# Managing the Metabolism of Transition Cows

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## Summary
Transition cows must exquisitely coordinate their metabolism to meet tremendous increases in nutrient demand during early lactation, particularly the demand for glucose production by liver. Excessive mobilization of nonesterified fatty acids (NEFA) from body fat during the transition period presents challenges to liver function, including the capacity of liver to produce glucose. Strategies to either reduce the supply of NEFA to the liver or optimize the metabolism of NEFA by liver include maximizing dry matter intake of well-formulated transition rations, dietary supplementation with choline, or short-term drenching strategies using propylene glycol. Supplementation of other nutrients (methionine analogs and conjugated linoleic acid) has been shown to improve performance during early lactation; however, their mode of action does not appear to be related directly to liver metabolism. Research investigating nutritional grouping strategies for dry cows indicates that the two-group dry cow system is preferred to a one-group dry cow system; however, there may be interactions of grouping system with body condition score on postpartum performance.

## Introduction
Transition cow biology and management has become a focal point for research in nutrition and physiology during the past fifteen years (Bell, 1995; Drackley, 1999; Grummer, 1995; Overton et al., 2000). Several driving forces have underpinned the evolution of this research. First, it was recognized that many of the metabolic disorders afflicting cows during the periparturient period are interrelated in their occurrence (Curtis et al., 1985) and approximately 50% of cows have one or more adverse health events during this period (Ferguson, 2001). Furthermore, of cows that leave dairy herds, approximately 25% leave during the first 60 days in milk (with an uncertain additional percentage of animals leaving dairy herds after 60 days in milk) because of downstream effects of periparturient difficulty (Godden et al., 2002).

For cows to successfully transition to lactation, metabolic adaptations that enable increased synthesis of glucose, mobilization of sufficient (but not excessive) body fat reserves to meet the energetic demands of lactation, and calcium mobilization to meet the increased demands for calcium. The adaptations that must occur in the dairy cow to successfully adapt to increased demand for calcium have been reviewed previously at this conference (Goff, 1999; Goff, 2001). Therefore, the purpose of this paper will be to briefly review the key metabolic adaptations related to energy metabolism that must occur for cows to successfully transition to lactation, provide some insight into "managing metabolism" of transition dairy cows, and to provide some "bottom line" recommendations for ration formulation and grouping of transition cows.

## Metabolic Adaptations in Transition Cows
The primary series of metabolic adaptations that must occur to underpin a successful transition to lactation relates to increased glucose synthesis by liver and decreased glucose oxidation by peripheral tissues (i.e., muscle) at the onset of lactation. Glucose represents an overriding metabolic demand during the transition period because of the requirements of the mammary gland for lactose synthesis. Data in Figure 1 indicate that the liver of the cow must more than double its glucose production in the immediate periparturient period in order to meet this demand.

# Practical Application of New Forage Quality Tests

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## Introduction

Routine evaluation of forage quality by the grower, crop consultant, feeder, or nutritionist has generally been related to the fiber content of the forage measured in a commercial forage testing laboratory and the energy content of the forage predicted from its fiber content. Indexes of forage quality, relative feed value (RFV; Rohweder et al., 1978) and milk per ton of forage dry matter (Undersander et al.; 1993), were based on energy content of the forage predicted from acid detergent fiber (ADF) content and dry matter (DM) intake potential of the forage predicted from neutral detergent fiber (NDF) content. The RFV index has evolved to the point where it is commonly available on commercial forage test reports, used routinely in evaluations and comparisons of hay-crop forage quality, and used in the marketing of hays. Data from Wisconsin quality-tested hay auctions show that hay buyers pay $0.90 per point of RFV above the RFV of a base quality alfalfa (Undersander, 2002). The milk per ton index has evolved to the point where it is commonly used in agronomic performance trials, because an estimate of forage DM yield often obtained in these types of trials multiplied times the estimate of milk produced per ton of forage DM provides an estimate of the milk produced per acre which combines yield and quality into a single term. This index, milk per ton or per acre, has become the focal point of corn silage commercial hybrid performance trials (Lauer et al., 2001; Lauer et al., 1997) and the corn silage hybrid-breeding program (Coors et al., 2001) at the University of Wisconsin - Madison.

The University of Wisconsin Marshfield Soil and Forage Analysis Laboratory, Cumberland Valley Analytical Services (Maugansville, MD), and Dairy One (Ithaca, NY) perform wet chemistry in vitro NDF digestibility (NDFD; % of NDF) measurements. At the time of writing this paper, Dairyland Laboratories (Arcadia, WI) is developing a wet chemistry in vitro NDFD anlaysis. Near infrared (NIR) calibrations for determining NDFD on hay-crop forage and corn silage samples are available at the UW Marshfield Soil and Forage Analysis Laboratory and some commercial forage testing laboratories. A summative energy equation (Weiss, 1996) has been used at some commercial forage testing laboratories to calculate the energy content of forages for several years; equation components include crude protein (CP), fat, non-fiber carbohydrate (NFC) and NDF, and the corresponding digestibility coefficients for these nutrients. Use of the summative energy approach is becoming more common with its inclusion in NRC, 2001.

We (Shaver et al., 2002) revised the summative equation of Weiss (1996) as follows:

- the CP and fat components were not altered,
- the NDF digestibility coefficient calculated using a lignin and NDF based equation was replaced by a direct laboratory measure of NDFD,
- the NFC component with constant digestibility was left unchanged for alfalfa and grasses, and
- the NFC component for corn silage was replaced with starch and non-starch NFC components with the starch digestibility coefficient varied in relationship to whole-plant DM content and kernel processing (Schwab and Shaver, 2001).

The revised summative energy equation has been made available to commercial forage testing laboratories and some have programmed it into their reporting system. Forage energy values generated from the revised summative energy equation (1x-maintenance TDN and 3x-maintenace $NE_L$) can be used in ration formulation packages that allow feedstuff energy values to be inputted, which does not include the NRC-2001 model or packages that incorporate its energy system completely. With the NRC-2001 model, NDF digestibility (% of NDF) can be inputted directly in the feed composition screen; this will influence the calculated energy value of the ration. However, the NRC-2001 model does not recognize the influence of NDFD on DM intake that was reported by Oba and Allen (1999).

The milk per ton index of Undersander et al. (1993) has been modified (Schwab and Shaver, 2001), and an easy to use Excel 5.0 spreadsheet called Milk2000 has been developed (http://www.uwex.edu/ces/forage/pubs/milk2000.xls). MILK2000 uses forage energy content estimated from the revised summative equation (Shaver et al., 2002) and forage DM intake calculated from NDF (Mertens, 1987) and in vitro NDFD (Oba and Allen, 1999) to predict milk production per ton of forage DM. In MILK2000, the intake of energy from forage for a 1350 lb. milking cow consuming a 30% NDF diet is calculated and the cow's maintenance energy requirement (proportioned according to the percentage of forage in the diet) is then subtracted from energy intake to provide an estimate of the energy available from forage for conversion to milk (NRC, 1989). Use of NDFD in the calculation of a revised RFV has been proposed (Shaver et al., 2002).

Fermentation analyses have long been used in university and industry research trials to assess silage quality. These analyses are now available for evaluating silage quality on farms through some commercial forage testing laboratories (Cumberland Valley Analytical Services, Maugansville, MD; Dairy One, Ithaca, NY; Dairyland Laboratories, Arcadia, WI; Rock River Laboratories, Watertown, WI).

### Use of Milk2000 Spreadsheet

Milk per ton and milk per acre calculations provide relative rankings of forage samples, but should not be considered as predictive of actual milk responses in specific situations for the following reasons:

- equations and calculations are simplified to reduce inputs for ease of use,
- farm to farm differences exist, and
- genetic, dietary, and environmental differences affecting feed utilization are not considered.

<u>Do not</u> use different values for yield or quality measurements that are not statistically different. Animal response calculations are more sensitive than our measurement techniques of yield and quality. The spreadsheet will show a milk/ton difference when yield and quality may not be statistically different.

Standard inputs that are needed for MILK2000 include DM percentage and yield, CP percentage, 48-hour in vitro NDFD (<u>not</u> dry matter digestibility), NDF percentage, and starch percentage (corn silage only). Ash and ether extract should be entered if available, but book values can be entered instead (for normal corn silage, 4.3% for ash and 3.2% ether extract and for alfalfa/grasses, 10.0% ash and 2.7% ether extract, are recommended). Non-fiber carbohydrate and non-starch NFC are calculated values within the spreadsheet.

The MILK2000 alfalfa/grass worksheet contains NRC (2001) RFV100 and high quality alfalfa in rows 12 and 13 as a quality reference. You can begin entering your samples in row 14: sample identification in column A, quality data in columns B through G, and DM yield in column H. Calculated results are found in columns I through T. Depending on your spreadsheet settings, it may be necessary to push F9 after entering data for calculation of results.

The MILK2000 corn silage worksheet contains NRC (2001) "normal" corn silage in row 12 as a quality reference. An example sample entry is included in row 13. You can begin entering your samples in row 14: sample identification in column A, processing in column B, quality data in columns C through J, and DM yield in column K. Calculated results are found in columns P through AC. Depending on your spreadsheet settings, it may be necessary to push F9 after entering data for calculation of results.

## Application of MILK2000

### Corn Silage

#### Harvest timing

The optimum whole-plant corn silage DM content is about 35% with lower milk yield found for corn silage harvested too wet and especially too dry (Bal et al., 1997). The economic impact of harvesting corn silage at DM contents ranging from 25% to 45% was calculated using MILK2000 to determine milk per ton and assuming a $12.00/cwt.milk price; the loss in gross milk revenue incurred by harvesting corn silage too dry was $15,000 to $20,000 annually per 100 cows.

#### Kernel processing

The results of corn silage kernel processing trials have been mixed; Bal et al. (2000b) reported a 3.3 lb/cow/day increase in 4% fat-corrected milk yield and a 4.2 percentage unit increase in total-tract starch digestion due to processing, while Dhiman et al. (2000) found no advantage to processing on milk yield or starch digestibility by dairy cows in two of three studies. The economic impact of corn silage kernel processing was calculated using MILK2000 to determine milk per ton and assuming a $12.00/cwt.milk price; the gain in gross milk revenue related to kernel processing was about $6,000 annually per 100 cows. This calculation was done on 40% DM corn silage, and the estimated response to processing would be less on 30% DM corn silage and greater on 45% DM corn silage. Potential benefits of processing beyond starch digestibility related to chopping at a longer length of cut with less sorting of cobs in the feed bunk were not considered in this calculation. To be considered excellent for degree of processing there should be more than 95% kernel breakage and no cobs should be greater than a 1/8$^{th}$ concentric ring.

#### Height of cutting

Increasing corn silage height of cutting by 14 inches reduced whole-plant NDF and ADF contents by 7%- and 4%-units, respectively (Satter et al., 2000). High cutting would also be expected to increase NDFD, because the more highly lignified portion of the stalk would be left in the field. Satter et al. (2000) projected the DM per acre yield loss associated with high cutting at 5% to 8%. The economic impact of high cutting was calculated using MILK2000 to determine milk per ton and assuming a $12.00/cwt.milk price; the gain in gross milk revenue related to high cutting equates to about $8,000 or $3,000 annually per 100 cows for milk $/ton DM or milk $/acre, respectively. Height of cutting offers some flexibility for manipulating the quality of corn silage. In some situations, potential benefits of high cutting for reducing nitrates, mycotoxins, and (or) soil erosion may have merit. High cutting increases whole-plant DM content (Satter et al., 2000), which may be a plus for custom operators hoping to get started early in the harvest season on immature corn silage.

#### Hybrids

The estimated economic impact of various corn silage hybrids is presented in Table 1. Only $bm_3$ and nutri-dense hybrids show a significant positive deviation from the mean of all hybrids tested for milk per ton of corn silage DM. Milk per acre for the nutri-dense hybrids was similar to the average for all hybrids tested. Although milk per ton was highest for $bm_3$ of the hybrid categories compared, milk per acre for $bm_3$ was lowest of the hybrid categories compared and was $347 per acre lower than the average of all hybrids tested. Dairy producers buying corn silage from a grower and dairy producers growing their own corn silage may have a widely different view of $bm_3$ hybrids. There were no advantages to leafy hybrids. This observation agrees with the results of feeding trials with leafy hybrids (Bal et al., 2000a; Kuehn et al., 1999), but not Clark et al. (2002). High-oil and waxy hybrids were worse than the average of all hybrids tested for milk per ton and per acre (high-oil) and milk per acre (waxy).

**Hay and Hay-crop Silage**

Milk production decline with diminishing alfalfa quality (increasing ADF and NDF contents) is well established (Nelson and Satter, 1990). The MILK2000 spreadsheet was used to assess the impact of alfalfa quality on estimated milk per ton of DM and per acre. For the first scenario, alfalfa NDF content was varied from 40% to 50% while holding NDFD constant at 50% of NDF. The milk per ton and milk per acre results and gross milk returns are presented in Table 2.

The estimated milk per ton benefit for alfalfa with a relative feed value (RFV) of 175 (40% NDF) over alfalfa with an RFV of 125 (50% NDF) equates to about $10,000 annually per 100 cows. Because of reduced yield for the immature alfalfa, the estimated milk per acre benefit for 175-RFV alfalfa over 125-RFV alfalfa equates to about $3,000 annually per 100 cows. Data from Wisconsin quality-tested hay auctions show that dairy producers pay $0.90 per point of RFV above the RFV of a base quality alfalfa (Undersander, 2002). So, 175-RFV alfalfa would sell for $45 more than 125-RFV alfalfa. Based on the estimated milk per ton, the 175-RFV alfalfa was worth $49 more per ton than 125-RFV alfalfa. Because of the premium price paid for high-quality alfalfa, it needs to be targeted to high producing cows with the potential for a production response from the high quality. Average-quality alfalfa can be targeted to low-producing cows and replacement heifers.

Table 1. Impact of various corn silage hybrids on estimated milk per ton and per acre[1,2].

| Hybrid | Milk lb/ton DM | Milk $/ton DM[3] | Milk lb/acre | Milk $/acre[3] |
|---|---|---|---|---|
| $bm_3$ (n=12) | 3410 | 409 | 21500 | 2581 |
| Bt (n=130) | 3140 | 377 | 25000 | 3000 |
| High Oil (n=12) | 3040 | 365 | 22500 | 2701 |
| Nutri-Dense (n=10) | 3240 | 389 | 24300 | 2917 |
| Leafy (n=70) | 3110 | 374 | 24600 | 2952 |
| Waxy (n=56) | 3090 | 371 | 22600 | 2712 |
| All Hybrids (n=2407) | 3110 | 374 | 24400 | 2928 |

[1]From MILK2000 (Schwab and Shaver, 2001; Schwab et al., 2001).
[2]Source: J.G. Lauer, UW-Madison Agronomy, 1995-2000 UW Silage Trials.
[3]Calculated using a $12.00/cwt. milk price.

Table 2. Impact of alfalfa quality on estimated milk per ton and per acre[1].

| Alfalfa (%CP, %NDF, RFV) | Milk lb/ton DM | Milk $/ton DM[2] | Milk lb/acre | Milk $/acre[2] |
|---|---|---|---|---|
| (22, 40, 175) | 2755 | 330 | 12398 | 1488 |
| (19, 45, 150) | 2549 | 306 | 12106 | 1453 |
| (16, 50, 125) | 2342 | 281 | 11710 | 1406 |

[1]Calculated using Milk2000 (http://www.uwex.edu/ces/forage/pubs/milk2000.xls).
[2]Calculated using a $12.00/cwt. milk price.

For the second scenario, alfalfa NDF content was set at either 40% or 50% while NDFD was varied from 40% to 60% of NDF within each concentration of NDF. The milk per ton results and gross milk returns are presented in Table 3. As NDFD decreased from 60% to 40% of NDF, milk per ton and $ per ton declined 671 lb and $80, respectively. This decline was greater than that observed with increasing NDF content from 40% to 50%, where milk per ton and $ per ton declined 413 lb and $50, respectively. Hay or hay-crop silage with low NDF content (40%) and low NDF digestibility (40%) shows lower predicted milk (lb or $) per ton than high NDF (50%), high NDFD (60% of NDF). The digestibility of NDF is a significant quality parameter that has been ignored in past forage evaluation schemes.

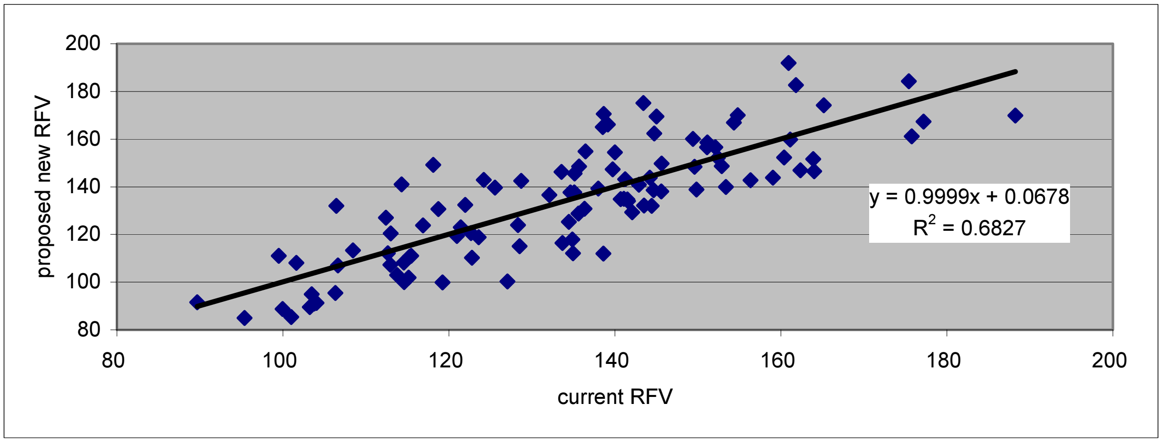
Table 3. Impact of alfalfa quality on estimated milk per ton and per acre[1].

| CP%, NDF% | NDFD % of NDF | Milk lb/ton DM[2] | Milk $/ton DM |
|---|---|---|---|
| (22, 40) | 60 | 3057 | 367 |
| (22, 40) | 50 | 2755 | 330 |
| (22, 40) | 40 | 2440 | 293 |
| | | | |
| (16, 50) | 60 | 2697 | 323 |
| (16, 50) | 50 | 2342 | 281 |
| (16, 50) | 40 | 1973 | 237 |

[1]Calculated using Milk2000 (http://www.uwex.edu/ces/forage/pubs/milk2000.xls).
[2]Calculated using a $12.00/cwt. milk price.

The RFV estimates used for forage evaluation and hay marketing are based on NDF and ADF concentrations, and have not considered differences in NDF digestibility. We (Shaver et al., 2002) proposed incorporating NDF digestibility measurements into the RFV calculations, where forage $NE_L$ and DM intake would be estimated in a manner similar to that described for estimating milk per ton. The regression of current versus proposed RFV estimates is presented in Figure 1. The graph and its low R-square value (0.68) show that the proposed RFV varies above and below its line of equality with the current RFV. For example, samples with a current RFV of 140 have proposed RFV ranging from 110 to 170. The use of NDF digestibility measurements in forage evaluation schemes may detect variation in forage quality not previously detected in schemes based solely on fiber concentrations. The foregoing discussion may partially explain why dairy producers often report widely different animal performance from lots of hay with the same RFV under the current system. Factors that cause NDFD to vary include plant species, varieties within a species, stage of maturity at harvest, climatic condition that the crop was grown under, and interactions between these factors. We are hopeful that the proposed system, which incorporates NDFD into the calculation of RFV, will yield a better relationship with animal performance, but this has yet to be confirmed in feeding experiments.

Figure 1. Current versus proposed relative feed value calculations.




## Silage Quality

Analyses commonly included in silage fermentation reports are pH, lactic, acetic, propionic and butyric acids, ammonia, and ethanol (Kung and Shaver, 2001). The pH of an ensiled sample is a measure of its acidity, but is also affected by the buffering capacity of the crop. In general, legume silages have a higher pH than corn or other grass silages and take longer to ensile because of their higher buffering capacity. Seldom do corn silages have a pH higher than 4.2. Such cases may be associated with extremely dry (>42% dry matter) silages that are overly mature or drought stricken. Because of its normally low pH (3.8), corn silage intake usually benefits from the addition of sodium bicarbonate prior to feeding to neutralize its acidity. Common reasons for legume silages having a pH higher than 4.6 to 4.8 include: ensiling at <30% dry matter (DM) which causes a clostridial fermentation, and ensiling at > 45-50% DM, which restricts fermentation. In the first example, a high pH due to clostridia is a definite indicator of an undesirable fermentation that has led to poor quality silage. However, in the second example, a high pH due to restricted fermentation is not always indicative of a poor fermentation or poor silage. But, silage from a restricted fermentation usually is unstable when exposed to air because insufficient amounts of acid were produced to inhibit secondary microbial growth.

Lactic acid should be the primary acid in good silage. This acid is stronger than the other acids in silage (acetic, propionic, and butyric), and therefore is usually responsible for most of the drop in silage pH. Further, fermentations that produce lactic acid result in the lowest losses of DM and energy from the crop during storage. Lactic acid should be at least 65 to 70% of the total silage acids in good silage. Extremely wet silages (< 25% DM), prolonged fermentations (due to high buffering capacity), loose packing, or slow silo filling can result in silages with high concentrations of acetic acid (>3 to 4% of DM). In such silages, energy and DM recovery are probably less than ideal. Silages treated with ammonia also tend to have higher concentrations of acetic acid than untreated silage, because the fermentation is prolonged by the addition of the ammonia that raises pH. A new microbial inoculant (Lactobacillus buchneri) designed for improving the aerobic stability of silages causes higher than normal concentrations of acetic acid in silages. However, production of acetic acid from this organism should not be mistaken for a poor fermentation and feeding treated silages with a high concentration of acetic acid does not appear to cause negative effects on animal intake.

The effect of high concentrations of acetic acid (> 4-6% of DM) in silages fed to animals is unclear at this time. In the past, some studies can be found where DM intake was depressed when silage high in acetic acid concentration was fed to ruminants. However, the depression in intake to high acetic acid in the diet has not been consistent. There has been speculation that decreased intake may be actually due to unidentified negative factors associated with a poor fermentation and not to acetic acid itself. For example, in recent studies, animals showed no indication of reduced intake when fed silages high in acetic acid due to inoculation with the bacteria Lactobacillus buchneri for improved aerobic stability. If a producer has intake problems due to silages with excessively high acetic acid (> 5-6% of DM), the amount of that silage should be reduced in the TMR.

A high concentration of butyric acid (>0.5% of DM) indicates that the silage has undergone clostridial fermentation, which is one of the poorest fermentations. Silages high in butyric acid are usually low in nutritive value and have higher ADF and NDF levels because many of the soluble nutrients have been degraded. Such silages may also be high in concentrations of soluble proteins and may contain small protein compounds called amines that have sometimes shown to adversely affect animal performance. High butyric acid has sometimes induced ketosis in lactating cows and because the energy value of silage is low, intake and production can suffer. As with other poor quality silages, total removal or dilution of the poor silage is advised.

High concentrations of ammonia (>12 to 15% of CP) are a result of excessive protein breakdown in the silo caused by a slow drop in pH or clostridial action. In general, wetter silages have higher concentrations of ammonia. Extremely wet silages (< 30% DM) have even higher ammonia concentrations because of the potential for clostridial fermentation. Silages packed too loosely and filled too slowly also tend to have high ammonia concentrations. Theoretically, high amounts of ammonia (by itself) in silage should not have negative effects on animal performance if the total dietary nitrogen fractions are in balance. However, if the high ammonia contributes to an excess of ruminally-degraded protein (RDP), this could have negative consequences on milk and reproductive performances. Blood or milk urea nitrogen can be used as an indicator of excess RDP. Often times, silage with high concentrations of ammonia coupled with butyric acid may also have significant concentrations of other undesirable end products, such as amines, that may reduce animal performance.

High concentrations of ethanol are usually an indicator of excessive metabolism by yeasts. Dry matter recovery is usually worse in silages with large numbers of yeasts. These silages are also usually very prone to spoilage when the silage is exposed to air. Usual amounts of ethanol in silages are low (< 1 to 2% of DM). Extremely high amounts of ethanol (> 3 to 4% of DM) in silages may cause off flavors in milk. We do not know the level at which ethanol becomes a problem in dairy cattle diets. Most ethanol that is consumed is probably converted to acetic acid in the rumen.

## References

Bal, M. A., J. G. Coors, and R. D. Shaver. 1997. Impact of the maturity of corn for use as silage in the diets of dairy cows on intake, digestion, and milk production. J. Dairy Sci. 80:2497-2503.

Bal, M. A., R. D. Shaver, H. Al-Jobeile, J. G. Coors, and J. G. Lauer. 2000a. Corn silage hybrid effects on intake, digestion, and milk production by dairy cows. J. Dairy Sci. 83:2849-2858.

Bal, M. A., R. D. Shaver, A. G. Jirovec, K. J. Shinners, and J. G. Coors. 2000b. Crop processing and chop length of corn silage: effects on intake, digestion, and milk production by dairy cows. J. Dairy Sci. 83:1264-1373.

Clark, P. W., S. Kelm, and M. I. Endres. 2002. Effect of feeding a corn hybrid selected for leafiness as silage or grain to lactating dairy cattle. J. Dairy Sci. 85:607-612.

Coors, J.G., T.J. Frey, and R.D. Shaver. 2001. Breeding for nutritional quality and yield in silage maize. p. 55. Abstracts. Proc. XVIth Eucarpia Congress. 10-14 September 2001. Edinburgh, Scotland.
Dhiman, T. R., M. A. Bal, Z. Wu, V. R. Moreira, R. D. Shaver, L. D. Satter, K. J. Shinners, and R. P. Walgenbach. 2000. Influence of mechanical processing on utilization of corn silage by lactating dairy cows. J. Dairy Sci. 83:2321-2528.

Kuehn, C. S., J. G. Linn, D. G. Johnson, H. G. Jung, and M. Endres. 1999. Effect of feeding silages from corn hybrids selected for leafiness or grain to lactating dairy cows. J. Dairy Sci. 82:2746-2755.

Kung, L., and R. Shaver. 2001. How good is your silage making? Hoard's Dairyman. Sept. 25, 2001. pg. 597.

Lauer, J., K. Kohn, and P. Flannery. 2001. Wisconsin Corn Hybrid Performance Trial Results: Grain and Silage. A3653. Univ. WI Extension. Madison, WI.

Lauer, J., K. Kohn, P. Flannery, and K. Hudelson. 1997. Wisconsin Corn Hybrid Performance Trial Results: Grain and Silage. A3653. Univ. WI Extension. Madison, WI.

Mertens, D. R. 1987. Predicting intake and digestibility using mathematical models of ruminal function. J. Anim. Sci. 64:1548-1558.

National Research Council. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. Natl. Acad. Sci., Washington D.C.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. 6th rev. ed. Natl. Acad, Sci., Washington, DC.

Nelson, W. F., and L. D. Satter. 1990. Effect of stage of maturity and method of preservation of alfalfa on production by lactating dairy cows. J. Dairy Sci. 73:1800-1811.

Oba, M. and M. S. Allen. 1999. Evaluation of the importance of the digestibility of neutral detergent fiber from forage: effects on dry matter intake and milk yield of dairy cows. J. Dairy Sci. 82:589-596.

Rohweder, D.A., R. E. Barnes, and Jorgensen, N. 1978. Proposed hay grading standards based on laboratory analysis for evaluating quality. J. Anim. Sci. 47:747-759.

Satter, L. D., V. Moreira, H. Santos, Z. Wu, and F. Kanitz. 2000. Relative feeding value of diverse corn silage hybrids. Pages 31-46 *in* Proc. of UW Arlington Dairy Day. Arlington, WI.

Schwab, E. C., and R. D. Shaver. 2001. Evaluation of corn silage nutritive value using MILK2000. Pages 21-24 *in* Proc. of 25th Forage Production and Use Symposium. WI Forage Council Annual Mtg. Eau Claire, WI.

Schwab, E., R. Shaver, P. Hoffman, J. Lauer, and J. Coors. 2001. MILK2000 Corn Silage Variety Evaluation. http://www.wisc.edu/dysci/uwex/nutritn/spreadsheets/Milk2000v31.xls.

Shaver, R. D., D. J. Undersander, E. C. Schwab, P. C. Hoffman, J. G. Lauer, D. K. Combs, and J. G. Coors. 2002. Evaluating Forage Quality for Lactating Dairy Cows. Proc. Intermountain Nutr. Conf. Salt Lake City, UT.

Undersander, D. J. 2002. Wisconsin tested hay auctions. http://www.uwex.edu/ces/forage/pubs/auction.htm.

Undersander, D.J., W.T. Howard, and R.D. Shaver. 1993. Milk per acre spreadsheet for combining yield and quality into a single term. J. Prod. Ag. 6:231-235.

Weiss, W. P. 1996. Estimating available energy content of ruminant feeds. Pages 1-11 *in* Proc. California Nutrition Conference, Fresno, CA.

# Managing Bunker, Trench, and Drive-over Pile Silages for Optimum Nutritive Value: Five Important Practices

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The points of the silage triangle are represented by persons responsible for (1) the dairy cattle, (2) the forage, and (3) the harvesting process. In some dairy operations, one person is responsible for all three points. But in many instances, both growing and harvesting (and ensiling) the crop are done completely on a contract basis, creating a situation where a different person is at each point of the triangle. When communication between the points of the triangle is ineffective, inefficiencies can result, which directly affect the bottom line.

Although a dairy cattle operation's nutritionist – often an outside consultant – is not a direct part of the triangle, he or she has an obvious vested interest in how well the triangle performs. The nutritionist might be the key person in assuring effective communication between the triangle's three points.

The nutritionist's major responsibility is generally to the dairy cattle point of the triangle, so among his/her major responsibilities could be (1) educating the client about proper silage management, and (2) fostering communication. Ideally, the nutritionist should moderate an annual meeting between the dairy manager, the forage crop grower, and the custom harvester. This can ensure that all involved understand and agree regarding expectations and implementation of the entire silage program. In other cases, a small dairy producer might be on the wrong end of a tight supply/demand situation and therefore lack the economic power to make demands on the crop grower and/or custom harvester. Then, the nutritionist must focus directly on the dairy producer, and make sure that the things directly under the producer's control are done correctly.

This paper focuses on five important silage management practices that are in the control of dairy producers and that are sometimes poorly implemented or overlooked entirely. These are (1) using an effective bacterial inoculant, (2) achieving a high silage density, (3) effective sealing, (4) properly managing the feedout face, and (5) discarding spoiled silage.

