrsen et al., 1982). Thus, this review will focus on the period of growth before breeding.

The period between 3 and 10 months of age is a critical time in mammary development. During this time, mammary growth is rapid and "allometric"; in other words, mammary tissues are growing at a faster rate than that of most other body tissues. The mammary paren-

more →

chyma extends into the mammary fat pad in a "broccoli-like" fashion and forms the daughter cells which are the foundation for later mammary development. The number of parenchymal cells present at puberty partly dictates the number of milk-secreting cells that will be present during lactation. The best method to assess the number of mammary cells is by measuring the amount of parenchymal DNA.

Growth of the mammary gland once again becomes isometric (same growth rate as other body tissues) shortly after puberty, about the 2nd or 3rd estrous cycle. When heifers are grown rapidly in the first year of life, puberty is attained 1 to 2 months earlier, and the allometric mammary growth phase likely is shortened. Rapidly-grown heifers have less mammary parenchymal DNA around the time of puberty, indicating impaired mammary development. For example, Sejrsen et al (1982) fed heifers at high or low intake of an energy-dense diet to gain 2.8 or 1.4 lb/day from 7 months of age to 700 pound body weight, and found that heifers fed high energy had 32% less mammary parenchymal DNA than those grown slowly.

However, the responses to diets which promote rapid body gains varies considerably, from decreases in parenchymal DNA as much as 50% in some studies to no decrease in others. For example, Capuco and coworkers (1995) observed a 48% impairment in mammary development when rapid gains were achieved from high intake of a corn silage-based diet but no impairment from high intake of an alfalfa-based diet. We conducted a study using the same laboratory techniques as Sejrsen et al., but using diets much higher in total protein and in rumen-undegraded protein (Radcliff et al., 1997). Diets were fed from 4 months of age to 2.3 months after puberty, when the heifers were killed. Compared to control heifers, heifers fed a high energy, high protein diet gained 2.7 lb/day, had more carcass and mammary fat, and reached puberty and were killed 1.6 months earlier, but, surprisingly, mammary development was not impaired as assessed by parenchymal DNA content.

Decreases in milk production have occurred in almost all studies in which heifers gained weight more rapidly than 2.0 lb/day before puberty, but the magnitude of the response has varied from 5 to 50%. Furthermore, decreased milk yields are not clearly related to impaired mammary development before puberty. For example, in a study by Little and Kay (1979), high gain heifers grew more slowly after puberty and thus calved at lighter body weight; therefore they devoted more energy to growth during their first lactation than control heifers. In later lactations, however, body weight was similar between groups, and rapidly-grown cows still produced 30% less milk and had 40% less mammary secretory tissue than control animals. In contrast, Capuco and coworkers (1995) found that rapidly-grown heifers fed a corn silage-based diet had 48% less mammary parenchymal DNA at puberty but subsequent milk production was only reduced 5%. Van Amburgh et al. (1998b) fed prepubertal heifers three different diets; the slowest group grew at 1.5 lb/day and calved at 24.5 months. The fastest group grew at 2.1 lb/day, calved at 21.3 months, and produced 5% less fat-corrected milk in their first lactation. We recently fed heifers a high forage diet or a high grain diet (high in energy and protein) from 4 months of age until confirmation of pregnancy (Table 1). Heifers fed high forage grew at 1.7 lb/day before puberty, calved at 23.4 months, and produced 19,540 pounds of milk (adjusted to 270-days) in the first lactatation. Accelerated heifers grew at 2.5 lb/day before puberty, calved at 20.4 months, and produced 10% less milk in the first lactation (17,600 pounds).

Does dietary protein make a difference?

We hypothesized that the ratio of protein to energy in the diet might explain some of the variation in effects of prepubertal diet on mammary development in heifers. Although we commonly evaluate diets based on protein as a percentage of dry matter, animals actually need a specific percentage of dietary calories to come from protein. So if the energy concentration of a diet is increased, the protein concentration also should be increased. According to the 1978 Nutrient Requirements for Dairy Catte developed by the National Research Council (NRC), prepubertal heifers should be fed diets with 54 g of crude protein (CP) per Mcal of metabolizable energy (ME). The 1989 NRC increased the recommended CP:ME ratio to 60 g/Mcal for heifers from 3 to 6 months of age and dropped it to 50 g/Mcal for heifers from 6 to 12 months of age. However, NRC recommendations were designed for growth rates of 1.6 to 1.8 lb/day, and they were based on optimal diets for body growth, not mammary development.

To determine if differences in dietary protein would account for some of the variation in mammary responses to high energy diets and rapid gains, I analyzed data from published studies in which rapid gains exceeded 2.0 lb/day and in which diets were adequately described (VandeHaar, 1997). Across the studies, mammary development of rapidly-grown heifers relative to their controls was positively correlated with the CP:ME ratio of the diets they were fed. Furthermore, CP:ME accounted for 51% of the variation in mammary parenchyma responses and 78% of the variation in milk yield responses to rapid growth rate.

This analysis suggests that inadequate protein might have been responsible for the impaired mammary development of heifers grown more rapidly than 2.0 lb/day in several published studies.

Dietary protein is only one among several factors that may explain the variation in mammary responses among different experiments. Potential sources of variation for responses in milk yield of 11 groups of rapidly-grown heifers also were examined in a multiple regression analysis. Three factors were most important in explaining the variation: weight gain of rapidly-grown heifers as a percent of controls, dietary metabolizable protein (MP) to metabolizable energy (ME) ratio, and calving body weight of rapidly grown heifers as a percent of controls. The average gain of control heifers in the studies was 1.6 lb/day. Based on this analysis, we would expect that if a heifer gains 2.0 lb/day and is fed a diet with MP:ME of 33 g/Mcal (~12% CP in a diet of 1.2 Mcal ME/lb), milk yield would be 89% of controls. If the heifers are fed high protein (~16% CP), the model predicts that milk yield would increase to 97% of controls. If heifers are fed a diet of 1.3 Mcal ME/lb and grow at 2.4 lb/day before breeding, milk yield would drop to 77% of controls if the diet was 14% CP (~33 g MP/Mcal ME), or 90% if controls if the diet was 20% CP (~42 g MP/Mcal ME). Finally, we predict that milk yield would drop another 6% if the rapidly-grown heifers weighed 50 lb less than controls at first calving. The implication of this model is that increasing the dietary protein of prepubertal diets may allow growth as rapid as 2.1 lb/day with mammary development that is essentially normal. This is consistent with the findings of Van Amburgh and coworkers (1998b).

Very few studies have been designed specifically to examine the effects of dietary protein on mammary development. Recently Lammers and Heinrichs (2000) fed prepubertal heifers diets with 46, 54, or 61 g of CP/Mcal ME beginning at 440 lb body weight for 20 weeks. They found that higher protein improved body weight gains from 2.2 to 2.4 lb/day and increased height, width, and girth by about 15%. High protein also increased teat length. However, data from our laboratory show absolutely no relationship between teat length and mammary parenchymal mass or DNA content.

We used 54 Holstein heifers to directly determine if high dietary protein would enhance mammary parenchymal development in prepubertal Holstein heifers fed a high-energy diet for rapid body growth (Whitlock et al., 1999). Heifers were fed either a low (14% CP), standard (16% CP), or high (19% CP) protein diet with the protein coming from expeller soybean meal (high in rumen-undegraded protein). All diets contained 1.3 Mcal ME/lb and were fed as a TMR from 3.5 months of age until slaughter at 6 weeks after puberty. Average daily gain for heifers on the low, standard, and high-protein treatments were 2.5, 2.6, and 2.6 lb/day, respectively. Dietary protein did not affect age or body weight of heifers at puberty, withers height gain, carcass composition, or mammary development. Heifers fed the high protein diet had 10% more mammary parenchyma at puberty but this was not statistically significant. We concluded that dietary protein does not have a major effect on mammary development of rapidly-grown dairy heifers. The data suggest that while feeding high protein may help, it will not prevent the commonly observed impairment of mammary development when prepubertal heifers are grown rapidly.

Is a genetic predisposition for rapid growth associated with decreased milk yield? The relationship of prepubertal growth and mammary development is further complicated by the interplay of genetics and management and whether the rapid growth is associated with lean or fat deposition. In the study of Van Amburgh et al (1998b), even though heifers grown at 2.1 instead of 1.5 lb/day produced 5% less milk, the correlation of prepubertal body weight gain and subsequent milk production of individual heifers was very poor. In the study of Radcliff et al. (2000), even though milk yield was decreased 10% by rapid growth, there was no relationship between milk yield and prepubertal growth rate of heifers within a dietary group. Based on data of Whitlock et al. (1999), heifers that naturally grow the fastest in a group tend to be the leanest, and increased body fat was associated with decreased mammary development. In fact, the correlation between lean body gain and mammary development was slightly positive.

We expect that within a group of heifers that are fed and managed the same, those that are the fattest at the time of puberty and breeding will produce less milk as cows. On the other hand, those that grow the fastest may produce as much milk if not more than their herdmates. These fast growing heifers might have the highest natural growth hormone concentrations, the greatest appetites, or the best immune systems, all factors which could result in more milk once they are cows. I occasionally hear the comment, "Our heifers grow fast and calve at 20 months, and they produce 20,000 pounds of milk in their first lactation. They obviously don't have impaired mammary development." The problem with this logic is that these same heifers might have produced 22,000 pounds if they had been managed to grow a little slower and calve a little later.

Our current understanding of mammary development is that heifers that are grown more rapidly than 2.0

more →

lb/day are at great risk for decreased milk yield in first lactation. The fact that decreased mammary development and subsequent milk yield are not always observed indicates that specific feeding and management practices might reduce this risk. But what these practices are is not clear. Based on our data and my analysis of the literature, I make the following conclusions and recommendations:

1. Heifers grown faster than 1.8 lb/day will likely produce less milk as cows if they are fed diets with protein at or below NRC recommendations. This is most commonly a problem when heifers are fed diets high in corn silage with inadequate protein supplementation.
2. Feeding high protein (60 to 65 g CP/Mcal ME) can reduce the risk of impaired mammary development and may enable gains as rapid as 2.1 lb/day with very little decrease in subsequent milk production. However, even with high protein, all available data show that feeding heifers for gains faster than 2.1 lb/day will decrease milk yield by at least 10%.
3. Accelerated growth programs, with a goal of calving at 22 months, require excellent management after puberty. Delayed breeding may cause overfattening in too many heifers. Also these heifers often grow slower than expected after breeding. Unless the heifers are fed and managed to maintain high rates of gain, they will likely calve at light body weights, which can compromise milk production.
4. Fat body composition may be a greater risk factor for impaired mammary development than is rapid growth. Furthermore, some heifers may have the genetic potential to gain at 2.2 lb/day without becoming fat and without impaired mammary development. But others may become fat and have impaired mammary development when growing only 1.8 lb/day.
5. The effect of rapid growth on younger heifers (from birth to 4 months) has been studied very little. Available data suggest that this is one time that a focus on faster growth may be beneficial, but more research is needed to show if mammary development is normal when heifers are grown rapidly from 6 to 16 weeks.
6. Heifers should be bred on size not age. If a group of heifers has already grown too fast and is already at the proper size for breeding at 10 months of age, go ahead and breed them-the damage has already been done. However, a major adjustment to the young heifer program should be made.

Effect of heifer feeding program on lifetime profitability

Although the cost of raising a heifer to first calving is not trivial, it is substantially less than the gross income generated from subsequent milk sales. Thus, in developing a cost-effective heifer rearing program, one must weigh the costs of heifer rearing versus the potential impact on net income of the animal after calving. Early calving may decrease heifer costs, but if mammary development or body size at calving is decreased, early calving may be an expensive mistake.

Some dairy management experts have attempted to examine the economics of early calving with a simple formula. They assume that if raising a heifer to first calving costs $1,200, then heifer costs are $50 per month. With this simple model, lifetime profit is increased $150 if calving is expedited from 24 to 21 months and there is no loss in milk production. But even if milk production is decreased 10% in the first lactation, early calving may still be profitable on paper with an average cost approach. For example, let's assume that the average cost of milk production is $2 less than the price of milk or that the average return to milk production is $2 per cwt of milk. With this logic, a 10% decrease in milk (about 2,000 pounds) would result in $40 less profit after calving, so the net lifetime gain would be $110 ($150 to $40). Even if the average return to milk was $3 per cwt and the decrease in first lactation milk production was 20% (4,000 pounds), the producer would still make $30 more on an animal that calved 3 months earlier.

The problem with this approach is that the marginal monthly costs for growing a heifer an extra month are much less than the average monthly costs to raise a heifer. And the marginal costs associated with producing an extra 100 pounds of milk are much less than the average costs to produce 100 pounds of milk. Thus the above simplistic analysis favors accelerated growth and early calving in two ways. It overestimates the cost savings of early calving and it underestimates the loss in net income of the heifer after calving. So lets consider an analysis using marginal costs.

Whereas early calving decreases housing costs and some other fixed costs, it does not decrease many types of heifer-rearing costs, such as the costs of feeding young calves milk, vaccination costs, and breeding costs. Furthermore, daily feed costs most certainly will increase with an accelerated growth program, and perhaps even some nonfeed costs will increase. For example, better housing and ventilation may be needed. So how much do we really save for each month of earlier calving? According to enterprise budget figures by Radcliff et al. (1997), the actual savings for each month saved in raising a heifer from 4 months of age up to breeding size of 800 pounds was $27, or about half the average monthly cost of raising a heifer. However, the standard growth heifers of Radcliff were fed relatively expensive stored forages. If grazing or byproduct feeds or restricted feeding of grains had been part of the standard growth system, the marginal cost savings would have been even less. In any case, let's assume that decreasing the age of calving by 3 months would save about $80 in a confined heifer-rearing system.

Now let's examine the marginal return to an extra 100 lb (cwt) of milk, which will be much greater than the average return to a cwt of milk. Compared to a cow that produces 20,000 pounds of milk, one producing 16,000 pounds will need less feed to make milk, but she needs as much feed to maintain herself. Furthermore, the low producer requires almost as much labor for milking, feeding, and bedding and she needs as much stall space in the barn and milking parlor. The marginal return to milk approaches the extra milk income minus the extra feed costs to make it (commonly called the margin or income over feed costs). Thus the loss in milk income when considering marginal costs for a cow is more typically $7 per cwt of milk (this obviously varies with changing milk and feed prices, but for simplicity, I will use the $7 figure as a typical value).

Possible returns from various responses to rapid growth are shown in Table 2. If calving 3 months early does not impair milk production, lifetime profit might increase $80. However, if milk production is impaired 10% (or about 2000 pounds) in the first lactation, then lifetime profits will decrease $60. And the decrease in lifetime profits can be even greater if production is decreased more than 10% or carries into later lactations as some research suggests. In any case, no study yet has shown that heifers can grow faster than 2 pounds per day or calve before 22 months without at least a 5 to 10% loss in milk for the first lactation. Until we discover how to eliminate the risk of impaired mammary development with accelerated heifer growth, it is risky business. It's kind of like blackjack, but with heifers, anything less than 22 months means you're busted!

Perhaps high protein diets before puberty can overcome this impairment, but more studies are needed before we can be confident that feeding high protein will eliminate the risk of impaired mammary development. Feeding more protein before puberty would cost ~$15 per heifer. At the present time, this $15 cost seems a reasonable investment given that in some studies even prepubertal gains of 2.0 lb/day have impaired mammary development at protein levels commonly used on farms.

One important factor in the decision on whether to breed heifers for earlier calving is the availability of space to house heifers relative to availability of space to house lactating cows. If heifer space is in short supply, perhaps earlier breeding even at a lighter body weight should be considered.

For most well-managed, intensive-feeding operations, the most profitable age for first calving is likely 22 to 24 months. First calving at greater than 24 months will likely reduce profitability, unless feed or fixed costs are unusually low, as may be the case for heifers grown on pasture. Pasture generally has a very low cost per Mcal of ME. Even in pasture systems, however, gains of 1.8 lb/day are attainable through intensive-grazing or grain supplementation, and 22 to 24 months may be most profitable.

Goals for heifer growth

Targets for heifer rearing in intensive management conditions are:

- Age at first calving = 22 to 24 months
- Body weight after calving = 1,250 pounds
- Height at calving = 56 inches at the withers
- Body condition score at calving = 3.0 to 3.5
- Growth rate from 3 to 10 months of age = 1.7 to 2.0 lb/day

To achieve these goals for calving, heifers should be compared to the recommended weights and heights of Figures 1 and 2, and bred at 13 to 15 months, standing 51 inches at the withers and weighing 850 pounds.

Feeding heifers to achieve these goals

Nutrition models are needed in evaluating diets to determine if the supply of nutrients from the diet matches the nutrient requirements of the animal. So how good are our models of heifer nutrition? The short answer is not very good.

In the study of Radcliff et al. (1997), we fed heifers diets with 75% grain or 90% forage ad libitum for rapid or standard gains. Heifers fed a high grain TMR ate 20% more than predicted by the 1984 Beef NRC, and slightly more than predicted by the 1996 Beef NRC, Spartan Dairy Ration program, or equations developed at VPI (Hubbert, 1991; Quigley et al., 1986). Heifers fed a high forage TMR ate less than predicted by the 1984 or 1996 Beef NRC models or equation of Quigley et al. and about the same amount as predicted by Spartan Dairy or Hubbert. Overall, the recent equation from VPI was reasonably accurate under the feeding conditions of our heifers.

More importantly, however, heifers fed the high forage TMR gained more than twice as much as predicted by the 1989 Dairy NRC. Predictions for gain were close to

more →

actual gains for heifers fed the high grain TMR. Van Amburgh et al. (1998a) recently published observed vs. expected gains for 270 heifers based on actual energy intake and found similar results. The 1989 Dairy NRC underpredicted gains of heifers grown at 1.3 lb/day by half, but was reasonably accurate for heifers gaining 1.8 lb/day. The Cornell Net Carbohydrate and Protein System (CNCPS), a much more mechanistic model than the 1989 Dairy NRC, was no better. So why do these models underpredict gains? The most likely explanation is that modern Holstein heifers fed high forage TMRs grow with more lean gain and less fat gain than expected and thus more total gain per unit feed energy input. Another possibility is that dietary forage is retained in the digestive tract longer than expected in heifers so that digestibility and consequently gains are greater than expected as well.

Most computer ration models also are not very good at describing the protein nutrition of heifers with the major problem being the prediction of microbial protein yield. Whereas the 1989 Dairy NRC underpredicts microbial protein for young heifers, the the CNCPS overpredicts microbial yield for prepubertal heifers (Van Amburgh et al., 1998a). But in any case, the crude protein system works fine for growing heifers if it is used with a bit of common sense. Heifers should be fed mostly true protein sources (such as soybean meal) as the CP supplements, but a little urea or other form of non-protein nitrogen is okay if fermentable starch is available.

Regarding our ability to feed heifers to meet growth targets, I conclude the following:

1. Dairy heifers fed high forage TMRs ad libitum are more efficient in using consumed energy than current models predict. Furthermore, current models are often inaccurate at predicting feed intake.
2. Under good environmental conditions and management, dairy heifers usually will grow considerably faster than expected when fed a TMR for ad libitum intake. In other words, if you balance a diet for 1.8 lb/day, the heifers may very likely grow 2.3 lb/day.
3. Under poor environmental conditions, heifers may grow considerably slower than predicted. Some models do try to account for such conditions; however, environmental conditions are often difficult to accurately define, so accuracy of the model may still be a problem.
4. Don't assume any computer program will accurately predict gains in Holstein heifers. Let the heifers be the judge of any feeding program. If weights cannot be measured with a scale, use a weigh tape. Height and body condition should also be assessed routinely. The critical times to evaluate are at weaning, at about 5 months, at breeding, and just after calving.
5. For prepubertal heifers, complicated models for formulating diets for heifers usually are no better than simple ones. For protein, the crude protein model as found in 1989 Dairy NRC can work well if most protein comes from true protein sources of average rumen-undegradability. Diets should contain 56 to 60 g of CP per Mcal of ME or ~100 g CP per Mcal NEm with rumen-undegradable protein at 25 to 35% of the total protein.

Recommended daily gains and dietary energy and protein concentrations are given in Table 3. These recommendations assume feed will be offered as a TMR for ad libitum intake. Although NRC works well when heifers are fed at restricted intake, NRC tables were not developed for ad libitum feeding. Ad libitum feeding may be desirable in group-feeding situations. Thus, my recommendations for dietary energy concentration are lower than those of NRC 1989 to achieve target gains of 1.8 lb/day. Instead the recommendations are based on data from the study of Radcliff et al. (1997, unpublished data), in which heifers were group-housed in a comfortable yet confined environment, were kept healthy, had water and feed available all day with plenty of bunk space, and were fed their diet as a TMR. In some situations, higher energy diets may be needed to meet the target gains.

Summary

A good heifer rearing program is critical to produce animals at first calving that have well-developed mammary glands capable of producing to the animal's genetic potential and that have good body size and body condition capable of high feed intake and delivery of nutrients to the mammary gland. Weight gains more rapid than 2.0 lb/day before puberty generally decrease development of the mammary gland and subsequent milk production. Feeding more protein when heifers are grown rapidly may reduce the risk for impaired mammary development and is probably worth the added expense when trying to achieve postpartum body weights of ~1,250 pounds and calving at 22 to 24 months. Although calving earlier than 22 months may decrease the costs of raising heifers further, odds are that future milk production will be impaired so lifetime profitability may actually decrease. The costs associated with heifer-rearing should be thought of as an investment, not just an expense. Trying to cut these costs with accelerated growth programs may work, but the risk is high that accelerated growth will be an expensive mistake. I'd rather take my chances at blackjack!

Literature Cited

Capuco, A. V., J. J. Smith, D. R. Waldo, and C. E. Rexroad, Jr. 1995. J. Dairy Sci. 78:2709.
Dyk, P. B., R. S. Emery, J. L. Liesman, H. F. Bucholtz, and M. J. VandeHaar. 1995. J. Dairy Sci. 78(Suppl.1):264.
Grummer, R. R., P. C. Hoffman, M. L. Luck, and S. J. Bertics. 1995. J. Dairy Sci. 78:172.
Heinrichs, A. J., and G. L. Hargrove. 1987. J. Dairy Sci. 70:653.
Hoffman, P.C. 1997. J. Anim. Sci. 75:836-845.
Hoffman, P. C., and D. A. Funk. 1992. J. Dairy Sci. 75:2504.
Hoffman, P. C., N. M Brehm, S. G. Price, and A. Prill-Adams. 1996. J. Dairy Sci. 79:2024.
Hubbert, C. J. 1991. Graduate Thesis, Virginia Polytechnic Institute and State University, Blacksburg, R. E. James, advisor.
Keown, J. F., and R. W. Everett. 1986. J. Dairy Sci. 69:1891.
Lammers, B.P., and A.J. Heinrichs. J Dairy Sci. 83:977-983.
Little, W. and R. M. Kay. 1979. Anim. Prod. 29:131.
Radcliff, R. P., M. J. VandeHaar, A. L. Skidmore, L. T. Chapin, B. R. Radke, J. W. Lloyd, E. P. Stanisiewski, and H. A. Tucker. 1997. J. Dairy Sci. 80:1996-2003.
Radcliff R.P., M.J. VandeHaar, L.T. Chapin, T.E. Pilbeam, D.K. Beede, E.P. Stanisiewski, and H.A. Tucker. 2000. J Dairy Sci 83:23-29.
Quigley, J. D., R. E. James, and M. L. McGilliard. 1986. J. Dairy Sci. 69:2863-2867.
Sejrsen, K., J. T. Huber, H. A. Tucker and R. M. Akers. 1982. J. Dairy Sci. 65:793.
Sinha, Y. N., and H. A. Tucker. 1969. J. Dairy Sci. 52:507.
Van Amburgh, M. E., D. G. Fox, D. M. Galton, D.E. Bauman, and L.E. Chase. 1998a. J. Dairy Sci. 81:509-526.
Van Amburgh, M. E., D. M. Galton, D. E. Bauman, R. W. Everett, D. G. Fox, L. E. Chase, and H. N. Erb. 1998b. J. Dairy Sci. 81:527-538.
VandeHaar, M. J. 1997. J. Dairy Sci. 80 (Suppl. 1):216.
Whitlock B.K., M.J. VandeHaar, and H.A. Tucker 1999 J Dairy Sci 82(Suppl 1):51.

Table 1. Accelerated growth and milk production (Radcliff et al, 2000).

	Control	Rapid Gain	Significant?
Diet ME, Mcal/lb	1.0	1.3	
Diet CP, % of DM	17	19	
Daily gain before puberty, lb/day	1.7	2.5	yes
Body condition score at 800 lb.	3.5	4.2	yes
Inseminations per heifer	1.4	1.8	no
Age at calving, mo.	23.4	20.4	yes
Body weight after calving, lb.	1,186	1,133	no
Body condition score at calving	3.7	3.5	no
Calving rate (heifers calved/heifers in treatment)	33/35	31/35	no
Energy-corrected milk yield (305 day), lb.	19,540	17,590	yes

Table 2. Marginal costs and returns in heifer raising.

Calving age (months)	Marginal heifer costs	Milk Response	Marginal cow net income	Lifetime marginal profit
24	$0	0	$0	$0
21	–$80	0	$0	+$80
21	–$80	–5% for 1st lact (–1,000 lbs.)	–$70	+$10
21	–$80	–10% for 1st lact (–2,000 lbs.)	–$140	–$60
20	–$110	–20% for 1st lact (–4,000 lbs.)	–$280	–$170
20	–$110	–10% for 3 lactations (–6,000 lbs.)	–$420	–$310

more →

Table 3. Growth goals and recommendations for feeding Holstein heifers ad libitum.[1]

Age months	Weight lb	Gain lb/day	Height inches[2]	ME[3] Mcal/lb	NE[4] Mcal/lb	% CP[5]	CP:ME g/Mcal[6]
2	167	1.76	34.1	1.33	0.80	18.4	63
4	279	1.96	37.6	1.27	0.76	17.6	63
6	398	2.00	40.8	1.18	0.71	16.4	63
8	517	1.97	43.9	1.12	0.67	14.8	60
10	634	1.93	46.7	1.12	0.67	14.8	60
12	748	1.89	48.7	1.08	.065	12.6	53
16	970	1.81	51.7	1.08	0.65	12.6	53
22	1,290	1.76	54.8	1.08	0.65	12.6	53
23	1,343	1.76	55.2	1.08	0.65	13.3	56
24 precalf	1,400		55.6	1.20	0.72	14.8	56
24 postcalf	1,250		55.6	1.30	0.78	18.0	63

[1]Targets for other breeds can be calculated with goal of 90% of mature weight at 24 months.
[2]Height at the withers.
[3]Concentration of metabolized energy in diets. ME is approximately NEm divided by 0.6.
[4]Special rumen-undegraded protein sources are not needed. Most supplemental CP should come from true protein sources as legume forages and soybean meal; however, urea could be used in limited amounts as long as the rumen-undegraded protein was 25 to 35% of total CP.
[5]To calculate the CP:ME ratio, multiply %CP by 10, divide by Mcal ME/lb, and divide by 2.2

Figure 1. Recommended body weights for Holstein heifers with calving at 24 months.

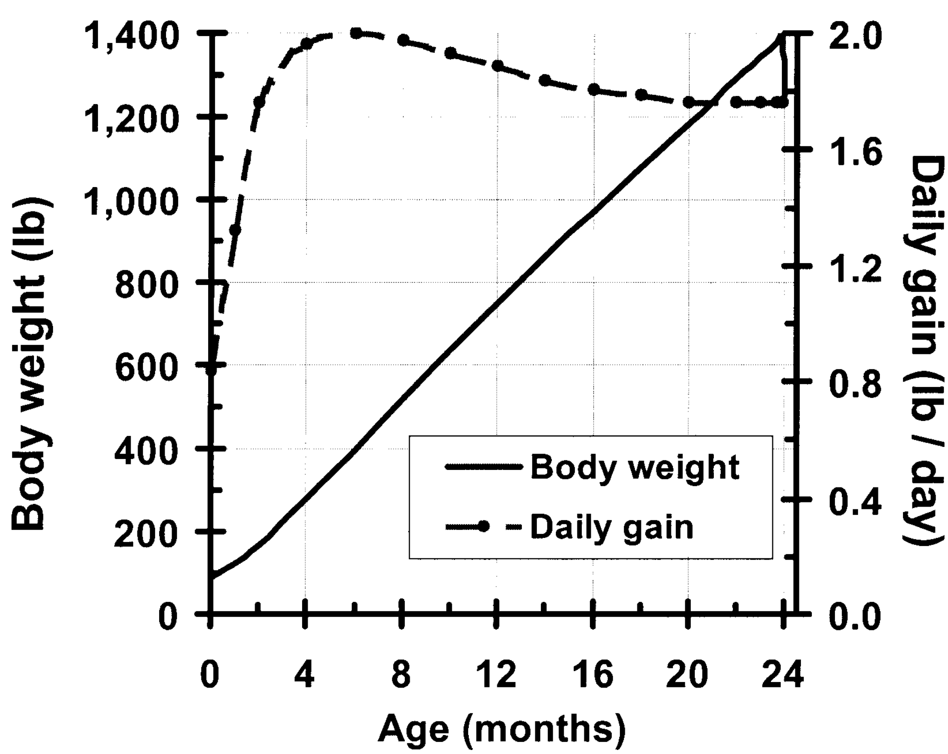
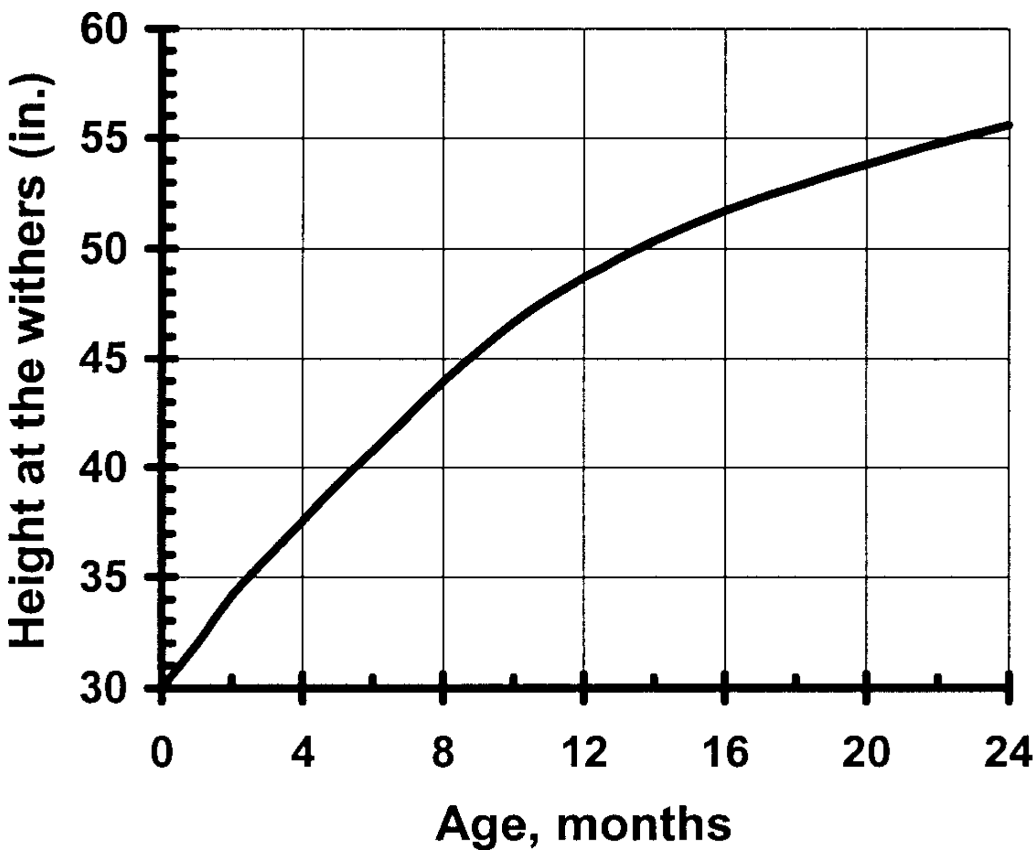


Figure 2. Recommended heights for Holstein heifers with calving at 24 months.



No See Ums: Hidden Aspects to Communicating With Your Mexican Workers

ANN C. SCHAUBER, Diversity Specialist—Oregon State University Extension Service 307 Ballard Hall Corvallis, OR 97331
Tel: 541-737-2315   Fax: 541-737-3290   ann.schauber@orst.edu

Have you ever been giving your Mexican workers instructions to do a specific job and they are listening intently to you nodding their heads up and down? Their head nodding is an indication to you that they understand what you want them to do. So, you hurry over to your next job, confident that they know what to do. A little while later, you see them doing something completely different than what you told them to do? What happened?

The obvious barrier to effective communication with your Spanish-speaking workers seems to be the language barrier. Many of you have commented that if I could just speak their language more fluently, or they could speak mine, I would be able to communicate with them more effectively. What we don't realize is that the language barrier is only a tiny barrier compared to the much deeper cultural barrier that exists between the two of you. The reason that I say the cultural barrier is greater than the language barrier is that you can see and hear the language barrier. The cultural barrier is hidden from view and sometimes the cultural differences are so subtle that they can easily be misinterpreted. You can learn the language by taking classes or having one of your workers teach you. There are not as many opportunities to take classes in the cultural communication differences between the two groups and your workers may not be totally conscious of what their culture is even though they act from their cultural context in everything they do. It is a grand puzzle out of which a whole new field of study called Intercultural Communication is emerging.

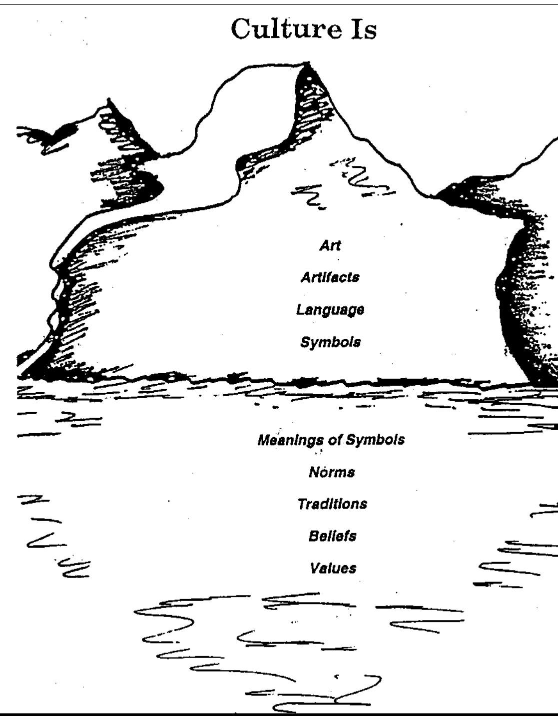
In this presentation, we will focus on these cultural differences with an emphasis on values and how that drives the way we communicate as well as the meanings that we derive when we talk face to face with one another. I will focus my points on the differences between Mexicans and United Statesians. (United Statesian, this is a new word. Well, it makes sense, though. The equivalent to the word Mexican is United Statesian. They both refer to a national origin. We might more commonly say American, but Mexico is a part of America. Mexicans consider themselves to be Americans, even though many of them have adapted to our way of describing ourselves as Americans and them as Mexicans. When I studied the Spanish language in Costa Rica, my teachers told our class without hesitation that we were Estados Unidensians and we had better get used to saying it. I find it to be a mouthful and difficult to say in both English and Spanish, so I will refer to people who are white like myself to be Anglos for the rest of this presentation). Specifically, I will look at the Mexican worker and the Anglo boss.