## Use a Bacterial Inoculant

For detailed summaries on the effect of bacterial inoculants on silage fermentation, preservation efficiency, and nutritive value, see reviews by Muck (1993); Kung and Muck (1997); and Muck and Kung (1997).

Evaluation of silage additives began in 1975 in the Department of Animal Sciences and Industry. A summary of results from over 200 laboratory-scale studies, which involved nearly 1,000 silages and 25,000 silos, indicate that bacterial inoculants are beneficial in over 90% of the comparisons. Inoculated silages have faster and more efficient fermentations -- pH is lower, particularly during the first 2 to 4 days of the ensiling process for hay crop forages, and lactic acid content and the lactic to acetic acid ratio are higher than in untreated silages. Inoculated silages also have lower ethanol and ammonia-nitrogen values compared to untreated silages. Results from 28 farm-scale trials, which evaluated 71 silages, showed that bacterial inoculants consistently improved fermentation efficiency, DM recovery, feed to gain ratio, and live weight gain per ton of crop ensiled in both corn and sorghum silages (Bolsen et al., 1992).

**Economics of bacterial inoculants.** A "bottom line" calculation of the value of inoculating corn silage and alfalfa haylage for dairy cows is presented in Table 2. The dairy herd in this example has an average milk production 87 lbs per cow per day and a daily DM intake of 54.2 lbs (Table 1). The increase in net income, calculated on a per ton of crop ensiled or per cow per day or per cow per year basis, is realized from increases in both preservation and feed utilization improvements. The additional "cow days" per ton of crop ensiled, because of the increased DM recovery, and the increased milk per cow per day from the inoculated silage or haylage (0.25 lbs) produced a $6.67 increase in net return per ton of corn ensiled and a $14.95 increase in net return per ton of alfalfa ensiled.

**Recommendations.** Why leave the critical fermentation phase to chance by assuming that the epiphytic microorganisms (those occurring naturally on the forage) are going to be effective in preserving the silage crop? Even if a dairy or beef cattle producer's silage has been acceptable in the past--because silage-making conditions in most regions of North America are generally good-- there are always opportunities for improvement.

Although whole-plant corn and sorghum ensile easily, research data clearly show that the quality of the fermentation and subsequent preservation and utilization efficiencies are improved with bacterial inoculants. Alfalfa (and other legumes) is usually difficult to ensile because of a low sugar content and high buffering capacity. However, adding an inoculant helps ensure that as much of the available substrate as possible is converted to lactic acid, which removes some of the risk of having a poorly preserved, low-quality silage.

Finally, if producers already are doing a good job but using a bacterial inoculant for the first time, they probably will not see a dramatic difference in their silage. But the benefit will be there -- additional silage DM recovery and significantly more beef or milk production per ton of crop ensiled.

Table 1. Silage, haylage, and grain mix inputs in the example dairy herd ration.

| Ration | Dry matter intake, lbs | Dry matter, % | Amount as-fed, lbs | $ per lb | Daily ration cost, $ |
|---|---|---|---|---|---|
| Corn silage | 11.4 | 35.0 | 32.6 | 0.015 | 0.49 |
| Alfalfa haylage | 11.2 | 40.0 | 28.0 | 0.03 | 0.84 |
| Grain mix | 31.6 | 87.5 | 35.1 | 0.075 | 2.63 |
| Total | 54.2 | | 95.7 | | 3.96 |

Table 2. Comparison of preservation efficiency and feed utilization efficiency with and without an inoculant.

| | Corn silage | | Alfalfa haylage | |
|---|---|---|---|---|
| | Untreated | Inoculant | Untreated | Inoculant |
| Preservation efficiency: | | | | |
| Dry matter recovery, % | 90.0 | 91.25 | 87.5 | 90.0 |
| Dry matter recovered per ton ensiled, lbs | 1800 | 1825 | 1750 | 1800 |
| Amount fed daily, lbs | 32.6 | 32.6 | 28.0 | 28.0 |
| "Cow days" per ton ensiled | 55.2 | 56.0 (+0.8) | 62.5 | 64.3 (+1.8) |
| Milk gained per ton ensiled, lbs | | 69.6[1] | | 156.6[5] |
| Milk value gained per ton ensiled, $ | | $8.70[2] | | $19.57[6] |
| Utilization efficiency: | | | | |
| Increased milk yield/cow/day, lbs | Inoculated corn silage = 0.25 lbs increase in milk/cow/day. | | Inoculated alfalfa haylage = 0.25 lbs increase in milk/cow/day. | |
| Milk gained per ton of crop ensiled, lbs | 56.0 cow days × 0.25 lbs of milk = 14.0 lbs milk gained/ton ensiled. | | 64.3 cow days × 0.25 lbs of milk = 16.0 lbs milk gained/ton ensiled. | |
| Milk value gained per ton ensiled, $ | 14.0 lbs of milk × $0.125/lb = $1.75 gained value/ton ensiled. | | 16.0 lbs of milk × $0.125/lb = $2.00 gained value/ton ensiled. | |
| Combined efficiencies | ($8.70 + $1.75) × ($2.78 + $1.00)[3,4] = $6.67 gained value/ton of crop ensiled. | | ($19.57 + $2.00 × ($5.62 + $1.00)[7,4] = $14.95 gained value/ton of crop ensiled. | |
| Bottom line: | | | | |
| Additional cost | 32.6 lbs × 305 days ÷ 2000 = 5.0 tons/cow/yr. 5.0 tons ÷ 0.9125 = 6.1 tons to ensile/cow/yr[8]. 6.1 tons × $1.00/ton = $6.10/cow/yr. $6.10 ÷ 305 days = $0.02/cow/day. | | 28.0 lbs × 305 days ÷ 2000 = 4.3 tons/cow/yr. 4.3 tons ÷ 0.90 = 5.3 tons to ensile/cow/yr[8]. 5.3 tons × $1.00/ton = $5.30/cow/yr. $5.30 ÷ 305 days = $0.017/cow/day. | |
| Additional income | 5.0 tons × $6.67 = $33.35/cow/yr. $33.35 ÷ 305 days = $0.11/cow/day. | | 4.3 tons × $14.95 = $64.28/cow/yr. $64.28 ÷305 days = $0.21/cow/day. | |
| Increased net income | $0.11 - $0.02 = $0.09/cow/day. $0.09 × 305 days = $27.45 /cow/yr. | | $0.21 - $0.017 = $0.19/cow/day. $0.193 ×305 days = $57.95 /cow/yr. | |

[1]87.0 lbs of milk/cow/day × 0.8 "cow days" gained per ton ensiled. [2]69.6 lbs of milk × $0.125 per lb = $8.70 gained value per ton ensiled. [3]Haylage + grain mix costs/cow/day = $3.47 × 0.8 cow days = $2.78 added cost per ton ensiled. [4]Treatment (inoculate) cost = $1.00 per ton ensiled. [5]87.0 lbs of milk/cow/day × 1.8 "cow days" gained per ton ensiled. [6]156.6 lbs of milk × $0.125 per lb = $19.57 gained value per ton ensiled. [7]Corn Silage + grain mix costs/cow/day = $3.12 × 1.8 cow day = $5.62 added cost per ton ensiled. [8]Assumes a 91.25% "forage in" vs. "silage out" for the corn silage; 90.0% for alfalfa haylage. An additional 10 percent was included in the tons ensiled as an inventory insurance protection.

## Achieve a Higher Silage Density

First, density and crop dry matter (DM) content determine the porosity of the silage, which affects the rate at which air can enter the silage mass at the feedout face. Second, the higher the density, the greater the capacity of the silo. Thus, higher densities typically reduce the annual storage cost per ton of crop by both increasing the amount of crop entering the silo and reducing crop losses during storage. Recommendations have usually been to spread the chopped forage in thin layers and pack continuously with heavy, single-wheeled tractors. But the factors that affect silage density in a bunker, trench, or drive-over pile silo are not completely understood. Ruppel *et al*. (1995) measured the DM losses in alfalfa silage in bunker silos and developed an equation to relate these losses to the density of the ensiled forage (Table 3). They found that tractor weight and packing time per ton were important factors; however, the variability in density suggested there were other important factors not considered.

In a recent study, Muck and Holmes (1999) measured silage densities over a wide range of bunker silos in Wisconsin, and the densities were correlated with crop/forage characteristics as well as harvesting and filling practices. Samples were collected from 168 bunker silos and a questionnaire completed about how each bunker was filled. Four core samples were taken from each bunker feedout face and core depth, height of the core hole above the floor, and height of silage above the core hole were recorded. Density and particle size distribution were also measured.
The range of DM contents, densities, and average particle size observed in the hay crop and corn silages are shown in Table 4. As expected, the range in DM content was narrower for the corn silages compared to the hay crop silages. The average DM content of the corn silages was in the recommended range of 30-35%. But several of the haylages were too wet (less than 30% DM), which can lead to effluent loss and a clostridial fermentation, or too dry (more than 50% DM), which can lead to extensive heat damage, mold, and the risk of a fire. The average DM density for the hay crop and corn silages was similar and slightly higher than a commonly recommended minimum DM density of 14.0 lbs/ft$^3$. Some producers were achieving very high DM densities, while others were severely underpacking. One very practical issue was packing time relative to the chopped forage delivery rate to the bunker. Packing time per ton was highest (1 to 4 min/ton on a fresh basis) under low delivery rates (less than 30 tons/h on a fresh basis). Packing times were consistently less than 1 min/ton (on a fresh basis) at delivery rates above 60 tons/hour.

There are several key factors that dairy producers can control to achieve higher densities, which will minimize DM and nutrient losses during ensiling, storage, and feedout.

**Forage delivery rate.** Reducing the delivery rate is somewhat difficult to accomplish, as very few dairy producers or silage contractors are inclined to slow the harvest rate so that additional packing can be accomplished.

**Packing tractor weight.** This can be increased by adding weight to the front of the tractor or 3-point hitch and filling the tires with water.

**Number of tractors.** Adding a second or third packing tractor as delivery rate increases can help keep packing time in the optimum range of 1 to 3 minutes per ton of fresh forage.

**Forage layer thickness.** Chopped forage should be spread in thin layers (6 to 12 inches). In a properly-packed bunker silo, the tires of the packing tractor should pass over the entire surface before the next forage layer is distributed.

**Filling the silo to a greater depth.** Greater silage depth increases density, but there are practical limits to the final forage depth in a bunker, trench, or drive-over pile. Safety of employees who operate packing tractors and who unload silage at the feedout face becomes a concern. Packing in bunkers that are filled beyond their capacity and the chance of an avalanch of silage from the feedout face pose serious risks.

Table 3. Dry matter loss as influenced by silage density.

| Density (lbs of DM/ft$^3$) | DM loss at 180 days (% of the DM ensiled) |
|---|---|
| 10 | 20.2 |
| 14 | 16.8 |
| 16 | 15.1 |
| 18 | 13.4 |
| 22 | 10.0 |

Table 4. Summary of core sample analysis from the bunker silos

| Silage characteristic | Hay crop silage (87 silos) | | Corn silage (81 silos) | |
|---|---|---|---|---|
| | Avg | Range | Avg | Range |
| Dry matter, % | 42 | 24-67 | 34 | 25-46 |
| Density on a fresh basis, lbs/ft$^3$ | 37 | 13-61 | 43 | 23-60 |
| Density on a DM basis, lbs/ft$^3$ | 14.8 | 6.6-27.1 | 14.5 | 7.8-23.6 |
| Avg particle size, inches | 0.46 | 0.3-1.2 | 0.43 | 0.3-0.7 |

## Protect Silage from Air and Water

Until recently, most large bunker, trench, or drive-over pile silos were left unsealed. Why? Because producers viewed covering silos with plastic and tires to be awkward, cumbersome, and labor intensive. Many believed the silage saved was not worth the time and effort required. But if left unprotected, DM losses in the top 1 to 3 feet can exceed 60 to 70% (Bolsen *et al*., 1993). This is particularly disturbing when considering, in a typical horizontal silo, 15 to 25% of the silage might be within the top three feet. When the silo is opened, the spoilage is only apparent in the top 6 to 12 inches of silage, obscuring the fact that this area of spoiled silage represents substantially more silage as originally stored (Holthaus *et al*., 1995).

The most common sealing method is to place a polyethylene sheet (6 mil) over the ensiled forage and anchor it down with discarded tires (approximately 20 to 25 tires per 100 ft$^2$ of surface area). Dairy producers who do not seal need to take a second look at the economics of this highly troublesome ‘technology’ before they reject it as unnecessary and uneconomical. The loss from a 40- x 100-foot silo filled with corn silage can exceed \$2,000. Loss from a 100- x 250-foot silo can exceed \$10,000.

## Manage the Feedout Face

The silage feedout "face" should be maintained as a smooth surface that is perpendicular to the floor and sides in bunker, trench, and drive-over pile silos. This will minimize the surface area exposed to air. The rate of feedout through the silage mass must be sufficient to prevent the exposed silage from heating and spoiling. An average removal rate 6-12 inches from the face per day is a common recommendation. However, during periods of warm, humid weather, a removal rate of 18 inches or more might be required to prevent aerobic spoilage, particularly for high-moisture (HM) ensiled grains and whole-plant corn, sorghum, and winter cereal silages. Hoffman and Ocker (1997) fed aerobically stable and unstable HM shelled corn to mid-lactation cows for three, 14-day periods. Milk yield of the cows fed the aerobically deteriorated HM corn declined by approximately 7 lbs per cow per day during each period compared to cows fed fresh, aerobically stable HM corn.

## Discard Spoiled Silage

Sealing a silage mass using a polyethylene sheet anchored with tires is not 100 percent effective. Aerobic spoilage occurs to some degree in virtually all ‘sealed’ silos; and the discarding of surface spoilage is not always a common practice on the farm. But results of a recent study at Kansas State University showed that feeding surface spoilage had a significant negative impact on the nutritive value of a whole-plant corn silage-based ration (Whitlock *et al*., 2000).

The original top three feet of corn silage in a bunker silo was allowed to spoil, and it was fed to steers fitted with ruminal cannulas. The four experimental rations contained 90% silage and 10% supplement (on a DM basis), and the proportions of silage in the rations were: A) 100% normal, B) 75% normal: 25% spoiled; C) 50% normal:50% spoiled, and D) 25% normal:75% spoiled.

The proportion of the original top 18-inch and bottom 18-inch spoilage layers in the composited surface-spoiled silage was 24 and 76%, respectively. The original top 18-inch layer was visually quite typical of an unsealed layer of silage that had undergone several months of exposure to air and rainfall. It had a foul odor, was black in color, and had a slimy, ‘mud-like’ texture. Its extensive deterioration during storage was reflected in very high pH, ash, and fiber values. The original bottom 18-inch layer had an aroma and appearance usually associated with wet, high-acid corn silages, i.e., a bright yellow to orange color, a low pH, and a very strong acetic acid smell.

The addition of surface-spoiled silage had large negative associative effects on DM intake and organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) digestibility (Table 5). The first 25% increment of spoilage had the greatest negative impact. When the rumen contents were evacuated, the spoiled silage had also partially or totally destroyed the integrity of the forage mat in the rumen. The results clearly showed that surface spoilage reduced the nutritive value of corn silage-based rations more than was expected.

Table 5. Effect of the level of spoiled silage on DM intake and nutrient digestibilities

| Item | Ratio of normal:spoiled silage in the ration | | | |
|---|---|---|---|---|
| | 100% normal | 75:25 | 50:50 | 25:75 |
| Spoilage layer, %[1] | 0 | 5.4 | 10.7 | 16.0 |
| DM intake, lbs/day | 17.5[a] | 16.2[b] | 15.3[b,c] | 14.7[c] |
| | ------------------------- Digestibility, % ------------------------- | | | |
| OM | 75.6[a] | 70.6[b] | 69.0[b] | 67.8[b] |
| CP | 74.6[a] | 70.5[b] | 68.0[b] | 62.8[c] |
| NDF | 63.2[a] | 56.0[b] | 52.5[b] | 52.3[b] |
| ADF | 56.1[a] | 46.2[b] | 41.3[b] | 40.5[b] |

[1] The percent of the "slimy" layer silage in the ration (DM basis).
[a,b,c] Means within a row differ (P<.05).

## References


Bolsen, K. K., R. N. Sonon, Jr., B. Dalke, R. Pope, J. G. Riley, and A. Laytimi. 1992. Evaluation of inoculant and NPN silage additives: a summary of 26 trials and 65 farm-scale silages. Kansas Agric. Exp. Sta. Rpt. of Prog. 651:101-102.

Bolsen, K. K., J. T. Dickerson, B. E. Brent, R. N. Sonon, Jr., B. S. Dalke, C. J. Lin, and J. E. Boyer, Jr. 1993. Rate and extent of top spoilage in horizontal silos. J. Dairy Sci. 76: 2940-2962.

Hoffman, P.C. and Ocker, S.M. 1997. Quantification of milk yield losses associated with feeding aerobically unstable high moisture corn. J. Dairy Sci. 80(Suppl.1): 234 (Abstr.).

Holthaus, D. L., M. A. Young, B. E. Brent, and K .K. Bolsen. 1995. Losses from top spoilage in horizontal silos. Kansas Agric. Exp. Sta. Rpt. of Prog. 727 : 59-62.

Kung Jr., L., and R. E. Muck. 1997. Animal response to silage additives. p. 200-212. *In* Silage: Field to Feedbunk. NRAES-99. NRAES. Ithaca, NY.

Muck, R. E. 1993. The role of silage additives in making high quality silage. p. 106-116. *In* Proc. Nat. Silage Prod. Conf. NRAES-67, Ithaca, NY.

Muck, R. E., and L. Kung, Jr. 1997. Effects of silage additives on ensiling. p. 187-199. *In* Silage: Field to Feedbunk. NRAES-99. NRAES. Ithaca, NY.

Muck, R. E. and B. J. Holmes. (1999) Factors affecting bunker silo densities. 1999. The XII International Silage Conference. Uppsala, Sweden. pp 278 – 279.

Ruppel, K. A., R. E. Pitt, L. E. Chase, and D. M. Galton. 1995. Bunker silo management and its relationship to forage preservation on dairy farms. J. Dairy Sci. 78:141-153.

Whitlock, L.A., T. Wistuba, M.K. Siefers, R.V. Pope, B.E. Brent, and K.K. Bolsen. 2000. Effect of level of surface-spoiled silage on the nutritive value of corn silage-based rations. Kansas Agric. Exp. Sta. Rpt. of Prog. 850: 22-24.

# The Cows Are Always Right!: Evaluating Rations

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If you're going to evaluate how a ration is working in a herd, prepare to get manure on you. Much of the focus on ration evaluation has been on herd production and health records and feed analyses. These are very valuable tools, but you cannot properly evaluate rations without getting out among the cows that are eating them. An important part of evaluating a ration is directly assessing the feeds, management, and the interaction of the cows with what they are fed. This involves looking at cow behavior, bunk management, manure evaluation, water availability, rumination, cow appearance, body condition, cow comfort, feed availability, feed quality, and on. As you walk the herd, keep your senses (all of them, maybe excepting taste) open so you notice what is going on, and pick up on things that are normal and out of the ordinary. Use the information you gather in the barn to build a case: do the variety of pieces of information point the same direction, suggesting what should be changed or kept the same in the ration, feeds, and management? You should probably go out to the barns at different times of the day to see how things vary. Staying in the milk house or office won't give you all the information you need. So, let's get out there.

## The Barn and Laneways

After checking to find out which groups have bulls in them, we go out to the barn. Take the route the cows have to go from the parlor to the barn or paddock. Take the time to be quiet and watch and listen:

- Do the cows appear to have comfortable, non-skid footing?
- Are there many rocks or holes in the laneways? How deep is the mud?
- How far do the cows have to walk from the parlor to their barn/corral?
- Is ventilation in the barn good?
- Are the cows using the stalls comfortably?
- Is the barn comfortable / are fans and cooling systems working?
- How many hours a day are the cows in the barn?

If cows can't breathe, rest, or walk comfortably, they are likely to milk less. A comfortable cow can put her energy towards making milk, rather than surviving her environment. Slick surfaces that make cows do a four-footed shuffle, rough surfaces that have them tip-toeing on sore feet, or deep mud that could suck the boots off of an unwary extension specialist make it more likely that the cows will make fewer trips to the bunk. Rocks in the laneways make for bruised feet and lameness. If <u>you</u> can't reasonably traverse the path from the parlor to pen, the cows are being asked to expend more energy than they should. Watch the cows as they move: they will tell you what's comfortable (perfect opportunity to use the lameness scoring system). The distance from the milking parlor to where the cows rest and eat determines how much additional energy they have to devote to walking over and above the base level included in maintenance requirements. That must be subtracted from the energy available for milk production. Cows don't appear to be as sensitive to ammonia as people are, but the humidity and odor in a barn can give an indication of whether the air exchanges are adequate.

Giving a cow a comfortable place to lie down, get off her feet, ruminate, and rest is crucial to keeping her healthy and productive. If cows are not using the stalls, if they are lying half in – half out of stalls, or if they just stand in the stalls, reassess whether the stall design, dimensions and bedding are what they should be.

Heat-stressed cows are more prone to ruminal acidosis, sorting their feed, and slug feeding. Just think: at the very least, if cows are panting or breathing heavily, they are not chewing their cuds, and this does not help rumen health. Keeping cooling systems in good working order is the best way to deal with heat stress. We do recommend that heat stress rations contain more potassium, sodium, and magnesium, and as much if not more forage, but any ration changes to deal with heat stress are just band-aids – you need to cool the cows. About forage and heat stress: feeding more concentrate during heat stress is a bad idea. There is no research information to support it. Since heat stress makes cows more susceptible to rumen acidosis, feeding them adequate fiber, more and more palatable forage, and possibly less starch can keep them healthier, they won't lose more milk than they would normally, but they'll be better prepared to perform when cooler weather comes.

If cows spend much time away from the barn, they have that much more time where they can't eat, drink or rest. Generally, the suggestion is that cows be grouped so that they spend no more than 2 hours per milking away from their barn. Anecdotally, the more time cows spend standing on concrete with no chance to lie down, the greater the chance of hoof problems.

- Waterers near the exit to the parlor?
- Are the waterers working, filling adequately, clean?

Milk is 87% water. No water, no milk. Period. Cows are lazy. The more convenient we can make it for them to have good, fresh water and feed when they want it, the better they will produce. Water intake can be affected by level of production, feed, sodium, and protein intake, and environmental temperature, not to mention the base amount of water that cows need for maintenance. Cows require about 0.36 gallons of water per pound of milk (NRC, 2001). That water can come from feed or drinking water. Water intakes under heat stress can increase by more than half, as temperature increases.

- Is there feed in the bunk? Is it well mixed? Particle size?
- Does the feed in the bunk look like the formulation on paper?
- Has the feed heated? Is it musty? Apparently palatable?
- Are there clumps of spoiled silage in the bunk?
- Is there adequate bunk space?
- Do cows have fresh feed available when they come back from the parlor?
- Is feed pushed up several times a day?

With the exception of those few managers who have figured out how to properly feed to an empty bunk, no feed means less milk. Granted you need to have animals to feed the weighback to, but having 3-5% of the feed left over that looks and smells like the feed you originally fed will help to assure that the cows get the feed they need to make milk, grow, breed, and gain body condition. TMRs should be well mixed, or what's the point? If the particle size is too fine, the animals may not get enough effective (chewable) fiber to keep their rumens functioning well, too coarse, and they will sort the feed. You can get an idea if the cows are sorting by watching them eat: If they nudge feed back and forth with their muzzles and then dive towards the floor, they are usually pushing forage out of the way and eating grain. Moistening the feed with water or a liquid feed (molasses? wet brewers' grains?) so it holds together, and then making sure most of the forage is cut so it is 1 – 2 inches long at most will help to prevent sorting. The feed in the bunk should resemble the formulation on paper. Check mixer weights and feed dry matters against the formulation.

If the feed has problems with heating or mustiness, you need to go look at the individual feeds to find the source of the problem. More on that later. If the feed is unpalatable, the cows will eat less of it. If it contains molds, you may be in for problems from mycotoxins. The clumps of spoiled silage that make it to the bunk, often from not cleaning the spoiled material from the top of the silo, can cause cows here and there in the herd to come down with diarrhea, because not all cows consume the spoilage.

If feed bunk space is limited, your cows may slug feed, eating large meals in short periods when they think that the getting is good. That could lead to ruminal acidosis, or lower feed efficiency. Making sure that fresh feed is available in the bunk each time the cows come back from milking, and pushing up at least once between feedings can help increase and even out the intakes. Just consider, when a cow comes back to the barn, if there is feed, she'll likely stand there and eat, if not, she'll probably go lie down. Once she lies down, it takes active effort for her to get up and eat once the fresh feed is delivered – she may not do it. If possible, adjust cow numbers per pen to increase bunk space per cow.

Many of those questions don't have to do with the ration, per se, but can affect their maintenance requirements, how well the cows eat, and their health.

### The Cows

- Out of every 10 cows, how many are ruminating?
- Do the cows appear to be sorting their feed? What are they sorting for?
- Are cows eating dirt? Eagerly eating buffer or salt?
- Do the animals look dull, or bright and healthy?
- Are the cows nervous or calm?
- Is the average body condition score acceptable for the group? Is there much variation in condition score within a group?
- Are there many lame cows?

Rule of thumb is that, except for cows that are eating, sleeping or drinking, or if they are heat stressed, 4 to 5 of every 10 animals should be chewing their cuds. Cows may ruminate up to 10 hours a day, so don't tell yourself that it's long enough since feeding that they don't have to. If they are not ruminating, look farther for the cause. Cows sorting? Low effective fiber in the ration?

Cows have very few hobbies – checking fences, checking gates, leaning on people who step into their stalls, and sorting their feed. See the first section of this paper for more description on what to do to decrease sorting. If the cows are sorting their feed, the manure will be variable (possibly from stiff to diarrhea) in a group that is supposed to be eating the same ration and you will have no idea of what ration individual animals are actually eating. If cows are sorting, you've just hired every single animal as its own nutritional consultant. Cows are lousy nutritionists. Ruminal acidosis and digestive upset may be the consequence. So you need to find a way to come up with an appropriate ration that the cows can't sort to resolve this problem.

Cattle often eat dirt, or start consuming more salt or buffer when they have some form of digestive upset, or during heat stress.

Calmness, appearance and body condition: These are a matter of considering general animal health and how well the current ration and feeding system are meeting their requirements. Very variable body condition scores in a group raise questions about the management of moving cattle in the herd, or whether all animals are getting enough of the desired, unsorted ration. Could the diet be related to the cows' dull or bright appearance (excesses, deficiencies, or acidosis)? Cows being nervous may relate to ration, but more often it relates to how the employees work with the animals. Calm cows are easier to work with, and I would bet that they make more milk than nervous animals with the same potential. Screaming, yelling, running the animals, and general carrying on and cowboying (worst sense of the term) are counterproductive. Don't tolerate it.

Lameness suggests problems with ruminal acidosis, walking surfaces, or how much time animals spend standing on concrete, especially wet concrete. Find out which is the root of the problem, and see what needs to be done to fix it. Sore-footed cows will not be as likely to walk to feed, mount, etc. That can leave you with animals who prefer to slug feed and lay down, or just eat less. This is a great place to apply the lameness scoring system to get an idea of just where a herd stands, so to speak.

### Manure Evaluation

Manure evaluation is a simple way to find out what a cow is doing with her ration. Changes in manure consistency and particle size can offer information about how well the rumen is working. If the rumen is working properly, there's enough forage/fiber in the ration, and feed/feeding management is good, the manure will be slightly stacked with two to three dimples on top, the fiber particles in the manure will be quite small, and there won't be lots of identifiable, undigested feed to be seen. If the rumen is not working well, such as during ruminal acidosis, the feed may pass undigested to the large intestine where it will ferment leading to foamy manure, diarrhea, mucin casts, and possibly a fair amount of identifiable, undigested feed in the patty. If there is no disease going through the herd at the time, the manure can tell a great deal about the ration.

In the barn or lot:

- ♦ Is the manure foamy with many trapped air bubbles?
- ♦ Is the manure very loose (diarrhea)?
- ♦ Is there much variation in manure consistency within a feeding group?

Foamy or very loose manure usually suggest that the rumen is not working well, such as during ruminal acidosis and more feed is being fermented in the large intestine. The gas produced by the hindgut bacteria is trapped in the manure and makes it foamy; the acid they produce (same acids as bacteria produce in the rumen) may be part of the cause of the diarrhea. Diarrhea can also be cause by cattle eating spoiled or moldy feed. If the manure consistency varies within a group, the cows are probably sorting their feed, and/or only certain animals consumed spoiled material.

- ♦ Are there pieces of "mucous" in the manure?
- ♦ Is whole or ground grain apparent in the manure?

The "mucous" sometimes seen in the manure are actually mucin or fibrin casts. They look a bit like sausage casings, ranging in length from short shreds less than an inch long, to tubes of material several feet long. They are not actually part of the intestine. If the lining of the intestine is damaged, the cow secretes mucin or fibrin over that damage. The mucin or fibrin takes the form of the section of gut it was in, and is eventually shed out into the manure. One reported cause of these casts is increased acidity in the large intestine – excessive fermentation in the large intestine would cause this. Mucin casts are taken as a sign of acidosis in the feedlot industry. These casts can show up in manure of any consistency. When you do a "toe test" and drag the tip of your boot across a cow patty, if something in the pile moves after your foot has moved past, it is likely a mucin cast.

Whole grain (corn, barley, wheat) that has not been properly processed before feeding often shows up in the manure. Unless the outer hull is cut, crushed, or otherwise damaged by processing or rumination, neither bacteria nor enzymes may digest it well. And it will show up in the manure. Back in the early 1900's, they used to have recommendations about how many hogs to stock with cattle if the cattle were fed unground corn…..

If appreciable ground grain is seen in the manure, it may be escaping the rumen too fast. A high producing cow may have a bit more ground grain in her manure because of a higher intake and higher rate of passage, and "a bit" may not be a problem. However, that grain does represent feed that was not digested never had the chance to support milk production. If the source of the undigested ground grain appears to be corn, and corn meal is fed, sieving the corn may give an idea of whether it should be ground finer so that it is better digested. Ground corn that does not pass through a number 4 or number 8 standard sieve represent partial kernels or coarsely ground corn. These are the particles that seem most likely to be visible in the manure. Finding much of them in a sample of ground corn suggests that the corn should be ground more finely.

- Is the manure very dry/stiff?

You expect manure like this in dry cows, not in cattle that are producing well. It may be due to not feeding enough protein, or rumen degradable protein.

### How To: Evaluating Particles In Manure

The particles in feed tell how well things were digested in the rumen and the rest of the gut, but can be difficult to see, unless you rinse them clear of the rest of the manure.