As an aside, I do want to say that these basic cross-cultural communication principles apply in other situations in your lives where you experience difference. For example, I have found an understanding of cross-cultural communication to be very helpful in working through disagreements with my husband. After all women come from a different planet than men do... wouldn't you agree?... at least that is what the author John Gray says.

A Cultural Model

To understand better what I am saying, I would like to use a metaphor of an iceberg. I want to shift the focus for the moment from your Mexican worker to yourself. How many of you have seen an iceberg? What is it about an iceberg that makes it very unique?

Figure 1: An iceberg: a metaphor for culture



When you see an iceberg, what you see is only the tip. Most of the iceberg is under water. This is similar to

more →

what culture is. By culture, I am referring to any group of people who have shared practices, beliefs, and values. The part of culture that we see and acknowledge is the part of the iceberg that is above water. That is, the language, the arts and artifacts, and symbols of a group of people. What we don't see is what is under the water, that is, the meanings behind the symbols, the norms or rules that we live by, the traditions, the beliefs and the values. Down deeper still is a set of universal human needs which goes across all cultures but is communicated up through the differences. For example, all people have a need to feel respected. However, respect is shown in Mexican culture through indirect eye contact with superiors and elders and with Anglos respect is shown through direct eye contact. Both cultural groups have the same need for respect but it is given differently. When someone is talking to you and looking down or averting their eyes, that is, not looking directly at you, what do you begin to think about that person? Right, you begin to look on them with suspicion. Maybe they are not telling you the truth. Maybe they are not listening or maybe they are not interested in what you have to say. Without knowing the cultural norm, you come to a conclusion that is the exact opposite of what is really being communicated. This person is really showing you respect, the very thing you wanted from that person. This is an example of why I say that the cultural divide is much greater than the language divide.

What I find fascinating about culture is that we all learned it, we all believe that our way is the best way because our mothers and teachers told us so, we internalize it, so that we are not even aware that it is a part of who we are. It is like tying our shoes. We do it automatically without thinking on a daily basis. We also hand our cultures down from generation to generation. Our culture changes, but the deepest part of our culture, that is, the part under the water, changes very slowly.

It is a good thing that we have a culture. It tells us what to do, how to say something, and how to make meaning out of our experience. We all need to make sense out of our experience with the world. It is just that differing cultures have learned different ways to make meaning.

Through the study of different cultural groups, we have begun to crack this cultural communication code through identifying differences in values, beliefs, nonverbal behaviors, and norms.

Value Differences

I would like to focus now on looking at a few contrasting values between Mexicans and Anglos and how that plays out on the dairy farm. I want to look at differences in family and group orientation and how that affects a sense of pride, loyalty, and getting the job done. I will talk more about the issue of respect and why the Mexican worker nodded his head "yes" when he really didn't know what you were talking about. I will also talk about what it means to tell the truth. Finally, I will talk about the differences in the concept of time.

Family/Group Focus

Oregon dairy producers whom I talked to said that most, if not all, of their Mexican workers come from one extended family. This has worked well for the owner/manager as well as the workers because the family of workers take care of one another in making sure that the job gets done well while also taking care of their own family needs. For example, one dairy owner said that he allows his workers to take the time that they need to return to Mexico every year. Some workers will be gone for as long as two to six months. Before the worker leaves, however, he has his replacement trained. For example, one brother or cousin arrives from Mexico and is trained by his brother/cousin who is currently working on the dairy. Once the new arrival learns the job well, the brother/cousin leaves for an extended stay in Mexico and usually returns to the dairy to relieve another relative. I must caution you though, that you need to make sure that your workers understand whether or not there is a job for both the replacement and the returning worker or only for one of them. You do not need a worker to return from Mexico with the expectation that his old job is waiting for him when it is not.

What I find most impressive about this new, flexible hiring practice found on dairy farms today is that it is not only culturally appropriate and makes good business sense, it is also way beyond where much of corporate America is in addressing the needs of a changing workforce. To quote one Oregon dairy owner, "I need to pay attention to my worker's family needs. If I have a disgruntled wife, I know I will have a disgruntled employee."

Let's take a look at what is going on here from a contrasting value perspective. Why has this worked to hire Mexicans from only one extended family and how is it that the result is better quality work and more dependable workers?

When we look at contrasting values with peoples around the world, we find that there are groups of people who put more emphasis on doing or getting the job done and others who put more emphasis on relationships with others. Generally, we all do both, but there is a difference in which takes higher priority. In Mexican culture and in fact most all of the cultural groups which are Spanish-speaking, the relationship takes a higher priority over accomplishment of jobs. In the mainstream United States culture, we reverse that preference. We must be "doing" something to feel a sense of satisfaction. For example, how many of you are thinking right now about what you are going to do right after my presentation? How many of you make a daily "to do" list? It is not that relationships are not important to us, it is just that our emphasis is put on what each of us as individuals can accomplish in a day rather than "Have I spent time talking with the people in my office?"

For Mexicans, spending time with their group is of the utmost importance. The immediate family, which is defined in much broader terms than how we define family in the mainstream U.S., is the primary group from whom they derive a sense of satisfaction, connection, and identity. It is as if there is a string tied from their belly button to every one of their extended family members, even the ones still living in Mexico. Every move they make affects everyone else in their immediate family, which consists of grandparents, parents, children, aunts, uncles, cousins, and even "padrinos", that is the Godparents of their children.

Cultures, which are more group than individual oriented, take care of their own. They make sure that each member pulls their weight because whatever one member does affects the entire group. That is why hiring Mexicans from one family, makes good business sense. You are meeting their needs to be with their family members, to provide for their family both in the U.S. and in Mexico, and in turn, they will take care of making sure that together they do a good job on the dairy. In fact, the more sense of ownership that you give them to take care of what needs to be done on the dairy farm, the more sense of pride and satisfaction that they will take in doing a good job. As one dairy producer said, "I want them to think that this is their dairy." What happens then is that you have less turn over in employees, they take care of hiring their own replacements, and you build loyalty to your dairy enterprise.

For those of you in the audience who are thinking, wait a minute, this is not fair. Aren't you supposed to advertise a position and make it an equal opportunity for anyone who wants the job to apply and be hired? Let's take a look at that question for just a moment. There are two fundamental U.S. values embedded in that question. The first is a sense of fairness and the second is the belief in equality. Both of these values are built on the belief in another value, the importance of the individual over the group.

I don't want to spend a lot of time talking about the U.S. values of fairness, equality, and the importance of the individual. I simply want to say that if you are feeling uncomfortable with the idea of hiring Mexican workers who are from one family, it may be coming from your own sense of values. I would ask you to think about what these values mean to you. For example, what does it mean to be fair to you? The second question I would think about is what are my labor needs on the dairy farm? If the answer is good reliable workers, then the next question is, "What can I do to ensure that I have the best workers possible?" It is an issue of adapting our U.S. traditional way of hiring to a more culturally appropriate way in this circumstance. It is forward thinking.

Respect and Authority

While fairness is perhaps the most fundamental of mainstream U.S. values, respect is the most fundamental of Mexican values. Respect is important to us in the U.S. also, but the meaning is slightly different when applied from a Mexican perspective.

When you look at "respeto" from the Mexican perspective, you find a very emotionally charged value that is tied to relationships with others, especially hierarchical relationships. For example, if you are the owner/manager of your operation, by the nature of your authority, you are respected. In the mainstream U.S., the nature of your position does not necessarily entitle you to respect, instead, you have to earn it. From a Mexican perspective, respect is assumed by the nature of your position.

How does this play out on the dairy farm? As the owner/manager, you are giving out instructions to your Mexican workers of what to do that day. They listen attentively and nod their heads, as if, you think, they understand. A few minutes later, you see them doing something entirely opposite of what you had just told them to do. What happened here?

I can think of two possibilities, both having to do with the issue of respect. One is that you are the owner/manager. You have a lot of things on your mind to get done that day. Telling the workers what you need done is just one of a long list of tasks to complete. As you are telling the workers what they need to do, they are reading your body language that says that you are in a hurry. You have a lot of things to do. They sense that and as a sign of respect, they do not interrupt you. Instead, they nod to communicate that they are listening to you and they respect you. In their minds, they are hoping that one in their group will understand what you wanted them to do. As soon as you leave, they will immediately ask one another what you said. If they don't know, they cannot go back and ask you because that would be disrespectful of you.

more →

The second possibility is similar in that they know that you want them to understand and because they regard you with respect they nod to say that they want to do the right thing and are listening intently to you. A lower level employee does not interrupt the boss. They also don't want to look stupid in front of you, the boss. They want to please you and look good. Again, in their minds, they are hoping that one of them understood what you wanted.

How can you prevent these two possibilities from unfolding? The answer is simple. Complete the communication loop. Get feedback from them that tells you that they understand. But be careful how you do it. It is just as important that you as the boss show your workers respect. Asking, "Did you understand?" or "Do you have any questions?" is a very direct and somewhat confrontative way of getting feedback from a cultural group that uses much more indirect communication styles. No Mexican worker wants to show his lack of understanding in front of his boss. You and I are comfortable with a very direct communication style so those two questions would not be offensive to us. A way to check to see if they understood is first, to not appear to be in a hurry. Take a moment to greet them individually. Second, after you have given instructions, ask "Did I make that clear?" or "In what points have I confused you?" There is a subtle difference in this second set of questions. The first puts the responsibility on understanding what is communicated on them. The second puts it on you. It is a safer environment for them to speak up and say what they are not clear about.

I'd like to make one more point with regard to showing respect to others. Have you ever noticed that if you are at a social gathering of Mexican people, they make a point of formally greeting everyone in the room when they first arrive? The same goes for when it is time to leave. My Mexican friends will say, I need to go now, but will take over a half-hour to finally get out the door. The reason is that they will go around and formally say good-bye to everyone in the room, even if they do not know that person very well. I find that to be in definite contrast to my own way of doing things, although I do prefer the Mexican way. I find it much easier to slip in, say hi to a few folks, and later slip out when no one is looking. My point here is that taking time to greet one another is a very important way of showing respect to others. You as the boss will always receive respect from the workers and their family. It will strengthen your work relationship with them if you also show them respect through a formal daily greeting.

Telling the Truth

A few of you have shared with me that when something goes wrong in the milking parlor and you ask for what happened and who did what, your workers lie to you. You see that they are not willing to take responsibility for their actions. You could be right, but there might also be something else going on that is culturally based.

In the mainstream U.S. culture, we believe that telling the truth is to give the facts as they exist. Be straight. Be direct. If you don't tell exactly what happened, you are not telling the truth. We value honesty. For example, who here can quote what George Washington said about the cherry tree? And how do we describe Abraham Lincoln? Being directly honest is ingrained in us.

It is a little different in the Mexican culture. Truth is connected to the interpersonal relationship. Again, this is a subtle difference, which is so easy to miss, because we tend to interpret behaviors according to our own "cultural script". In Mexico, there are many different kinds of truth. What the truth is depends on the situation and the relationship of the people involved. For example, sometimes telling the truth is based on loyalty to the person you have a strong relationship with. What if an INS officer approaches a 12-year-old Mexican boy and asks him if his parents are here legally? If they are not legal, what is the most truthful answer for that boy? How does he take responsibility in this situation? If he gives the facts and tells the immigration officer that his parents are not legal, he dramatically changes the life of his parents and his entire family. If he tells the officer that his parents are legal, he is being loyal to his parents but not to the immigration officer. If you were in his shoes, what would be the correct answer? You might say, well, in that case, I would tell a lie to the immigration officer but it is justifiable in this circumstance. To the Mexican, being loyal to your parents is telling the truth. It is a different way to look at telling the truth than we do. It is relationship based.

So in the milking parlor, someone is not cleaning the milking equipment very well. As the boss, you ask, who is not cleaning the milking equipment correctly? No answer. Not because no one wants to take responsibility, but because no one wants to look bad in front of the boss. It is a relationship issue. As the boss, however, all you want are the facts so that you can solve the problem. You come from a culture that values a direct style of communication. It is efficient and effective.

A more indirect approach to handling the situation may be more effective. One way is to make the problem the responsibility of the group. Don't focus on who is not cleaning the equipment thoroughly. Make sure they all know what the problem is and tell them as a group what the consequences to the dairy operation are if you lose your quality bonus. Tell them that if they see someone who does not know how to do a thorough job in cleaning the equipment that they have a responsibility to show that person how to thoroughly clean the equipment. This works if all of your Mexican workers are considered to be a close group. If they are not close, you will have to check the equipment yourself until you can find out who doesn't know how to clean them properly or you will have to rely on a third party informant. Someone in the group will let you know without letting anyone else know that he told you. When you do learn who the culprit is, the best way to work with that person is in a supportive way. Show him what you need without making him lose face, that is be embarrassed or feel stupid. The indirect approach is tricky, but it results in more satisfied workers, more loyalty to the boss, and better quality work overall.

Time

When we think of Mexico, we often think of the land of "mañana". However, there is more to this view of Mexican time. Again, like the other values I have talked about, the issue of time is intertwined with the importance of relationship or connections between people, with being less concerned about "doing" things, and more focused in "being" in the moment. For example, in Mexican culture, interruptions are commonplace and are not considered rude, as we would consider them. It is more common for Mexicans to be in the midst of many things happening at the same time. We tend to segment what we do, that is, do one thing at a time. If a Mexican is waiting on you in a deli, he or she might be waiting on several people at once. To the Anglo, time is money. The Anglo needs to be served so that she can get going with what else she has to do. She doesn't want her server waiting on several people at the same time. This messes up her schedule, her plan. To the Mexican, time is life and relationship. The one thing the Mexican knows he has is time and the most important thing to do with time is to enjoy being with others. When a Mexican is talking with you, he gives you his complete focus and attention because being with you in that moment is of greatest importance. Therefore, as an owner/operator, the most powerful way to show respect to your workers is to be with them in the moment when you are interacting with them. I do think many of you do that because you have told me how much you enjoy working with them and how you consider them to be almost as family members. As one dairyman told me, "Before the Mexicans came to work with us, we were scraping the bottom of the barrel to find good workers. Now, with the Mexicans, we have really good workers."

Steps to Communicating Effectively

Let me review then, some simple steps to consider when you want to work effectively with your Mexican employees. First, is to acknowledge that you have a culturally learned way of seeing the world, communicating with others, and making meaning out of your experience. Mexicans have their own cultural way of being in the world. When communication breaks down between you and your Mexican workers, stop and rethink about what may be going on. It may be something other than what you first imagined. Be clear about what your desired outcome is. It may be to have a safe, effective, profitable dairy operation. Then, considering what you now know about value differences and how that transfers into behavior, consider culturally appropriate communication that will get you your desired outcome with the least amount of added headaches possible. This translates into taking time to be in the moment when you are with your workers, treating each worker with respect, and possibly using more indirect styles of communication.

When I began this talk, I said that the barriers to communication were not just language barriers. A greater barrier is the cultural communication barrier. It takes a lot of work to become conscious of how your own communication style comes from your own culture and then to recognize and accept that there are other cultures which are just as valid as yours, but very different. It is difficult work to do. But the potential outcome is to have a life which is enriched with different ways of seeing and being in the world and a thriving dairy business. And you are up to the challenge, because after all, you are way ahead of most American businesses. And heck, you can always start practicing these cultural communication skills on your spouse or closest partner at home.

As a Final Note

If you are interested in this topic, I would like to suggest three books that you may want to read. They are three of my favorites! They are:

- Good Neighbors: Communicating with the Mexicans, by John Condon, Yarmouth: Intercultural Press, Inc., 1985.
- The Silent Language, by Edward T. Hall, New York: Doubleday, 1959.
- The Spirit Catches You and You Fall Down: a Hmong child, her American doctors, and the collision of two cultures, by Anne Fadiman, New York: Farrar, Straus, Giroux, 1997.

This last book is a page turner and it is more a demonstration how the most well meaning good people miss the real meaning of the message when working cross-culturally.

Evaluating Nutritional Management Changes

MICHAEL HUTJENS—Department of Animal Sciences University of Illinois
Tel: 217-333-2928 Fax: 217-333-7088 hutjensm@uiuc.edu

Every day dairy managers and/or cows make feeding changes on the farm. Some changes are intentional (such as reformulation of rations) while other just "happen" (such as heat stress). The skilled manager, feed consultant, and veterinarian are continually evaluating and "reading" cows. This paper discusses areas to monitor, potential responses, and economic evaluations of feeding program changes. Each person should develop her or his checklist to implement on the farms they work with or own.

Using milk production tools

Milk production records continue to be a valuable tool to evaluate nutritional changes and responses. Several different aspects can be evaluated.

1. Management level milk (MLM) or 150-day milk converts milk production to a common base: 150th day of milk production, same lactation number (usually second lactation), and the same milk components (fat and protein). If MLM changes due to a ration change, the impact of longer days in milk, freshening patterns, age of cows, and component changes are corrected. Thus, the dairy manager can evaluate if the feeding change has had an impact. As a guideline, a shift of two pounds in MLM due to the feeding change may be significant. MLM can also be used to evaluate BST response in treated cows.
2. Profiling milk yield by days in milk (DIM) and lactation number are excellent ways to recognize feeding and management deficiencies or imbalances. Table 1 lists guideline values for Holstein cows summarized by Mid-States DHI records in 1993 (no impact of BST was possible in this data set).

Dairy managers and nutritionists can plot milk yield to determine if cow groups (based on DIM) shift profile guidelines as their lactations continue. Impact of previous lactation can also be evaluated (such as sophomore slump). This analysis can also measure response to BST. The following groups and feeding interpretations could be considered.

- 0 to 50 DIM — Transition cow management; Dry matter intake prepartum and postpartum; Metabolic disorders
- 50 to 100 DIM — Body condition changes; Level of dry matter intake; Impact of ketosis and acidosis; Lack of amino acids (protein shortage)
- Over 100 DIM — Dry matter intake relationship to milk yield; Low body condition score (energy shortage); Ration nutrient density and sources

3. Summit milk yield is the average of the higher two milk weights collected in the initial three measurements on DHI test. While this value is similar to peak milk, summit milk reflects the shape of the milk production curve in early lactation. Table 1 lists summit milk based on lactation number and days in milk. Multiplying pounds of summit milk by 225 (some individuals will use 200) can provide an estimate on the amount of milk that can be produced in the total lactation. The time when peak milk occurs should be 50 to 70 days after calving (50 to 100 DIM in Table 1). If peak milk occurs earlier or

Table 1. Milk production profiles for Holstein herds (Source: Mid-States DHI).

Milk yield (lb)	Lactation (number)	Summit milk (lb)	<50 DIM	50 to 100 DIM	100 to 200 DIM	>200 DIM
23,000	1	75	64	72	69	61
	2	97	86	90	79	62
	3+	104	89	95	85	65
21,000	1	69	59	66	63	54
	2	89	80	83	72	56
	3+	96	81	88	77	59
19,000	1	64	56	61	57	49
	2	82	73	76	66	51
	3+	88	76	80	70	53
17,000	1	59	52	56	52	44
	2	75	67	68	59	45
	3+	80	70	73	64	48

more →

later than this time period, true peak milk may not have been achieved.

4. Milk fat test patterns can reflect changes in rumen pH, nutrients delivered in the ration dry matter, and shifts in body weight loss. Table 2 lists normal breed component values.

Table 2. Normal milk fat and milk protein relationship for various breeds of dairy cattle in 1999 (adapted from Hoards, 2000).

Breed	Milk Fat (%)	Milk Protein (%)	Ratio (% protein/ % fat)
Ayrshire	3.86	3.32	0.86
Brown Swiss	3.95	3.44	0.87
Guernsey	4.42	3.49	0.79
Holstein	3.66	3.15	0.86
Jersey	4.57	3.73	0.82

Evaluate milk fat profiles by lactation number and days in milk. The following days in milk can provide clues to feeding effects related to milk fat test.

a. Less than 50 days in milk. High milk fat tests (over 1.0 percentage point above breed average such as 5.6 for Jersey cows) reflect excessive weight loss. Low fat tests can reflect energy shortages.
b. From 50 to 150 days in milk. Milk fat test will be at their lowest point unless negative rumen effects have occurred. For high producing Holsteins, a milk fat test between 3.0 to 3.3 percent is not a concern.
c. From 150 to the end of lactation: Milk fat should be normal for the breed (Table 2).

5. Milk protein test patterns should follow milk fat test patterns listed above. Breed averages for 1999 listed in Table 2 reflect total protein values (0.19 units higher than true protein initiated in 2000). If milk protein tests are below breed average or the ratio of milk protein to milk fat is below breed average, the genetic protein level is not being achieved. The following areas should be reviewed if milk protein test are too low.
   d. The amount of fermentable carbohydrate is low reducing microbial protein production. Evaluate levels of starch, sugar, and fermentable fiber.
   e. Evaluate the level of total protein, levels of rumen degradable and undegradable protein, and amino acid balance.
   f. Determine if rumen factors may be limiting microbial growth (such as rumen acidosis).
   g. Feeding unsaturated and rumen unprotected fats and oils can reduce milk protein test. Total milk yield may have increased while total amount of protein remains constant.
   h. Low ration dry matter intake and digestibility can reduce microbial yield and intake of undegradable protein.
6. The ratio of milk protein to milk fat can be used to determine if milk fat depression has occurred. Milk fat inversions can be defined as when individual cows have milk fat tests that are less than 0.2 point below milk protein test. For example, a Holstein cow with a 3.0 percent milk protein test and 2.8 percent milk fat test or lower would be inverted using the current true protein test. Before 2000, milk protein was 0.19 unit higher because milk was tested for total protein. The following guidelines can be used to determine a feeding practice has led to a milk fat test inversion.
   a. If over 10 percent of the cows in the herd have milk fat inversions greater than 0.2 points.
   b. Cows one full point below the breed average milk fat percent (for example, Jersey cows below 3.6).

Measuring blood values

Wisconsin workers have developed guidelines on biological tests that could be conducted on a herd to evaluate nutrition related problems. Two types of tests can be used.

- Tests to determine the proportion or percent of cows in the herd being affected (requires a minimum of 12 cows) including rumen pH, plasma fatty acids, and blood ketones
  i. Tests to determine the herd average occurrence of the problem (requires 8 or more cows) including urine pH (with feeding anionic salts) and milk urea nitrogen

Rumen pH is measured by testing 12 or more cows four hours after eating using a rumen tap or rumenocentesis (a needle is inserted in the lower left side of the cow and a small sample of rumen fluid extracted). If over 25 percent of the cows have rumen pH values below 5.5, sub-acute rumen acidosis (SARA) may be occurring.

Serum beta hydroxybutyrate acid (BHBA) is measured by taking a blood serum sample from cows 5 to 50 days after calving at 4 to 5 hours after eating a meal. Serum level over 14.4 mg per deciliter in 10 percent or more of the sampled cows indicated sub-clinical ketosis (values over 26 are ketotic cows). Sub-clinical ketosis could reflect a poor transition cow program, low dry matter intake, heavy cows, and/or metabolic disorders.

Plasma non-esterified fatty acids (NEFA) reflect if cows are mobilizing body weight to meet energy shortages. Blood is taken from cows 2 day to 14 days before calving. Test those cows that actually calve in the 2 to 4 day prepartum (cows do not calve on time and blood samples can not be taken if the cow has calved early). Sample cows just prior to the main feeding. If greater than 10 percent of the 12 cows sampled are over 0.400 milliequivalent per liter, a potential energy deficiency may be occurring in the herd leading to metabolic disorders.

Urine pH from cows receiving anionic products to prevent milk fever and minimize hypocalcemia (low blood calcium) should average 6.0 to 6.5 for Holstein cows. Collect urine samples after cows were fed anionic products for a minimum of 2 to 3 days. Sample a minimum of eight cows at four to eight hours after the cows have consumed feed (especially if dry cows are fed once a day).

Milk urea nitrogen (MUN) or blood urea nitrogen (BUN) reflects if an optimal balance of protein (especially degradable and soluble protein fractions) and fermentable carbohydrate occurs. Sample eight cows per group to determine if the average is between 12 to 16 milligrams per deciliter for MUN or BUN. For BUN analysis, sample 2 to 4 hours after a major meal has been consumed. Looking at groups of 8 to 10 cows (by lactation, days in milk, feed group, or level of milk production) should be used to evaluate MUN values.

Feed particle size

Illinois workers use the following set of sieves to measure corn particle size.

- Top screen (number 4 and 4750 micron) captures whole and large particles
- Second screen (number 8 and 2360 microns) represents cracked corn
- Third screen (number 16 or 1180 micron) represents "cow" corn particles
- Fourth screen (number 30 or 600 micron) represents "pig" corn particles
- The pan which represents powder or feed grade starch

In a typical Midwest ration containing hay, haylage, corn silage, and typical concentrate level, no dry corn should appear on the number 4 screen (passes undigested), less than 10 percent on the number 8 screen, 25 to 35 percent on the number 16 screen (slow released starch in the rumen and small intestine digestion), 50 to 60 percent on the number 30 screen (finely ground feed for rumen fermentation) and less than 15 percent in the pan (rapid available starch for the rumen microbes). If the ration contains higher levels of wet haylage, lower amounts of corn, and by-product feeds, the corn particle size could be reduced. Reducing corn particle size will increase the risk of rumen acidosis. Brass U.S. Standard sieves can be purchased from Fisher Scientific (800-766-7000) or Seedboro Equipment Company (312-738-3700). Prices will vary from $200 to $260 per set of five. Another approach to measure finely ground corn is to use a flour sifter (similar to a number 14 or 16 screen) to estimate particle size. Finely processed corn will have one third remaining in the flour sifter (two thirds will pass through).

Measuring forage particle size using the Penn State particle boxes continues to be a popular way to objectively evaluate if forage and TMR have optimal forage particle size. Place a 200 to 300 gram sample in the box and shake until all feed has been exposed to the holes in each box. Compare the weight in each box to the guidelines in Table 3. Recent field observations indicate if the top screen in TMR is over 15 percent, cows may sort the ration. To calculate the amount of effective fiber, subtract the percent in the bottom box from 100 and calculate the amount of effective NDF contributed by silage by multiplying the pounds of silage dry matter times the percent silage NDF times the percent silage in the top and middle box. Feed particles in the middle box may be more important than the top box only. The Penn State box can also be used to evaluate weigh back or orts to determine if feed sorting has occurred. One guideline is the percent of feed in each box in the weight back should be plus/minus five percentage points of the original TMR

Table 3. Penn State particle size box guidelines expressed as the percent in each box on an as fed basis.

Feed measured	Top % of total	Middle	Box
Total mixed ration	8 to 15	35 to 45	<50
Haylage	>20	30 to 50	<40
Corn silage (3/4" TLC, processed)	10 to 20	40 to 60	<35
Corn silage (3/8" TLC, unprocessed)	<5	>50	<50

Manure evaluation

Dairy managers watch manure changes as a guide when making feed changes. Fresh, undisturbed piles of feces or droppings may provide valuable clues on the nutritional status of the cow. Three aspects of manure evaluation can be considered.

more →

Washing manure

Washing manure through a screen (6 to 8 squares to the inch) allows the dairy manager to quickly find or "see" if feed processing and digestion is optimal. Take a cup of fresh manure and wash it with a stream of warm water (cold water takes longer) through the screen removing the digested material. It typically takes about 30 seconds if your screen has sides allowing for more water pressure. Look for the following remaining feed particles. Finding pieces of barley or corn grain with white starch remaining indicates that some feed value was lost. If the seed and starch pieces are hard, additional grinding or processing may be needed to expose the starch to rumen microbial fermentation or lower gut enzymatic digestion. Corn kernels from corn silage reflect that the seed was too hard for digestion and chewing by the cow. Mature and dry corn silage can cause this observation as grain is hard. Some corn silage varieties can be selected for softer kernels allowing for more digestion. Whole cottonseeds or soybean splits (half of a soybean seed) that appear in the washed manure reflect a loss of feed nutrients. The cottonseeds are not caught in the rumen mat and do not allow for rechewing. If roasted soybean seeds are hard, they must be processed finer. Wisconsin workers suggest breaking soybeans into fourths or eighths. Forage particles over ½ inch long may reflect a lack of long forage particles to maintain the rumen mat and adequate cud chewing. A higher rate of passage reduces the time needed in the rumen to digest the fiber properly.

Scoring manure

Michigan workers developed a scoring system to evaluate fresh manure. Consistency is dependent on water and fiber content of the manure, type of feed, and passage rate. A scale of 1 to 5 is listed below with a score 3 optimal.

- Score 1. This manure is very liquid with the consistency of pea soup. The manure may actually "arc" from the cow. Excess protein or starch, too much mineral, or lack of fiber can lead to this score. Excess urea in the hindgut can create an osmotic gradient drawing water in the manure. Cows with diarrhea will be in this category.
- Score 2. This manure appears runny and does not form a distinct pile. It will measure less than on inch in height and splatters when it hits the ground or concrete. Cows on lush pasture will commonly have this manure score. Low fiber or a lack of functional fiber can also lead to this manure score.
- Score 3. This is the optimal score! The manure has a porridge-like appearance, will stack up 1 1/2 to 2 inches, have several concentric rings, a small depression or dimple in the middle, make a plopping sound with it hits concrete floors, and it will stick to the toe of your shoe.
- Score 4. The manure is thicker and stacks up over 2 inches. Dry cows and older heifers may have this type of manure (this may reflect that low quality forages are fed and/or a shortage of protein). Adding more grain or protein can lower this manure score.
- Score 5. This manure appears as firm fecal balls. Feeding a straw-based diet or dehydration would contribute to this score. Cows with a digestive blockage may exhibit this score.

Manure scores 1 and 5 are not desirable and may reflect a health problem besides dietary limitations. Score 2 and 4 manure may reflect a need to rebalance the ration. As cows progress through their lactation, manure score may also shift as outlined below.

- Fresh cows (score 2 to 2½)
- Early lactation cows (2½ to 3)
- Late lactation cows (3 to 3½)
- Far off dry cows (3 to 4)
- Close up dry cows (2½ to 3½)

Increasing the amount of degradable, soluble, or total protein, deceasing the amount or physical form of the fiber increasing starch level, decreasing grain particle size (such as fine grinding or steam flaking), and consuming excess minerals (especially potassium and sodium) can cause manure scores to decline.

Manure color

The color of manure is influenced by feed, amount of bile, and passage rate. Manure from cows on pasture is dark green while hay-based rations are brown. Manure from high grain-based diets are more gray-like. Slower rates of passage cause the color to darken and become more ball-shaped with a shine on the surface due to mucus coating. Score 1 may be more pale due to more water and less bile content. Hemorrhage in the small intestine causes black and tar-like manure while bleeding in the rectum results in red to brown discoloration or streaks of red.

Metabolic disorders

Monitoring metabolic disorders can provide the dairy manager and nutritionists with benchmarks to consider if a feeding problem exists. Texas worker surveyed 61 high producing Holstein managers (herd average was 24,442 pounds of milk per cow) to determine the occurrence of metabolic disorders in their herds. The following rates were reported.

- Milk fever 7.2%
- Ketosis 3.7%
- Displaced abomasums 3.3%
- Downer cows 1.1%
- Retained placenta 9.0%

Another disorder is low levels of low blood calcium (also called hypocalcemia) when the blood calcium level drops below 8 milligrams per deciliter. Low blood calcium can impair smooth muscle contraction affecting digestive and reproductive tracts. Florida and Colorado workers sreported nearly 60 percent of high producing Holstein cows were classified as hypocalcemic cows. Twinning (four percent is normal) adds nutrition demands to the dry cow leading to potential metabolic disorders. Dairy managers must accurately collect data on their herd to build a profile to assist problem solving and potential weak links.

Evaluating Silage Fermentation

To evaluate silage fermentation, dairy managers and consulting nutritionists can send a sample of silage to commercial labs. Optimal fermentation profiles are summarized in Table 4. The cost of this analysis will range from $20 to $30 a sample. By evaluating the fermentation characteristics, forage quality at ensiling, moisture content, and silage storage characteristics can be evaluated and improved next year. Levels of acetic acid increase as dry matter content drops. Higher levels of butyric acid indicate a fermentation problem. While higher lactic acid is considered “desirable” fermented silage, it may not prevent aerobic secondary fermentation. A certain amount of acetic acid is desirable to minimize possible yeast and mold organism growth. High levels of butyric acid contribute to an aerobic environment. Wisconsin workers reported that wet haylage can contain 0.5 to 1.5 percent butyric acid on a dry matter basis. Butyric acid is an undesirable volatile fatty acid (VFA) produced during poor silage fermentation. The butyric acid is consumed by the cow and converted to beta hydroxybutyric acid (BHBA) leading to ketosis and metabolic disorders. If cows consume over 50 grams of the butyric acid (for example, 22 pounds of haylage dry matter containing 0.5 percent butyric acid on a dry matter basis would provide 50 grams of butyric acid), animals are at risk. Higher levels of ammonia and other nitrogen compounds may exist reducing forage quality in these high butyric acid silages. Clostridium organisms can exist when unfavorable fermentation patterns (pH over 5) and higher butyric acid level occur. Butyric acid could be a “marker” of poor silage quality.

Table 4. Recommended fermentation profile for ensiled feeds (Source: Dairyland, 2000).