- For each group of cows, take 4 or 5 samples of feces from individual cow pies: try to select for variation in appearance representative of the group. Make sure the samples are not contaminated with feed or bedding. Eight ounce sample cups with lids are very good sample holders.
- Fill the cup completely and cap. Filled cups can be placed in a breeding sleeve to be carried.
- Get a screen or kitchen strainer (do not return it to the kitchen) with 1/16 inch (1.6 mm) openings. This is a qualitative, on farm evaluation, so getting very specific about mesh size is not crucial. A strainer that is 7 inches (17.8 cm) in diameter and 4 inches (10.2 cm) deep works well.
- Transfer a manure sample into the strainer, using a steady stream of water to rinse the cup into the strainer. Rinse the sample gently but thoroughly until the water runs clear. Squeeze the water out of the sample and transfer it back to the sample cup so that all of the samples taken can be compared side by side.

Does fiber in the sample appear to be coarse (more than 0.5 inches long, whole pieces of corn stalk)? Does any cottonseed present still have the lint still on it? Does the feed retain its color (grass that's still green, citrus that's still orange, etc.)? Is there much (relative term) whole grain in the sample? Much ground grain? These things suggest that the rumen isn't working well – feed left before it was well digested. Manure evaluation is qualitative, so you will need to assess whether there appears to be too much or an acceptable amount of coarser fiber or undigested grain in the manure. There is no common, on-farm way to evaluate the proportion of manure your samples represent, so do not try to over-interpret the information they offer.

**My Observation:** Effectiveness of fiber to keep the rumen working well is not only related to particle size, but to a variety of factors that affect rate of digestion. For example, grass neutral detergent fiber (NDF) tends to ferment more slowly than does fiber in legume forages. Additionally, the particles from grass tend to be more needle-shaped, and those from legumes to be more square. In my experience, grass has tended to be a more effective NDF source than legume forages possibly because the fiber is retained in the rumen for a longer period of time. One to 3 inch long pieces of very tender or pliable grasses can sometimes be found in the feces - they seem to be able to bend and escape the rumen. The NDF has to be in the rumen to be effective. A greater amount of NDF from a more rapidly fermented NDF source would have to be fed to provide the same amount of effective NDF as from a more slowly fermenting source. Take as an example that a small amount of chopped straw included in a ration can quickly resolve problems due to effective NDF inadequacy of the ration. Alfalfa can be an excellent feed, but it can be a poor choice as a major source of effective fiber. The need to provide adequate effective NDF to allow for proper rumen function and ration digestion is a balancing act with providing adequate nutrients. Best done with high quality forages and feeds in adequate quantities.

### Feed Evaluation

- Are any of the feeds apparently moldy or spoiled?
- Do the feeds appear to contain any undesirable foreign material?
- Are older shipments of feed being rotated forward when a new shipment is brought in?
- Are feeds being fed in a timely manner so they do not spoil?
- Is the silo managed to keep a clean, undisturbed face?
- Can adequate amounts of silage be fed relative to the width of the silo to keep the face fresh and non-moldy?

These cover points of management needed to avoid feeding toxins, spoiled feed, or unpalatable feed to the cows. Your cows' intake, health, and production can depend upon it.

- Are the correct feeds being mixed in the right amounts and order?
- Are the mixer wagon scales accurate?

These simply verify that the ration on paper is translated into the ration the cows receive. Accurate weights are needed or else you've got no way to know what is being fed, what direction to consider changing the ration, or that the changed ration is actually what is being fed.

- How different is the particle size of silage in the silo from silage in the mixer?

Over-mixing, or adding the silage too early in the mixing sequence can grind the fiber and reduce particle size. Not a good thing if it means that the ground ration does not meet the cows' effective fiber requirements. On the other hand, hay may have to be added earlier in the mixing sequence to chop it finely enough so that the cows do not sort it.

- Are the feeds of adequate quality quantity to meet cow requirements over the course of a lactation/year, or will something run out?

Plan ahead for feed and forage supplies so that the cows can get a properly balance ration year round.

## Pulling it Together

So, what to do with the information from evaluating a herd? Combine all the information on cow health (digestive upset, acidosis, laminitis, etc.), cow performance (milk and milkfat yields), rumination (at least 40% of cows not eating or sleeping should be chewing their cuds), cow observations (sorting the ration or not, comfortable or not), manure evaluation, ration & feed evaluation, etc. The story it tells gives a body of evidence that something within the ration or in cow and feeding management does or does not need to be modified.

## Reference

National Research Council. 2001. Nutrient requirements of dairy cattle, 7th rev. ed. National Academy Press, Washington, DC.

# Marketing Cows for Increased Profitability

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Dairy producers do an excellent job of producing high quality milk. Unfortunately, the same cannot always be said about the dairymen's contribution to the beef supply each year through elimination of market (cull) cows and bulls. Although substantial quantities of quality milk are the primary concern of dairy producers, approximately 33% of beef production in the U.S is from market dairy cows (Smith et al., 1994b). A 2000 study, conducted by the Food Safety and Inspection Service (FSIS) of the United States Department of Agriculture (USDA), reported that dairy cattle represented over 50% of cattle harvested in 43% of the nation's largest slaughter plants (FSIS-USDA, 2000). Sales of market cows from the dairy equals approximately 5%, and can represent as much as 15%, of total income of the dairy (Dairy Beef, 2002).

A popular misconception of producers is that the majority of beef from cows and bulls is used solely for ground beef; therefore, it is thought that proper handling and the timely marketing of dairy cattle is of less concern. Producers should realize that beef cuts from cows and bulls are fabricated and sold to supermarket and food service operators. Furthermore, beef from cows and bulls may be used as entrée items in family steakhouses, on airlines, sliced beef sandwiches in fast-food establishments, and "quick-to-fix" supermarket beef items (for example, fajitas).

Production efficiency must be high for dairy producers to make a profit. Several compounds have been developed in recent years that are capable of increasing milk production, as well as reproductive efficiency. Proper administration of injectable products need not be compromised for the sake of convenience. Producers must remember to administer products subcutaneously, if possible. Conservatively, it is estimated a healthy dairy cow can receive between 25 to 30 injections per lactation (includes bovine somatotropin, reproductive hormones, and vaccination injections). With that number of injections per lactation, there are several possibilities for injection-site lesions, and therefore, lost beef product. Most injections are administered in the proper manner (subcutaneously) and location (neck region). However, the idea that "sometimes it's just easier to administer injections in the round or hip" should be discouraged. Also, it is important to remember that injection-site lesions have been identified at the processing plant 12 to 13 months post-injection.

In the National Cattlemen's Beef Association's Non-Fed Beef Report, Smith et al. (1994a) noted producers were losing $69.90/head from culled cows in 1994, and in 1999, the loss was $68.82/head (Roeber et al., 2001). It was suggested that as much as $27.50/head could be recuperated if cull cows were fed a high-energy diet prior to being shipped for harvesting (Roeber et al., 2001).

## Antibiotic Usage and Residue Violation

Food safety is an important issue for the dairy industry. Antibiotics have significantly improved the health and production efficiency of food-producing animals; however, consumer concern exists in relation to bacterial resistance in humans from products consumed from food-producing animals administered antibiotics. The resistance of bacteria to antibiotics has been shown to alter the dynamics of the flora in the human intestinal tract.

Dairy cows and veal calves are the two classes of cattle with the greatest violation of antibiotic residues according to the USDA National Residue Monitoring program. Colorado State University researchers reported 1.7% of dairy cows violated antibiotic residues in 1990, 2.2 and 1.54% in 1991 and 1993, respectively. Antibiotic residue violations were the primary concern of beef industry representatives surveyed in the 2001 National Market Cow and Bull Quality Audit. In a 1999 FSIS study, dairy cows violated residue regulations twice as often as beef cows when using on-site rapid screening tests (FSIS-USDA, 2000). In similar studies conducted in 2000, dairy cows violated residue limits three times as often when tested using a 7-plate bioassay (FSIS-USDA, 2000).

Occurrence of antibiotic residues is usually due to an inadequate clearance time between administration and slaughter, and extra-label usage of health products. Furthermore, withdrawal time is often not the same for both meat and milk. Extra-labeled product use must be avoided unless a valid veterinarian/client/patient relationship has been established. If your farm experiences an antibiotic residue violation, your veterinarian may be your only friend and ally.

The FSIS oversees the National Residue Program (NRP) to test meat products for residue levels resulting from antibiotic administration. A survey was conducted by the FSIS to determine uniformity of residue testing in 30 slaughter plants. The 30 plants were randomly selected from the 40 highest-volume plants in the United States. In 60% (18/30) of the plants surveyed, cull dairy cows represented 20 to 72% of cattle processed daily (FSIS-USDA, 2000).

The FSIS-NRP survey reports that, at certain slaughter facilities, only “high-residue-risk” condemned cows were tested for residues, while at other locations, no testing was performed on “high-residue-risk” cows. And, in the majority of locations, cows labeled as “downers” were tested for residues. Due to insufficient time and labor, there seems to be a lack of consistency and uniformity in testing at slaughter plants nationwide.

The most common antibiotic residue testing method used in slaughter facilities is Fast Antimicrobial Screen Test (FAST), while the second most utilized method of testing is Swab Test on Premises (STOP). Implementation of FAST started in pilot plants in 1995 and STOP was first introduced in 1979. Considered an appropriate replacement for STOP, which solely detects antibiotic residues in kidney tissues, FAST detects both antibiotic and sulfonamide drug residues in kidney and liver tissues (FSIS-USDA, 1996).

Dairy producers need to implement on-farm residual testing programs (meat and milk) to avoid introducing food borne residues to consumers. However, producers are unlikely to implement Hazard Analysis of Critical Control Points (HACCP) testing programs voluntarily. Approximately only 10% of the dairy producers in the United States have volunteered to implement a 10-point Milk and Dairy Beef Quality Assurance Program to prevent antibiotic residues (Gardner, 1997). Many of the antibiotic residue worries involving the dairy industry could be decreased with proper medical record documentation, increased education, and the adaptation of national standards for milk and dairy beef (Cullor, 1997).

On-farm urine-based antibiotic tests are available to ensure only antibiotic-free animals are sent to slaughter. Important to understand is that no residue test is perfect. Commercial antibiotic tests claiming 100% sensitivity and specificity were likely performed with a limited sample size or without appropriate representation (Gardner, 1997). Furthermore, many evaluations performed in a laboratory setting typically overestimate the sensitivity and specificity of a test as compared to a more realistic field test. A test's qualitative outcome (positive or negative) will depend on the level of substance being tested (Gardner, 1997).

## Management strategies to increase profitability of market cows

University research has indicated additional feeding of market cows can increase body condition score (BCS), carcass value, and carcass characteristics (Jones et al., 1983; Apple et al., 1999). Matulis et al. (1987) reported average daily gain was most efficient in market cows fed corn and corn by-products for 29 to 56 days. Similarly, researchers at Colorado State University (Schnell et al., 1997) found market cows were significantly less efficient during the first 14 days on feed. Averaged daily gains increased linearly from 28 to 56 days in market dairy and beef cows (Schnell et al., 1997). Fat color (white versus yellow fat) whitened within 28 days of feeding (dairy breeds used in this study exhibited the whitest fat over that of the beef breeds). White fat has been associated with increased consumer acceptance and more palatable steaks (Schnell et al., 1997). Market cows with moderate body condition yield higher quality carcasses that can be fabricated into boneless subprimal cuts (Apple et al., 1999). Fat cover also has been reported to decrease bruising associated with transport (Smith et al., 1994b).

Seasonality also is an important aspect of increasing profitability of market cows. Figures from the USDA over the past 10 years suggest that the time at which cows are sold will affect the price dairy producers will receive for their cows. Prices generally are lowest during the months of November and December while the highest prices received are during March, April, and May (Figure 1). The main reason for reduced prices in the fall months are attributed to the sale of culled beef cows after weaning calves. Maintaining and feeding market dairy cows until the spring months should increase profit from the sale of market dairy cows.

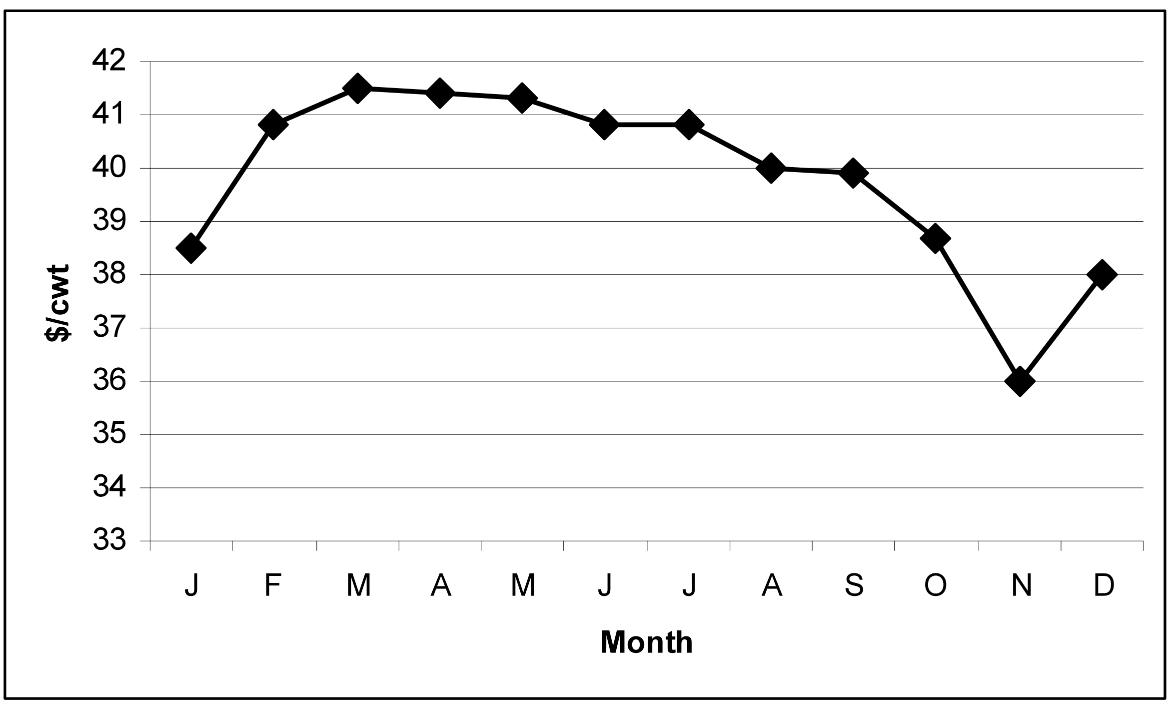


Figure 1. Selling price of market cows during the previous 10 years by month. Source: USDA/AMS, 1991-2001.

## Additional feeding of market cows research

During 2001-2002, we (Rogers et al., 2002) conducted a two-phase study, funded by the National Cattlemen's Beef Association with Beef Check-Off dollars, to identify management strategies to decrease antibiotic residue violations and increase carcass merit in market dairy cows. Specifically, our objectives were to determine the influence of additional feeding (30 or 60 days) of market dairy cows on carcass quality and to determine antibiotic meat withdrawal in dairy cows.

In phase I, 77 non-lactating Holstein market cows that were to be sold for a variety of reasons (milk production, reproduction, disease/disorders) were obtained from four commercial dairies and assigned to a control group (no additional days of feeding) or to one of two feeding treatments (30 or 60 days of additional feeding).

Prior to the experimental feeding period, all cows were weighed, assigned a body condition score (BCS) of 1 to 5, where 1 = thin and 5 = obese (Wildman et al., 1982). Additionally fed cows were administered an oral probiotic gel paste (30 g; RXV-BP-1 Bovine, AGRIpharm®, Grapevine, TX) which contained a bovine specific mixture of bacteria. Furthermore, additionally fed cows were treated intramammary with cephapirin sodium (ToDAY®, Fort Dodge Animal Health, Fort Dodge, IA).

Using commodities commonly found on Southwest dairies, a total mixed ration (TMR) was formulated. The TMR consisted of 60% high-energy concentrate and 40% quality alfalfa hay (Table 1). Cows were fed the TMR twice daily. Bunks were visually evaluated prior to feeding and the amount of feed was adjusted for pen intake. Weigh-backs were recorded on a weekly basis.

Cows used as the control (0 days of additional feed) were transported to Lonestar Packing (San Angelo, TX) from local dairies at the same time as additionally fed cows. Carcass data was collected and included hot carcass weight (HCW), ribeye area (REA), percent kidney, pelvic, heart fat (%KPH), backfat, marbling, and fat coloring. Marbling scores were converted to a scale where 100 = Practically Devoid, and 200 to 900, in increments of 100, represent Traces, Slight, Small, Modest, Moderate, Slightly Abundant, Moderately Abundant, and Abundant, respectively. Yellow fat was scored on a 5-point scale, where 0 = none to 4 = severe.

In phase II, unhealthy (predominately medicated for mastitis) dairy cows (n = 62) were administered penicillin G procaine (Pfi-Pen G; Pfizer Animal Health, New York, NY; 1 mL/100 lbs BW, i.m.; 10 day meat withdrawal) and urine was collected and tested with a β-lactam specific enzyme-linked immunosorbent assay (ELISA; Meatsafe™ Residue Test; SilverLake Research, Monrovia, CA). Urine testing occurred from two days prior to label withdrawal time and continued until clearance of antibiotic residue was evident using the commercial antibiotic test.

**Results for Phase I.** Feed intake did not differ between feeding treatments (average = 39 lb/day per cow). Body condition scores increased in cows fed for 60 days (BCS = 3.2) compared to cows fed for 30 days (BCS = 2.8; Table 2). Average daily gain was greater in cows fed for 30 days (3.1 lb/day) than cows fed for 60 days (2 lb/day). This illustrates the feeding efficiency of cows during the early time of additional feeding (between 30 and 60 days) as shown in previous university research.

Additional feeding did not influence any carcass characteristics studied except percent KPH, which was different among feeding groups (Table 3). Hot carcass weights, marbling scores, ribeye area, and backfat were all similar among treatments. Likewise, fat color did not differ between treatments.

Incidence of condemnation was 8.3, 10, and 0% for control (0 days of additional feeding), 30 and 60 days of additional feeding, respectively. Condemnations resulted from various conditions (for example, lymphoma, septicemia, and pyemia) and were not the result of antibiotic residues. Although not statistically significant, additional feeding decreased the incidence of carcass condemnation.

Table 1. Total mixed ration of 60% grain and 40% forage fed to market dairy cows for 30 or 60 days.

| | |
|---|---|
| Corn, flaked | 38.9% |
| Soybean hulls | 11.9% |
| Soybean meal | 3.5% |
| Molasses | 2.8% |
| Mineral Mix | 1.9% |
| Fat, animal | 1.0% |
| Alfalfa hay | 40% |

Table 2. Body condition score (BCS) and average daily gain (ADG) of market dairy cows fed 0, 30, or 60 days.

| | Treatment | | |
|---|---|---|---|
| Trait | 0 d | 30 d | 60 d |
| Pre-BCS | --- | 2.2 | 2.6 |
| Post-BCS | 2.6 | 2.8 | 3.2 |
| ADG (lb) | -- | 3.1[a] | 2.0[b] |

[a,b] Statistically different ($P < 0.05$).

Table 3. Hot carcass weight (HCW), ribeye area (REA), percent kidney, heart and pelvic fat (% KPH), fat thickness and fat color of carcasses from market dairy cows fed 0, 30, or 60 days.

| | Treatment | | |
|---|---|---|---|
| Trait | 0 d | 30 d | 60 d |
| HCW (lb) | 625 | 603 | 651 |
| REA (in$^2$) | 12.2 | 12.5 | 12.1 |
| % KPH | 1.6[b] | 1.0[b] | 2.1[a] |
| Fat thickness (in) | 0.13 | 0.10 | 0.13 |
| Fat color[c] | 0.52 | 0.19 | 0.39 |

[a,b] Statistically different ($P < 0.05$).
[c]Using a 5-point scale for visual appearance of yellow fat (0 = none to 4 = severe).

**Results from Phase II.** Thirty-one percent of cows (19/62) treated with penicillin G procaine exceeded the 10 day label withdrawal recommendation by an average of 3.1 days (range 1 to 8 days; Figure 2). As with most dairy operations, cows were not weighed prior to medication. Therefore, the actual weight of the cow to determine the precise dosage of penicillin needed was unknown at the time of treatment. Unhealthy cows will likely have reduced feed intake and water. Furthermore, metabolism is probably decreased in unhealthy cows and may partially explain why 31% of cows treated with penicillin G procaine exceeded the label withdrawal period.

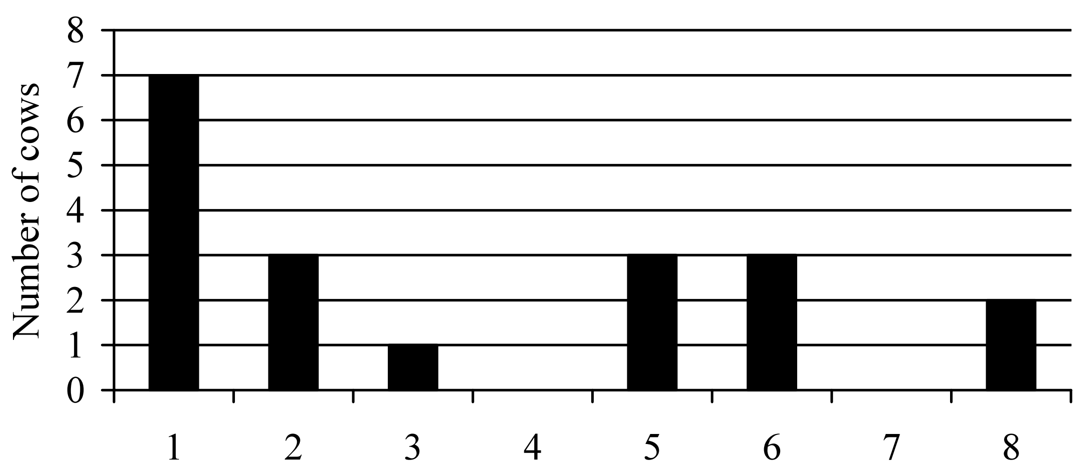


Figure 2. Number of cows exceeding 10-day withdrawal of penicillin G procaine.

Results of our research study suggests feeding market cows can increase body condition (fat cover), average daily gain and decrease condemnation, but may not significantly influence carcass characteristics. Furthermore, antibiotic-treated market cows may exceed recommended meat withdrawal times and cause antibiotic residue violation at processing. Health and the ability to gain weight are extremely variable in market cows; therefore, not all market cows are suitable “candidates” for additional feeding protocols. Dairy producers should evaluate individual market cows and consider management strategies, such as additional feeding, to decrease the incidence of carcass condemnation and antibiotic residues in meat tissues.

## Take Home Messages

- Dairy producers are beef producers.

- Prudent use of antibiotics is of utmost importance.
    - Record keeping of all cows receiving medications.
    - Veterinarian/client/patient relationship is necessary.

- Profit can be increased from the sale of market (cull) dairy cows.
    - Seasonality is important; spring is better.
    - Additional feeding for 30 to 60 days (most efficient) when feed costs are minimized.

- Not all market cows are “candidates” for retaining and additional feeding.
- Health of animal plays a major role.
    - Some cows should be euthanized on-farm.
    - Some cows should be sold locally in a timely manner.
    - Some cows can be fed efficiently for 30 to 60 days.

## Literature Cited

Apple, J.K., J.C. Davis, J. Stephenson, J.E. Hankins, J.R. Davis, and S.L. Beaty. 1999. Influence of body condition score on carcass characteristics and subprimal yield from cull beef cows. J. Anim. Sci. 77:2660-2669.

Cullor, J.S. 1997. HACCP (Hazard Analysis of Critical Control Points): Is it coming to the dairy? J. Dairy Sci. 80:3449-3452.

Dairy Beef: Maximizing Quality and Profits. 2002. Dairy producer? You’re in the beef business too. Available from: URL: http://dairybeef.ucdavis.edu/home.htm

FSIS-USDA. Food Safety and Inspection Service – United States Department of Agriculture. 1996. Domestic Residue Data Book: Explanation of the 1996 FSIS National Residue Program. Available from: URL: http://www.fsis.usda.gov/ophs/redbook1/redbook1.htm

FSIS-USDA. Food Safety and Inspection Service – United States Department of Agriculture. 2000. Report on a survey of the National Residue Program Uniform Application in cull cow plants. Available from: URL: http://www.fsis.usda.gov/oa/topics/cullcow.htm

Gardner, I.A. 1997. Testing to fulfill HACCP (Hazard Analysis of Critical Control Points) requirements: Principles and examples. J. Dairy Sci. 80:3453-3457.

Jones, S.D.M. 1983. Tissue growth in young and mature cull Holstein cows fed a high energy diet. J. Anim. Sci. 56:64-70.

Matulis, R.J., F.K. McKeith, D.B. Faulkner, L.L. Berger, and P. George. 1987. Growth and carcass characteristics of cull cows after different times-on-feed. J. Anim. Sci. 65:669-674.

Roeber, D.L., P.D. Mies, C.D. Smith, K.E. Belk, T.G. Field, J.D. Tatum, J.A. Scanga, and G.C. Smith. 2001. National market cow and bull beef quality audit – 1999: A survey of producer-related defects in market cows and bulls. J. Anim. Sci. 79:658-665.

Rogers, C.A., A.C. Fitzgerald, M.A. Carr, B.R. Covey, J.D. Thomas, and M.L. Looper. 2002. Strategies to reduce antibiotic residues in market dairy cows. Proc. Western Sec. Am. Soc. Anim. Sci. 53:49-52.

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. J. Anim. Sci. 75:1195-1202.

Smith, G.C., J.B. Morgan, J.D. Tatum, C.C. Kukay, M.T. Smith, T.D. Schnell, and G.G. Hilton. 1994a. Improving the consistency and competitiveness of non-fed beef, and improving the salvage value of cull cow and bulls. Final Report of the National Non-Fed Beef Quality Audit. National Cattlemen's Beef Association, Englewood, CO.

Smith, G.C., J.B. Morgan, J.D. Tatum, C.C. Kukay, M.T. Smith, T.D. Schnell, and G.G. Hilton. 1994b. Opportunities for enhancing value and improving the quality of beef. Final Report of the National Non-Fed Beef Quality Audit – Special Section: Dairy Cattle. National Cattlemen's Beef Association, Englewood, CO.

Wildman, E.E., G.M. Jones, P.E. Wagner, and R.L. Boman. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. J. Dairy Sci. 65:495
501.

# Keeping Calves Healthy

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*What defines a successful calf enterprise?* Calves are alive. Calves are healthy. Calves are growing well.

*What does it take to achieve these three goals?* Calf care tasks must be done properly all the time and on time.

This afternoon our goal is to review these calf care tasks. I have chosen to start with newborn care. We will follow these calves through weaning. Intensive calf feeding programs are not included because Dr. Van Amburgh has dealt with that topic.

Most of the following text is organized either as outlines or as checklists. These may be duplicated and used on the farm as a way to evaluate current rearing practices. Our on-farm goal is to determine if tasks are being done properly all the time and if tasks are being performed in a timely fashion.

## Newborn Calf Care

**Goals**

1. Help the calf to adapt to her new environment.
2. Help the calf maintain good health.

**Living Outside the Dam**

*Help get a dry hair coat*. The dam will usually lick off the calf. We can finish the job with a couple of bath towels. Our goal is a fluffy hair coat that helps the calf adapt from 102° F. inside the dam to outdoor temperature. In freezing weather, a draft-free warm place will help finish the manual-drying job. Examples would be a hutch with a heat lamp, a warming box with a heater.

*Help the calf stand up*. If she is not up in the range of 15 to 30 minutes, provide assistance. By just helping her stand up we have jump-started her metabolism about four times the resting rate.

*Help her get a good first meal soon after birth.* She needs lots of energy to adapt to this world outside her dam. Colostrum contains twice as much dry matter as whole milk. It is high in both fat and protein to meet the calf's immediate needs after birth.

**Keeping Healthy**

*Help her keep away from adult cow manure.* As little as one teaspoonful of manure in her gut prior to colostrum feeding can be fatal.

*Help her keep pathogens out of her umbilical cord.* Dip the navel with 7 percent tincture of iodine. Navel dipping (a) cleans off the outside of the umbilical cord, (b) kills residual bacteria on the outside of the cord as well as inside the open end, and (c) dries the umbilical cord tissue discouraging pathogen movement up the cord and into the liver.

*Help her build adequate immunity through transfer of her dam's colostral antibodies into her blood.* Feed an adequate amount of good quality colostrum as soon as possible after birth. If the calf is unable to nurse use an esophageal tube feeder. If good quality colostrum is unavailable add an effective colostrum supplement. There is no substitute for early feeding.

**Feeding Preweaned Calves: Colostrum**

How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential?

Let's consider procedures for feeding colostrum. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. All feeding equipment that comes in contact with colostrum is scrubbed after every use.

_____ 2. When periodically cultured for bacteria, colostrum as fed to calves is not contaminated with environmental bacteria thus reducing septicemia and scours. Badly contaminated colostrum may also substantially reduce the rate of antibody transfer as well.

_____ 3. Colostrum contaminated with mastitis and blood is discarded.

_____ 4. Colostrum quality (antibody concentration) is estimated and the best quality available fed to heifer calves. While only a very rough guide to quality, a Colostrometer® may be used to exclude the lowest quality colostrum. Feeding more of poor quality colostrum is not an effective substitute for a good quality product.

_____ 5. Colostrum is fed to heifer calves no more than four hours after birth and to at least one-half of the heifer calves within one hour after birth. One-half of a heifer's ability to absorb antibodies is gone within six hours; three-quarters of this capability is gone within twelve hours after birth.

_____ 6. Plenty of good quality colostrum is fed. Average and large calves are fed four quarts within the first six hours. Smaller calves are fed proportionately less but still more than two quarts.

_____ 7. When only low quality colostrum (low antibody concentration) is available, an effective colostrum supplement is added to boost its antibody content.

_____ 8. When possible, fresh or refrigerated colostrum is fed rather than frozen colostrum. Thus, the calf gets a full dose of maternal immune cells as well as the maternal antibodies.

**Feeding Preweaned Calves: Milk Replacer**

How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential?

Let's consider procedures for feeding milk replacer. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. All feeding equipment that comes in contact with milk is scrubbed after every use.

_____ 2. Equipment sanitation procedures meet these standards: (a) prewash rinse between 105-110°; (b) chlorinated hot water wash consistently over 120° and includes manual brushing; (c) acid rinse between 50-100°; and (d) equipment dries between uses.

_____ 3. Milk replacer is stored so that it remains both clean and dry to promote good mixing and reduce scours.

_____ 4. Milk replacer is mixed at the temperature recommended by the manufacturer to promote even distribution of fat and reduce denaturing of proteins.