Measurement	Legume/grass mixture			Corn Silage	H.M. Corn
Dry matter (%)	<35	35 to 50	>50	35 to 40	70 to 75
PH	4.0 to 4.3	4.3 to 4.7	4.7 to 5.0	3.8 to 4.2	4.0 to 4.5
Lactic acid (%)	6.0 to 8.0	4.0 to 6.0	2.0 to 4.0	5.0 to 10.0	1.0 to 2.0
Acetic acid (%)	1.0 to 3.0	0.5 to 2.5	0.5 to 2.0	1.0 to 3.0	<0.5
Propionic acid (%)	<0.5	<0.25	<0.10	<0.10	<0.10
Butyric acid (%)	<0.5	<0.25	<0.10	<0.10	<0.10
Ethanol (%DM)	<1.0	<1.0	<0.5	<3.0	<2.0
Ammonia (% CP)	<15.0	<12.0	<10.0	<8.0	<10.0
Lactic/Acetate	>2.0	>2.5	>2.5	>3.0	>3.0
Lactic (% total)	>60	>70	>70	>70	>70

Evaluating Nutrient Intake and Additives

Evaluating nutrient changes in the feeding program is a common approach to evaluating milk responses. The following guidelines can assist dairy managers to determine if their feeding programs are optimal. Dry matter intake guidelines can be a key factor to compare and evaluate nutritional changes.

- For each pound of additional dry matter intake (above current intake), milk production increases by two pounds.
- The initial 11 to 13 pounds of dry matter intake consumed by Holstein cows are needed to meet the maintenance energy requirements (10 Mcal of net energy). Subtracting 13 pounds of dry matter from total dry matter intake calculates energy available for milk production. Multiply the remaining dry matter by 2 to estimate milk production potential. For example, a high group of Holstein cows consuming 53 pounds of dry matter can support 80 pounds of milk (53 lb of DM - 13 lb of DM for maintenance equals 40 pounds of DM times 2 results in 80 pounds of milk).

more →

- Dividing the pounds of Holstein milk (3.5 percent milk fat) by the pounds of dry matter reflects efficiency of converting dry matter to milk. A value greater than 1.5 (for example 80 lb of milk divided by 53 is 1.51) is excellent. A value below 1.3 should be evaluated (milk yield is too low or cows are eating too much or both).
- If a feeding change occurs and dry matter intake increases by two pounds or more, continue the change. Increasing feeding frequency, adding a bunk stabilizer (propionic acid-based product), adding buffer, or shifting forage sources are examples that could increase dry matter intake.
- Monitor feed weigh backs targeting 2 to 4 percent of the total fed to a group of cows. Using the Penn State Particle box, shake the orts and determine if orts are within five percent of the original TMR.

Shifting nutrient level is another approach to evaluate if cows will respond. The following strategies and timelines may be helpful.

- If added protein or amino acids are fed, a production response can be expected in one week. Monitor milk protein test along with milk yield.
- Adding one pound of fat or oil can increase milk production 3 to 4 pounds of milk. Monitor milk fat test along with milk yield.
- Increasing minerals will not increase milk production (impacts reproduction and health). Allow six months to a year before evaluating responses.

Feed additives continue to be controversial when evaluating feeding programs. When deciding if an additive will be beneficial, determine how the additive will impact the herd (high dry matter intake, less heat stress, improve rumen pH, or the biological response). Once the additive has been selected, insure the optimal level of additive is fed based on research results. Finally, determine the length of time required before a response can be expected. Two examples are listed below.

- Sodium bicarbonate

  Response: Increase dry matter intake
  Level: 0.75 percent of the ration dry matter
  Time to respond: 2 to 3 weeks
  Cost: 5 to 8 cents per cow

- Biotin

  Response: Improve foot health
  Level: 20 milligrams per cow per day
  Time to response: 6 to 12 months
  Cost: 6 to 10 cents per cow per day

Carefully evaluate the role of additives as they can result in a benefit to cost ratio as high as 12 to 1 or increase feed costs 5 to 10 percent without a desired response.

Economic Evaluations and Comparisons

A key measure when evaluating feeding changes is the impact on profitability. Several measurements are listed below for consideration. Each value can have advantages and disadvantages.

Feed cost per cow per day does not reflect milk yield, stage of lactation, or nutrient requirements. A target value in Illinois is less than $3.50 per cow per day for Holstein cows at 70 pounds of milk. A better application of this value is divide the components to determine if your costs are optimal for your herd's production and local feed costs (Table 5).

Table 5. Illinois feed costs for a group of cows averaging 70 pounds of milk.

Feed	D.M. intake (lb/day)	Cost/lb DM ($)	Total cost ($/day)
Forages	25	0.04	1.00
Grain energy	15	0.05	0.75
Protein supplement	5	0.10	0.50
By-product (cottonseed)	4	0.08	0.32
Mineral & vitamins	1	0.30	0.30
Feed consultant			0.10
Totals	50		$2.97

Feed cost per pounds of dry matter is a useful term when comparing similar regions, breeds, and levels of milk production. A target value in Illinois is less than six cents per pound of dry matter for Holstein cows at 70 pounds of milk.

Feed cost per 100 pounds (cwt) of milk has the advantage of standardizing milk yield allowing for comparisons between groups and farms within a region. Milk yield per cow and feed costs will impact this value. A target value in Illinois is less than $4.50 per cwt for Holstein cows.

Income over feed costs (IOFC) is a popular value as it provides a benchmark for herd or groups of cows reflecting profitability, current feed prices, and actual milk prices. If dairy managers have calculated fix costs and other variable costs, IOFC can be used to determine breakeven prices, optimal dry off time, and culling strategies. A target value in Illinois is over $5 per cow per day.

Marginal milk response reflects the profit if additional pounds of milk can be achieved. Generally, this approach is profitable if cows respond to the feeding change because maintenance costs and fixed costs have been covered by previous production. For example if adding one pound of fat increases milk yield by four pounds and fat costs 30 cents, then the marginal milk profit is 18 cents if milk is valued at 12 cents a pound.

Cost per unit of nutrient allows dairy managers to compare the relative cost of a nutrient. If corn is priced at five cents per pound (dry matter basis), one unit of net energy is worth $0.054 cents per Mcal of net energy. If corn is the base energy feed resource, forages, by-product feeds, and other cereal grains can be compared on their cost per unit of nutrient.

Feed efficiency can be calculated by expressing the pounds of milk produced per pound of dry matter or other nutrient basis (such as percent nitrogen recovery as milk protein or energy captured as milk and tissue). A target value in Illinois is over 1.4 pounds of milk per pound of dry matter for Holstein cows.

U.S. Top Dairies: Benchmarks for Success

MARK W. STEPHENSON, Ph.D—Cornell Program on Dairy Markets and Policy, ARME, Warren Hall, Ithaca, NY 14853
Tel: 607-255-0324 Fax: 607-255-9984 mws5@cornell.edu

The year 2000 will be a low milk price year for dairy producers. Barring a serious natural disaster such as widespread flooding or drought, we cannot expect the average level of prices at the farm to be much better than $1.75-$2.00 per hundredweight below the levels of 1999. For many dairy producers this is a sobering prospect. For others, the market correction has been well anticipated and, while it may dampen their short-term outlook, they will not take their eyes off of their long-term goals. 1997 was a similar year for producers and it was the year that a new initiative called the *U.S. Top Dairies Program* was launched.

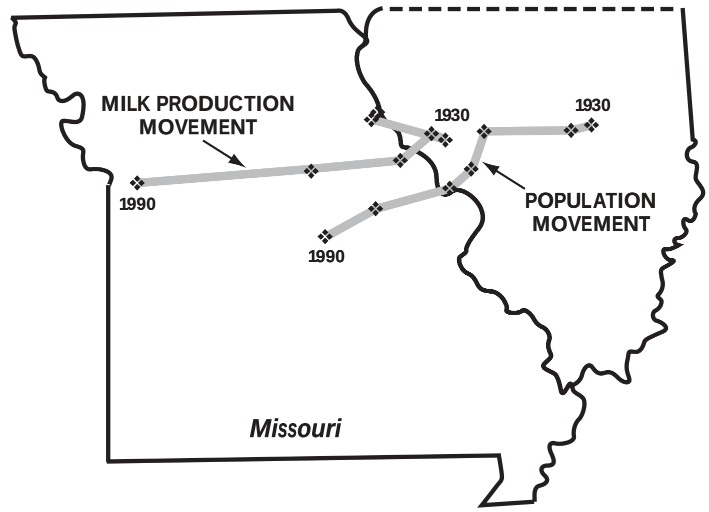
A handful of producers in the Northeast were asking questions about the lowest cost region of the country to locate a dairy farm. They had witnessed the tremendous growth of milk production in the western states and were wondering if Idaho or New Mexico was the dairy area of the future. They were further questioning whether they should relocate in one of the currently growing regions. It is useful to examine the reasons behind the growth in the western states as well as to look carefully at the actual returns from dairies across the country, before making such a critical decision.

The Growth of Western Milk Supplies

One hundred years ago, New York was the top milk producing state. Around 1914, Wisconsin surpassed New York and held the lead by a wide margin for the next eighty years. In 1994 California surpassed Wisconsin to become our number one milk producing state. There have been many reasons for the increase milk production in California, but one of the biggest has been a rapidly growing market.

A "centroid" is a geographically weighted average number. If you visualize the United States as a cut-out on a two dimensional surface, or platter, with people stacked up as weights where they actually live, the centroid would be the balancing point of that plane. That point has been moving south and west for many years. The corresponding centroid of milk production has always been located to the northwest of the population, but it has followed population in quite a parallel fashion-milk supplies have grown where there was a local population to demand dairy products. The figure in the next column gives some idea of the relationship between the centroid movements.

A first lesson to be learned is that it is advantageous to be near your markets. A closer examination of the centroid movements does reveal that in the past two decades, the milk production centroid has outpaced the population movement to the west. There could be several plausible reasons for this: there are agronomic resources (climate and soils) better suited to milk production in the West, the momentum of historic production decisions has carried production past it's equilibrium, or that the efficiency of our food distribution system has reduced costs to the point that it really doesn't make much difference where products are produced. Perhaps there is a bit of truth in each of those possibilities.



The West certainly has excellent agronomic resources. California is an enormous garden and looks as though anything that is watered can be grown somewhere in the state. Alfalfa is no exception. The quality of that forage may be equaled, but it is not surpassed anywhere, and the irrigated yields are tremendous. That being said, I don't believe that the soils and climate are the overriding reasons for the phenomenal growth of milk production.

Historic production decisions have played a role in California's rise to the top. In the 1920 to 30s the 40 quart can was being widely embraced as a universal standard for shipping milk to the market. During that same time, the dairy industry in California was experimenting with bulk tanks. The new and larger dairy farms that were being built to supply the growing demand in San Francisco and Los Angles really could justify the single large expense of on-farm cooler technology. The 10 to 30 cow operations that were a standard in Wisconsin at the time could not. It would be another thirty years before herd sizes in other parts of the country were large enough to move up to a bulk tank. The bulk tank was a pivotal technology in the evolution of the dairy industry and its early adoption by western dairy farms helped to accelerate the growth in that region.

One hundred years ago, raw milk was being shipped by train as far as 400 miles into the metropolitan areas of the Northeast and butter and cheese was coming in from

more ⟶

the Midwest. The technology of transportation and the distribution of finished products nowadays is truly amazing. A pound of cheese or butter can be sent from California to New York for as little as five cents. Local production is not as important as it once was leaving dairy producers free to consider exactly where the lowest cost of milk production might really be achieved.

Regional Costs of Production

Many Land Grant Universities have collected and summarized costs of production over the years. For example, Cornell University has had the Dairy Farm Business Summary (DFBS) project for more than fifty years. These efforts have provided invaluable benchmarks for dairy producers to examine their own operations. As useful as the DFBS has been, it was inadequate to answer the questions that many of the producers in New York were asking. If it only cost 5 to 7 cents per pound to ship cheese from one end of the country to the other then theoretically, milk prices in California and New York might only differ by 50 to 70 cents per hundredweight (100 pounds of milk can be transformed into about 10 pounds of cheese). The potentially small difference in milk prices liberates producers from the observation that you need to be close to your market and it also makes you aware that your competition may not be limited to your New York neighbors.

The USDA's estimates of regional costs of production provide a starting point for assessing your competition. The surveys of milk producers used to compile these data are meant to be statistically valid and represent the general population in the region. Because of the ten-fold difference in average farm size between the northeast and western regions, a statistically valid comparison is not really a meaningful comparison of the achievable differences in costs of production. The returns-to-scale on dairy farms is substantial and we should be comparing "apples to apples". The New York DFBS in general represents larger-than-average farms and the dataset can be queried for farms in a particular size range. However, not every state has a DFBS program and the data that are available have been collected and reported in different ways. The only truly valid comparison would be a collection and summarization of original data.

The first *U.S. Top Dairies* program was an attempt to look at "best practice" farms in all of the major dairy regions of the country. Academics, dairy cooperatives, processors and regulatory agencies were asked to nominate "best practice" dairy operations in their region of the country. The selection was not necessarily to be the largest farms, but rather farms likely to be the low cost producers in each area. Those dairy producers were sent letters of invitation to complete a financial survey, modeled after the New York DFBS, and in August of 1997 the results would be shared among this group at a meeting in Orlando, Florida. Approximately 100 producers from all over the country accepted that invitation.

Tables at the end of paper (tables 1 to 9) summarize data that was collected. Because there were too few observations to make state-by-state comparisons, a geographic separation was made between "Eastern" and "Western" operations. Rather than being any strict definition of geography, the sample data presented themselves with no observations from a line running roughly from North Dakota to Louisiana. The financial performance summary is shown with five different methods of comparison. The "average" column is the simple average of all observations in the data. The "eastern" and "western" columns are the average of the farms in regions described above. And, the "Top 5" farms represent the average values of the five most profitable farms as determined by the highest rate of return on assets in the two geographic separations. These two regions of the country make an interesting cleavage of the sample because of the predominance of different farming systems in each area. Many interesting observations can be drawn from the summary. Although the farms represented covered quite a range in size, they were on average very large farms. The western farms averaged more than twice as many cows as the eastern operations but the eastern farms averaged more than six times the total crop acres. The two groups also had statistically different milk yields with the eastern farms averaging 22,588 and the western producers averaging 19,390 pounds per cow per year. Although the profile of income and expenses differed quite a bit between these two groups, the net farm income was almost identical with eastern farms averaging $218,936 and western farms averaging $206,928.

A perception of many people is that farms in the east have a much higher milk price while western farms enjoy lower costs of production. Both of these dogmas were challenged by the data. Eastern farms did have a higher milk price averaging $14.84 than the western farms at $14.06, but the difference was not as large as many people suspect. The notion of lower costs of production in the West was truly challenged. A buildup of the operating, or cash cost per hundredweight revealed that eastern farms spent $12.09 while the western farms spent $12.51 in that year. This meant that the margin, or net return over operating costs, was $1.55 for the western farms and $2.75 for the eastern farms. Smaller margins on the western farms, but coupled with their larger farm size yielded nearly identical net farm incomes.

The Evolution of U.S. Top Dairies

The first *Top Dairies* workshop gathered financial data with a mail-in survey. Producers at that workshop had asked if the one-month turn around between submission of data and reporting could be shortened. Technology has made their requests possible. Annual farm data can be collected remotely using the internet and a farm summary is instantly generated. Moreover, all farms can participate and they can examine their businesses in ways that were never before possible. They can remotely query the database of financial submissions to generate benchmarks of their own design. For example, a farm may wish to look at operations of a similar size in their region of the country. They might wish to further constrain the request to Jersey herds with a substantial portion of forage consumption through grazing. If at least three records meet their request, a report is generated that compares their farm with the query of the database. Farms can also look at operations with high rates of returns on assets and see what business practices are consistent with high profit levels. A thorough examination of your own operation's strengths and weaknesses is possible. Scatterplots with hundreds of combinations of variables can also be generated showing your farm relative to all others in the database. Users can be assured that this is a highly secured web site and that all individual information is held in strictest confidence. You cannot view individual data other than your own.

This year, more than 500 farms from across the country have submitted their data. Every entry is screened to ensure that the data collected is of high quality. The real strength of this approach is in the interrogation of the data for suitable benchmarks for an individual farm to measure performance. But it is also possible to generate summaries that provide insights into farms grouped by different categories. A second set of tables (tables 10 to 12) follows which looks at the 1999 data and summarizes financial performance by herd size and by purchased versus grown feed.

The Future of U.S. Top Dairies

The U.S. Top Dairies program is a grass roots effort and is growing rapidly. Academics from different disciplines-Animal Science as well as Agricultural Economics-across the country are working with consultants and other industry representatives to encourage producers to become involved. It is not possible to know where you are going if you don't know where you are. A financial "benchmark" tells you exactly where you stand relative to your competition and can point you in the direction of your next step. For some, the next step may be relocation or a satellite expansion in a different part of the country. For others, it may be a move toward grazing or more simply the awareness of a need to trim costs out of a particular expense category such as concentrate purchases or machinery repairs.

The second workshop, *U.S. Top Dairies-2000*, was held this fall. Participants from across the country again gathered to exchange ideas about best practices on dairy farms with an eye toward the bottom line. Individual producers may be unable to substantially alter the price that they receive for milk, but they are in control of their costs of production. Milk is profitably produced in all fifty of the United States. Understanding how the top dairies in each region have achieved high profits may help anyone become a more profitable producer. Please feel free to visit and use the U.S. Top Dairies web site located at *http://cpdmp.cornell.edu/topdairies* and click "go to the on-line data entry and query page" at the bottom. Participants who submit data have unlimited access to database queries for the year(s) in which they have submitted data. Guests can have limited access to queries from earlier submissions.