_____ 5. Milk replacer is 100-105° when drunk by the calves to promote favorable feed conversion.

_____ 6. Milk replacer is fed regularly at the same time daily according to the same routine preferably by the same caretakers to promote good eating habits and favorable feed conversion.

_____ 7. When periodically cultured for bacteria, milk replacer mix as fed to calves is not contaminated by environmental bacteria thus reducing scours.

_____ 8. For farms feeding waste milk, when periodically cultured for bacteria, the waste milk as fed to calves is not contaminated by environmental bacteria thus reducing scours and improving feeding conversion rates.

**Feeding Preweaned Calves: Water**
How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential? Growing requires lots of water.

Let's consider procedures for water. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. During the entire preweaning period calves have free-choice access to water.

_____ 2. Good quality water is provided that is free of urine and feces.

_____ 3. Good quality water is provided that has low concentrations of pathogens, noxious minerals, chemicals, and inert and organic contaminants.

_____ 4. Access to water is not restricted due to stuck valves, freezing weather, water too high to reach, or excessive contamination.

**Feeding Preweaned Calves: Starter Grain**
How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential? Growing requires lots of protein and energy found in grain. Rumen development depends on starches found in grains, too.

Let's consider procedures for starter grain. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. During the entire preweaning period calves have free-choice access to starter grain.

_____ 2. Good quality starter grain is provided that is free of mold, urine and feces.

_____ 3. Good quality starter grain is provided that is clean and dry.

_____ 4. Prior to calves regularly eating at least a cupful of starter grain daily, the starter grain is replaced daily.

_____ 5. Good quality starter grain is provided that is palatable. Less than 5 percent will pass through a 0.8mm screen – about the size of window screening. At least 80 percent of the grain pellets are still whole after a day in a grain bucket.

_____ 6. Access to starter grain is not restricted due to lack of palatability, contamination, being frozen or the grain bucket being too high to reach.

**Washing Milk Containers Checklist**

1. Are the containers rinsed before going into the wash water?

Organic compounds destroy the bacteria-killing power of chlorine in the wash water. Dirt and milk are organic compounds. Most of them will rinse off easily before washing.

High temperatures change milk proteins. It makes them stick to surfaces. We don't want milk protein to stick to milk containers. Thus, we try to rinse the protein off the containers before we wash them in hot water.

Always use lukewarm water. **DO NOT rinse with hot water.**

2. Are the containers washed in hot soapy water with a germicide? Are they brushed vigorously?

Milk fats, proteins and sugars are sources of food for bacteria. We brush container surfaces vigorously to loosen these solids. These milk solids are suspended in the wash water.

If wash water temperatures fall below 120 (49 C) the suspended solids will stick to container surfaces. Do not put containers into wash water below 120 that contains suspended milk solids. The containers will come out dirtier than when they went into the water.

3. Are the containers rinsed in an acid solution after washing?

Even with the best rinsing and washing small amounts of milk solids remain on containers. Small numbers of bacteria remain there, too. An acid rinse lowers the surface pH. Most bacteria grow very poorly in very acid conditions.

Pipeline acid at the rate of about 1 ounce per 5 gallons (30 ml per 19 liters) of lukewarm water will lower container surface pH adequately. Manual wash acid/sanitizers dilute at about the same rate. They are preferred for this step. They keep the pH lower longer than milk line acid.

4. Are the containers allowed to completely dry between uses?

Bacteria require moisture in order to grow. If we dry our containers between uses the rate of bacterial regrowth slows down.

Avoid stacking pails inside each other until completely dry. Never sit freshly washed pails upside down on a concrete floor. That creates a bacterial incubator (warm, damp, and dark).

Let's consider procedures for sanitizing feeding equipment. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____1. I rinse my milk containers in lukewarm water before washing them.

_____2. I wash my milk containers in water above120° F (49 C).

_____3. I use soap and chlorine in my wash water.

_____4. I rinse my milk containers in an acid solution after washing.

_____5. I allow my milk containers to completely dry between uses.

### Calf Weaning Checklist

*How long has she been eating starter grain?*

*Has she been eating starter grain for at least 3 weeks?* Start counting days on grain when she regularly cleans up a measurable amount daily. That's roughly ½ cup.

Assuming she has access to water, after a calf begins to eat grain she takes about three weeks of fermentation in her rumen to develop papillae. They are tiny finger-like growths on the inside of the rumen wall. They are essential for absorbing nutrients from rumen fermentation.

*How much starter grain is she eating?* Is she eating 1 ½ to 2 quarts (that's about the same as pounds) daily? If a 150-pound calf eats this much starter grain daily she can meet her maintenance needs and grow 1 pound a day in 50° weather. Bigger calves need more for maintenance. Higher growth goals require more. Colder weather conditions require more. How regularly is she eating grain?

*Is she eating at least a minimum of 2 quarts daily*? That is different that an average of 2 quarts varying from less than a quart one day to more than 3 quarts two days later. One characteristic of rumen maturity is regular feed intake. Irregular intake is associated with acidotic rumen conditions and undesirable digestion. Calves with greater rumen maturity tend to even out their grain intake (assuming they have free-choice access to starter grain and water).

*Is the calf generally healthy and growing?* No matter how it is done weaning is stressful for a calf. Even if calves continue to grow at weaning, the rate of growth falls off for about 5 to 7 days after weaning. If a calf's immune system is in any way depressed (scours, respiratory illness, navel infection, dehorning, change in housing, exceptionally hot or cold weather, poor bedding), it's good management to delay weaning until conditions change.

Let's consider procedures for weaning calves. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____1. Nearly all my calves have been eating grain for at least three weeks before I <u>begin</u> weaning them.

_____2. Nearly all my calves are eating 2 quarts of starter grain a day before I wean them.

_____3. Nearly all my calves are eating enough starter grain every day before I wean them.

_____4. If a calf is stressed (depressed immune system) I wait until she has recovered before I wean her.

## Weaning Calves: Four Management Strategies

**Least management intensive**

Feed a uniform amount of milk or milk replacer to all calves (usually two quarts twice a day). Delay weaning until calves are about ten to twelve weeks of age. Abruptly stop feeding milk to all calves. Usually all of the calves are eating at least two quarts of starter grain daily; many calves are eating much more grain than this. Calves are often moved to group housing the same time they are weaned. Usually about three calves out of ten will require medical treatment for weaning stress-induced pneumonia.

**A little more management intensive**

Feed a uniform amount of milk or milk replacer to all calves (usually two quarts twice a day). Wean calves around eight to nine weeks of age. At eight weeks start observing grain consumption abruptly stop feeding milk to all calves that are regularly eating starter grain. Continue milk feeding if a calf is eating less than two quarts of grain daily. Usually less than one calf out of ten will require additional time prior to weaning. Calves are often kept in the individual housing for a few days after weaning. Only about two calves out of ten will require medical treatment for weaning stress-induced pneumonia.

**Much more management intensive**

Feed a uniform amount of milk or milk replacer to all calves (usually two quarts twice a day). Wean calves around seven to eight weeks of age. At six weeks start observing grain consumption. Either gradually or abruptly stop feeding milk to all calves that are regularly eating at least two quarts of grain daily for three or four days in a row. Continue milk feeding until a calf is regularly eating this much grain. Usually less than one calf out of eight will require additional time prior to weaning. Hold calves in individual housing for five to seven days after weaning. Only about one calf out of ten will require medical treatment for weaning stress-induced pneumonia.

**Most management intensive**

Feed milk or milk replacer in proportion to the size of the calf (usually starts at two quarts twice a day at birth and increases to about four quarts twice a day by four weeks of age). The success of increased milk feeding rates is tied to strictly following proper sanitation procedures. Feeding larger amounts of milk or milk replacer contaminated with bacteria always makes calves sick.

No set age for weaning. At two weeks start observing grain consumption (both how long the calf has been eating grain and how much consumed daily). When grain consumption has been regular for two weeks (usually during fourth week) reduce milk feeding to one-half. Most calf operations save the most labor by dropping one milk feeding. Stop feeding milk completely when a calf is regularly eating two or more quarts of starter grain daily for three or four days in a row. Calves should be expected to vary widely at this point. Some are ready to wean at thirty-five days while others are not ready until forty-nine days. Hold calves in individual housing for five to seven days after weaning. Only about one calf out of twenty will require medical treatment for weaning stress-induced pneumonia.

**Transition Calf Feeding Management Checklist**

1. Does the transition calf ration contain at least 18 percent crude protein?

The growing calf needs lots of good quality protein for muscle and immune system development. Usually the rate of post-weaning feed intake can be encouraged by continuing the same grain mix as was fed in the pre-weaning housing. These calves will need 7 to 10 pounds of grain mix daily to have enough protein for maintenance and growth in excess of 1.5 pounds a day.

2. Does the transition calf ration contain mostly grain and limited amounts of roughage for the first week after weaning?

Most just weaned calves have been living on grain and water (and in some cases, a limited amount of milk). Before they can digest and use the nutrients in roughages like a mature ruminant they need to grow a large number of fiber digesting microbes in their rumens. This growth period is about 10 to 14 days. During this time they continue to live on protein and energy from grain. By eating a limited amount of roughage in addition to grain they encourage the multiplication of ruminal fiber digesting microbes.

3. Does the transition calf ration have enough energy per pound for both maintenance and to meet the farm's growth goals?

The relative size of a transition calf's rumen to her body size is still small compared to an adult cow. By feeding an energy dense ration to these small growing heifers we compensate for this relatively small rumen. That's why grazing heifers consuming high protein grass do so much better when the grass is supplemented by a high energy grain mix. That's why confined transition heifers consuming free choice high protein hay do so much better when supplemented by a high energy grain mix.

4. Does the feeding program focus on feeding the rumen microbes rather than the heifer?

As transition heifers grow older changes in their ration are almost the rule rather than the exception. Often these changes involve introducing a new roughage source. For example, changing from dry hay to haylage or changing from haylage to a mix of corn silage and haylage or changing from grazing grass to stored feeds in the fall. The microbial mix that most efficiently digests each of these roughages varies from one to another. It makes sense to introduce small amounts of roughage that is going to be in the next ration a week or two before transition age heifers have to depend heavily on the new roughage as their sole source of nutrition.

Let's consider procedures for feeding transition calves. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____1. The transition calf ration contains 18 percent crude protein.

_____2. Transition calves are fed free choice starter grain for the first week after moving into group housing.

_____3. Transition calves are fed free choice grain and limited hay the first two weeks after moving into group housing.

_____4. Transition calves are fed a ration with an energy density of at least 3.0 Mcal of ME per Kg of DM until they are about four months old.

_____5. Changes in roughages are preceded by feeding limited amounts of the new roughage for a week or two prior to the overall change.

See the National Research Council publication, Nutrient Requirement of Dairy Cattle. 2001. Chapter 10 "Nutrient Requirements of the Young Calf" Table 10 "Daily Energy and Protein Requirements of Weaned (Ruminant) Calves" for additional details.

# A Systematic Approach to Calf and Heifer Rearing: "Intensified" Feeding and the Target Growth System

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Growth is an essential component of the dairy enterprise, yet many of us that work in the dairy industry have had little training or background in applied aspects of animal growth. We are more comfortable with concepts involving milk yield and composition primarily because that is where we generate income. However, to improve calf and heifer management, we must understand basic concepts of applied growth so that better recommendations can be developed.

For several years our laboratory has been investigating nutritional and management practices of calves and heifers in an effort to reduce the age at first calving. Interest in this area stems from several factors, primary of which is the economic investment required for the heifer replacement program by the dairy industry which is equivalent to 15 to 20% of the cost to produce milk. Our research group made several observations that precipitated a series of ongoing experiments that will be discussed in this paper.

Those observations were:

1) Studies that have investigated pre-pubertal "accelerated growth" in an effort to lower age at first calving never started treatments earlier than 3 months of age and most were well into the ruminant phase of growth and as late as 8 months of age. Thus, from a systematic perspective we might have lost a significant amount of time and opportunity with regard to lowering the AFC. If we are being systematic, why not start at birth? Further, early postnatal growth is the most efficient time to deposit protein and develop skeletal growth and attain the highest feed efficiencies. What do we do as an industry to capitalize on this capacity for lean growth?

2) Recent evaluations of nutrient requirements for Holstein heifers suggested that the system of equations we use to calculate requirements does not adequately represent the composition of gain and thus the energy and protein requirements for growth during the pre-pubertal phase of life. Further, this inability to meet the "true" requirements might have confounded our expectations and interpretation of accelerated growth studies. Most of the equations we use to derive nutrient requirements for Holstein heifers were derived from Angus and Hereford steers slaughtered in excess of 500 lb bodyweight. Thus little direct data exists for the weight range or cattle type we work with.

3) On farm management of calf rearing typically follows nutrition programs developed for early weaning and thus controlled restricted liquid feeding levels in an effort to encourage dry feed intake. Considering this practice, in light of the 1996 National Animal Health Monitoring Service data indicating that neonatal calf mortality was greater than 10%, we were led to think about calf management from a different perspective. The shift in perspective involved the following questions: 1) do standard calf nutrition programs contribute to the observed morbidity and mortality and 2) is the practice of restricting liquid feed intake the most biologically sound approach to achieving calf growth and health. If milk or milk replacer intake is limited, are there enough nutrients in early life that will allow the calf to develop an adequate immune response?

4) Finally, we know of no other neonatal system that is successful at enhancing future productivity by restricting milk intake in an effort to force weaning, humans included. Compared to every other neonatal management system, dairy calves are the only animals that we purposely restrict milk or milk replacer intake from day of birth (10% body weight intake – fixed over the feeding period). Beef calves, lambs, piglets, dogs, cats, horses and humans, all suckle on demand at least for the first four to six weeks of life. Is there a benefit to increased nutrient intake during the first few weeks of life for normal development and immune system responsiveness?

From the perspective of a nutritionist, one of the most over-looked groups of animals on the dairy farm has been the milk-fed and transitional calf. There are several reasons for the lack of a mechanistic approach to "ration formulation" for the young calf, primary of which has been the unavailability of tools for calculating nutrient requirements and supply. With the release of the 2001 National Research Council Nutrient Requirements of Dairy Cattle, a more useful approach to feeding calves has been developed. The new Dairy NRC (National Research Council, 2001) employs a more mechanistic approach to calf growth and development than previously utilized in the United States, and with adoption of the system the industry will be encouraged to re-evaluate the one-size fits all approach to calf feeding that currently exists.

The objectives of this paper will be 1) to review current feeding recommendations published by manufacturers of milk replacers and evaluated by the new 2001 Dairy NRC and 2) to describe new data that helps us refine our predictions of nutrient requirements for milk fed and transitioning calves, and, 3) to discuss data that suggests increased nutrient intake during early life enhances calf development and milk yield in at least the first lactation.

Milk replacer formulation and feeding guidelines have been developing on a widespread, commercial basis since the 1950s. Roy (1964) examined the origins of commercial milk replacer and clarified the context in which developments like fat concentration, ingredient choices, and feeding practices were made. It is clear from the review of Davis and Drackley (1998) that considerable research has been completed over the last 50 years to elucidate the specific nutrient requirements of the young calf, as well as the potential benefits (or risks) of various feeding practices. It is therefore logical to assume that the advances in this nutrition technology would be subsequently reflected in the feeding instructions used to tag calf milk replacer products developed for and by the dairy industry.

However, the results of this investigation of milk replacer products currently on the market illustrate that technological advances of the last 50 years are not well represented by current industry recommendations. Field observations, as well as the market research results of large milk replacer manufacturers, indicate that calf raisers are unaware of the disconnect in the research and development of a system because while adhering to the old paradigms of minimized liquid feed intake they continue to complain about animal performance, including growth and health.

Likewise, dairy calf raisers should be encouraged to adapt their feeding practices to allow for significant changes in management so that implementation of a more systematic approach may yield economically beneficial results. An assessment of economic feasibility should be based not only on the investment in heifer rearing, but also on the return on that investment. It has been recognized that replacement heifer management decisions interact with the biological aspects of growth, thereby influencing the future profitability of the heifer (Mourits, 2000; Quigley et al., 1996). It is intuitive that the biologically correct growth system is the best method for the rearing of an animal of any species. If "biologically correct" does not equate to "economically optimal", then we would argue that there is a bottleneck in the management system.

## Evaluation of Current Feeding Approaches

The following examples are used to demonstrate labeled feeding rates for a group of randomly selected commercially available milk replacers. For this exercise we fed an example calf with the 2001 Dairy NRC Model (National Research Council, 2001) according the feeding instructions provided by the milk replacer manufacturer on the product tag. For this exercise calves were characterized in the following way:

1) Twelve to fourteen days of age - It is reasonable to believe that by this stage of development a calf is more than capable of the dry matter intake specified by label recommendations, but she is not likely be consuming a quantity of starter grain sufficient to contribute to an appreciable amount of metabolizable energy.

2) One hundred pounds body weight - Average Holstein calf birth weights are between 86 and 95 lb (Diaz et al., 2001, Tikofsky et al., 2001), and calves generally do not gain a significant amount of weight in the first two weeks of life due to a variety of challenges including health, environmental change, and feeding management.

All of the milk replacers were made from all milk protein sources. The 2001 Dairy NRC uses metabolizable energy (ME) and apparently digestible protein (ADP) as the respective energy and protein "currencies" which is a welcome departure from previous approaches.

Based on the energy and protein allowable gains presented in Table 1, the goal as described by the feeding instructions of these samples of standard milk replacers (A, B, C, and D) is some production level between a near-maintenance gain of 0.22 lb/d and 0.88 lb/d assuming a thermo-neutral environment. These expected gains are consistent with research observations (Diaz et al., 2001, Bartlett, 2001). Evaluations of milk replacers E and F demonstrate energy and protein allowable gains between 1.65 and 2.00 lb/d, and an acceptable balance between the energy and protein allowable gain, unlike the previous milk replacers.

Table 1. Energy (ME) allowable gain (lb/d) and apparently digestible protein (ADP) allowable gain (lb/d) of example calf fed variety of milk replacer formulations according to labeled instructions as evaluated by the 2001 Nutrient Requirements of Dairy Cattle (National Research Council, 2001).

| Milk replacer | Formulation[a] (CP%:fat%) | Gross energy (Mcal/lb)[b] | DMI (lb/day) | Dilution (%) | Energy allowable gain (lb/d) | Protein allowable gain (lb/d) |
|---|---|---|---|---|---|---|
| A | 22 : 12 | 2.14 | 0.93 | 10.4 | 0.22 | 0.55 |
| B | 22 : 20 | 2.34 | 1.00 | 10.4 | 0.48 | 0.62 |
| C | 18 : 21 | 2.33 | 1.25 | 11.6 | 0.88 | 0.64 |
| D | 20 : 20 | 2.32 | 1.25 | 11.6 | 0.79 | 0.73 |
| E | 28 : 20 | 2.31 | 1.98 | 15.3 | 1.65 | 1.86 |
| F | 28 : 15 | 2.27 | 2.25 | 17.4 | 2.00 | 2.20 |

[a]All milk replacers manufactured with all milk protein sources. The fat source was mostly lard or choice white grease.

[b]Calculated value, assuming gross energy values (kcal/g) for lactose, protein, and fat common to milk replacers are 3.95, 5.86 and 9.21, respectively (Davis and Drackley, 1998). Assuming ash content of all milk replacer is 7% and lactose is calculated by difference (100 – ash – fat – protein).

From a systematic perspective, setting manageable targets for both weaning weight and feed efficiency would indicate that milk replacers E and F are more appropriately labeled and formulated for meeting those goals.

The feeding examples described in Table 1 were according to the labeled feeding rates on the product tag. Many question whether feeding more of a 20% CP, 20% fat milk replacer would allow calves to achieve the same performance as calves fed a higher protein milk replacer. Comparisons of "off-label" feeding rates are found in Table 3.

The requirement for protein is energy driven, subsequently any increase in energy intake will increase the demand for protein and a given product might not provide the best balance of nutrients. This is illuminated in Table 2 by the data summarized by Davis and Drackley (1998) and described by Drackley (2000). The data summarized by Drackley (2000) demonstrate that the protein requirement is a function of the energy allowable gain. As the energy intake increases the protein required to meet the energy allowable gain increases, thus there is no single protein value that meets the nutrient requirement of the calf.

From the data found in Table 3, it is apparent that traditional milk replacer formulations were designed to be fed at close to labeled rates. Exceeding that level of intake in all cases except for milk replacers E and F demonstrates a deficiency in protein allowable gain, which will lead to an accumulation of fat and a reduction in protein deposition and feed efficiency (Bartlett, 2001, Diaz et al., 2001). All of the slaughter work conducted in the last few years (Bartlett, 2001, Diaz, et al., 2001, Tikofsky et al., 2001) supports the predictions of the 2001 NRC calf model.

Table 2. Effect of rate of body weight gain with constant initial body weight (100 lb) on protein requirements of pre-weaned dairy calves (adapted from Davis and Drackley, 1998) (From Drackley, 2000).

| Rate of gain (lb/d) | ME, (Mcal/d) | ADP (g/d) | Required DMI[1], (lb/d) | CP required, (% of DM) |
|---|---|---|---|---|
| 0 | 1.75 | 28 | 0.84 | 8.3 |
| 0.50 | 2.30 | 82 | 1.11 | 18.1 |
| 1.00 | 3.01 | 136 | 1.45 | 22.9 |
| 1.50 | 3.80 | 189 | 1.83 | 25.3 |
| 2.00 | 4.64 | 243 | 2.24 | 26.6 |
| 2.50 | 5.53 | 297 | 2.67 | 27.2 |
| 3.00 | 6.46 | 350 | 3.12 | 27.6 |

[1]Amount of milk replacer DM containing 2075 kcal ME/lb DM need to meet ME requirements.

Table 3. Nutrient balance as calculated by the 2001 Nutrient Requirements of Dairy Cattle (National Research Council, 2001) based on off-label increased feeding rates of milk replacers.

| Milk replacer | Formulation[a] (CP%:fat%) | Gross energy (Mcal/lb) | DMI (kg/day) | Dilution (%) | Energy allowable gain (lb/d) | Protein allowable gain (lb/d) |
|---|---|---|---|---|---|---|
| A | 22 : 12 | 2.14 | 2.20 | 10.4 | 1.85 | 1.63 |
| B | 22 : 20 | 2.34 | 2.20 | 10.4 | 2.07 | 1.63 |
| C | 18 : 21 | 2.33 | 2.20 | 11.6 | 2.05 | 1.28 |
| D | 20 : 20 | 2.32 | 2.20 | 11.6 | 2.07 | 1.45 |
| E | 28 : 20 | 2.31 | 3.30 | 15.3 | 3.30 | 3.35 |
| F | 28 : 15 | 2.27 | 3.30 | 17.4 | 3.15 | 3.35 |

[a]Same milk replacers as in Table 1.

All of the examples in Tables 1 and 2 assume thermo-neutral conditions. Due to their body weight to surface area ratio, calves become cold stressed at moderate temperatures. Again the 2001 Dairy NRC calf model was employed to evaluate feeding recommendations. The model has an environmental component that allows the user to evaluate the affect of temperature on maintenance requirements. Two milk replacers were used, a 20:20 CP:fat and a 28:20 CP:fat inputted at labeled feeding rates and temperatures were decreased from 68°F to 50°F and to 32°F for a 100 lb calf (Table 4).

Table 4. Effect of cold stress on predicted calf growth using the 2001 Dairy NRC calf model (National Research Council, 2001). A 100 lb calf was used as the model calf.

| Temperature, degrees F | Milk replacer formulation and intake, lb/d | Energy allowable gain, lb/d | Protein allowable gain, lb/d |
|---|---|---|---|
| | 20:20 | | |
| 68 | 1.0 | 0.46 | 0.53 |
| 50 | 1.0 | 0.05 | 0.53 |
| 32 | 1.0 | 0.00 | 0.53 |
| | 28:20 | | |
| 68 | 2.0 | 1.96 | 1.96 |
| 50 | 2.0 | 1.67 | 1.96 |
| 32 | 2.0 | 1.41 | 1.96 |

From this exercise it becomes apparent that a calf will be cold stressed at a relatively moderate temperature of 50°F (Table 4). Most 100 lb calves have not begun to develop a rumen and dry matter intakes aside from milk replacer or milk, are usually very limited. The calf fed a traditional amount of the 20:20 CP:fat milk replacer will be very close to negative energy balance at 50°F and will definitely be mobilizing adipose tissue at 32°F. When a calf reaches this point, immune status can be easily compromised and the calf becomes susceptible to factors other than cold. The empty body fat content of 100 lb calves is 3.5 to 4%, (3.5 to 4 lb) of which approximately half can be mobilized to support heat production. The calf fed the 28:20 CP:fat milk replacer will receive enough nutrients to maintain adequate growth through the cold stress conditions and we could expect more immune competence from this calf, assuming an adequate dry cow vaccination and colostrum program was in place. Some milk replacer feeding instructions suggest feeding a supplemental fat during periods of cold stress. Most of those products are 7% CP and 60% fat. Adding 0.25 lb/d of a 7:60 fat source to supplement the intake of the calf fed 1.0 lb of the 20:20 CP:fat milk replacer at a temperature of 32°F increases the energy allowable gain to 0.22 lb/d, just slightly above maintenance. Feeding more of an appropriately balanced diet to meet the requirements for both energy and protein allowable gain would appear to be the most systematic solution to this cold-stress challenge. Incidentally, it is during periods of cold stress that many producers will indicate they notice greater acceptability and intake of starter grain compared to warmer periods – this is most likely in response to a tremendous need for energy to maintain body temperature and survival.

## Current Research and Application

Recently, several studies have been conducted to determine the effect of nutrition on body composition changes in milk fed calves (Bartlett, 2001, Blome, 2001, Diaz et al. 2001, Tikofsky et al., 2001). From this work we determined that under normal feeding conditions, maximum protein deposition in the calf would be achieved at a protein content of approximately 28% (Bartlett, 2001; Diaz et al., 2001). This data is consistent with the predictions of the Dairy NRC 2001, although some refinements can be made. In addition, the level of fat in milk replacer was investigated (Bartlett, 2001; Tikofsky et al., 2001) and from the analyses of body composition data and the calf performance data, fat levels of 15% to 20% appeared adequate for normal growth and development in Holstein milk fed calves. Work currently underway at Virginia Tech with Jersey calves suggests higher fat levels might be required (Scott Bascom, personal communication).

A consistent question surrounding this research and that potential application of this research is what is the long-term impact of increased feeding rates of milk fed calves? Several studies exist in the literature, which serve to address that question. Brown et al., 2002 conducted a study to determine if feeding increased amounts of milk replacer decreased mammary development in milk fed calves. The study was conducted in two phases, two to eight weeks and then eight to fourteen weeks. Calves were assigned to a either a high or low rate of gain prior to weaning and then maintained on that level or switched an alternate rate of gain post-weaning (Table 5). The heifer calves were then slaughtered and mammary development determined. During pre-weaning, the high calves were fed a 28.5% CP, 15% fat milk replacer whereas the low calves were fed a 20%CP, 20% fat milk replacer. Mammary parenchyma growth was enhanced by 32% during the high milk feeding phase and mammary DNA and RNA was enhanced by 47% during the high milk feeding phase. This increase in mammary development was not observed once the calves were weaned, indicating the calf is more sensitive to level of nutrition prior to weaning and that the enhancement mammary development cannot be "recovered" once we wean the animal.

Table 5. Effect of two levels of nutrient intake from 2 to 8 weeks and 9 to 14 wks of age on mammary development in Holstein heifer calves. Data indicates that mammary development was enhanced by liquid feed intake prior to weaning, but the effect was not observed once weaning occurred. (Brown et al., 2002)

| | Low-Low | Low-High | High-Low | High-High |
|---|---|---|---|---|
| Daily gain 2 to 8 wk, lb/d | 0.84 | 0.84 | 1.47 | 1.47 |
| Daily gain 9 to 14 wk, lb/d | 0.97 | 2.41 | 0.97 | 2.41 |
| Final bodyweight, lb | 176 | 234 | 192 | 267 |
| Total mammary wt., g/100 kg bodyweight | 253 | 391 | 266 | 512 |
| Parenchymal wt., g/100 kg bodyweight | 16 | 15 | 22 | 23 |
| Parenchymal DNA, mg/100kg bodyweight | 45 | 42 | 79 | 86 |
| Parenchymal RNA, mg/100kg BW | 140 | 132 | 194 | 219 |

Sejrsen et al., (2000) also reported data supporting this observation and that once the calves were weaned mammary development was decreased by increased nutrient intake. Further, there are three studies that have investigated either the effect of suckling versus controlled intakes or ad-libitum feeding of calves from birth to 42 or 56 days of life (Bar-Peled et al, 1997; Foldager and Krohn, 1994; Foldager et al, 1997). In each of these studies, increased nutrient intake prior to 56 days of life resulted in increased milk yield during the first lactation that ranged from 1,000 to 3,000 additional pounds compared to more restricted fed calves during the same period. This data further suggests there is factors not well defined that allow the calf to be more productive throughout her life. Similar responses have been observed in baby pigs that indicate enhanced early nutrition has long-term positive effects on health and productivity. Research is underway in our laboratory to further define these factors.

**Cornell Lactation Data.** The following data was generated from the Cornell University Dairy Herd. In 1997 all of our herd heifers were moved to an "intensified" feeding management system. The following study data is controlled, therefore it allows us to make a comparison within herd of the first lactation milk yield compared to the mature cattle in the herd that were never on an intensified system of rearing. The study described here was a pre-pubertal fatty acid feeding study and all heifers were fed the intensified system (Smith and Van Amburgh, 2002). Heifers were assigned in a restricted randomization to accommodate pen-feeding conditions at the Cornell Teaching and Research Center Dairy Unit. Calves were fed a 30% CP, 20% fat milk replacer at 2% BW DM intake and were provided a starter grain that was 25.7% CP (DM basis) and contained 1.18 Mcals NEm and 0.47 Mcals NEg per lb. Calves were weaned by eight weeks and were then group fed one of four diets: Control – no fatty acid supplementation; Sunflower oil – sunflower oil added to equal the fat level of the CLA diet; Ener GII – Ener GII added to equal the fat level of the CLA diet; and a calcium salt of conjugated linoleic acid (CLA) – mixed isomers. Heifers were fed treatment diets until they were 630 lb on average and averaged 182 days on treatment. Diets were balanced to be similar in metabolizable energy (ME) and protein (MP) allowable gain (~ 1.0 kg/d ME and MP allowable gain) using the CNCPS (Fox et al., 2000) and the gains were designed to allow for 22 mo age at first calving. Heifers entered the breeding window when they weighed approximately 750 lb BW. The target breeding system described by Fox et al., (1999) and the 2001 Dairy NRC (National Research Council, 2001) was utilized. Based on an average mature weight of 1,476 lb, heifers were targeted to be pregnant by approximately 812 lb (55% of mature weight) independent of age and to weigh 1,210 lb (82% of mature weight) post-calving at first calving. A common post-treatment diet was fed to all heifers after they were removed from treatment and was designed to achieve the target post-calving body weight. During lactation, the heifers were fed a common diet, housed as a group, milked three times per day and given bST per label. Breeding was based on a voluntary weight period of approximately 45 days.

There was no significant difference in 3.5% fat corrected milk among the fatty acid treatments (Table 6); therefore, the heifers were re-stratified independent of the original treatments. The heifers were stratified by age at first calving independent of the original study. Heifers were categorized by those calving less than 21 mo, 22-23 mo. and 24 mo and greater (Table 7). Although there were no heifers fed less to serve as controls for rate of gain effects on lactation performance, the production of the heifers in the first lactation compared with the mature cattle production levels is above average. First lactation heifers should produce at 80% or better of the lactation milk yield of the mature cattle in the herd (82 to 85% is excellent). The third lactation cattle at the Cornell Dairy Unit are currently producing ~ 28,522 lb milk per lactation. Thus, the first lactation heifers are producing at 88% of the mature cattle in the herd. The heifers that calved in early (20 mo) are most likely the smaller mature size cattle within the herd and achieved puberty at an earlier age, whereas the larger mature size cattle (24 mo) achieved puberty at a slightly heavier weight, which lead to a greater AFC. Note, however, there is no difference in milk yield among heifers calving at an average age of 20 mo, compared with the older animals.

This data demonstrates that a systematic approach to calf and heifer management from birth coupled with an appropriate rearing strategy and adherence to a target growth approach will allow heifers to achieve lower ages at first calving without a milk loss or at least reduce the variation in milk yield associated with age at calving. Whether this increase in performance relative to the mature cattle in the herd is due to the more intensive calf rearing system is unknown, and a study to determine this directly is underway.

Table 6. Management and production characteristics of Holstein heifers fed a control diet or diets supplemented with either sunflower oil, a commercially available calcium salt of primarily palm oil (Ener GII), or a calcium salt of conjugated linoleic acid during the prepubertal period. Data are preliminary and are presented as least square means.

| | Control | Sunflower oil | Ener GII | Ca CLA | Std. Dev. |
|---|---|---|---|---|---|
| N | 16 | 16 | 17 | 16 | |
| Pre-pubertal daily gain, lb | 1.90 | 1.92 | 1.96 | 1.87 | 0.15 |
| Age first calving, mo | 21.8 | 21.6 | 22.3 | 22.3 | 1.5 |
| Days in milk | 299 | 294 | 294 | 290 | 10 |
| Body weight at calving, lb | 1,228 | 1,199 | 1,240 | 1,267 | 75 |
| Milk yield, 3.5% FCM, lb | 25,057 | 24,599 | 25,538 | 25,344 | 2,451 |

Table 7. A post-hoc analysis of the management and production characteristics of Holstein heifers ranked by age at first calving, independent of dietary treatment.
Data are preliminary and are presented as least square means.

| Age first calving rank, mo | <21 | 21 - 23 | >23 | Std. Dev. | P |
|---|---|---|---|---|---|
| N | 19 | 27 | 19 | | |
| Pre-pubertal daily gain, lb | 2.16$^{a}$ | 2.03 | 1.96$^{b}$ | 0.2 | 0.05 |
| Age first calving, mo | 20.2$^{a}$ | 21.8 | 24.2$^{b}$ | 0.6 | 0.001 |
| Days in milk | 298 | 299 | 285 | 14.0 | 0.7 |
| Post -calving weight, lb | 1,177$^{a}$ | 1,218 | 1,314$^{b}$ | 42.0 | 0.001 |
| Milk yield , 3.5% FCM, lb | 24,817 | 25,485 | 24,976 | 2,405 | 0.6 |

$^{abc}$Values with superscripts within row differ P < 0.05.

## References

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

Bartlett, K. S. 2001. Interactions of protein and energy supply from milk replacers on growth and body composition of dairy calves. M. S. Thesis. University of Illinois, Urbana-Champaign.

Blome, R. 2002. Growth, nutrient utilization, and body composition of dairy calves fed milk replacers containing different amounts of protein. M. S. Thesis. Univ. of Illinois, Urbana-Champaign.

Brown, E. G., M. J. Vandehaar, K. M. Daniels, J. S. Liesman, L. T. Chapin and M. S. Weber Nielsen. 2002. Increasing energy and protein intake of Holstein heifer calves increases mammary development. J. Dairy Sci. 85:80 (Abstr.)

Davis, C. L. and J. K. Drackley, 1998. The Development, Nutrition, and Management of the Young Calf. Iowa State University Press, Ames, IA.

Diaz, M. C., M. E. Van Amburgh, J. M. Smith, J. M. Kelsey and E. L. Hutten. 2001. Composition of growth of Holstein calves fed milk replacer from birth to 105 kilogram body weight. J. Dairy Sci. 84:830-842.

Drackley, J. K. 2000. Calf nutrition related to heifer growth and longevity. Pp. 153-168. Proc. Minnesota Nutrition Conference. Department of Animal Science, University of Minnesota.

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

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

Fox, D. G., T. P. Tylutki, M. E. Van Amburgh, L. E. Chase, A.N. Pell, T. R. Overton, L.O. Tedeschi, C. N. Rassmussen and V. J. Durbal. 2000 The Cornell University Nutrient Management Planning System: The Net Carbohydrate and Protein System for evaluating herd nutrition and nutrient excretion. CNCPS version 4.0. Animal Science Department Mimeo 213.

Fox, D.G., M. E. Van Amburgh, and T. P. Tylutki. 1999. Predicting requirements for growth, maturity and body reserves in dairy cattle. J. Dairy Sci. 82:1968-1977.

Mourits, M. C. M. 2000. Economic Modelling to Optimize Dairy Heifer Management Decisions. Ph.D. Thesis, Wageningen University.

National Research Council. 1989. Nutrient Requirements of Dairy Cattle. Sixth rev. Ed., Natl. Acad. Sci., Washington, D. C.

National Research Council. 1996. Nutrient Requirements of Beef Cattle., Seventh rev. Ed., Natl. Acad. Sci., Washington, D. C.

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

Quigley III, J. D., C. S. T. Nyabadza, G. Benedictus, and A. Brand. 1996. Monitoring replacement rearing: objectives and materials and methods. In: Herd Health and Production Management in Dairy Practice A. Brand, J. P. T. M. Noordhuizen, and Y.H.Schukken, eds. Wageningen Press, Wageningen.pp. 75-102.

Roy, J. B. H. 1964. The nutrition of intensively-reared calves. Vet. Rec. 76:511-526.

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

Smith, J.M. and M. E. Van Amburgh. 2002. Effect of feeding conjugated linoleic acid and other fatty acids during the prepubertal period on the composition of growth and lactation yield of Holstein heifers. Proc. Cornell Nutr. Conference. Pp. 159 – 173. East Syracuse, NY.

Tikofsky, J. N., M. E. Van Amburgh and D. A. Ross. 2001. Effect of varying carbohydrate and fat levels on body composition of milk replacer-fed calves. J. Animal Sci. 79:2260-2267.

# Keeping Calves Healthy

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*What defines a successful calf enterprise?* Calves are alive. Calves are healthy. Calves are growing well.

*What does it take to achieve these three goals?* Calf care tasks must be done properly all the time and on time.

This afternoon our goal is to review these calf care tasks. I have chosen to start with newborn care. We will follow these calves through weaning. Intensive calf feeding programs are not included because Dr. Van Amburgh has dealt with that topic.

Most of the following text is organized either as outlines or as checklists. These may be duplicated and used on the farm as a way to evaluate current rearing practices. Our on-farm goal is to determine if tasks are being done properly all the time and if tasks are being performed in a timely fashion.

## Newborn Calf Care

### Goals

1. Help the calf to adapt to her new environment.
2. Help the calf maintain good health.

### Living Outside the Dam

*Help get a dry hair coat*. The dam will usually lick off the calf. We can finish the job with a couple of bath towels. Our goal is a fluffy hair coat that helps the calf adapt from 102° F. inside the dam to outdoor temperature. In freezing weather, a draft-free warm place will help finish the manual-drying job. Examples would be a hutch with a heat lamp, a warming box with a heater.

*Help the calf stand up*. If she is not up in the range of 15 to 30 minutes, provide assistance. By just helping her stand up we have jump-started her metabolism about four times the resting rate.

*Help her get a good first meal soon after birth.* She needs lots of energy to adapt to this world outside her dam. Colostrum contains twice as much dry matter as whole milk. It is high in both fat and protein to meet the calf's immediate needs after birth.

### Keeping Healthy

*Help her keep away from adult cow manure.* As little as one teaspoonful of manure in her gut prior to colostrum feeding can be fatal.

*Help her keep pathogens out of her umbilical cord.* Dip the navel with 7 percent tincture of iodine. Navel dipping (a) cleans off the outside of the umbilical cord, (b) kills residual bacteria on the outside of the cord as well as inside the open end, and (c) dries the umbilical cord tissue discouraging pathogen movement up the cord and into the liver.

*Help her build adequate immunity through transfer of her dam's colostral antibodies into her blood.* Feed an adequate amount of good quality colostrum as soon as possible after birth. If the calf is unable to nurse use an esophageal tube feeder. If good quality colostrum is unavailable add an effective colostrum supplement. There is no substitute for early feeding.

**Feeding Preweaned Calves: Colostrum**
How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential?

Let's consider procedures for feeding colostrum. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. All feeding equipment that comes in contact with colostrum is scrubbed after every use.

_____ 2. When periodically cultured for bacteria, colostrum as fed to calves is not contaminated with environmental bacteria thus reducing septicemia and scours. Badly contaminated colostrum may also substantially reduce the rate of antibody transfer as well.

_____ 3. Colostrum contaminated with mastitis and blood is discarded.

_____ 4. Colostrum quality (antibody concentration) is estimated and the best quality available fed to heifer calves. While only a very rough guide to quality, a Colostrometer® may be used to exclude the lowest quality colostrum. Feeding more of poor quality colostrum is not an effective substitute for a good quality product.

_____ 5. Colostrum is fed to heifer calves no more than four hours after birth and to at least one-half of the heifer calves within one hour after birth. One-half of a heifer's ability to absorb antibodies is gone within six hours; three-quarters of this capability is gone within twelve hours after birth.

_____ 6. Plenty of good quality colostrum is fed. Average and large calves are fed four quarts within the first six hours. Smaller calves are fed proportionately less but still more than two quarts.

_____ 7. When only low quality colostrum (low antibody concentration) is available, an effective colostrum supplement is added to boost its antibody content.

_____ 8. When possible, fresh or refrigerated colostrum is fed rather than frozen colostrum. Thus, the calf gets a full dose of maternal immune cells as well as the maternal antibodies.

**Feeding Preweaned Calves: Milk Replacer**
How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential?

Let's consider procedures for feeding milk replacer. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. All feeding equipment that comes in contact with milk is scrubbed after every use.

_____ 2. Equipment sanitation procedures meet these standards: (a) prewash rinse between 105-110°; (b) chlorinated hot water wash consistently over 120° and includes manual brushing; (c) acid rinse between 50-100°; and (d) equipment dries between uses.

_____ 3. Milk replacer is stored so that it remains both clean and dry to promote good mixing and reduce scours.

_____ 4. Milk replacer is mixed at the temperature recommended by the manufacturer to promote even distribution of fat and reduce denaturing of proteins.

_____ 5. Milk replacer is 100-105° when drunk by the calves to promote favorable feed conversion.

_____ 6. Milk replacer is fed regularly at the same time daily according to the same routine preferably by the same caretakers to promote good eating habits and favorable feed conversion.

_____ 7. When periodically cultured for bacteria, milk replacer mix as fed to calves is not contaminated by environmental bacteria thus reducing scours.

_____ 8. For farms feeding waste milk, when periodically cultured for bacteria, the waste milk as fed to calves is not contaminated by environmental bacteria thus reducing scours and improving feeding conversion rates.

**Feeding Preweaned Calves: Water**
How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential? Growing requires lots of water.

Let's consider procedures for water. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. During the entire preweaning period calves have free-choice access to water.

_____ 2. Good quality water is provided that is free of urine and feces.

_____ 3. Good quality water is provided that has low concentrations of pathogens, noxious minerals, chemicals, and inert and organic contaminants.

_____ 4. Access to water is not restricted due to stuck valves, freezing weather, water too high to reach, or excessive contamination.

**Feeding Preweaned Calves: Starter Grain**
How do your procedures measure up? Do they provide the opportunity for your calves to grow into their genetic potential? Growing requires lots of protein and energy found in grain. Rumen development depends on starches found in grains, too.

Let's consider procedures for starter grain. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____ 1. During the entire preweaning period calves have free-choice access to starter grain.

_____ 2. Good quality starter grain is provided that is free of mold, urine and feces.

_____ 3. Good quality starter grain is provided that is clean and dry.

_____ 4. Prior to calves regularly eating at least a cupful of starter grain daily, the starter grain is replaced daily.

_____ 5. Good quality starter grain is provided that is palatable. Less than 5 percent will pass through a 0.8mm screen – about the size of window screening. At least 80 percent of the grain pellets are still whole after a day in a grain bucket.

_____ 6. Access to starter grain is not restricted due to lack of palatability, contamination, being frozen or the grain bucket being too high to reach.

**Washing Milk Containers Checklist**

1. Are the containers rinsed before going into the wash water?

Organic compounds destroy the bacteria-killing power of chlorine in the wash water. Dirt and milk are organic compounds. Most of them will rinse off easily before washing.

High temperatures change milk proteins. It makes them stick to surfaces. We don't want milk protein to stick to milk containers. Thus, we try to rinse the protein off the containers before we wash them in hot water.

Always use lukewarm water. **DO NOT rinse with hot water.**

2. Are the containers washed in hot soapy water with a germicide? Are they brushed vigorously?

Milk fats, proteins and sugars are sources of food for bacteria. We brush container surfaces vigorously to loosen these solids. These milk solids are suspended in the wash water.

If wash water temperatures fall below 120 (49 C) the suspended solids will stick to container surfaces. Do not put containers into wash water below 120 that contains suspended milk solids. The containers will come out dirtier than when they went into the water.

3. Are the containers rinsed in an acid solution after washing?

Even with the best rinsing and washing small amounts of milk solids remain on containers. Small numbers of bacteria remain there, too. An acid rinse lowers the surface pH. Most bacteria grow very poorly in very acid conditions.

Pipeline acid at the rate of about 1 ounce per 5 gallons (30 ml per 19 liters) of lukewarm water will lower container surface pH adequately. Manual wash acid/sanitizers dilute at about the same rate. They are preferred for this step. They keep the pH lower longer than milk line acid.

4. Are the containers allowed to completely dry between uses?

Bacteria require moisture in order to grow. If we dry our containers between uses the rate of bacterial regrowth slows down.

Avoid stacking pails inside each other until completely dry. Never sit freshly washed pails upside down on a concrete floor. That creates a bacterial incubator (warm, damp, and dark).

Let's consider procedures for sanitizing feeding equipment. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____1. I rinse my milk containers in lukewarm water before washing them.

_____2. I wash my milk containers in water above120° F (49 C).

_____3. I use soap and chlorine in my wash water.

_____4. I rinse my milk containers in an acid solution after washing.

_____5. I allow my milk containers to completely dry between uses.

**Calf Weaning Checklist**

*How long has she been eating starter grain?*

*Has she been eating starter grain for at least 3 weeks?* Start counting days on grain when she regularly cleans up a measurable amount daily. That's roughly ½ cup.

Assuming she has access to water, after a calf begins to eat grain she takes about three weeks of fermentation in her rumen to develop papillae. They are tiny finger-like growths on the inside of the rumen wall. They are essential for absorbing nutrients from rumen fermentation.

*How much starter grain is she eating?* Is she eating 1 ½ to 2 quarts (that's about the same as pounds) daily? If a 150-pound calf eats this much starter grain daily she can meet her maintenance needs and grow 1 pound a day in 50° weather. Bigger calves need more for maintenance. Higher growth goals require more. Colder weather conditions require more. How regularly is she eating grain?

*Is she eating at least a minimum of 2 quarts daily*? That is different that an average of 2 quarts varying from less than a quart one day to more than 3 quarts two days later. One characteristic of rumen maturity is regular feed intake. Irregular intake is associated with acidotic rumen conditions and undesirable digestion. Calves with greater rumen maturity tend to even out their grain intake (assuming they have free-choice access to starter grain and water).

*Is the calf generally healthy and growing?* No matter how it is done weaning is stressful for a calf. Even if calves continue to grow at weaning, the rate of growth falls off for about 5 to 7 days after weaning. If a calf's immune system is in any way depressed (scours, respiratory illness, navel infection, dehorning, change in housing, exceptionally hot or cold weather, poor bedding), it's good management to delay weaning until conditions change.

Let's consider procedures for weaning calves. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____1. Nearly all my calves have been eating grain for at least three weeks before I <u>begin</u> weaning them.

_____2. Nearly all my calves are eating 2 quarts of starter grain a day before I wean them.

_____3. Nearly all my calves are eating enough starter grain every day before I wean them.

_____4. If a calf is stressed (depressed immune system) I wait until she has recovered before I wean her.

## Weaning Calves: Four Management Strategies

### Least management intensive

Feed a uniform amount of milk or milk replacer to all calves (usually two quarts twice a day). Delay weaning until calves are about ten to twelve weeks of age. Abruptly stop feeding milk to all calves. Usually all of the calves are eating at least two quarts of starter grain daily; many calves are eating much more grain than this. Calves are often moved to group housing the same time they are weaned. Usually about three calves out of ten will require medical treatment for weaning stress-induced pneumonia.

### A little more management intensive

Feed a uniform amount of milk or milk replacer to all calves (usually two quarts twice a day). Wean calves around eight to nine weeks of age. At eight weeks start observing grain consumption abruptly stop feeding milk to all calves that are regularly eating starter grain. Continue milk feeding if a calf is eating less than two quarts of grain daily. Usually less than one calf out of ten will require additional time prior to weaning. Calves are often kept in the individual housing for a few days after weaning. Only about two calves out of ten will require medical treatment for weaning stress-induced pneumonia.

### Much more management intensive

Feed a uniform amount of milk or milk replacer to all calves (usually two quarts twice a day). Wean calves around seven to eight weeks of age. At six weeks start observing grain consumption. Either gradually or abruptly stop feeding milk to all calves that are regularly eating at least two quarts of grain daily for three or four days in a row. Continue milk feeding until a calf is regularly eating this much grain. Usually less than one calf out of eight will require additional time prior to weaning. Hold calves in individual housing for five to seven days after weaning. Only about one calf out of ten will require medical treatment for weaning stress-induced pneumonia.

### Most management intensive

Feed milk or milk replacer in proportion to the size of the calf (usually starts at two quarts twice a day at birth and increases to about four quarts twice a day by four weeks of age). The success of increased milk feeding rates is tied to strictly following proper sanitation procedures. Feeding larger amounts of milk or milk replacer contaminated with bacteria always makes calves sick.

No set age for weaning. At two weeks start observing grain consumption (both how long the calf has been eating grain and how much consumed daily). When grain consumption has been regular for two weeks (usually during fourth week) reduce milk feeding to one-half. Most calf operations save the most labor by dropping one milk feeding. Stop feeding milk completely when a calf is regularly eating two or more quarts of starter grain daily for three or four days in a row. Calves should be expected to vary widely at this point. Some are ready to wean at thirty-five days while others are not ready until forty-nine days. Hold calves in individual housing for five to seven days after weaning. Only about one calf out of twenty will require medical treatment for weaning stress-induced pneumonia.

**Transition Calf Feeding Management Checklist**

1. Does the transition calf ration contain at least 18 percent crude protein?

The growing calf needs lots of good quality protein for muscle and immune system development. Usually the rate of post-weaning feed intake can be encouraged by continuing the same grain mix as was fed in the pre-weaning housing. These calves will need 7 to 10 pounds of grain mix daily to have enough protein for maintenance and growth in excess of 1.5 pounds a day.

2. Does the transition calf ration contain mostly grain and limited amounts of roughage for the first week after weaning?

Most just weaned calves have been living on grain and water (and in some cases, a limited amount of milk). Before they can digest and use the nutrients in roughages like a mature ruminant they need to grow a large number of fiber digesting microbes in their rumens. This growth period is about 10 to 14 days. During this time they continue to live on protein and energy from grain. By eating a limited amount of roughage in addition to grain they encourage the multiplication of ruminal fiber digesting microbes.

3. Does the transition calf ration have enough energy per pound for both maintenance and to meet the farm's growth goals?

The relative size of a transition calf's rumen to her body size is still small compared to an adult cow. By feeding an energy dense ration to these small growing heifers we compensate for this relatively small rumen. That's why grazing heifers consuming high protein grass do so much better when the grass is supplemented by a high energy grain mix. That's why confined transition heifers consuming free choice high protein hay do so much better when supplemented by a high energy grain mix.

4. Does the feeding program focus on feeding the rumen microbes rather than the heifer?

As transition heifers grow older changes in their ration are almost the rule rather than the exception. Often these changes involve introducing a new roughage source. For example, changing from dry hay to haylage or changing from haylage to a mix of corn silage and haylage or changing from grazing grass to stored feeds in the fall. The microbial mix that most efficiently digests each of these roughages varies from one to another. It makes sense to introduce small amounts of roughage that is going to be in the next ration a week or two before transition age heifers have to depend heavily on the new roughage as their sole source of nutrition.

Let's consider procedures for feeding transition calves. Compare your routines with the standards that follow. Rather than just answering "yes" or no you may wish to use these scores: 1=never, 2=seldom, 3=often, 4=usually, and 5=almost always.

_____1. The transition calf ration contains 18 percent crude protein.

_____2. Transition calves are fed free choice starter grain for the first week after moving into group housing.

_____3. Transition calves are fed free choice grain and limited hay the first two weeks after moving into group housing.

_____4. Transition calves are fed a ration with an energy density of at least 3.0 Mcal of ME per Kg of DM until they are about four months old.

_____5. Changes in roughages are preceded by feeding limited amounts of the new roughage for a week or two prior to the overall change.

See the National Research Council publication, Nutrient Requirement of Dairy Cattle. 2001. Chapter 10 "Nutrient Requirements of the Young Calf" Table 10 "Daily Energy and Protein Requirements of Weaned (Ruminant) Calves" for additional details.

# Marketing Cows for Increased Profitability

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Dairy producers do an excellent job of producing high quality milk. Unfortunately, the same cannot always be said about the dairymen's contribution to the beef supply each year through elimination of market (cull) cows and bulls. Although substantial quantities of quality milk are the primary concern of dairy producers, approximately 33% of beef production in the U.S is from market dairy cows (Smith et al., 1994b). A 2000 study, conducted by the Food Safety and Inspection Service (FSIS) of the United States Department of Agriculture (USDA), reported that dairy cattle represented over 50% of cattle harvested in 43% of the nation's largest slaughter plants (FSIS-USDA, 2000). Sales of market cows from the dairy equals approximately 5%, and can represent as much as 15%, of total income of the dairy (Dairy Beef, 2002).

A popular misconception of producers is that the majority of beef from cows and bulls is used solely for ground beef; therefore, it is thought that proper handling and the timely marketing of dairy cattle is of less concern. Producers should realize that beef cuts from cows and bulls are fabricated and sold to supermarket and food service operators. Furthermore, beef from cows and bulls may be used as entrée items in family steakhouses, on airlines, sliced beef sandwiches in fast-food establishments, and "quick-to-fix" supermarket beef items (for example, fajitas).

Production efficiency must be high for dairy producers to make a profit. Several compounds have been developed in recent years that are capable of increasing milk production, as well as reproductive efficiency. Proper administration of injectable products need not be compromised for the sake of convenience. Producers must remember to administer products subcutaneously, if possible. Conservatively, it is estimated a healthy dairy cow can receive between 25 to 30 injections per lactation (includes bovine somatotropin, reproductive hormones, and vaccination injections). With that number of injections per lactation, there are several possibilities for injection-site lesions, and therefore, lost beef product. Most injections are administered in the proper manner (subcutaneously) and location (neck region). However, the idea that "sometimes it's just easier to administer injections in the round or hip" should be discouraged. Also, it is important to remember that injection-site lesions have been identified at the processing plant 12 to 13 months post-injection.

In the National Cattlemen's Beef Association's Non-Fed Beef Report, Smith et al. (1994a) noted producers were losing \$69.90/head from culled cows in 1994, and in 1999, the loss was \$68.82/head (Roeber et al., 2001). It was suggested that as much as \$27.50/head could be recuperated if cull cows were fed a high-energy diet prior to being shipped for harvesting (Roeber et al., 2001).

## Antibiotic Usage and Residue Violation

Food safety is an important issue for the dairy industry. Antibiotics have significantly improved the health and production efficiency of food-producing animals; however, consumer concern exists in relation to bacterial resistance in humans from products consumed from food-producing animals administered antibiotics. The resistance of bacteria to antibiotics has been shown to alter the dynamics of the flora in the human intestinal tract.

Dairy cows and veal calves are the two classes of cattle with the greatest violation of antibiotic residues according to the USDA National Residue Monitoring program. Colorado State University researchers reported 1.7% of dairy cows violated antibiotic residues in 1990, 2.2 and 1.54% in 1991 and 1993, respectively. Antibiotic residue violations were the primary concern of beef industry representatives surveyed in the 2001 National Market Cow and Bull Quality Audit. In a 1999 FSIS study, dairy cows violated residue regulations twice as often as beef cows when using on-site rapid screening tests (FSIS-USDA, 2000). In similar studies conducted in 2000, dairy cows violated residue limits three times as often when tested using a 7-plate bioassay (FSIS-USDA, 2000).

Occurrence of antibiotic residues is usually due to an inadequate clearance time between administration and slaughter, and extra-label usage of health products. Furthermore, withdrawal time is often not the same for both meat and milk. Extra-labeled product use must be avoided unless a valid veterinarian/client/patient relationship has been established. If your farm experiences an antibiotic residue violation, your veterinarian may be your only friend and ally.

The FSIS oversees the National Residue Program (NRP) to test meat products for residue levels resulting from antibiotic administration. A survey was conducted by the FSIS to determine uniformity of residue testing in 30 slaughter plants. The 30 plants were randomly selected from the 40 highest-volume plants in the United States. In 60% (18/30) of the plants surveyed, cull dairy cows represented 20 to 72% of cattle processed daily (FSIS-USDA, 2000).

The FSIS-NRP survey reports that, at certain slaughter facilities, only "high-residue-risk" condemned cows were tested for residues, while at other locations, no testing was performed on "high-residue-risk" cows. And, in the majority of locations, cows labeled as "downers" were tested for residues. Due to insufficient time and labor, there seems to be a lack of consistency and uniformity in testing at slaughter plants nationwide.

The most common antibiotic residue testing method used in slaughter facilities is Fast Antimicrobial Screen Test (FAST), while the second most utilized method of testing is Swab Test on Premises (STOP). Implementation of FAST started in pilot plants in 1995 and STOP was first introduced in 1979. Considered an appropriate replacement for STOP, which solely detects antibiotic residues in kidney tissues, FAST detects both antibiotic and sulfonamide drug residues in kidney and liver tissues (FSIS-USDA, 1996).

Dairy producers need to implement on-farm residual testing programs (meat and milk) to avoid introducing food borne residues to consumers. However, producers are unlikely to implement Hazard Analysis of Critical Control Points (HACCP) testing programs voluntarily. Approximately only 10% of the dairy producers in the United States have volunteered to implement a 10-point Milk and Dairy Beef Quality Assurance Program to prevent antibiotic residues (Gardner, 1997). Many of the antibiotic residue worries involving the dairy industry could be decreased with proper medical record documentation, increased education, and the adaptation of national standards for milk and dairy beef (Cullor, 1997).

On-farm urine-based antibiotic tests are available to ensure only antibiotic-free animals are sent to slaughter. Important to understand is that no residue test is perfect. Commercial antibiotic tests claiming 100% sensitivity and specificity were likely performed with a limited sample size or without appropriate representation (Gardner, 1997). Furthermore, many evaluations performed in a laboratory setting typically overestimate the sensitivity and specificity of a test as compared to a more realistic field test. A test's qualitative outcome (positive or negative) will depend on the level of substance being tested (Gardner, 1997).

## Management strategies to increase profitability of market cows

University research has indicated additional feeding of market cows can increase body condition score (BCS), carcass value, and carcass characteristics (Jones et al., 1983; Apple et al., 1999). Matulis et al. (1987) reported average daily gain was most efficient in market cows fed corn and corn by-products for 29 to 56 days. Similarly, researchers at Colorado State University (Schnell et al., 1997) found market cows were significantly less efficient during the first 14 days on feed. Averaged daily gains increased linearly from 28 to 56 days in market dairy and beef cows (Schnell et al., 1997). Fat color (white versus yellow fat) whitened within 28 days of feeding (dairy breeds used in this study exhibited the whitest fat over that of the beef breeds). White fat has been associated with increased consumer acceptance and more palatable steaks (Schnell et al., 1997). Market cows with moderate body condition yield higher quality carcasses that can be fabricated into boneless subprimal cuts (Apple et al., 1999). Fat cover also has been reported to decrease bruising associated with transport (Smith et al., 1994b).

Seasonality also is an important aspect of increasing profitability of market cows. Figures from the USDA over the past 10 years suggest that the time at which cows are sold will affect the price dairy producers will receive for their cows. Prices generally are lowest during the months of November and December while the highest prices received are during March, April, and May (Figure 1). The main reason for reduced prices in the fall months are attributed to the sale of culled beef cows after weaning calves. Maintaining and feeding market dairy cows until the spring months should increase profit from the sale of market dairy cows.