Table 1. Descriptive Statistics

Values for 1996	Average	Western	Eastern	Western Top 5	Eastern Top 5
Cows	980	1419	655	1214	629
Heifers	510	615	432	517	461
Percent custom raised	18%	20%	17%	31%	14%
Milk sold per dairy	20,168,780	27,654,684	14,630,333	22,026,043	14,078,959
Milk sold per cow	21,228	19,390	22,588	19,628	22,567
Milk sold per worker	1,291,990	1,637,631	1,035,959	1,688,509	1,062,397
Cows per worker	63	86	46	89	46
Total crop acres per cow	0.99	0.24	1.55	0.00	1.59
Crop acres	608	151	946	2	1005
Acres owned	419	132	632	0	583
Acres rented	341	45	561	2	697

more →

Table 2. Receipts, Expenses, Net Farm Income, and Return on Assets

Values for 1996	Average	Western	Eastern	Western Top 5	Eastern Top 5
Receipts					
Milk	$2,819,110	$3,932,417	$2,076,905	$3,321,184	$2,141,690
Dairy cattle	$106,016	$133,536	$87,669	$95,847	$51,855
Dairy calves	$21,543	$26,853	$18,003	$8,041	$8,924
Other livestock	$13,746	$27,055	$4,873	$27,315	$9,281
Crops	$35,892	$14,896	$49,888	$0	$28,684
Custom machine work	$3,221	$43	$5,339	$0	$2,161
Government receipts	$10,016	$4,526	$13,676	$0	$19,241
Other receipts	$48,392	$44,948	$50,687	$25,052	$194,568
Total receipts	$3,057,935	$4,184,274	$2,307,042	$3,477,439	$2,456,406
Expenses					
Hired labor	$365,814	$398,866	$343,779	$251,858	$353,974
Dairy grain & concentrate	$835,212	$1,262,251	$550,519	$1,096,738	$565,321
Dairy roughage	$289,990	$642,444	$55,021	$457,483	$11,020
Nondairy feed	$50,694	$50,687	$50,699	$0	$0
Machinery hire, rent & lease	$33,470	$30,865	$35,207	$15,848	$39,248
Machinery repairs	$75,917	$72,707	$78,058	$73,407	$89,372
Fuel, oil & grease	$32,251	$30,081	$33,698	$24,779	$29,217
Replacement livestock	$163,828	$317,496	$61,384	$83,542	$4,800
Milking supplies	$52,166	$75,467	$36,632	$58,723	$43,026
Breeding	$19,622	$24,924	$16,087	$17,390	$18,453
Veterinary & medicine	$60,200	$67,547	$55,301	$81,441	$57,565
Cattle rent & lease	$5,173	$3,364	$6,379	$2,400	$3,494
Custom boarding	$16,705	$17,801	$15,974	$23,712	$21,965
Other bST & marketing	$110,627	$117,432	$106,090	$161,753	$117,281
Fertilizer & lime	$26,054	$8,661	$37,649	$0	$35,089
Seeds & plants	$14,043	$1,555	$22,369	$0	$27,341
Spray & other	$23,539	$14,247	$29,733	$0	$54,090
Land, bldg. & fence repair	$24,492	$14,783	$30,965	$16,490	$50,845
Real estate taxes	$17,886	$17,249	$18,311	$2,467	$22,085
Rent & lease	$60,699	$72,193	$53,036	$119,376	$69,804
Insurance	$25,329	$31,278	$21,363	$17,090	$23,440
Utilities	$50,302	$65,957	$39,866	$53,944	$37,779
Interest	$148,945	$196,355	$117,338	$163,367	$122,563
Miscellaneous	$82,795	$127,729	$52,839	$46,760	$44,600
Total Operating	$2,585,752	$3,661,938	$1,868,294	$2,768,567	$1,842,370
Expansion livestock	$73,434	$102,196	$54,259	$151,653	$19,484
Machinery & bldg. expense	$184,595	$213,159	$165,553	$73,409	$92,023
Net Farm Income	$214,154	$206,982	$218,936	$483,809	$502,529
Operator’s and unpaid family	$113,372	$104,425	$119,337	$84,000	$134,000
Rate of Return on Assets	3.97	3.44	4.32	20.08	14.12

Table 3. Receipts & Expenses per Hundredweight					
Values for 1996	Average	Western	Eastern	Western Top 5	Eastern Top 5
Milk	$14.52	$14.06	$14.84	$14.75	$15.19
Dairy cattle	$0.51	$0.42	$0.58	$0.43	$0.37
Dairy calves	$0.10	$0.09	$0.11	$0.05	$0.06
Other livestock	$0.05	$0.09	$0.03	$0.11	$0.06
Crops	$0.32	$0.09	$0.48	$0.00	$0.19
Custom machine work	$0.01	$0.00	$0.01	$0.00	$0.01
Government receipts	$0.08	$0.03	$0.11	$0.00	$0.14
Other receipts	$0.31	$0.18	$0.40	$0.14	$1.41
Total receipts	$15.90	$14.96	$16.55	$15.47	$17.43
Expenses					
Hired labor	$1.96	$1.37	$2.37	$1.15	$2.51
Dairy grain & concentrate	$4.41	$4.79	$4.14	$4.84	$4.04
Dairy roughage	$1.02	$1.98	$0.36	$1.88	$0.08
Nondairy feed	$0.15	$0.08	$0.20	$0.00	$0.00
Machinery hire, rent & lease	$0.20	$0.15	$0.24	$0.07	$0.26
Machinery repairs	$0.45	$0.30	$0.55	$0.30	$0.62
Fuel, oil & grease	$0.21	$0.13	$0.26	$0.12	$0.21
Replacement livestock	$0.56	$0.84	$0.36	$0.41	$0.04
Milking supplies	$0.26	$0.29	$0.25	$0.26	$0.29
Breeding	$0.10	$0.09	$0.10	$0.07	$0.12
Veterinary & medicine	$0.33	$0.24	$0.40	$0.34	$0.40
Cattle rent & lease	$0.03	$0.02	$0.04	$0.02	$0.02
Custom boarding	$0.11	$0.09	$0.11	$0.16	$0.17
Other bST & marketing	$0.61	$0.36	$0.79	$0.68	$0.85
Fertilizer & lime	$0.22	$0.14	$0.28	$0.00	$0.25
Seeds & plants	$0.12	$0.02	$0.19	$0.00	$0.19
Spray & other	$0.18	$0.08	$0.26	$0.00	$0.37
Land, bldg. & fence repair	$0.17	$0.07	$0.25	$0.09	$0.35
Real estate taxes	$0.11	$0.05	$0.15	$0.01	$0.16
Rent & lease	$0.35	$0.25	$0.43	$0.48	$0.47
Insurance	$0.15	$0.11	$0.17	$0.08	$0.16
Utilities	$0.29	$0.26	$0.31	$0.23	$0.28
Interest	$0.74	$0.67	$0.80	$0.67	$0.81
Miscellaneous	$0.42	$0.43	$0.42	$0.22	$0.33
Total Operating	$13.16	$12.82	$13.40	$12.08	$12.99
Expansion livestock	$0.48	$0.60	$0.40	$0.63	$0.12
Machinery & bldg. expense	$1.16	$1.00	$1.27	$0.31	$0.67
Net farm income per cwt.	$1.10	$0.54	$1.48	$2.46	$3.65

more →

Table 4. Receipts and Expenses per Cow

Values for 1996	Average	Western	Eastern	Western Top 5	Eastern Top 5
Milk	$3,091	$2,718	$3,349	$2,881	$3,430
Dairy cattle	$109	$80	$128	$80	$81
Dairy calves	$22	$17	$26	$11	$15
Other livestock	$12	$19	$7	$19	$14
Crops	$68	$17	$103	$0	$43
Custom machine work	$2	$0	$3	$0	$3
Government receipts	$16	$6	$23	$0	$29
Other receipts	$66	$40	$85	$28	$292
Total receipts	$3,387	$2,897	$3,724	$3,020	$3,906
Expenses					
Hired labor	$426	$271	$533	$226	$553
Dairy grain & concentrate	$930	$926	$933	$960	$913
Dairy roughage	$211	$394	$86	$345	$16
Nondairy feed	$32	$16	$43	$0	$0
Machinery hire, rent & lease	$44	$28	$54	$13	$58
Machinery repairs	$97	$59	$123	$56	$141
Fuel, oil & grease	$45	$24	$59	$23	$45
Replacement livestock	$114	$162	$81	$85	$10
Milking supplies	$56	$56	$56	$53	$66
Breeding	$20	$17	$22	$12	$28
Veterinary & medicine	$72	$47	$89	$65	$91
Cattle rent & lease	$6	$3	$8	$3	$4
Custom boarding	$24	$20	$26	$33	$40
Other bST & marketing	$134	$71	$177	$130	$195
Fertilizer & lime	$45	$20	$62	$0	$54
Seeds & plants	$26	$3	$41	$0	$43
Spray & other	$40	$16	$56	$0	$83
Land, bldg. & fence repair	$39	$13	$56	$18	$80
Real estate taxes	$25	$11	$34	$2	$37
Rent & lease	$76	$49	$94	$89	$99
Insurance	$31	$22	$38	$16	$36
Utilities	$62	$51	$70	$43	$62
Interest	$159	$132	$178	$125	$183
Miscellaneous	$88	$76	$95	$41	$68
Total Operating	$2,801	$2,488	$3,017	$2,338	$2,904
Expansion livestock	$100	$116	$90	$130	$27
Machinery & bldg. depreciation	$243	$182	$285	$59	$148
Net farm income per cwt.	$242	$112	$332	$493	$826

Table 5. Balance Sheet					
Values for 1996	Average	Western	Eastern	Western Top 5	Eastern Top 5
Farm cash, checking & savings	$26,054	$25,907	$26,152	$9,701	$27,086
Accounts receivable	$186,557	$289,860	$117,689	$221,496	$116,960
Prepaid expenses	$70,637	$109,646	$44,631	$159,892	$24,201
Feed & supplies	$332,372	$353,990	$317,960	$262,537	$380,788
Total Current	$615,620	$779,402	$506,431	$653,626	$549,035
Intermediate Assets					
Dairy cows	$1,053,631	$1,511,663	$748,277	$1,227,906	$723,700
Heifers	$350,712	$500,226	$251,036	$276,042	$314,204
Bulls & other	$13,964	$27,355	$5,037	$9,220	$860
Machinery & equipment	$505,702	$401,226	$575,353	$340,205	$530,543
Farm Credit & other stock	$57,226	$65,625	$51,627	$58,781	$70,311
Total Intermediate	1,981,235	$2,506,096	$1,631,329	$1,912,154	$1,639,618
Land & buildings	$1,802,557	$2,203,792	$1,535,068	$282,480	$1,301,771
Other assets	$175,991	$300,372	$93,069	$101,929	$17,656
Total Assets	$4,575,403	$5,789,662	$3,765,897	$2,950,188	$3,508,080
Current Debt					
Operating & short term	$468,458	$792,846	$252,199	$525,060	$77,950
Accounts payable	$113,405	$205,280	$52,155	$251,617	$38,580
Current portion of int. & long	$99,327	$129,467	$79,233	$221,270	$132,068
Total Current Debt	$681,189	$1,127,593	$383,587	$997,948	$248,597
Intermediate Debt	811,062	1,208,738	545,945	834,477	820,796
Long Term Debt	$701,054	$538,406	$809,486	$0	$549,619
NPV of Leases	$23,067	$22,008	$23,773	$44,670	$34,206
Total Liabilities	$2,216,373	$2,896,745	$1,762,791	$1,877,094	$1,653,221
Net worth	$2,359,030	$2,892,917	$2,003,106	$1,073,094	$1,854,859
Debt/Asset Ratio	46.49	48.77	44.98	60.06	44.28

more →

Table 6. Cost and Returns per Hundredweight

Values for 1996	Average	Western	Eastern	Western Top 5	Eastern Top 5
Dairy grain & concentrate	$4.41	$4.79	$4.14	$4.84	$4.04
Dairy roughage	$1.02	$1.98	$0.36	$1.88	$0.08
Nondairy feed	$0.15	$0.08	$0.20	$0.00	$0.00
Crop expense	$0.53	$0.24	$0.72	$0.00	$0.81
Less Crop sales & govt. recpts.	$0.39	$0.12	$0.58	$0.00	$0.33
Net Feed & Crop	$5.71	$6.98	$4.84	$6.72	$4.59
Hired labor	$1.96	$1.37	$2.37	$1.15	$2.51
Operator's & unpaid family lab.	$0.88	$0.69	$1.02	$0.44	$0.98
Total labor	$2.84	$2.06	$3.39	$1.59	$3.49
Machine repairs, fuel & hire	$0.86	$0.58	$1.06	$0.49	$1.09
Custom work	$0.01	$0.00	$0.01	$0.00	$0.01
Net machinery expense	$0.85	$0.58	$1.04	$0.49	$1.07
Replacement livestock	$1.03	$1.44	$0.75	$1.04	$0.17
Less Cattle sales	$0.61	$0.50	$0.69	$0.48	$0.43
Net cattle purchases	$0.42	$0.93	$0.06	$0.56	($0.27)
Milk marketing & livestock exp.	$1.44	$1.08	$1.68	$1.53	$1.86
Real estate repair, taxes & rent	$0.64	$0.37	$0.82	$0.58	$0.99
Depreciation mach. & real estate	$1.16	$1.00	$1.27	$0.31	$0.67
Interest paid	$0.74	$0.67	$0.80	$0.67	$0.81
Interest on equity	$1.23	$1.01	$1.39	$0.47	$1.17
Total interest	$1.98	$1.68	$2.19	$1.14	$1.98
Other operating & misc. exp.	$0.86	$0.80	$0.90	$0.53	$0.76
Less Miscellaneous income	$0.36	$0.27	$0.43	$0.25	$1.46
Net misc. expense	$0.50	$0.53	$0.47	$0.28	($0.70)
Operating Cost	$12.26	$12.51	$12.09	$11.98	$10.87
Total Cost	$15.54	$15.21	$15.76	$13.20	$13.69
Net Return over Operating	$2.26	$1.55	$2.75	$2.76	$4.32

Table 7. Concerns for the Future *(1 = "High Concern" and 10 = "Not a Concern")*					
Variable	Average	Western	Eastern	Western Top 5	Eastern Top 5
Milk Price Volatility	3.6	1.9	4.4	2.0	2.4
Feed Prices	3.6	1.8	4.5	1.0	3.6
Environmental Regulations	3.2	4.1	2.8	3.8	3.2
Neighbor Relations	4.4	6.2	3.5	6.8	2.8
Attracting Employees	4.2	5.5	3.6	7.0	3.4
Retaining Employees	4.1	4.4	3.9	4.0	4.0
Motivating Employees	3.8	3.8	3.8	3.8	4.0
Market Access	5.7	4.3	6.5	6.0	4.2
Federal Order Reform	4.9	5.1	4.8	7.3	4.0
Access to Local Input Suppliers	6.8	6.2	7.0	8.3	5.6
Intergenerational Transfer	5.3	5.9	5.1	4.0	5.2
Access to Debt Capital	6.2	5.5	6.5	6.0	5.0

Table 8. Rate Future of Dairying in Your Area *(Percent of Responses)*					
Rating	Average	Western	Eastern	Western Top 5	Eastern Top 5
Excellent	26	16	32	20	40
Good	43	37	47	40	60
Average	15	21	12	40	0
Fair	11	26	3	0	0
Poor	4	0	6	0	0

Table 9. Investment Over the Next Three Years *(Percent of Responses)*					
Rating	Average	Western	Eastern	Western Top 5	Eastern Top 5
Herd Size	69%	60%	74%	80%	80%
Housing	63%	35%	79%	60%	80%
Milking	43%	40%	44%	60%	40%
Manure Handling	57%	50%	62%	60%	60%
Feed Storage	69%	55%	76%	80%	60%
Replacements	67%	70%	65%	80%	80%

Table 10. Key Statistics by Herd Size				
Values for 1999	less than 200 cows	200–500 cows	500–1200 cows	greater than 1,200 cows
Herd Size	91	317	738	1904
Milk per Cow	18,806	20,977	22,910	20,610
Return on Assets	4.1%	8.7%	9.2%	8.2%
Return over Operating Costs	$4.14	$3.53	$3.05	$2.44
Crop Acres per Cow	2.6	2.1	1.6	0.6

more →

Table 11. Key Statistics by Crop Acres per Cow *(Adjusted to similar herd sizes)*			
Values for 1999	less than 1.0 acres per cow	1.0–2.0 acres per cow	more than 2.0 acres per cow
Herd Size	711	741	722
Milk per Cow	19,723	22,953	22,212
Return on Assets	3.5%	9.9%	9.4%
Return over Operating Costs	$2.50	$3.26	$3.69
Crop Acres per Cow	0.4	1.6	2.5

Table 12. Key Statistics by Region				
Values for 1999	Western	Eastern	Western Top 5	Eastern Top 5
Herd Size	1,112	193	1,234	370
Milk per Cow	20,674	19,388	20,586	20,819
Return on Assets	5.1%	6.0%	13.5%	27.3%
Return over Operating Costs	$2.19	$4.05	$2.56	$7.20
Crop Acres per Cow	0.4	2.2	0.0	1.0

Monitoring the Dairy Herd

THOMAS J. FUHRMANN, DVM—51 W. Elliot Rd. Suite 106, Tempe, AZ. 85284
Tel: 480-831-6358 Fax: 480-831-5884

Simply stated, successful large dairies get it done through people. Large dairy owners and managers might do well to ask themselves "do I know the results of the decisions my employees make daily?" For example, cow #100 is 85 days in milk and appears nervous. Will my herdsperson identify her? Is this cow in heat? Will my herdsperson breed her? Should this cow be bred in the morning or the afternoon? If the estrous mucous appears abnormal, should this cow be inseminated? Should she be treated? What will my herdsperson do? How will I know?