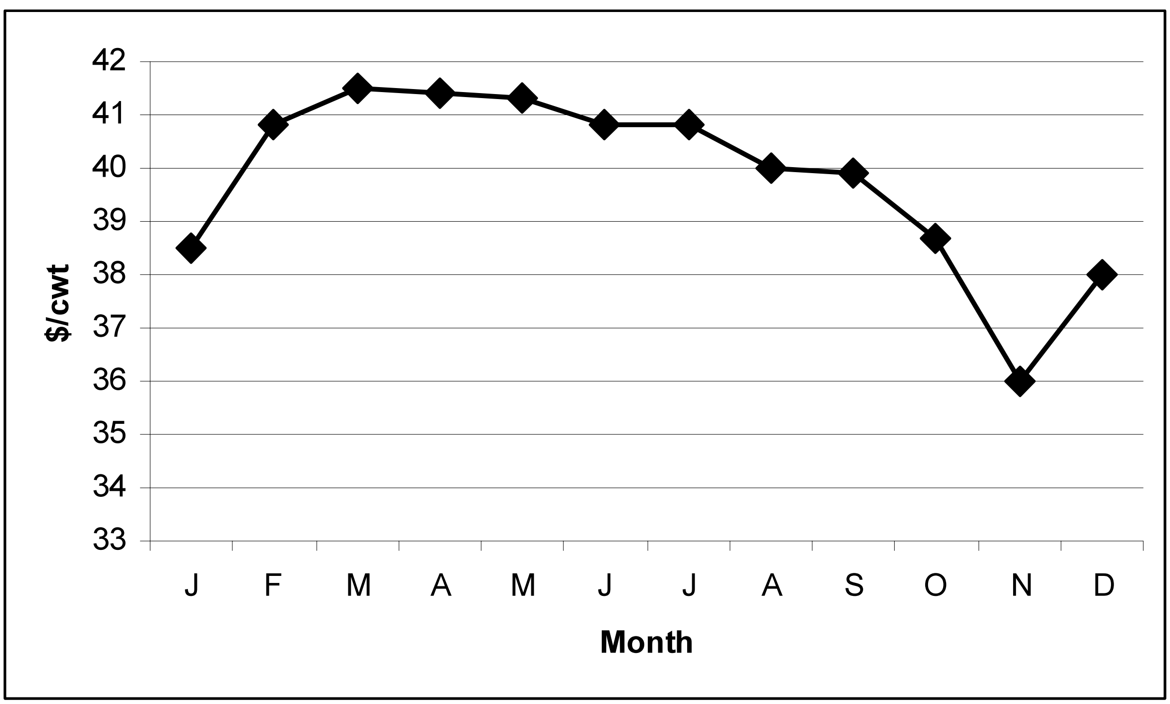



Figure 1. Selling price of market cows during the previous 10 years by month. Source: USDA/AMS, 1991-2001.

## Additional feeding of market cows research

During 2001-2002, we (Rogers et al., 2002) conducted a two-phase study, funded by the National Cattlemen's Beef Association with Beef Check-Off dollars, to identify management strategies to decrease antibiotic residue violations and increase carcass merit in market dairy cows. Specifically, our objectives were to determine the influence of additional feeding (30 or 60 days) of market dairy cows on carcass quality and to determine antibiotic meat withdrawal in dairy cows.

In phase I, 77 non-lactating Holstein market cows that were to be sold for a variety of reasons (milk production, reproduction, disease/disorders) were obtained from four commercial dairies and assigned to a control group (no additional days of feeding) or to one of two feeding treatments (30 or 60 days of additional feeding).

Prior to the experimental feeding period, all cows were weighed, assigned a body condition score (BCS) of 1 to 5, where 1 = thin and 5 = obese (Wildman et al., 1982). Additionally fed cows were administered an oral probiotic gel paste (30 g; RXV-BP-1 Bovine, AGRIpharm®, Grapevine, TX) which contained a bovine specific mixture of bacteria. Furthermore, additionally fed cows were treated intramammary with cephapirin sodium (ToDAY®, Fort Dodge Animal Health, Fort Dodge, IA).

Using commodities commonly found on Southwest dairies, a total mixed ration (TMR) was formulated. The TMR consisted of 60% high-energy concentrate and 40% quality alfalfa hay (Table 1). Cows were fed the TMR twice daily. Bunks were visually evaluated prior to feeding and the amount of feed was adjusted for pen intake. Weigh-backs were recorded on a weekly basis.

Cows used as the control (0 days of additional feed) were transported to Lonestar Packing (San Angelo, TX) from local dairies at the same time as additionally fed cows. Carcass data was collected and included hot carcass weight (HCW), ribeye area (REA), percent kidney, pelvic, heart fat (%KPH), backfat, marbling, and fat coloring. Marbling scores were converted to a scale where 100 = Practically Devoid, and 200 to 900, in increments of 100, represent Traces, Slight, Small, Modest, Moderate, Slightly Abundant, Moderately Abundant, and Abundant, respectively. Yellow fat was scored on a 5-point scale, where 0 = none to 4 = severe.

In phase II, unhealthy (predominately medicated for mastitis) dairy cows (n = 62) were administered penicillin G procaine (Pfi-Pen G; Pfizer Animal Health, New York, NY; 1 mL/100 lbs BW, i.m.; 10 day meat withdrawal) and urine was collected and tested with a β-lactam specific enzyme-linked immunosorbent assay (ELISA; Meatsafe™ Residue Test; SilverLake Research, Monrovia, CA). Urine testing occurred from two days prior to label withdrawal time and continued until clearance of antibiotic residue was evident using the commercial antibiotic test.

**Results for Phase I.** Feed intake did not differ between feeding treatments (average = 39 lb/day per cow). Body condition scores increased in cows fed for 60 days (BCS = 3.2) compared to cows fed for 30 days (BCS = 2.8; Table 2). Average daily gain was greater in cows fed for 30 days (3.1 lb/day) than cows fed for 60 days (2 lb/day). This illustrates the feeding efficiency of cows during the early time of additional feeding (between 30 and 60 days) as shown in previous university research.

Additional feeding did not influence any carcass characteristics studied except percent KPH, which was different among feeding groups (Table 3). Hot carcass weights, marbling scores, ribeye area, and backfat were all similar among treatments. Likewise, fat color did not differ between treatments.

Incidence of condemnation was 8.3, 10, and 0% for control (0 days of additional feeding), 30 and 60 days of additional feeding, respectively. Condemnations resulted from various conditions (for example, lymphoma, septicemia, and pyemia) and were not the result of antibiotic residues. Although not statistically significant, additional feeding decreased the incidence of carcass condemnation.

Table 1. Total mixed ration of 60% grain and 40% forage fed to market dairy cows for 30 or 60 days.

| | |
|---|---|
| Corn, flaked | 38.9% |
| Soybean hulls | 11.9% |
| Soybean meal | 3.5% |
| Molasses | 2.8% |
| Mineral Mix | 1.9% |
| Fat, animal | 1.0% |
| Alfalfa hay | 40% |

Table 2. Body condition score (BCS) and average daily gain (ADG) of market dairy cows fed 0, 30, or 60 days.

| | Treatment | | |
|---|---|---|---|
| Trait | 0 d | 30 d | 60 d |
| Pre-BCS | --- | 2.2 | 2.6 |
| Post-BCS | 2.6 | 2.8 | 3.2 |
| ADG (lb) | -- | 3.1[a] | 2.0[b] |

[a,b] Statistically different ($P < 0.05$).

Table 3. Hot carcass weight (HCW), ribeye area (REA), percent kidney, heart and pelvic fat (% KPH), fat thickness and fat color of carcasses from market dairy cows fed 0, 30, or 60 days.

| | Treatment | | |
|---|---|---|---|
| Trait | 0 d | 30 d | 60 d |
| HCW (lb) | 625 | 603 | 651 |
| REA ($in^2$) | 12.2 | 12.5 | 12.1 |
| % KPH | 1.6[b] | 1.0[b] | 2.1[a] |
| Fat thickness (in) | 0.13 | 0.10 | 0.13 |
| Fat color[c] | 0.52 | 0.19 | 0.39 |

[a,b] Statistically different ($P < 0.05$).
[c]Using a 5-point scale for visual appearance of yellow fat (0 = none to 4 = severe).

**Results from Phase II.** Thirty-one percent of cows (19/62) treated with penicillin G procaine exceeded the 10 day label withdrawal recommendation by an average of 3.1 days (range 1 to 8 days; Figure 2). As with most dairy operations, cows were not weighed prior to medication. Therefore, the actual weight of the cow to determine the precise dosage of penicillin needed was unknown at the time of treatment. Unhealthy cows will likely have reduced feed intake and water. Furthermore, metabolism is probably decreased in unhealthy cows and may partially explain why 31% of cows treated with penicillin G procaine exceeded the label withdrawal period.

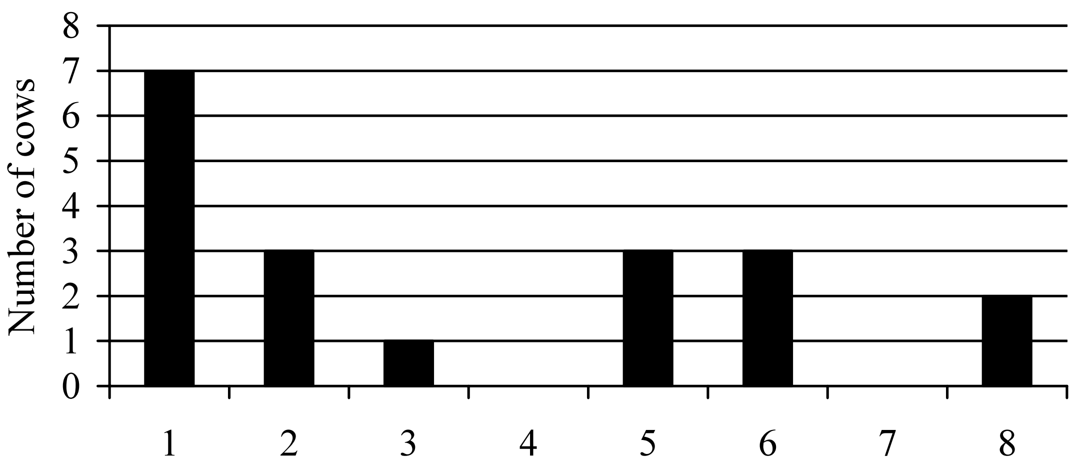



Figure 2. Number of cows exceeding 10-day withdrawal of penicillin G procaine.

Results of our research study suggests feeding market cows can increase body condition (fat cover), average daily gain and decrease condemnation, but may not significantly influence carcass characteristics. Furthermore, antibiotic-treated market cows may exceed recommended meat withdrawal times and cause antibiotic residue violation at processing. Health and the ability to gain weight are extremely variable in market cows; therefore, not all market cows are suitable "candidates" for additional feeding protocols. Dairy producers should evaluate individual market cows and consider management strategies, such as additional feeding, to decrease the incidence of carcass condemnation and antibiotic residues in meat tissues.

## Take Home Messages

- Dairy producers are beef producers.

- Prudent use of antibiotics is of utmost importance.
    - Record keeping of all cows receiving medications.
    - Veterinarian/client/patient relationship is necessary.

- Profit can be increased from the sale of market (cull) dairy cows.
    - Seasonality is important; spring is better.
    - Additional feeding for 30 to 60 days (most efficient) when feed costs are minimized.

- Not all market cows are "candidates" for retaining and additional feeding.
- Health of animal plays a major role.
    - Some cows should be euthanized on-farm.
    - Some cows should be sold locally in a timely manner.
    - Some cows can be fed efficiently for 30 to 60 days.

## Literature Cited


Apple, J.K., J.C. Davis, J. Stephenson, J.E. Hankins, J.R. Davis, and S.L. Beaty. 1999. Influence of body condition score on carcass characteristics and subprimal yield from cull beef cows. J. Anim. Sci. 77:2660-2669.

Cullor, J.S. 1997. HACCP (Hazard Analysis of Critical Control Points): Is it coming to the dairy? J. Dairy Sci. 80:3449-3452.

Dairy Beef: Maximizing Quality and Profits. 2002. Dairy producer? You're in the beef business too. Available from: URL: http://dairybeef.ucdavis.edu/home.htm

FSIS-USDA. Food Safety and Inspection Service – United States Department of Agriculture. 1996. Domestic Residue Data Book: Explanation of the 1996 FSIS National Residue Program. Available from: URL: http://www.fsis.usda.gov/ophs/redbook1/redbook1.htm

FSIS-USDA. Food Safety and Inspection Service – United States Department of Agriculture. 2000. Report on a survey of the National Residue Program Uniform Application in cull cow plants. Available from: URL: http://www.fsis.usda.gov/oa/topics/cullcow.htm

Gardner, I.A. 1997. Testing to fulfill HACCP (Hazard Analysis of Critical Control Points) requirements: Principles and examples. J. Dairy Sci. 80:3453-3457.

Jones, S.D.M. 1983. Tissue growth in young and mature cull Holstein cows fed a high energy diet. J. Anim. Sci. 56:64-70.

Matulis, R.J., F.K. McKeith, D.B. Faulkner, L.L. Berger, and P. George. 1987. Growth and carcass characteristics of cull cows after different times-on-feed. J. Anim. Sci. 65:669-674.

Roeber, D.L., P.D. Mies, C.D. Smith, K.E. Belk, T.G. Field, J.D. Tatum, J.A. Scanga, and G.C. Smith. 2001. National market cow and bull beef quality audit – 1999: A survey of producer-related defects in market cows and bulls. J. Anim. Sci. 79:658-665.

Rogers, C.A., A.C. Fitzgerald, M.A. Carr, B.R. Covey, J.D. Thomas, and M.L. Looper. 2002. Strategies to reduce antibiotic residues in market dairy cows. Proc. Western Sec. Am. Soc. Anim. Sci. 53:49-52.

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. J. Anim. Sci. 75:1195-1202.

Smith, G.C., J.B. Morgan, J.D. Tatum, C.C. Kukay, M.T. Smith, T.D. Schnell, and G.G. Hilton. 1994a. Improving the consistency and competitiveness of non-fed beef, and improving the salvage value of cull cow and bulls. Final Report of the National Non-Fed Beef Quality Audit. National Cattlemen's Beef Association, Englewood, CO.

Smith, G.C., J.B. Morgan, J.D. Tatum, C.C. Kukay, M.T. Smith, T.D. Schnell, and G.G. Hilton. 1994b. Opportunities for enhancing value and improving the quality of beef. Final Report of the National Non-Fed Beef Quality Audit – Special Section: Dairy Cattle. National Cattlemen's Beef Association, Englewood, CO.

Wildman, E.E., G.M. Jones, P.E. Wagner, and R.L. Boman. 1982. A dairy cow body condition scoring system and its relationship to selected production characteristics. J. Dairy Sci. 65:495
501.

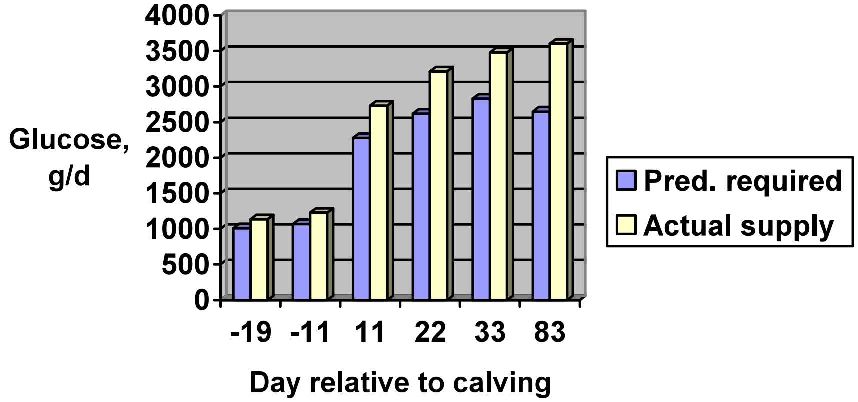



Figure 1. Predicted whole-body glucose requirements compared with actual supply of glucose by gut and liver during the transition period and early lactation. Data are from Reynolds et al. (2000). Predictions are as described by Overton (1998).

A second key metabolic adaptation relates to mobilization of body reserves, particularly body fat stores, in support of the increased energetic demands during early lactation paired with insufficient energy intake. This mobilization of body fat occurs through release of NEFA into the bloodstream (Figure 3). These NEFA are used for energy by body tissues and as precursors for synthesis of milk fat; however, available data suggest that the liver takes up NEFA in proportion to their supply (Emery et al., 1992). Unfortunately, the liver typically does not have sufficient capacity to completely dispose of NEFA through export into the blood or catabolism for energy (Figure 2), and thus transition cows are predisposed to accumulate triglycerides in the liver tissue. The primary consequence of this triglyceride accumulation appears to be impaired liver function, including decreased capacity for ureagenesis and gluconeogenesis.

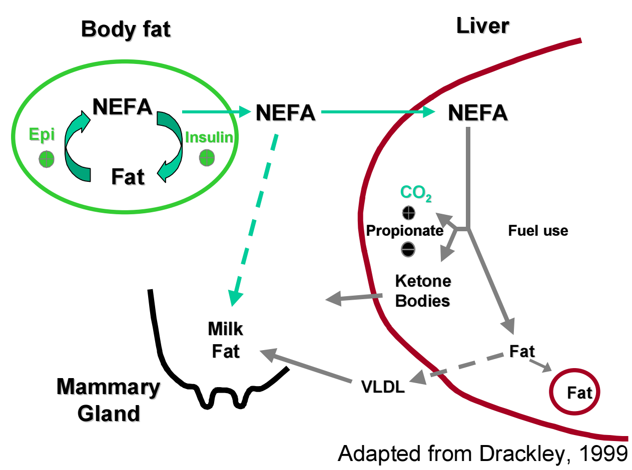


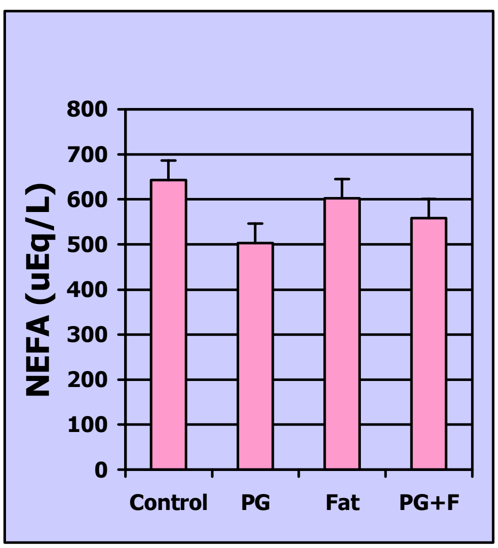

Figure 2. Schematic of metabolism of nonesterified fatty acids (NEFA) in the dairy cow (adapted from Drackley, 1999).

## Strategies to Manage Liver Metabolism in Transition Cows

Our guiding principle based collectively upon these data is that management of NEFA during the transition period is an important factor influencing liver health, the capacity of liver to make glucose, and subsequently production and metabolic disorder incidence in transition cows. The two primary approaches that can be taken are:

1) decrease the supply of NEFA to liver through diet and feeding management (perhaps use of glucogenic supplements)
2) optimize capacity of liver to dispose of NEFA either by burning them for fuel or exporting them as triglycerides in lipoproteins (VLDL)

Good close-up and fresh cow nutritional programs, combined with excellent feeding management to achieve high levels of dry matter intake throughout the transition period, achieves 80 to 90% of the potential of the first strategy and should always be the first area of focus for management. Contrary to popular belief, data supporting that niacin supplementation to the diet decreases plasma concentrations of NEFA are limited; nevertheless, a practical recommendation would be to include niacin (12 g/d) in diets fed to herds struggling with overconditioned cows. Glucogenic supplements such as propylene glycol are effective at decreasing concentrations of NEFA and B-hydroxybutyrate (BHBA; the predominant ketone body found in blood); however, propylene glycol must be drenched or fed such that it is consumed as a bolus in order to be effective in decreasing concentrations of NEFA and BHBA (Christensen et al., 1997), and thus presents both cost and labor challenges. The duration of treatment in most experiments reported in the literature ranges from 10 to 40 days per cow. Recently, two experiments have been conducted (Pickett et al., 2002; Stokes and Goff, 2001) that report beneficial effects of drenching propylene glycol beginning on the day of calving and continuing for one or two subsequent days (Figure 3) -- these short-term treatments are much more acceptable from a cost and labor standpoint and have more potential for commercial application.



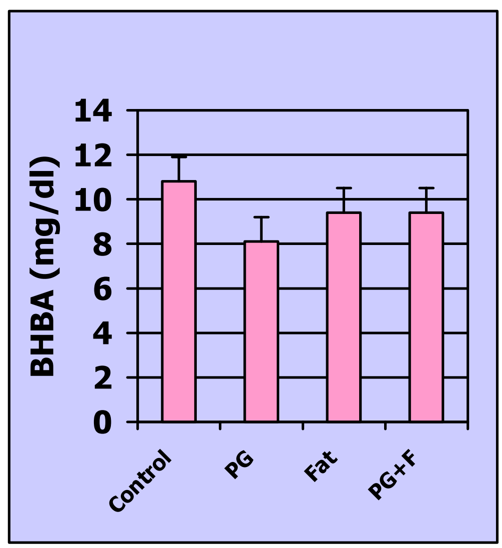




Figure 3. Concentrations of NEFA (left pane) and BHBA (right pane) during the first 21 days postcalving for cows drenched with either a control, propylene glycol (500 ml/day; PG), fat (1 lb/day), or a combination of propylene glycol and fat for the first 3 days postcalving (PG decreased concentrations of NEFA ($P < 0.03$), but did not affect concentrations of BHBA ($P < 0.20$). From Pickett et al. (2002).

Propylene glycol exerts its effects on NEFA primarily by triggering the release of insulin following the bolus of glucose produced when propylene glycol is administered as a drench. Hayirli et al. (2002) recently evaluated administration of slow-release human insulin as a means of decreasing NEFA and triglyceride accumulation. They found that administration of 0.06 IU/lb body weight of slow release insulin on day 3 postcalving decreased plasma NEFA and liver triglyceride concentrations during the first week of lactation, and tended to increase dry matter intake and milk production. Administration of slow release insulin at dosages larger than this dosage decreased dry matter intake and milk production in this study.

In addition to the potential for strategies to increase the concentrations of insulin in transition dairy cows to decrease NEFA, one strategy to increase the effectiveness of insulin has been investigated. Chromium (Cr) has been demonstrated to potentiate insulin action in nonruminants. Two experiments (Hayirli et al., 2001; Smith et al., 2002) demonstrated that administration of up to 0.06 mg of Cr as Cr-methionine per kilogram of metabolic body weight decreased concentrations of NEFA during the prepartum period and resulted in increased dry matter intake and milk production postcalving.

Recently, another strategy related to decreasing energy demands on the transition cow has been suggested to potentially decrease reliance on body reserves and thereby reduce the supply of NEFA to the liver. In typical midlactation cows, approximately 50% of the fatty acids secreted as milk fat are taken up by the mammary gland from the bloodstream as preformed fatty acids. The remaining 50% of fatty acids in milk are synthesized de novo in the mammary gland, and account for approximately 50% of the energetic cost of milk synthesis (NRC, 2001). Conjugated linoleic acids (CLA), specifically the *trans*-10, *cis*-12 isomer of CLA, have been discovered to be potent inhibitors of milk fat synthesis (Bauman et al., 2000). Giesy et al. (1999) fed cows 50 g/d of a mixture of CLA isomers (35% *trans*-10, *cis*-12 by weight) in a Ca-salt form from day 13 through 80 postpartum. They reported few effects of CLA supplementation on cow performance during days 14 through 28 postcalving; however, milk yield was increased, and percentage and yield of milk fat were decreased, during days 35 through 80 postpartum. Energy balance was not affected by treatment during either period. Given that supplementation with CLA in their experiment began after concentrations of NEFA have returned to relatively low levels in the blood (Overton and Piepenbrink, 1999), we hypothesized that supplementation of CLA during the entire transition period and early lactation would be more effective in terms of potentially decreasing energy demand during early lactation. Bernal-Santos et al. (2001) fed cows 30.4 g/day of a mixture of CLA isomers (29% *trans*-10, *cis*-12 by weight) in a Ca-salt form from 14 days before expected calving through 140 days of lactation. Results were similar to those of Giesy et al. (1999) in that milk yield and milk fat percentage during the first two weeks postpartum were not affected by CLA supplementation; however, milk fat percentage was decreased by 13% and milk yield tended to be increased (6.6 lb/day) during the entire postpartum period in cows administered the CLA supplement. Energy balance and concentrations of NEFA and BHBA in plasma were not affected by treatment. Therefore, contrary to our hypothesis, CLA supplementation does not appear to substantially reduce reliance on body fat stores; however, energy spared from milk fat synthesis apparently was redirected to lactose synthesis and may offer the opportunity to use CLA as a management tool to increase peak milk yield.

Even when the first strategy is in place on individual dairy farms, we believe that there are opportunities to further improve liver health by employing nutritional strategies to optimize the capacity of liver to dispose of NEFA rather than accumulate them as fat in liver tissue. As mentioned above, the two disposal routes of NEFA from liver involve burning them for fuel and exporting them back into the blood as triglycerides in very low density lipoproteins (VLDL; Figure 2). Choline, methionine, lysine, and essential fatty acids (linoleic and linolenic acids) all are candidates for modulating these aspects of liver fatty acid metabolism. We determined that choline supplementation to diets fed to transition cows decreased the rate of triglyceride accumulation in liver tissue and tended to quadratically increase milk yield during early lactation (Piepenbrink and Overton, 2002). Methionine supplied as 2-hydroxy-(4-methylthio)-butanoic acid (HMB) did not affect liver fatty acid metabolism; however, milk yield increased in a quadratic fashion to HMB supplementation (Table 1). Mashek et al. (2002) reported recently that addition in vitro of linoleic or linolenic acids altered hepatic fatty acid metabolism; however, the effects of feeding essential fatty acids on liver metabolism in the intact cow are not known. Further research must be conducted to determine the specific roles of choline, methionine, lysine, and essential fatty acids in liver fatty acid metabolism and to determine the interactions among supply of these nutrients.

Table 1. Yields of milk and milk components by cows fed increasing amounts of 2-hydroxy-4-(methylthio)-butanoic acid (HMB) during the transition period and early lactation (Piepenbrink et al., 2001).

| | Treatment | | | | Effect, P < | | |
|---|---|---|---|---|---|---|---|
| Item | Control | + HMB | ++ HMB | SEM | TRT Linear | TRT Quad. | TRT x week |
| Milk, lb/d | 92.6 | 99.2 | 92.6 | 2.9 | 0.99 | 0.05 | 0.13 |
| Fat, % | 4.20 | 4.00 | 4.07 | 0.13 | 0.46 | 0.36 | 0.80 |
| Fat, lb/d | 3.79 | 3.88 | 3.70 | 0.11 | 0.59 | 0.32 | 0.40 |
| 3.5% FCM, lb/d | 101.4 | 105.8 | 100.1 | 2.6 | 0.70 | 0.11 | 0.28 |
| CP, % | 2.80 | 2.77 | 2.84 | 0.06 | 0.65 | 0.33 | 0.26 |
| CP, lb/d | 2.56 | 2.69 | 2.58 | 0.09 | 0.77 | 0.22 | 0.69 |
| Lactose, % | 4.70 | 4.69 | 4.73 | 0.05 | 0.62 | 0.69 | 0.76 |
| Lactose, lb/d | 4.34 | 4.65 | 4.39 | 0.13 | 0.86 | 0.05 | 0.19 |
| Total solids, % | 12.46 | 12.22 | 12.38 | 0.19 | 0.78 | 0.36 | 0.94 |
| Total solids, lb/d | 11.40 | 11.99 | 11.35 | 0.31 | 0.94 | 0.09 | 0.53 |

## Grouping Strategies and Diet Formulation For Close-Up Cows

Modern dry cow nutritional grouping strategies involve a two-group system -- a "far off" group consisting of cows from dry off through approximately 21 days prepartum and a "close-up" group consisting of cows from approximately 21 days prepartum through parturition. We would recommend energy densities of approximately 0.59 to 0.63 Mcal/lb of net energy for lactation ($NE_L$) for diets fed to cows in the far off group. Recently, observational studies at Penn State University and the University of Missouri have suggested that feeding close-up diets containing large amounts of nonforage fiber sources may increase dry matter intake of close-up cows compared to close-up diets containing larger amounts of starch-based cereals. We have determined that periparturient dry matter intake and postpartum milk production and composition are comparable when diets based upon nonforage fiber sources or starch-based cereals are fed (Smith et al., 2002); however, we are continuing to investigate the metabolic implications of changing dietary carbohydrate source on postabsorptive metabolism in transition cows. More detailed recommendations for diets fed to close-up cows, with differentiation of mineral composition based upon anionic versus nonanionic approaches to manage hypocalcemia, are provided in Table 2.

More uncertain is the length of time that cows should be fed the close-up diet. Two experiments have been published recently that provide us with some insight on this topic. Robinson et al. (2001) fed cows and first-calf heifers either a control close-up diet or a close-up diet supplemented with additional energy and protein on commercial dairy farms in the western US and determined that there was a significant increase in milk yield over a full lactation when heifers and cows were fed these diets for 15 days compared with 5 days (Figure 4). Additional supplementation of energy and protein to the diet yielded more milk during the full lactation only when it was fed for 15 days prepartum. In a larger study involving over 13,000 cows on five dairy farms in the western US, Corbett (2002) determined that cows increased predicted 305-day milk production (Figure 5) and decreased occurrence of metabolic disorders as they spent up to 21 days in the close-up group (Figure 6).

These experiments, however, did not explore feeding the close-up diet for longer than the 21 day period currently recommended. Mashek and Beede (2001) fed cows on two commercial dairy farms the close-up diet for an average of either 18 days or 37 days prepartum. There was a slight improvement in energy status of cows fed the close-up diet for 37 days prepartum; however, differences in milk production during early lactation were not significant. Health effects were farm-specific -- one farm had an increased incidence of retained placenta when fed the close-up diet for an average of 37 days prepartum.

Table 2. General goals for diet formulation for closeup cows

| | Standard | Anionic |
|---|---|---|
| • $NE_{L,}$ Mcal/lb | 0.72 to 0.74 | |
| • Metabolizable protein, g/d | 1100 to 1200 | |
| • NFC, % | 34 to 36 | |
| • Dietary Ca, g/d | 100 | 140 |
| • Dietary Ca, % | 0.90 | 1.2 |
| • Dietary P, % | 0.3 to 0.4 | 0.3 to 0.4 |
| • Mg, % | 0.4 to 0.42 | 0.4 to 0.42 |
| • Cl, % | 0.3 | 0.8 to 1.2 |
| • K, % | < 1.3 | < 1.3 |
| • Na, % | 0.1 to 0.2 | |
| • S, % | 0.20 | 0.3 to 0.4 |
| • Vitamin A (IU/d) | 100000 | 100000 |
| • Vitamin D (IU/d) | 30000 | 30000 |
| • Vitamin E (IU/d) | 1800 | 1800 |

We recently completed an experiment on two commercial dairy farms in New York involving nearly 350 cows in which we fed cows either a two-group dry cow program or the close-up diet for the entire dry period (Contreras et al., 2002). Differences in productive performance during the first five monthly test days were not significant among treatments. In looking at interactions of body condition score at dry off with performance during the subsequent lactation, we found that cows with initial body condition score less than 3.0 (mean = 2.8) tended to produce more milk (94.8 lb/day versus 91.0 lb/day) across the first five monthly test days than did cows with body condition score of 3.25 or greater (mean = 3.4). Furthermore, a trend existed for an interaction of body condition score at dry off such that thinner cows fed a two-group dry cow program produced the most milk (97.2 lb/day) during the first five monthly test days, cows fed the close-up diet for the entire dry period were intermediate (92.6 lb/day for both body condition score groups), and heavier cows fed a two-group dry cow program produced the least milk (89.5 lb/day) during the first five monthly test days. Thinner cows lost less body condition during early lactation and had reproductive performance comparable to that of heavier cows. The implications of these data are that replenishment of body condition during late lactation to a body condition score of 3.25 or 3.50 as commonly recommended may not be important for productive and reproductive performance if cows are fed "modern" transition cow feeding programs. Secondly, these data also imply that perhaps heavier cows will benefit from spending the entire dry period in the close-up group. Certainly, more research investigating the interactions of body condition score and nutritional strategies for transition cows is merited.

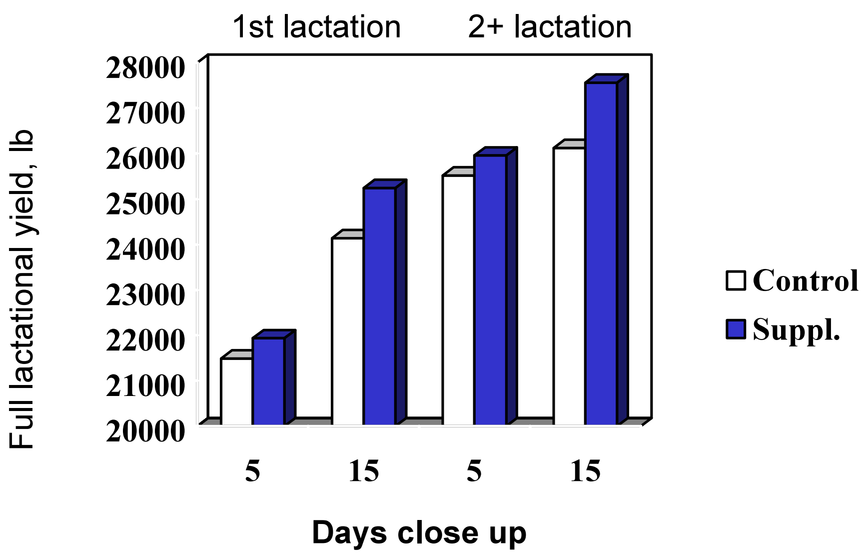
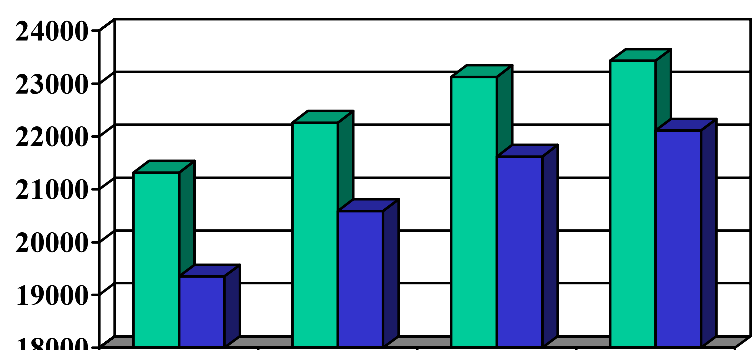
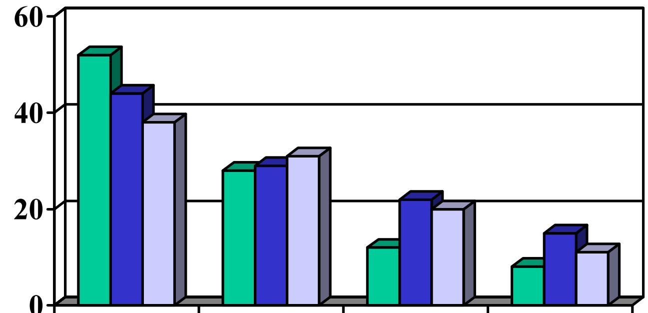



Figure 4. Full lactational milk yields of cows in first and second or greater lactation as affected by feeding either a control or supplemented diet for either 5 or 15 days close-up (Robinson et al., 2001).




| | 0-7 days | 8-14 days | 15-21 days | >21 days |
|---|---|---|---|---|
| Fresh 1-1 to 5-1 | 21316 | 22262 | 23126 | 23430 |
| Fresh 6-1 to 8-1 | 19349 | 20593 | 21619 | 22112 |

Figure 5. Predicted 305-day milk production as affected by days in the close-up group (Corbett, 2002).




| | 0-7 days | 8-14 days | 15-21 days | >21 days |
|---|---|---|---|---|
| Milk Fevers | 52 | 28 | 12 | 8 |
| Retained Placentas | 44 | 29 | 22 | 15 |
| Uterine Infections | 38 | 31 | 20 | 11 |

Figure 6. Occurrence of metabolic disorders as affected by days in the close-up group (Corbett, 2002).

## Current Research and Implications for the Dairy Industry

Currently, our laboratory is engaged in experiments to elucidate the specific roles of individual nutrients in liver metabolism of transition cows and to determine the interactions of metabolism and health that likely provide the biological basis for the myriad of factors that we include in the category of "management" on commercial dairy farms. Collectively, this research will provide much of the basis for managing metabolism of transition dairy cows within transition cow nutrition and management programs in the future.

## Literature Cited


Bauman, D.E., L.H. Baumgard, B.A. Corl and J.M. Griinari. 2000. Biosynthesis of conjugated linoleic acid in ruminants. Proc. Am. Soc. Anim. Sci., 1999. Available at: http://www.asas.org/jas/symposia/proceedings/0937.pdf

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

Bernal-Santos, G., J.W. Perfield II, T.R. Overton and D.E. Bauman. 2001. Production responses of dairy cows to dietary supplementation with conjugated linoleic acid (CLA) during the transition period and early lactation. J. Dairy Sci. 84(Suppl. 1):82 (Abstr.).

Christensen, J. O., R. R. Grummer, F. E. Rasmussen, and S. J. Bertics. 1997. Effect of method of delivery of propylene glycol on plasma metabolites of feed-restricted cattle. J. Dairy Sci. 80:563-568.

Contreras, L. L., C. M. Ryan, and T. R. Overton. 2002. Effects of dry cow grouping strategy and body condition score at dry off on performance of dairy cows during early lactation. J. Dairy Sci. 85(Suppl. 1):185. (Abstr.)

Corbett, R. B. 2002. Influence of days fed a close-up dry cow ration and heat stress on subsequent milk production in western dairy herds. J. Dairy Sci. 85(Suppl. 1):191-192. (Abstr.)

Curtis, C. R., H. N. Erb, C. H. 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.

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

Emery, R. S., J. S. Liesman, and T. H. Herdt. 1992. Metabolism of long-chain fatty acids by ruminant liver. J. Nutr. 122:832-837.

Ferguson, J. D. 2001. Nutrition and reproduction in dairy herds. In Proc. 2001 Intermountain Nutr. Conf., Salt Lake City, UT. Utah State Univ., Logan. pp. 65-82.

Giesy, J. G., S. Viswanadha, T. W. Hanson, L. R. Falen, M. A. McGuire, C. H. Skarie and A. Vinci. 1999. Effects of calcium salts of conjugated linoleic acid (CLA) on estimated energy balance in Holstein cows early in lactation. J. Dairy Sci. 82(Suppl. 1):74. (Abstr.).

Godden, S., J. Fetrow, P. Rapnicki, S. Eicker, and S. Stewart. 2002. Culling patterns in lactation. Proceedings Monsanto Dairy Business Science Symposium CD-ROM. St. Louis, MO.

Goff, J. P. 1999. Physiologic factors to consider in order to prevent periparturient disease in the dairy cow, with special emphasis on milk fever. Proceedings 4th Western Dairy Management Conference, Las Vegas, NV pp. 99–112.

Goff, J. P. 2001. Managing the transition/fresh cow. Proceedings 5th Western Dairy Management Conference, Las Vegas, NV pp. 99-106.

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

Hayirli, A., S. J. Bertics, and R. R. Grummer. 2002. Effects of slow-release insulin on production, liver triglyceride, and metabolic profiles of Holsteins in early lactation. J. Dairy Sci. 85:2180-2191.

Hayirli, A., D. R. Bremmer, S. J. Bertics, M. T. Socha, and R. R. Grummer. 2001. Effect of chromium supplementation on production and metabolic parameters in periparturient dairy cows. J. Dairy Sci. 84:1218-1230.

Mashek, D. G., and D. K. Beede. 2001. Peripartum responses of dairy cows fed energy-dense diets for 3 or 6 weeks prepartum. J. Dairy Sci. 84:115-125.

Mashek, D. G., S. J. Bertics, and R. R. Grummer. 2002. Metabolic fate of long-chain unsaturated fatty acids and their effects on palmitic acid metabolism and gluconeogenesis in bovine hepatocytes. J. Dairy Sci. 85:2283-2289.

National Research Council. 2001. Nutrient requirements of dairy cattle. 7th rev. ed. National Academy Press, Washington, DC.

Overton, T. R. 1998. Substrate utilization for hepatic gluconeogenesis in the transition dairy cow. *In* Proc. Cornell Nutr. Conf. Feed Manuf., Cornell Univ., Ithaca, NY, pp. 237-246.

Overton, T. R., and M. S. Piepenbrink. 1999. Liver metabolism and the transition cow. *In* Proc. Cornell Nutr. Conf. Feed Manuf., Cornell Univ., Ithaca, NY, pp. 118-127.

Overton, T. R., M. S. Piepenbrink, and M. R. Waldron. 2000. Interactions of liver metabolism and health in transition dairy cows. Proc. Cornell Nutr. Conf. Rochester, NY. pp. 251-261.

Pickett, M. M., M. S. Piepenbrink, and T. R. Overton. 2002. Effects of propylene glycol or fat drench on plasma metabolites, liver composition, and production of dairy cows during the periparturient period. J. Dairy Sci. 86:(submitted).

Piepenbrink, M. S., and T. R. Overton. 2002. Liver metabolism and production of cows fed increasing amounts of rumen-protected choline during the periparturient period. J. Dairy Sci. 85:(submitted)

Piepenbrink, M. S., A. L. Bork, M. R. Waldron, T. R. Overton, M. Vazquez-Anon, and M. D. Holt. 2001. Feeding 2-hydroxy-4-(methylthio)-butanoic acid to transition dairy cows improves milk production but not hepatic lipid metabolism. J. Dairy Sci. 84(Suppl. 1):35. (Abstr.)

Reynolds, C. K., P. C. Aikman, D. J. Humphries, and D. E. Beever. 2000. Splanchnic metabolism in transition dairy cows. J. Dairy Sci. 83(Suppl. 1):257.(Abstr.)

Robinson, P.H., J. M. Moorby, M. Arana, R. Hinders, T. Graham, L. Castelanelli, and N. Barney. 2001. Influence of close-up dry period protein supplementation on productive and reproductive performance of Holstein cows in their subsequent lactation. J. Dairy Sci. 84:2273-2283.

Smith, K. L., M. R. Waldron, T. R. Overton, J. K. Drackley, and M. T. Socha. 2002. Performance of dairy cows as affected by prepartum carbohydrate source and supplementation with chromium throughout the periparturient period. J. Dairy Sci. 85(Suppl. 1):23. (Abstr.)

Stokes, S. R., and J. P. Goff. 2001. Evaluation of calcium propionate and propylene glycol administered into the esophagus at calving. The Professional Animal Scientist. 17:115-122.

# Meeting the Demand for Dairy Replacements

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## Panelists

Douglas Maddox, RuAnn Dairy and Maddox Dairy, Riverdale, California
John Noble, Noblehurst Farms, Inc., Pavilion, New York

## Introduction

The cost of raising dairy replacement heifers accounts for 15 to 20% of the total costs of the dairy enterprise. On an individual animal basis, a previous economic analysis reveals that it costs approximately $1,300 to raise a Holstein heifer from birth to calving at 24 months of age.

Rising average replacement rates, from 30% in 1996 to 38% in 2001, coupled with the need to fill new or expanded facilities, has fueled strong demand for heifers during the past few years. The strong demand for replacements has led to increased prices for dairy heifers throughout the United States, especially in the west (Figure 1). Reported prices for top springers at sales yards have averaged $1,900 (range: $1,150 to $2,500) for the two-year period October 2000 to 2002.

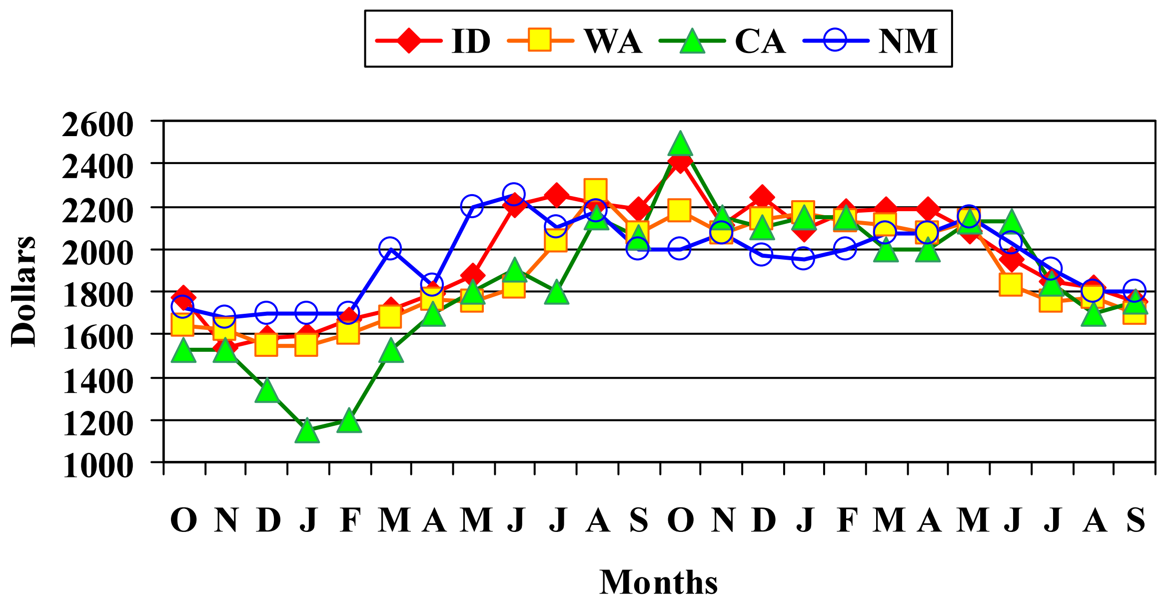


Figure 1. Reported prices for top springers at sales yards in Idaho (ID), Washington (WA), California (CA), and New Mexico (NM) during the two-year period October 2000 to 2002.

Given the high cost of purchasing replacement heifers and rising average culling rates, what can you do to meet the demand for dairy replacements? Let's discuss replacement heifer strategy and general management issues with our panelists Doug Maddox and John Noble. We'll begin with a brief background of each of our panelists.

Doug Maddox is a 1957 graduate of California Polytechnic State University, San Luis Obispo. In 1957, Doug and his family started RuAnn Dairy in Riverdale, CA. Over the years the dairy and farming operation gradually expanded through the purchase of neighboring farms. Maddox Dairy, with a capacity of 3,500 lactating cows, was built in 1980. Currently, Doug and his family milk nearly 5,300 Holsteins, of which approximately 75% are registered. The family also farms approximately 10,000 acres. The farming operation includes wine vineyards, almond trees, cotton, forages and various cash crops. An embryo transfer program has been an integral part of the management strategy at RuAnn and Maddox Dairies for the past 15 years. Doug and his family live in Riverdale, CA.

John Noble is a 1976 graduate of Cornell University. The original family dairy was started six generations ago, in the mid 1800's. Currently, Noblehurst Farms, Inc., milks 1,200 cows and is owned by twenty family and non-family members. In addition to being president of Noblehurst Farms, Inc., John is a partner in Linwood Management Group, a subsidiary of Noblehurst Farms, Inc. Linwood Management Group is responsible for the management of seven dairies and nearly 6,500 lactating cows. For the Linwood Management Group, John personally oversees two dairies, with 2,200 and 1,300 lactating cows, respectively. John and his family live in Pavilion, NY.

***Please briefly describe the housing for lactating cows, milking parlors, and production statistics at each of your farms.***

**Doug Maddox:**
At Maddox Dairy, the cows are housed in free stalls with outside lots. At RuAnn Dairy, half of the cows are housed in free stalls with outside lots. The other half of RuAnn is the original dairy, which consists of loose housing (outside lots) with sunshades. Any cows that do not adapt to free stalls, rather than beef them, they come to the original RuAnn Dairy. Four double 13-herringbone parlors are utilized at Maddox dairy, and we use double-10 herringbones in each of the parlors at RuAnn. We milk 3x and our RHA is 27,500 lb milk, 970 lb fat, and 880 lb protein.

**John Noble:**
At Noblehurst, all our cows are housed in free stall barns and milked in a double-22 parallel parlor. Currently, our RHA is 23,000 lb milk, 900 lb fat, and 700 lb protein.

***Please describe your heifer management system.***

**Doug Maddox:**
We raise all of our calves at Maddox Dairy. Our young calves are housed in either a calf barn (with a capacity of 700 calves) or individual hutches. After weaning at 60 days, calves are housed in dry lots with shades in groups of 15 at RuAnn Dairy and 25 at Maddox Dairy. Our key to growing heifers is to feed a high protein ration to support maximum growth along with enough energy to support the growth, but not too much energy to make the heifers fat. The ration usually contains alfalfa hay and grain.

**John Noble:**
Within three days of birth, our calves go to a calf ranch for the first 11 weeks. At the calf ranch, the calves are housed in calf barns (with a capacity of 100 calves) in an "all-in, all-out" management scheme. One barn is filled each week, and then when the calves are big enough, the group of calves are moved to another barn. The barn is cleaned, sanitized and kept empty for a week before refilling the barn. About 10 dairies have their calves raised at this calf ranch. All calves receive milk replacer until weaning at about 35 days of age. After weaning, the calves are transferred to a transition facility for about 6 weeks. Then the calves are moved to another facility until breeding age. The ration during this time consists of corn silage, alfalfa haylage, and grain. At breeding age, heifers either stay in our system, are bred and moved to various locations where we keep bred heifers, or are shipped south to heifer growers who breed and keep our heifers until two months prior to calving.

***Please describe your strategy for breeding your heifers and your overall goals for your heifers.***

**Doug Maddox:**
We sort our heifers at 14 months of age, so that we can put together a uniform group. If we have some small heifers at 14 months of age, we'll sort them and place them back in a previous pen. If we have a few extra-growthy heifers less than 14 months of age, we'll place them in with older heifers. But we don't want any heifers to calve at less than 22 months of age. Our goals for our heifers are to be 52 inches at the withers and approximately 850 to 900 lb at the time of breeding. Weight is not as important to me as height because an 800 lb heifer at breeding that is a short, round pig doesn't do me any good. Our embryo transfer program begins with our heifers as they reach breeding weight and age. Except for the elite heifers, we try and put embryos in all of our heifers. We'll use AI (with a calving ease bull) if a heifer doesn't settle after embryo transfer. The elite heifers receive AI, and the best of the elite heifers are flushed. I like the heifers to calve at 24 months of age, weigh 1,500 lb, and be 56 inches at the withers. To be honest, a lot of the heifers reach our goals at calving, and the ones that don't are often poor-doers that don't milk well. Our average peak milk production of our first lactation heifers is about 94 lb.

**John Noble:**
We will breed most heifers two or three times AI, then we use clean up bulls. We do not utilize embryo transfer in our heifers. Our goals are for our heifers to be 56 inches (at the withers), and 1,250 to 1,300 lb at calving at 23 to 24 months of age. Unfortunately we haven't been able to achieve our height goal of 56 inches at calving very often.

***What is the death loss in your heifers? Also, do you cull heifers prior to first calving?***

**Doug Maddox:**
Our death loss is about 1.8 % between birth and weaning and about 2.0 % between weaning and first calving. You wouldn't think that you should lose any heifers after weaning, but sometimes between 2 and 8 months of age, we do. If at 14 months of age we don't think a heifer is going to make it in our program, we'll sell them as open heifers, guaranteed to breed, of course.

**John Noble:**
Our death loss is 1.5% between birth and weaning, and probably less than 1% between weaning and first calving. Our culling gets more aggressive as we grow out our heifers, and we will cull poor-doers, heifers that don't appear to fit our system, and non-breeders.

***What is the average age of cows in your herd? How many cows and heifers are sold and purchased annually for dairy purposes? What is your annual replacement rate (cull rate and death loss)?***

**Doug Maddox:**
The average age of our cows is approximately 47 to 48 months of age. During the past year or so, we have sold about 200 cows and heifers. If a good cow doesn't get bred until close to the dry period, and I've got to carry her a long time, I'll sell her if I've got plenty of cows. We don't bring in (buy) any cows. Our annual replacement rate is about 36 %.

**John Noble:**
The average age of our cows is between 48 to 50 months of age. We have not bought or sold any cows or heifers recently. Our annual replacement rate is 34%.

***Let's talk about the embryo transfer program at RuAnn Dairy and Maddox Dairy.***

**Doug Maddox:**
We've been utilizing embryo transfer for about 15 years. Our herd veterinarian, who works exclusively for Maddox and RuAnn Dairies, is in charge of herd health and the embryo transfer program. As a courtesy, our veterinarian will also provide embryo transfer services to our neighbors.

***How are donors chosen?***

**Doug Maddox:**
Our criteria include the top 10% of our herd in production, type, and pedigree. I'd love to have all our donors be scored excellent, 10,000 lb over herdmates, with high components, but obviously that's not always possible. With our heifers, only the most elite are chosen to be donors. I'm a big believer of "like begets like." You want your donor cows and heifers to be fancy. If you want to have big, tall, straight, deep-ribbed, good-legged cattle, you pick them to be mothers (donors).

***As discussed earlier, most of your heifers receive embryos as a first choice. Do you utilize lactating cows as recipients, also?***

**Doug Maddox:**
Yes, we do. We take the cows that we catch standing in heat (that are clean and ready to breed), and put an embryo in them. We put embryos into cows primarily because we have some embryos that are from non-calving ease bulls. We divide our embryos up into calving ease and non-calving ease groups. The embryos from calving ease sires go into the heifers, and the embryos from non-calving ease sires go into cows. After embryo transfer, we're normally around 40 to 50% conception rate in our cows, and 60% or greater in our heifers. We'd like to put as many embryos as possible in our heifers to take advantage of the increased conception rate, but some of these bulls sire calves that are so big that they'll tear up the heifers.

***What is the typical reproductive timeline for a lactating donor?***

**Doug Maddox:**
We normally schedule the first flush to occur after the first standing heat after 60 days in milk. When we tried to flush them too soon after calving, we had problems. If you can do this after a standing heat, we have greater success. Now we get a pretty high percentage of cows pregnant after flushing, where it used to be that we didn't like embryo transfer because it was hard to get them bred back after flushing. Normally, we'll flush her twice on back-to-back estrous cycles and then return her to the AI program.

***Is embryo transfer performed year-round? What percentage of embryos are frozen compared to those transferred directly?***

**Doug Maddox:**
Embryo transfer is performed year-round, but we do cut it back during the hot months of July and August. Oh, probably 30% of the embryos are frozen for later use. We like to transfer embryos directly, but we also like to keep a bank of about 500 frozen embryos. That allows us to export some, and offer some for sale if a buyer comes in. In July and August when it's hot and we don't make a lot of embryos, it also allows us to put embryos in our cows. We'll do a little better on embryos during those months than AI, because of early embryonic death (in AI bred cows subjected to intense heat).

***Are you currently sexing embryos? If not, are you interested in sexing embryos in the future?***

**Doug Maddox:**
We are not currently sexing embryos. I would love to sex embryos if we could get it down to where it would be economically feasible.

***In the future, will sexed semen be integrated into your embryo transfer program?***

**Doug Maddox:**
This whole game will change when sexed semen becomes available. Yes, of course, we will utilize sexed semen in our embryo transfer program. If we had sexed semen, and performed embryo transfer on the top 10% of the herd, then took the top 50% of the resulting heifers as replacements, do you know what kind of herd you could have and how fast you could develop it? Now, we'd really be on the fast track.

***Describe the costs associated with your embryo transfer program.***

**Doug Maddox:**
There are about three different costs. The drug costs for FSH and prostaglandin are about $25 to $30 per flush. Next, you have the semen costs. We use some expensive bulls ($30 to 40 per dose). We want the best bulls that we can get. Then there's the labor cost of the veterinarian and technician. Then there's hidden costs, like what you lose due to extended days open because it may be difficult to get the cow bred after flushing. There's a hidden cost of reproductive efficiency and in (possible) decreased milk production. We had a cow that was going for a 50,000 lb record, so we flushed her three times. Well, during each flush she would drop in milk. Her record ended up closer to 45,000 lb. Did we lose 5,000 lb of milk? I don't really know, but I think we did. Easily, with all the costs described, it costs $100 per embryo produced.

***Has the embryo transfer program helped to meet your demand for replacement heifers? If not, what other strategies have helped meet your demand for replacement heifers?***

**Doug Maddox:**
It's important to realize that embryo transfer has not (directly) increased the number of heifers available for our replacement needs, rather embryo transfer has allowed us to improve the quality of our herd. Remember if a cow or heifer is going to have a calf, she'll have one whether she receives an embryo or gets pregnant from a jump bull. In the long term, embryo transfer should raise your production, raise the overall quality of the herd, and increase cow longevity. As cow longevity increases, fewer replacements may be needed annually. Another strategy we use to increase the number of pregnancies in our herd relates to our AI program at Maddox Dairy. Currently, we do not use any outside semen, that is, semen from AI studs in our AI program at Maddox Dairy. We pick twenty of our own bulls each year and collect 500 units of semen from each of these bulls. Then we'll use AI on cows that are housed with the bull that produced the semen. This management strategy results in 50 to 60 more pregnant cows per month than if we did not run the bull with the cows. Once we're finished with the AI doses from the bull, we send him to slaughter. Of course, the cows in our embryo transfer program at Maddox Dairy are bred with semen from the best bulls available.

***What recommendations do you have for producers who wish to begin an embryo transfer program?***

**Doug Maddox:**
Our original goal was to sell enough embryos (export) to pay for the embryo transfer program. Although we may sell $50,000 to 200,000 worth of embryos, we really don't always pay for the embryo transfer program with embryo sales. We sell 2,000 breeding bulls to commercial dairymen each year. That's what really allows us to keep the embryo transfer program, the registered cows, classification, and breed association programs. Also, we don't sell enough surplus cows or heifers each year to pay for the embryo transfer program. What differentiates dairymen are their goals for their herd and farm. I've talked with a lot of people that have begun to raise bulls because they need the extra income. But what people forget is that we've been in this business for 45 years and we've been investing in super genetics. If we didn't invest in super genetics, how long do you think we'd have our market? Also, it's very important to be a people person. When people come to visit, you've got to tell them about your cows and your entire program. A lot of people will start and stop (embryo transfer and raising bulls), because it doesn't fit their personality, operation, or particular situation.

***Let's go back to 1980. What would you change about the course of your dairy business?***

**Doug Maddox:**
That was about the time when we built the 3,500-cow Maddox Dairy. There were a lot of good things that we did. But, I probably would have gone all Jersey. Holsteins and concrete and free stalls have always been a problem. One of the reasons I think the industry is short of replacements is because Holsteins don't handle the concrete nearly as well as Jerseys do. We've always fought feet and leg problems, breeding problems, and death losses in that big herd. I think I could have done a better job with Jerseys. I think we could have developed quite a Jersey herd with the amount of embryo transfer we've done.

***Looking back, what would you change about your replacement heifer raising strategy?***

**Doug Maddox:**
We could have done a better job of raising our heifers. We were guilty of getting our heifers too fat early on. Recently, in the last few years we've gotten better at raising our heifers. We don't feed corn silage to heifers. We have structured our ration to be high protein, lower energy. I think we're doing a much better job of raising our heifers now.

***Let's talk about the sexed semen program that involves Noblehurst Farms, Inc.***

**John Noble:**
There are 10 dairy farmers that formed a company called "Advanced Dairy Genetics." Within Advanced Dairy Genetics there are three cluster herds. We pick young bulls from dams in our own herds and then have them housed and semen collected at Genex. After a predetermined amount of semen is collected and sorted, the bulls are sent to slaughter and other young bulls enter the program. As you can see we are trying to shorten the generation interval. We have been sorting semen on a very limited basis since May 1, 2002. We have been using sexed semen on a trial basis as we figure out how to operate the machine, and what the optimal concentration of the dose should be. So far (October 2002), we've used thirty-two units of sexed semen. The machine we're using is the MoFlo unit produced by Cytomation and XY, Inc., of Fort Collins, CO. We've committed to purchase the unit at a price between $250,000 to 300,000.

***Do you sort fresh semen or frozen-thawed semen? Will you inseminate heifers and lactating cows with sexed semen?***

**John Noble:**
After collection, the semen is transported to Advanced Dairy Genetics where we have a technician sort the fresh semen. We will only be utilizing sexed semen in virgin heifers.

***When the program is up to full speed, how many heifers will be inseminated with sexed semen? What will be the cost per dose of semen?***

**John Noble:**
We hope to inseminate 6,000 heifers per cluster. We are going to sample 8 bulls per cluster, and with 3 clusters, that works out to about 750 doses per bull. We calculate our costs to be about $50 per unit. That's to give us a three-year payback on the machine. Therefore, we are initially charging ourselves $50 per unit.

***Are you going to incorporate embryo transfer into the sexed semen program in the future?***

**John Noble:**
We might include embryo transfer into the program. Currently there are a few in the group that are using embryo transfer (without sexed semen), but for us, we don't have the resources at this time to utilize embryo transfer.

***What other strategy do you think you might use in the future to meet the demand for replacement heifers?***

**John Noble:**
We are constantly trying to upgrade our replacement heifer program and bring new animals into the system. I think a lot of dairies are trying to reduce the culling rate so that they can grow with a reasonable replacement program.

***At Noblehurst Farms, Inc., what areas might be improved to reduce the annual replacement rate? Also, has the annual replacement rate risen, stayed the same, or declined over the last four years?***

**John Noble:**
The transition period is the most difficult for us. We're also looking at bedding, free stall design, and getting the animals off concrete at least for a little while. There are a myriad of small management items that we are trying to adjust. The annual replacement rate has declined over the last four years.