Success is managing your employees to do it "your way". What is the method to define "your way" and to trust your employees will do it?

Case Studies

An 1,800 cow dairy in the Southern United States experienced a severe problem with fresh cow health for three months. Retrospective evaluation of records indicated the incidence of displaced abomassum from February to April was greater than 10%. Incidence of abomassal displacement was reduced to less than 2% in June.

A dairy in the Midwest milked 1,800 cows two times per day through a double 24 parallel parlor. For two years, their somatic cell count (SCC) remained below 250,000. In the summer of 2000, SCC rose to above 350,000 and attempts to change milking routine to improve SCC resulted in failure to get all cows milked twice in a 24 hour period. By fall of that year, 2000 could be milked twice in 20 hours and SCC is again below 250,000.

A 900 cow dairy in the upper Midwest persisted with heat detection rates of 45 to 55% according to Dairy Comp 305 record evaluation from January to June, 2000. During the second half of 2000, heat detection rates averaged greater than 65%.

Performance of these herds improved as a result of strategic management changes. The objective of this paper is to evaluate management strategies to improve productivity and profitability of dairy herds.

What is Management?

Management is often credited or blamed for the success or failure of dairy business productivity and profitability. It is a term widely used, but with an elusive definition. Management may be defined as the control of systems and people[1]. Systems are the method of doing work; workers implement systems[2]. Managers define and develop systems and then influence workers to implement systems properly.

To illustrate, milking routine is an example of a system. The appropriate milking routine designed for a specific parlor will produce optimum results when milkers implement each step of the routine properly. Optimum results must be defined by the manager and would probably include some measure of throughput and milk quality in the example of milking management. The manager then is responsible for defining the milking routine, coaching the employees to implement the routine and for monitoring results.

The process to manage employees includes five steps: 1. define the system or the work, 2. train or educate employees, 3. monitor results, 4. coach and discipline, 5. communicate to provide feedback.

1. Define the System

Work is a system[2]. Each system can be reduced to several steps, called processes. Each process can be further subdivided into tasks. Milking routine, the system, can be divided into several processes called milking procedures. As an example, the first milking procedure might be to prespray and forestrip each cow; the second milking procedure to wipe and attach units, and the third to post dip and move the opposite side cows out of the parlor. The first procedure, prespray and forestrip, can then be subdivided into tasks such as: 1.1 spray all four teats with the left hand, 1.2 forestrip three squirts of milk from each teat examining for abnormal milk, 1.3 respray and clean any of the four teats on which excessive dirt remains. This system, for example, can be applied to a double 25 parallel parlor with two milkers and a cow pusher as illustrated in figures 1 and 2.

2. Train or Educate Employees

Principles to train employees are well documented. These include: a. *prepare* the individual by describing the conditions of the work, b. *tell* the worker the steps of the work (flow charts are useful), c. *show* the worker (have him or her watch other milkers), d. have the individual *do* the work (with the lead milker), e. *summarize* the previous four points asking the individual to repeat key elements.

3. Monitor Results

Results are goals; these key indicators should be written out by the manager. For milking management

more →

these could include: bulk tank bacteria count and SCC, incidence of clinical mastitis and the number of cows milked per hour. Monitoring implies that the manager collects, analyzes, interprets and takes action on the key indicators. Comparing actual performance with the written key indicators is the basis for a manager to move to step four. Observing how workers apply the system (e.g. are milkers implementing the routine diagrammed on the flow chart?) becomes the basis for the specific form of coaching.

4. Coach and Discipline

Coaches neither own nor play the game, yet they build the game plan by organizing and training or retraining players[4]. Coaching brings out the best in others by recognizing employees for doing the work (implementing the system) correctly. Motivated workers are the result. Or managers apply discipline through retraining. They can be candid and honest when employees stray from implementing the system. Managers can be equally vigorous to inspire and build confidence in workers found to be implementing the system correctly. Each manager intuitively applies his or her own standards or judgments to the observations and interpretation of results. The larger the "gray area" in the manager's assessment between excellence and unacceptable, the more mediocre the results. Dairy managers certainly fail to coach or manage milkers by ignoring to correct (e.g. retrain) improper work habits or by failing to acknowledge good work.

5. Communicate, Provide Feedback

The number one factor to motivate employees is feedback on results[5]. Communication to employees needs to be direct, specific and timely. It can be done one-on-one or in meetings. Monthly data analysis can become the agenda for efficient monthly worker meetings. For example, when is the last time you communicated with nighttime milkers?

Strategies to Manage Change

Managing to improve implies managing change. Change occurs through one of two strategies: redesign the system of work or retrain workers to implement the existing system better. Change can be managed through a six step process. Improving milking management will be used to illustrate this process.

1. Define the problem and the system deficiency contributing to the problem

A 2,000 cow dairy herd maintained bulk tank SCC's of less than 250,000 for two years. Somatic cell count elevated rapidly to over 400,000 and clinical mastitis elevated to greater than 5%. Environmental Streptococcus bacteria were the dominant pathogen identified in bulk tank milk.

Territorial Milking routine with two milkers and a cow pusher was used in the double 20 parallel milking parlor. Data collection indicated that prep time was inadequate compared with industry standards; this contributed to both failure to adequately clean teat skin surface as well as provide adequate stimulation for milk letdown . Prep-lag time was short and extremely variable from cow-to-cow. Milking was slow and teats were not clean.

2. Formulate a plan for change

Change was proposed in two steps. An alternative milking routine was proposed (illustrated in a flow diagram) along with milker "buy in" and training.

3. Develop consensus

The dairy manager, milkers and consultant met to discuss the problem and proposed changes. Milkers were asked to critique the proposed routine and their role to implement it. Why should there be change? Is the new routine better? Can it be improved? Consensus occurred as everyone agreed the changes could be beneficial.

4. Redefine the new system

The new routine was depicted in a flow diagram. Differences between the old and new routines were clarified.

5. Demonstrate the new system

Teaching through example can be powerful; demonstrating how and why clarifies practical implementation of a proposed system. The dairy manager and consultant milked with each shift of milkers; the new routine was implemented. Prep time, prep-lag time and teat cleanliness were re-evaluated; all improved.

6. Coach to develop a new habit

Habits are consistent, unconscious patterns[7]. Breaking habits, such as an old milking routine, requires a conscious, consistent effort to replace a previous activity with a new activity over time. Managers coach change in milkers by observing milkers in the new routine, reinforcing the consistent positive implementation and retraining when milkers revert to old habit. Managers need to commit to three weeks of active coaching.

Summary

Proven personnel management principles can be applied to large dairies. Dairy owners may not have had opportunities to learn these principles and advisors often fail to provide specific, practical examples applicable to dairy operations.

Large dairy owners entrust both decision-making and delegation of tasks to middle management employees such as herdsmen, head milkers and feeders. Training middle managers to manage fellow employees can improve their decision making and consistency of results. Then as dairy owners manage to improve results, change can be orchestrated through a six step process that can improve productivity and profitability.

References

1. Gerber, Michael E. The E Myth, 1995. Harper Collins Publishers Inc; New York, NY.
2. Scholtes, Peter R. The Team Handbook, 1998. Joiner Associates Inc, Madison WI.
3. Erven, Bernard L. Proceedings of Employee Management for Animal Agriculture, August 10-11, 2000; Wichita KS.
4. Barmore, James A. "Engineering Change in a World Full of People and Cows". Monsanto Dairy Business, 7905 Black River Road, Verona, WI 53593.
5. Blanchard, Kenneth H. and S. Johnson, 1983. The One-Minute Manager, Berkley Books, NY.
6. Covey, Steven R. 1989. The Seven Habits of Highly Effective People, Simon & Schuster, NY.

more →

Figure 1. Territorial Milking Routine in a double 25 parallel parlor

MILKING ROUTINE

3 milkers:

milker 1:
- milks cows in sections 1 and 4

milker 2:
- milks cows in sections 2 and 5

milker 3:
- moves cows into the parlor
- milks cows in section 3
- initiates post dip on opposite side of parlor

MILKING PROCEEDURES

A. Predip and forestrip
- 3 squirts of milk from each teat
- repeat on each of 5 cows

B. Wipe and attach
- repeat on each of 5 cows

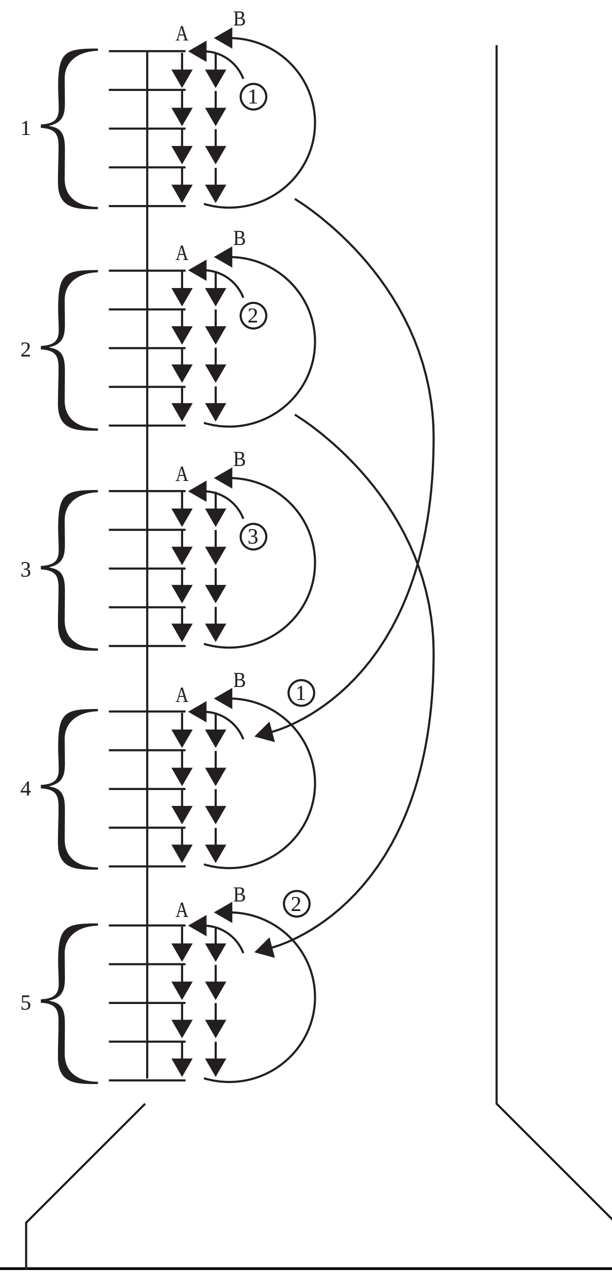
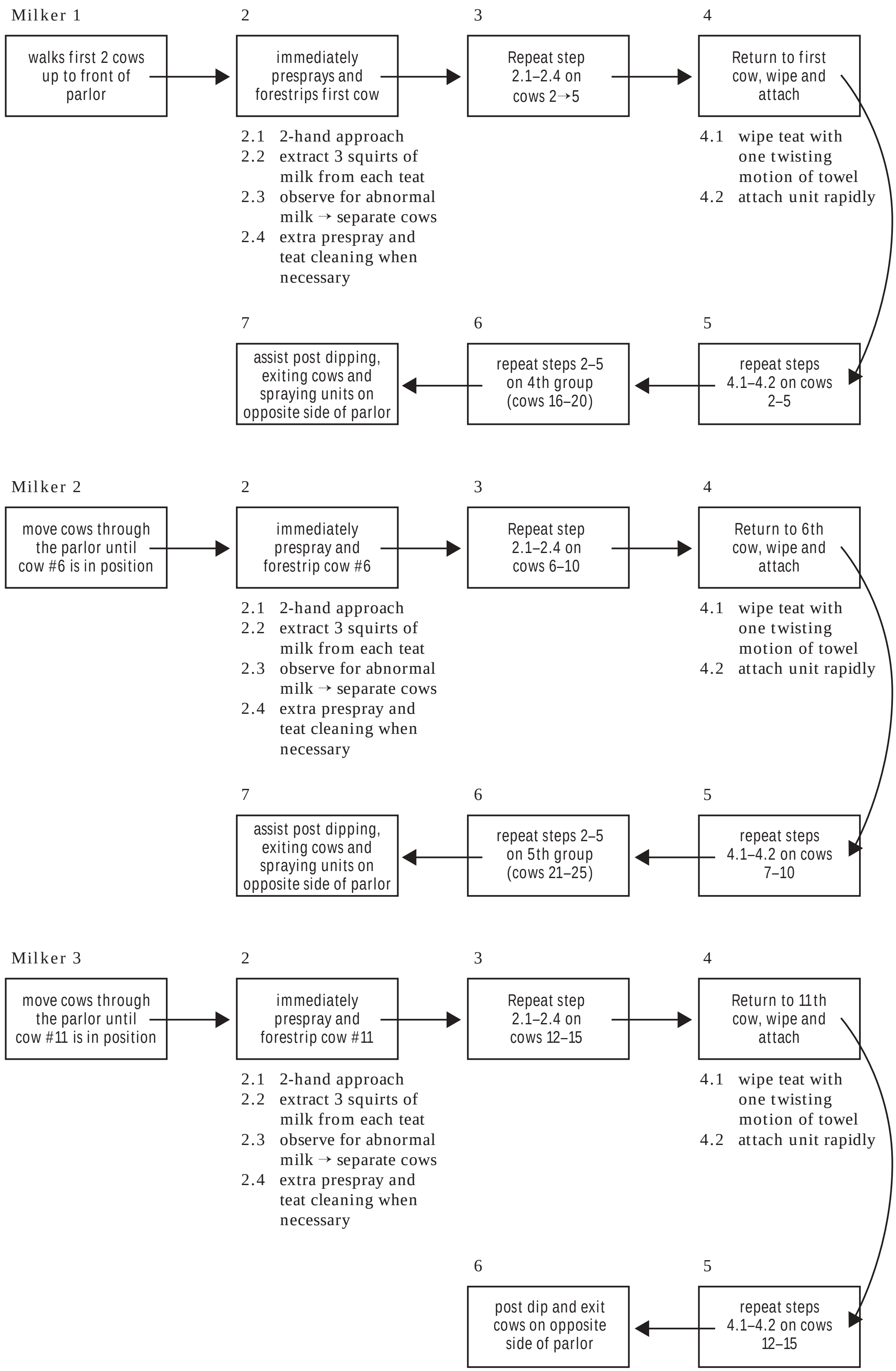


Figure 2. Territorial Milking Routine in a double 25 parallel parlor



Heat Stress Abatement in Four-Row Freestall Barns

M.J. BROUK, J.F. SMITH and J.P. HARNER, III—Kansas State University

Introduction

Heat stress abatement in freestall barns should be a major concern for dairy producers and dairy industry advisors. Under modern management systems, lactating dairy cows spend over 90% of the day in the freestall barn. Without effective freestall cooling systems, significant production and reproduction losses will occur. In terms of cow comfort, the effective temperature is a function of air temperature, humidity, air flow and solar radiation. Heat dissipation from the dairy cow at temperatures above 60°F is largely due to evaporative losses from the skin with a much smaller portion lost via lung cooling (Kibler, 1950). Thus, the goal of heat stress abatement in freestall barns should be to provide protection from solar radiation and maximize evaporative losses from the skin. Heat dissipation from the skin is increased by increasing air exchange, air flow and the evaporation of supplemental water applied to the skin.

Freestall Barn Design

Barn Orientation

The first freestall barn design criteria to be considered should be the orientation of the structure. Barns with a north-south orientation have a greater solar radiation exposure than barns with a east-west orientation (Figure 1). Sunlight can directly enter north-south oriented barns both in the morning and afternoon. While the afternoon sun is the most detrimental, during hot summer weather morning sun can also modify cow behavior. Because cows seek shade during the summer, direct sunlight will reduce stall usage. Thus, utilization of stalls located on east and west outside walls of north-south oriented barns are greatly impacted when in the direct sunlight. It is also important to consider that with greater sidewall heights, that afternoon sunlight can reach much of the west half of the structure. Protection from direct sunlight is vital for effective heat stress abatement. Barns with a east-west orientation will provide greater protection from direct sunlight than north-south orientations.

Air Exchange

Natural air exchange or building ventilation rates are influenced sidewall opening, eave opening, building width, ridge opening and wind speed. Mechanical ventilation rates should exceed 470 cfm (cubic feet per minute) per 1400 pound cow (Bickert, et al., 1997). During the summer, greater ventilation rates could potentially increase water evaporation rates and thus increase skin heat losses. During summer weather, open sidewalls will provide maximum air exchange. In general, open sidewall buildings will have ventilation rates which exceed the recommendations. In general, sidewall heights on 4- and 6-row freestall buildings should be 14-16 ft high and be a minimum of 75% open. However, when trying to achieve maximum water evaporation rates, increased air exchange is important to prevent significant increases in relative humidity inside the barn.

Building size and design can influence ventilation rates. Data presented in Figure 2 demonstrates the effect of building width upon ventilation rates at different wind speeds. As building width increases, greater wind velocities are required to provide adequate ventilation. While, 2-row barns may be adequately ventilated with a 1 mph wind, 6-row barns require 3 mph wind for adequate ventilation. In addition, stocking rates and available area influence the need for ventilation (Table 1). Heat units produced per square foot of building increase with increased stocking rates. When comparing 4- and 6-row barns, reduced area per cow increases the heat load in 6-row barns.

In addition to building width and sidewall height, ridge openings are required. Armstrong and others (1999) observed greater increases in afternoon respiration rates relative to morning rates when cows were housed in barns with ridge coverings as compared to open ridges. The ridge open should be 2 inches per 10 ft of building width.

Roof slope is another critical design consideration. Heat rises and roof pitch can either enhance or reduce air flow out the ridge opening. In 4- and 6- row buildings, roof slope should be 4/12 to enhance air flow and exchange. Utilizing less slope in these barns has been shown to increase afternoon respiration rates (Armstrong, et al., 1999). Two-row barns with a mono-slope roof often have a 3/12 or 2/12 pitch. This may be adequate considering the narrow width of the building. However, if 2 mono-slope units are built facing each other with only a feed road between, one essentially has a 4-row barn and the 4/12 roof pitch would be recommended.

Wind shadow can be a major problem in some cases. In general, to minimize the effect of wind shadow, build-

more ⟶

ing should be at least 100 ft apart or 1.5 times the building width. Any obstruction natural air flow reduces air exchange. Buildings, equipment and stored forages may all reduce air flow in freestall buildings if adequate separation is not allowed. The most noticeable problem associated with wind shadow is the fact that cattle will seek natural air flow. This will result in overcrowding in areas of the barn which are not affected by wind shadow.

Water Location and Requirements

Water intake increases during heat stress and one of the critical factors in managing heat stress is to provide adequate access to water. It is important to locate a water at each crossover and there should be a maximum of 25 stalls between crossovers. Crossovers should be 14 ft in width to allow cattle to pass through the crossover while others are drinking. Crossover width is critical to avoid bottlenecks in cow flow. Ideally, 2 feet of tank perimeter should be provided for each 10-20 cows in a pen. In warmer climates, total tank perimeter for a pen is equal to 15% of the pen size times 2. Data collected during the summer of 2000 indicated that a greater percentage of the water was consumed from the tank located in the center alley when three alleys were provided per pen. This may indicate that additional area and/or drinking space may be needed in this cross-over alley. In addition to enough water space, water flow rates must be adequate to maintain water levels. To meet peak flow demands, well capacity or pumping capacity should be 20-30 gallons per 100 cows.

Supplemental Cooling

Freestall barns which are correctly designed will provide maximum natural ventilation. However, additional cooling equipment is necessary if high levels of milk production are desired. In addition to maintaining high levels of production, heat abatement measures must be cost effective, returning greater profits to the dairy producer. Two studies were conducted in 1999 and 2000 to evaluate different cooling systems in 4-row freestall barns located in northeast Kansas.

1999 Study

Ninety-three multiparous Holstein cows averaging 130 DIM (days in milk) were assigned to one of three cooling treatments. Cows were blocked by lactation number, DIM and production. Cows were housed in one of three identical 100 cow pens on a commercial dairy farm equipped with 84 freestalls per pen (Table 2). The barn was 100-ft in width and 420-ft in length. The sidewall height was 12-ft and the roof had a 4/12 slope.

Treatment one (2S) was located in the southeast quarter of the building and had a double row of fans (14, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted every 24-ft over the freestalls. Each fan had an air delivery rate of 10,000-11,500 cfm and was angled down at 30°.

Treatment two (F&S) was located in the southwest quarter of the building and had a row of fans (7, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted over the freestalls and another row (7, 36-inch diameter circulation fans with 0.5 horsepower motors) over the cow feed lane. Both rows of fans were angled downward at 30° and had the same air delivery rate as those listed above.

Treatment three (F&2S) was located in the northwest quarter of the building and had a double row of fans (14, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted every 24-ft over the freestalls and a row of fans (7, 36-inch diameter circulation fans with 0.5 horsepower motors) mounted over the cow feed lane. The angle and air delivery rate was the same as described above.

Each pen was equipped with similar sprinkler systems consisting of 2.5 gph nozzles spaced every 78 inches on center at a height of 8-ft above the headlocks. Sprinklers were on a 15 minute cycle with 3 min on and 12 min off. Sprinklers were activated when the temperature was above 75°F. The designed application rate was .04 inches/ft sq of surface area which consisted of 12-ft sq/headlock or 24-inch feeding space. Total application rate was 50 gallons/cycle.

Fans of all treatments were activated when the temperature was above 70°F both day and night.

Initial treatment averages (Table 3) for DIM and milk production were similar for all treatments. Cows cooled with the F&S system produced 4.5 pounds more ($P<.05$) milk than the 2S system while those under the F&2S system were intermediate. Dry matter intake was numerically similar for all treatments. All cows increased body condition score during the trial. Cows under the 2S system tended to have a greater increase as compared to the F&S treatment. This is likely due to similar DMI and lower production for the 2S system.

2000 Study

During the summer of 2000 another study was conducted to determine if fans were only needed over the feedline. One hundred mid-lactation Holstein cows averaging 173 DIM and producing 97.6 lb/c/d of milk were blocked by milk production and DIM and randomly assigned to one of 4 pens of a 4-row freestall barn. Two replicates, north and south halves of the barn, contained 2 pens each. Fan treatments were 36 in. fans mounted every 24 ft. on the feed line (F) or 36 in. fans mounted every 24 ft. on the feed line and over the center of the head-to-head freestalls (F&S). All pens were equipped with feed line sprinklers that operated on a 15 min cycle (3 on and 12 off) when temperatures were above 75*F. All fans operated when the temperature was above 70*F. A switch back design with 5 two-wk periods was utilized to evaluate fan placement. Cows and treatments were switched at the start of each period within each replicate.

Cows were milked 2x and milk production was measured every two weeks throughout the 10 wk trial. All pens received the same diet. Amounts of feeds offered and refused were measured and recorded daily. Dry matter content of the diet and refusal of each was determined twice weekly. Cow respiration rates were measured on three separate days under heat stress. Fifteen cows were randomly selected from the 25 study cows in each pen and respiration rates were measured in the morning (0700-0800 hr), afternoon (1500-1600 hr) and at night (2200-2300 hr) on each of the three days.

Cows exposed to treatment F&S produced more (P<.01) milk (85.6 vs 79.8 lb/c/d) during the trial than those exposed to the F treatment. Respiration rates were lower (P<.06) in the morning (71.7 vs 79.3 breaths/c/m), at night (76.0 vs 80.1) and daily (79.4 vs 83.2) under the FS treatment compared to the F treatment. Afternoon respiration rates were unaffected by treatment. Pen feed intakes (54 vs 52.7 lb/c/d) tended to be greater (P=.11) when when FS was utilized rather than F.

This study clearly demonstrated that in a 4-row freestall barn greater milk production and a lower respiration rate was obtained by locating fans on both the feed line and over the freestalls. Based on respiration rates, the duration of heat stress was reduced by the F&S treatment demonstrated by lower respiration rates in the morning and at night. Appropriate fan location in combination with feed line sprinklers reduced heat stress in lactating dairy cattle housed in a 4-row freestall building.

Recommendations

Fans should be mounted above the cows on the feed line and above head-to-head freestalls in a 4-row freestall barn. If 36 in. fans are utilized, they should be located no more than 40 ft. apart. If 48 in. fans are used, they should be located no more than 30 ft. apart and operate when the temperature reaches 70°F. Fans should be mounted out of the reach of the cattle and in a manner that will not obstruct equipment movement. Feed line sprinklers should be utilized in addition to the fans. Feedline sprinkling systems should wet the back of the cow and then shut off to allow the water to evaporate prior to another cycle beginning. Sprinklers should operate when the temperature exceeds 75°F.

Summary

Effective freestall barn cooling is comprised of 3 steps. First, enhance natural ventilation through building design which allows for maximum natural ventilation and protection from solar radiation. Critical areas include barn orientation, sidewall height and clear opening, roof slope, ridge opening, building width and removal of wind shadow. Failure to follow design criteria will reduced natural ventilation. In addition, removal of natural and artificial barriers to wind will increase building ventilation rates.

Second, provide adequate water space and volume. Water consumption increases as temperatures increase. Therefore, it is critical to have adequate water available for all cows. Critical areas are water space per cow, water location, crossover width, and a correctly designed water delivery system.

Third, utilize effective supplemental cooling systems which are cost effective. Using feedline sprinklers which wet the cow and then allow the water to evaporate are very effective in reducing heat stress. For every pound of water evaporated, 1,000 BTUs of energy are required. By wetting the cow, a major portion of the energy utilized to evaporate the water is derived from the cow. By utilizing short wetting cycles, wet-dry cycles can be implemented each hour. In addition to the feedline sprinklers, fans are needed to increase air circulation. This not only provides some cooling effect but more importantly, increases the evaporation rates by moving drier, less humid air over the body surface of the cow.

Heat abatement measures can be effective and profit generating. Systems should enhance natural air exchange in the freestall building and increase body surface cooling of the cow.

References

Armstrong, D.V., P.E. Hillman, M.J. Meyer, J.F. Smith, S.R. Stokes and J.P. Harner III. 1999. Heat stress management in freestall barns in the western U.S. In: Proc. of the 1999 Western Dairy Management Conference. pp 87-95.

Brouk, M.J., J.F. Smith, J.P. Harner III, B.J. Pulkrabek, D.T. McCarty and J.E. Shirley. 1999. Performance of lactating dairy cattle housed in a four-row freestall barn equipped with three different cooling systems. In *Dairy Day 1999*, Ed J.S. Stevenson, Manhattan, Kansas: Kansas State University, Report of Progress 842, pp 23-27.

Bickert, W.G., G.R. Bodman, B.J. Holmes, D.W. Kammel, J.M. Zulovich and R.R. Stowell. 1997. Dairy Freestall Housing and Equipment, MWPS-7, Sixth Edition. Midwest Plan Service, Ames, IA.

Chastain, J.P. 2000. Designing and managing natural ventilation systems. In: Proc. of the 2000 Dairy Housing and Equipment Systems: Managing and planning for profitability. NRAES publication 129. pp 147-163.

more →

Kibler, H.H. 1950. Environmental physiology with special reference to domestic animals. X. Influence of temperature, 5 to 95°F, on evaporative cooling from the respiratory and exterior surfaces in Jersey and Holstein Cows. Missouri Agr Exp Sta Res Bul 46:1-18.

Smith, J.F., J.P. Harner, M.J. Brouk, D.V. Armstrong, M.J. Gamroth, M.J. Meyer, G. Boomer, G. Bethard, D. Putnam. 2000. Relocation and expansion planning for dairy producers. Publication MF2424 Kansas State University, Manhattan, KS.

Figure 1. Sun angles of a north-south oriented freestall barn.

Sun Angles for N-S Freestalls
August 21st—40° latitude

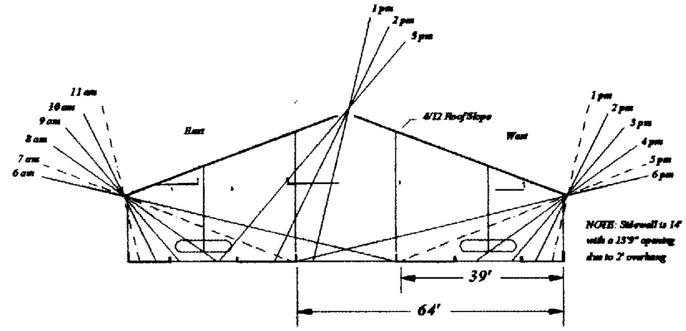
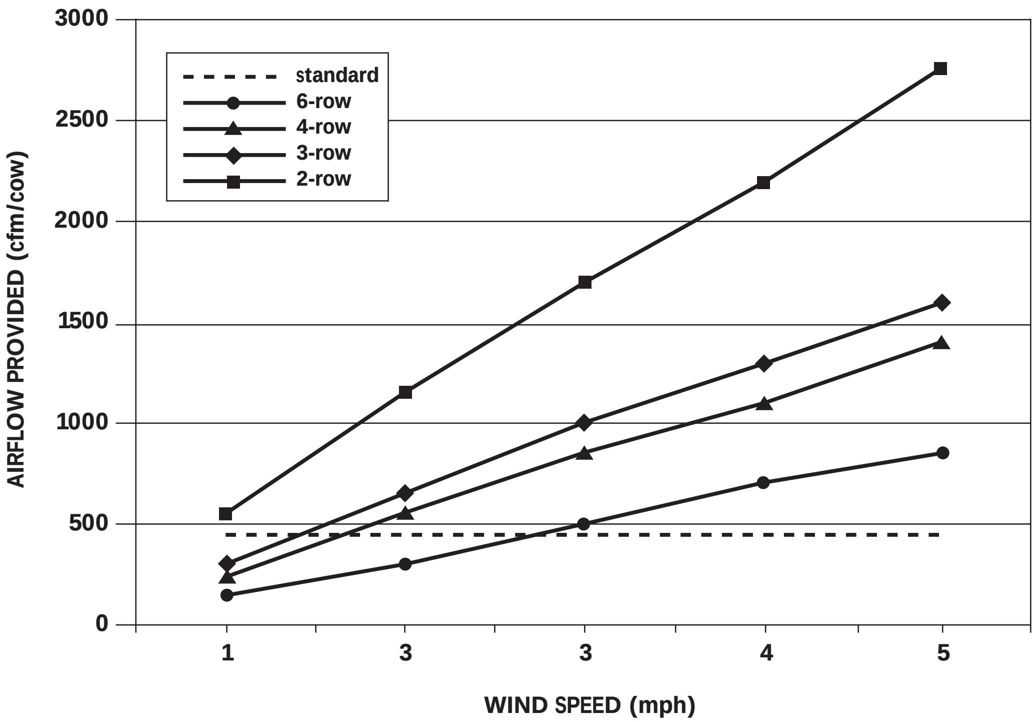


Figure 2. Effect of building width upon airflow rates.



Unitized air exchange rate of common barn configurations for low-to-moderate wind speeds (assumes 12-foot sidewall height; 9-foot effective opening height for 2- and 4-row barns, 8 ft. for 3-row 6-row configurations; wind approaches barns at an angle from perpendicular; and 1 cow per row per 4 feet of barn length).

Chastain, 2000.

Table 1. Available Feedline Space, Square Footage and Heat Produced by cows in Different Styles of Freestall Barns*										
							Stocking Percentage (cows/stalls)			
Barn Style	Pen Width (ft.)	Pen Length (ft.)	# Stalls	Sq. Ft./ Cow	Feedline Space	BTUs/ cow/ hr.	100% BTUs/ sq. ft.	110% BTUs/ sq. ft.	120% BTUs/ sq. ft.	130% BTUs/ sq. ft.
4-Row	39	240	100	94	29	4500	48	53	58	63
6-Row	47	240	160	71	18	4500	64	70	77	83
2-Row	39	240	100	94	29	4500	48	53	58	63
3-Row	47	240	160	71	18	4500	64	70	77	83

*Based on a cow weighing 1,500 pounds and producing 70 pounds of milk per day. (Smith, et al, 2000)

Table 2. Description of building and cooling treatments of 1999 study.

Building description:

Building type: 4 row

Orientation: East-West (2% slope to west)

Dimensions: width-100 ft, length-420 ft, sidewall height-12 ft, roof slope-4/12

Configuration: 4 pens with 84 stalls per pen and 100 headlocks per pen

Cooling System[1]	2S	F&S	F&2S
SPRINKLERS			
Sprinklers location	feed line	feed line	feed line
Nozzle rating, gph	25	25	25
Nozzle type	180°	180°	180°
Sprinkler cycle	on - 3 minutes	on - 3 minutes	on - 3 minutes
	off - 12 minutes	off - 12 minutes	off - 12 minutes
Sprinkler height, ft	8	8	8
FANS			
Rows over freestalls	2	1	2
Rows over feed line	0	1	1
Number of fans per row	8	8	8
Total number of fans	16	16	24
Fan spacing, ft	24	24	24
Fan Diameter & hp	36 in (½ hp)	36 in (½ hp)	36 in (½ hp)
Fan airflow/stall, cfm/stall	1,900	950	1,900
Fan airflow/headlock, cfm/head	0	800	800

[1]2S=two rows of fans over freestalls, F&S=one row of fans over the feedline and one row of fans over the freestalls and F&2S=one row of fans over the feedline and two rows of fans over the freestalls. (Brouk, et al. 1999)

more →

Table 3. Summary of milk yield, body condition, and feed intake of dairy cows housed in a four-row freestall barn with three different cooling systems during the summer of 1999.

	Cooling System[1]		
Item	2S	F&S	F&2S
Initial milk, lb	114.5	115.5	114.8
Initial days in milk	131	128	131
Average milk, lb	93.9[a]	98.8[b]	96.5[ab]
Dry matter intake, lb	55.6	56.2	56.3
Change in body condition	+.52	+.39	+.21

[1]2S=two rows of fans over freestalls, F&S=one row of fans over the feedline and one row of fans over the freestalls, F&2S=one row of fans over the feedline and two rows of fans over the freestalls.
[ab] Means with uncommon superscript differ ($P<0.05$) (Brouk, et al., 1999)

Kansas State University
Agricultural Experiment Station and
Cooperative Extension Service

It is the policy of Kansas State University Agricultural Experiment Station and Cooperative Extension Service that all persons shall have equal opportunity and access to its educational programs, services, activities, and materials without regard to race, color, religion, national origin, sex, age, or disability. Kansas State University is an equal opportunity organization. These materials may be available in alternative formats. Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, as amended. Kansas Sate University, County Extension Council, Extension Districts, and United States Department of Agriculture Cooperating. Marc A. Johnson, Director.