***What recommendations do you have for producers who wish to begin a semen-sexing program to help meet their need for replacement heifers?***

**John Noble:**
I believe it is very important to realize that we don't have to do it alone. Banding together groups of dairy farmers to accomplish specific tasks, whether it is buying inputs, or sexing semen, I think working together in small groups, we can be pretty effective.

***Let's go back to 1980. What would you change about the course of the dairy business at Noblehurst Farms, Inc.?***

**John Noble:**
With hindsight, I think I would have designed the barns a little bit differently, I would have used sand instead of sawdust and mattresses, but given the status of research and technology at the time, I'm not sure that I would have done a lot of things differently.

***Looking back, what would you change about your replacement heifer raising strategy?***

**John Noble:**
We originally expressed interest in sexed semen in 1976. Nevertheless, the technology was not ready yet. If I could have done something differently, I would have built facilities to house all of our heifers in-house. But, given the nature of concentrated animal feedlot operations, and the handling of manure, I think we're probably better off with a variety of facilities, even though it adds cost to our operation. That way we can keep the manure spread out.

## Summary

Rising average replacement rates, from 30% in 1996 to 38% in 2001, coupled with the need to fill new or expanded facilities, has fueled strong demand for heifers during the past few years. Doug Maddox has utilized an embryo transfer program to increase milk production and raise the overall quality of the RuAnn and Maddox Dairy herds for the past 15 years. Although Doug is quick to point out that embryo transfer has not directly increased the number of heifers available for his replacement needs, Doug admits that increased longevity of the herd due to embryo transfer may lead to fewer replacements needed annually. Other strategies which likely contribute to the achievement of replacement heifer needs at RuAnn and Maddox Dairies include 1) a below average annual replacement rate (36%), 2) below average heifer death loss, 3) utilizing embryo transfer during the hot months of July and August to create pregnancies, and 4) the collection and use of semen from selected bulls in the AI program while they are housed with lactating cows. Doug credits this last management strategy with 50 to 60 more pregnant cows per month compared to AI without natural service bulls housed with the cows.

Through the formation of Advanced Dairy Genetics, John Noble and 9 partners are attempting to directly increase the number of replacement heifers available to meet their needs. Through a closed, three-cluster herd approach, Advanced Dairy Genetics has selected bulls from each cluster herd, collected, and sorted the semen. Thirty-two heifers have been inseminated to date, with plans to inseminate 18,000 heifers. The success of the semen sexing endeavor is unknown at this time. Nevertheless, current strategies at Noblehurst Farms, Inc., which likely contribute to the achievement of replacement heifer needs are 1) the below average annual replacement rate (34%, which has been declining over the past few years), 2) below average heifer death loss, and 3) management attention to detail (transition cows, amount of time spent on concrete).

The success of Doug Maddox and John Noble is testimony that attention to detail in all facets of the dairy business, coupled with the integration and fine tuning of technology, and willingness to form partnerships with family members and fellow producers, can lead to meeting the demand for dairy replacements.

# Monitoring Reproduction From the Starting Gate

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## Introduction

Aggressive reproductive management comprises three strategies that can be implemented early during the breeding period of lactating dairy cows: 1) submit all cows for first postpartum AI service at the end of the voluntary waiting period, 2) identify nonpregnant cows early post-AI, and 3) quickly return cows failing to conceive to first AI service to second AI service. Although many dairy producers rely on estrus detection to inseminate cows, less than 50% of all estrus periods are accurately detected on an average dairy farm in the United States (Senger, 1994). This inefficiency in estrus detection can increase the average interval between AI services to 40 to 50 days (Stevenson and Call, 1983) and limits both reproductive efficiency and profitability. New tools for managing reproduction can be used to improve reproductive efficiency within a dairy herd. Use of hormonal synchronization systems that allow for fixed-time AI ensures that all cows receive AI at or near the end of the voluntary waiting period. New strategies also are being developed to identify nonpregnant cows early after they receive first AI service. Systems for aggressively returning cows that fail to conceive to first AI service currently are being tested and developed.

## First AI Service: To Synch or not to Synch - That is the Question

It is a fundamental principle of reproductive biology that artificially inseminating a cow is the first step toward establishing a pregnancy. Unfortunately, many cows do not receive their first postpartum AI service until after 100 days in milk. First postpartum AI service represents a unique opportunity for reproductive management of lactating dairy cows because all cows in the herd have a known pregnancy status at this time (e.g., nonpregnant), which allows for use of hormonal synchronization systems that use $PGF_2$_ without the risk of aborting a previously established pregnancy. Furthermore, reducing the interval from calving until first AI service for all cows in the herd has a profound effect on reproductive efficiency. The interval that must elapse from calving until a cow is eligible to receive her first AI service is termed the Voluntary Waiting Period (VWP). As the name implies, the duration of this interval is voluntary (i.e., a management decision) and traditionally varies from 40 to 70 days on most dairies.

To illustrate the advantages of programming cows to receive first AI service, we will compare reproductive data from two dairy farms in Wisconsin that employ two different strategies to initiate first postpartum AI service (Figure 1). For both graphs, days in milk (DIM) at first breeding is plotted on the vertical axis (y-axis) and time is plotted on the horizontal axis (x-axis). Each square represents an observation, or a cow within the herd, and a bold line has been drawn horizontally at 100 DIM. In both plots, cows receiving first AI service before 100 DIM fall below the bold line, whereas cows receiving first AI service after 100 DIM fall above the bold line. The upper plot in Figure 1 shows the pattern of cows receiving first AI service for cows in a herd managed using visual detection of estrus for first postpartum AI service, whereas the lower plot shows the pattern of cows receiving first AI service for cows managed in a herd that uses Presynch (a hormonal synchronization system described in the next section) and timed artificial insemination for first postpartum AI service.

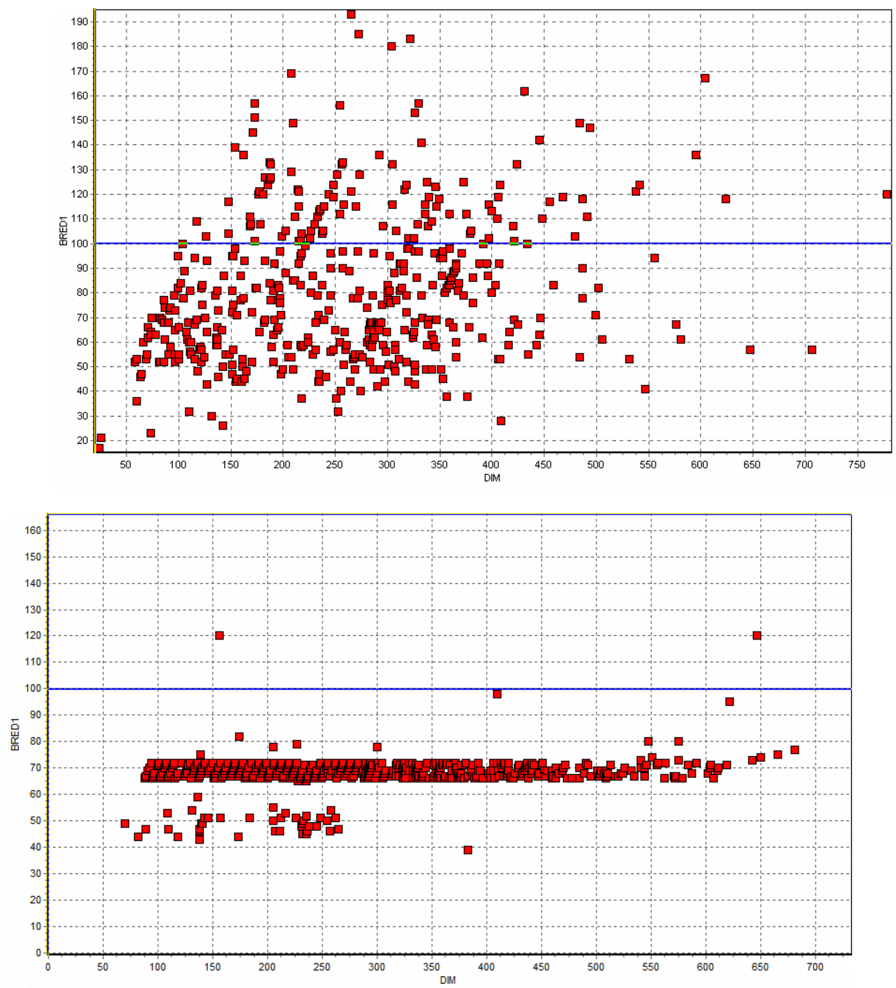


**Figure 1.** Days in milk at first breeding (y-axis) by time (x-axis) for cows managed using visual detection of estrus for first postpartum AI service (upper panel) and cows managed using Presynch and timed artificial insemination for first postpartum AI service (lower panel).

Nearly one-third of the cows in the herd shown in the upper panel of Figure 1 exceed 100 DIM before first AI service. It should be obvious that none of these cows has a chance of becoming pregnant before 100 DIM because they have not yet been inseminated. Although most dairy producers identify a set duration for the VWP, breeding decisions for individual cows often occur before the VWP elapses. The VWP for the farm illustrated in the upper panel of Figure 1 is 50 DIM; however, many cows are submitted for AI before this time. The decision to AI a cow for the first time postpartum is determined based on when (or if) a cow is detected in estrus rather than on a predetermined management decision. In such instances, the cow is managing the decision to breed rather than the dairy manager. The decision to inseminate a cow before the VWP elapses is motivated by one factor, and that factor is fear. Most producers fear the decision to not breed a cow detected in estrus because she may not be detected in estrus again until much later in lactation. Unfortunately, this risk is often realized on dairies that rely on visual estrus detection for AI because of poor estrus detection by dairy personnel and poor estrus expression by lactating dairy cows. We recently have shown that nearly one-third of lactating cows were not cycling by 60 DIM (Pursley et al., 2001).

If the upper graph reflects the reproductive performance to first AI on your farm, you should consider using a controlled breeding program to initiate first postpartum AI service. Use of a controlled breeding program such as Presynch for initiating first AI service exposes all cows in the herd to the risk of becoming pregnant at or very near the end of the VWP. In the lower panel of Figure 1, nearly all cows receive their first postpartum AI service between 65 and 73 DIM. In this scenario, the end of the VWP is roughly equal to the average day at first service for the entire herd. Of course, not all cows will conceive to first service; conception rates in lactating dairy cows are poor, and hormonal breeding programs increase pregnancy rate by increasing service rate, not conception rate. Figure 1 illustrates two extremes with regard to initiating first postpartum AI service. Many farms have adopted blended approaches in which cows receive AI to a standing estrus for a period of time after the VWP. Any cows not receiving AI by a predetermined DIM are enrolled into a controlled breeding protocol to receive a fixed-time AI service.

## Ovsynch, Pre-Synch, Co-Synch, the Kitchen-Synch: Hormonal Protocols for Timed AI

A variety of new timed insemination protocols have been introduced to the dairy industry since the introduction of Ovsynch in the mid 1990's. The variety of modifications of the original Ovsynch protocol has lead to much confusion among dairy producers and their reproductive consultants regarding the "best" timed insemination protocol to implement on a dairy. Three widely used timed insemination protocols include Ovsynch, Presynch, and Cosynch. The benefits and of each of these protocols are overviewed below.

### Ovsynch

Reproductive physiologists had long searched to develop a synchronization program that could overcome the problems and limitations associated with visual estrus detection. Such a program was developed at the University of Wisconsin-Madison in 1995 (Pursley et al., 1995) and is now commonly referred to as Ovsynch. Ovsynch, synchronizes follicular development, luteal regression, and time of ovulation, thereby allowing for TAI after the second GnRH injection and improving the AI service rate (Pursley et al., 1995). Ovulation of a dominant follicle in response to the second GnRH injection occurs in around 85% of high producing lactating cows receiving this protocol (Fricke et al., 1998), and ovulation occurs within 24 to 32 h after the second GnRH injection in synchronized cows followed by growth of a new follicular wave (Pursley et al., 1995). Using a 50 _g dose (1.0 ml) of Cystorelin for each injection of the Ovsynch protocol results in similar synchronization and conception rates as using a 100 _g dose (2.0 ml) of Cystorelin (Fricke et al., 1998). Although a reduced dose of Cystorelin has been shown to be effective, the labeled dose of $PGF_{2\_}$ should be used for all TAI protocols.

Many studies have shown Ovsynch to be a highly effective and economical strategy for improving reproductive performance in high-producing lactating dairy cows (Burke et al., 1996; Pursley et al., 1997a, b; Britt and Gaska, 1998). The first studies comparing use of Ovsynch in which conception rates of lactating dairy cows managed in confinement-based dairies receiving Ovsynch were similar to that of cows receiving AI after a standing estrus (Pursley et al., 1997a,b). However, several subsequent studies have reported that Ovsynch results in lower conception rates compared with AI after estrus (Jobst et al., 2000; Stevenson et al., 1999). In addition, the effectiveness of Ovsynch for breeding lactating dairy cow managed in grazing-based dairies remains equivocal (Cordoba and Fricke, 2001, 2002). Factors explaining the variation in conception rate to TAI among herds are unknown at this time but may include the proportion of anovular cows in the herd, the follicular dynamics of individual cows within the herds, or the ability of farm personnel to implement Ovsynch in their herds.

### Presynch

Results from Vasconcelos et al. (1999) using lactating dairy cows, and those of Moreira et al. (2000a) using dairy heifers suggested that initiation of Ovsynch between days 5 to 12 of the estrous cycle may result in improved conception rate over the original Ovsynch protocol. Hormonal pesynchronization of cows to group randomly cycling cows to initiate Ovsynch between days 5 to 12 of the estrous cycle can be accomplished using two injections of PGF$_2$_ administered 14 days apart before initiation of the first GnRH injection of Ovsynch. A presynchronization strategy in which two injections of PGF$_2$_ administered 14 d apart preceded initiation of Ovsynch by 12 d has shown to improve conception rate in lactating dairy cows compared to Ovsynch (Moriera et al., 2000c). Lactating dairy cows were randomly assigned to receive Ovsynch (n=262) or Presynch (n=264) for their first postpartum TAI, which was conducted 16 h after the second GnRH injection. The first and second PGF$_2$_ injections for Presynch cows were administered at 37 and 51 days in milk, respectively, and all cows received a TAI at 73 days in milk. Conception rate increased from 29% for Ovsynch to 43% for Presynch cows. Thus, use of Presynch for programming lactating dairy cows to receive their first postpartum TAI can improve first service conception rate in a dairy herd.

A common question regarding the original Presynch data from Moriera et al. (2000c) pertains to the importance of the 12-day interval between the second PGF$_2$_ injection and the first GnRH injection. If this interval could be extended to 14 rather than 12 days, the first four injections could be scheduled to occur on the same day during successive weeks. This becomes important for compliance on dairy farms that assign groups of cows to initiate the protocol weekly so that injection schedules do not get confused among the groups. To determine if two injections of PGF$_2$_ 14 d apart administered 14 d before initiation of Ovsynch, would change follicular dynamics, ovulation rate, and conception rate in lactating dairy cows (Navanukraw et al., 2002), nonpregnant lactating Holstein cows (n=257) >60 DIM were blocked by parity and were randomly assigned to each of two groups. Cows in the first group (Ovsynch, n=128) received 50 _g GnRH (d -10); 25 mg PGF$_2$_ (d -3) and 50 _g GnRH (d -1) beginning at a random stage of the estrous cycle. Cows in the second group (Presynch, n=129) received Ovsynch but with the addition of PGF$_2$_ (25 mg) injections on d -38 and -24. All cows received TAI (d 0) 18 h after the second GnRH injection. Although the proportion of cows ovulating after the first and second GnRH injections did not differ statistically between treatments (41.1 and 69.6 vs. 35.9 and 81.1% for Ovsynch vs. Presynch, respectively; $P$=0.58 and 0.17, Chi-square test), conception rate was greater ($P$<0.08) for cows receiving Presynch vs. Ovsynch (48.1 vs. 37.5%). These data support use of this modified Presynch protocol to increase conception rate of lactating dairy cows receiving TAI, and most dairies using Presynch have incorporated this modified protocol.

### Cosynch

The term Cosynch has been used for a specific modification of Ovsynch or Presynch in which cows receive TAI immediately after administration of the second GnRH injection. Use of Cosynch allows dairy managers to restrain cows for treatment purposes one less time compared to the original Ovsynch protocol, but more important, allows for all cow-handlings to occur at the same time each day. Although this may be advantageous from a management standpoint, optimal conception rates are not achieved using Cosynch (Pursley et al., 1998). Thus dairy farmers should be aware of data that has assessed conception rates at various times in relation to the second GnRH injection of the Ovsynch protocol shown in Table 1 before making a management decision to implement Cosynch.

To assess the optimal time of AI in relation to synchronized ovulation, lactating dairy cows (n = 733) from Wisconsin dairy herds with 22,000 to 26,000 pound rolling herd averages were randomly assigned to five groups by stage of lactation and parity (Pursley et al., 1998). Ovulation was synchronized using Ovsynch, and cows received AI at 0, 8, 16, 24, or 32 hours after the second injection of GnRH. In this study, the 0 h group is equivalent to the Cosynch protocol. As determined in a preliminary study, all cows ovulate 24 to 32 hours after the second GnRH injection. Injection times were varied so that all cows were inseminated at the same time, and the inseminators were blind to treatment group. Pregnancy status was determined 25 to 35 days after AI for all groups by using transrectal ultrasonography. Conception rate and calving rate was greater ($P<0.05$) for cows in the 0, 8, 16, and 24-hour groups compared with the 32-hour group (Table 2). Pregnancy loss was less ($P<0.05$) for the 0 hour group compared with all other groups, and there was a tendency for greater pregnancy loss in the 32-hour group ($P<0.1$; Table 1). Thus, although no statistical difference in conception rate occurs when breeding from 0 to 24 hours after the second GnRH injection, breeding too late (i.e., at 32 hours) decreases conception rate.

**Table 1.** Reproductive measures in lactating dairy cows inseminated at various times in relation to ovulation synchronized with an injection of GnRH (Adapted from Purlsey et al., 1998). In this experiment, the 0 hour group is equivalent to Cosynch.

| | Hours from second GnRH injection to TAI | | | | | |
|---|---|---|---|---|---|---|
| Item | 0 | 8 | 16 | 24 | 32 | Total |
| n | 149 | 148 | 149 | 143 | 143 | 732 |
| Conception rate (%) | 37 | 41 | 45 | 41 | 32** | 39 |
| Pregnancy loss (%) | 9** | 21 | 21 | 21 | 32 | 22 |
| Calving rate (%) | 31 | 31 | 33 | 29 | 20* | 29 |

*Differs within a row ($P<0.05$).
**Differs within a row ($P<0.10$).

## New Methods for Answering the Age-Old Question: Is She "Open"?

Early identification of nonpregnant cows post breeding improves reproductive efficiency and pregnancy rate in cattle by decreasing the interval between AI services and increasing AI service rate. New technologies to identify nonpregnant animals early post AI may play a key role in a reproductive management strategy to rapidly return these animals to AI service. Some tools that have recently become available include the ECF test and use of transrectal ultrasonography.

### The Early Conception Factor (ECF) Test

Recently, a new early pregnancy test has become commercially available for use in cattle. The Early Conception Factor (ECF) test (Concepto Diagnostics, Knoxville, TN) reportedly detects a pregnancy-associated glycoprotein within 48 h of conception. Early pregnancy factor (EPF) was first identified in pregnant mice (Morton et al., 1987) and later in sheep and cattle (Nancarrow et al., 1981) by using the rosette inhibition test. Two studies have compared results from the ECF test conducted between Days 3 to 7 and Days 11 to 15 post-AI to pregnancy diagnosis using palpation per rectum and ultrasound ranging from 25 to 60 post-AI (Adams and Jardon, 1999; Des Côteaux et al., 2000). One concern with these assessments is that animals with viable embryos during early pregnancy that subsequently undergo embryonic loss before pregnancy diagnosis using palpation per rectum or transrectal ultrasonography increase the rate of false positive results and bias the assessment. The fertilization rate after AI in beef cows is 90%, whereas embryonic survival rate is 93% by Day 8 and only 56% by Day 12 post AI (Diskin and Sreenan, 1980). Similarly, only 48% of embryos recovered from dairy cows on Day 7 after AI were classified as normal (Weibold, 1988). Thus, substantial pregnancy loss likely occurred before the establishment of pregnancy status using rectal palpation or transrectal ultrasonography in these studies.

To preclude this possibility, noninseminated Holstein cows (n=9) and heifers (n=8) were evaluated as an unequivocal source of nonpregnant animals, and Holstein cows (n=17) and heifers (n=1) inseminated at estrus and in which at least one embryo of transferable quality was recovered at a nonsurgical flush 6 d after artificial insemination were evaluated as an unequivocal source of pregnant animals (Cordoba et al., 2001). Blood samples were collected from all animals 6 d after estrus, which was immediately before embryo collection in pregnant animals. Each serum sample was evaluated using two ECF test cassettes (Test 1 and 2), and the result of each test cassette was interpreted by two independent readers (Reader 1 and 2). Results are shown in Table 2. Test sensitivity, specificity, positive predictive value, negative predictive value, and accuracy were 86%, 4%, 49%, 23%, and 46%, respectively. Although the observed agreement between readers (91% for Test 1; 89% for Test 2) and between tests for the same serum sample (94% for Reader 1; 91% for Reader 2) was high, the overall rates of false positive and false negative ECF test results were 96% and 14%, respectively.

**Table 2.** Early Conception Factor (ECF) test results for blood sera collected from pregnant and nonpregnant dairy cattle on Day 6 after estrus[1] (Adapted from Cordoba et al., 2001)

| | | | Pregnancy status[2] | |
|---|---|---|---|---|
| Test | Reader | ECF test result | Pregnant | Nonpregnant |
| 1 | 1 | Pregnant (+) | 16 | 16 |
| | | Nonpregnant (-) | 2 | 1 |
| 1 | 2 | Pregnant (+) | 14 | 17 |
| | | Nonpregnant (-) | 4 | 0 |
| 2 | 1 | Pregnant (+) | 17 | 17 |
| | | Nonpregnant (-) | 1 | 0 |
| 2 | 2 | Pregnant (+) | 15 | 15 |
| | | Nonpregnant (-) | 3 | 2 |

[1]Serum samples from pregnant (n=18) and nonpregnant (n=17) dairy cattle were evaluated using two ECF test cassettes (Test 1 and 2) and the result of each test was interpreted by two independent readers (Reader 1 and 2).

[2]For pregnant dairy cattle, sera were collected on Day 6 after estrus and immediately before collecting embryos from Holstein cows (n=17) and heifers (n=1) inseminated after a detected estrus and in which at least 1 embryo of excellent, good, or fair quality was recovered at a nonsurgical flush 6 d after AI; for nonpregnant dairy cattle, sera were collected on Day 6 after estrus from noninseminated Holstein cows (n=9) and heifers (n=8).

Results from our experiment show that the ECF test, in its present form, is an unreliable method for determining pregnancy status on Day 6 after estrus in dairy cattle. The predictive value of a negative ECF test result would be less than 50% (i.e., no better than a guess) in dairy herds exhibiting a conception rate greater than 25%. Dairy producers who choose to use this commercially available ECF test as a tool for early detection of nonpregnant dairy cattle can expect a high rate of embryonic loss when administering $PGF_{2\_}$ to animals based on a negative ECF test result.

### Transrectal Ultrasonography

The use of transrectal ultrasonography to assess pregnancy status early during gestation is among the most practical applications of ultrasound for dairy cattle reproduction. Pregnancy diagnosis in dairy heifers based on the presence of intraluminal uterine fluid before Day 16 is unreliable because small amounts of fluid are present in non-inseminated heifers as early as Day 10; however, accuracy of diagnosis based on fluid alone approached 100% by Day 20. The accuracy of pregnancy diagnosis in dairy heifers was not greater than 50% before Day 18 using a 5.0 MHz transducer, or before Day 16 using a 7.5 MHz transducer (Kastelic et al., 1991).

Under most on-farm conditions, pregnancy diagnosis can be rapidly and accurately diagnosed using ultrasound as early as 26 d post AI (Filteau and DesCôteaux, 1998; Kastelic et al., 1991). Sensitivity and specificity of pregnancy diagnosis using ultrasound was 44.8% and 82.3%, respectively, when conducted between 21 and 25 d post AI but increased to 97.7% and 87.7%, respectively, when conducted between 26 and 33 d post AI (Pieterse et al., 1990a). Although pregnancy status can be established early, care must be taken to ensure the accuracy of a diagnosis. For example, a false negative diagnosis was more likely when the uterus was located cranial to the pelvic inlet in beef cattle than when the uterus was within the pelvic cavity (Szenci et al., 1995).

Ultrasound is a rapid method for pregnancy diagnosis, and experienced palpators adapt to ultrasound technology quickly. The time required to assess pregnancy in beef heifers at the end of a 108-day breeding season averaged 11.3 seconds using palpation per rectum versus 16.1 seconds required to assess pregnancy and fetal age using ultrasound (Galland et al., 1994). Fetal age also affected time required for diagnosis with older fetuses requiring less total time for diagnosis (Galland et al., 1994). Although ultrasound at ≥ 45 d of gestation did not increase accuracy of pregnancy diagnosis for an experienced palpator, it may improve diagnostic accuracy of a less experienced one (Galland et al., 1994). Generally, two factors affect the speed at which ultrasound examinations can be conducted on a dairy farm: operator proficiency and availability and restraint of animals. When both factors are optimized, the speed of ultrasonography can approach that of palpation while exceeding palpation in the amount of information gathered from each animal.

## Early Embryonic Loss in Lactating Dairy Cows

Pregnancy loss contributes to reproductive inefficiency because fertility assessed at any point during pregnancy is a function of both conception rate and pregnancy loss. Conception rates at 28 to 32 d post-AI in lactating dairy cows range from 40 to 47% (Fricke et al., 1998; Pursley et al, 1997b), whereas conception rates in dairy heifers are nearly 75% (Pursley et al., 1997b). Similarly, pregnancy loss in lactating dairy cows is greater than that in dairy heifers (20% vs. 5%; Smith and Stevenson, 1995). Although the specific factors responsible for early embryonic loss in dairy cows are not known, they may be similar to those factors responsible for reduced conception rates.

Because pregnancy status can be determined earlier using ultrasound compared with palpation, the rate of pregnancy loss detected is often higher when a positive diagnosis is made earlier post breeding. Of cows diagnosed pregnant at 28 d post AI, 10 to 16% experience early embryonic loss by 56 d post AI (Fricke et al., 1998; Mee et al., 1994; Vasconcelos et al., 1997). Therefore, cows diagnosed pregnant at 28 d post AI using ultrasound should be scheduled for a subsequent examination around 60 d post AI, when the rate of embryonic loss per day decreases dramatically (Vasconcelos et al., 1997). Although the rate of pregnancy loss is significant in studies using ultrasound to assess the rate of loss, the technique of ultrasound itself has not been implicated as a cause of embryonic death in cattle (Ball and Logue, 1994; Baxter and Ward, 1997). Furthermore, ultrasound is a much less invasive technique for early pregnancy diagnosis than is rectal palpation (Paisley et al., 1978; Vaillancourt et al., 1979) and may minimize the rare incidence of palpation-induced abortions.

At present, there is no practical way to reduce early embryonic loss in lactating dairy cows. However, recognizing the occurrence and magnitude of early embryonic loss may actually present management opportunities by taking advantage of new reproductive technologies that increase AI service rate in a dairy herd. If used routinely, transrectal ultrasonography has the potential to improve reproductive efficiency within a herd by reducing the period from AI to pregnancy diagnosis to 26 to 28 d with a high degree of diagnostic accuracy (Pieterse et al., 1990a). Early pregnancy diagnosis, however, can only improve reproductive efficiency when a nonpregnancy diagnosis is coupled with a management strategy to rapidly return cows to AI service, and such strategies have not yet been empirically tested for their effects on conception rate. In addition, cows diagnosed pregnant at an early ultrasound exam have a greater risk of early embryonic loss and, therefore, must undergo subsequent pregnancy examinations to identify and rebreed cows that experience such loss. If left unidentified, cows experiencing embryonic loss after an early pregnancy diagnosis would actually reduce reproductive efficiency by extending their calving interval. This concept applies not only to ultrasound, but also to any method used to assess pregnancy status early post breeding.

### Programming First and Second AI Service: Presynch and Resynch

Timely rebreeding of lactating dairy cows that fail to conceive to first AI service is essential for improving reproductive efficiency and profitability in a dairy herd. Because AI conception rates of high producing lactating dairy cows are reported to be 40% or less (Pursley et al., 1997a; Fricke et al., 1998), 60% or more of lactating cows will fail to conceive to a given AI service. Now that it is relatively easy to program cows for first postpartum AI service, many producers are asking how best to identify nonpregnant cows and program them for second AI service.

We recently conducted a field trial to answer this question (Fricke and Welle, unpublished data). Our objective was to compare conception rate to first TAI service after a modified Presynch protocol with conception rates after resynchronization of ovulation using Ovsynch at three intervals post TAI (Resynch). Lactating dairy cows (n =711) on a commercial dairy farm in North-central Wisconsin were enrolled into this study on a weekly basis beginning on May 10, 2001 and ending on May 30, 2002. All cows received a modified Presynch protocol to receive first postpartum TAI as follows: 25 mg $PGF_2$_ (d 18 ± 3; d 32 ± 3; d 46 ± 3); 50 _g GnRH (d 60 ± 3); 25 mg $PGF_2$_ (d 67 ± 3) and 50 _g GnRH (d 69 ± 3) postpartum. All cows received TAI immediately after the second GnRH injection of the Presynch protocol (d 0) as per a Cosynch TAI schedule. At first TAI, cows were randomly assigned to each of three treatment groups for resynchronization of ovulation (Resynch) using Ovsynch [50 _g GnRH (d -9); 25 mg $PGF_2$_ (d -2) and 50 _g GnRH + TAI (d -0)] to induce a second TAI for cows failing to conceive to first TAI service. All cows (n=235) in the first group (Day 19) received a GnRH injection on d 19 post TAI and continued the Ovsynch protocol if diagnosed nonpregnant using transrectal ultrasound on d 26 post TAI. Cows (n=240) in the second (Day 26) and cows (n=236) in the third (Day 33) groups initiated the Ovsynch protocol if diagnosed nonpregnant using transrectal ultrasound on d 26 post-TAI or d 33 post-TAI, respectively. Preliminary results from this study are shown in Table 3.

**Table 3.** Conception rate to first timed artificial insemination (Presynch), second timed artificial insemination (Resynch), and pregnancy loss for cows conceiving to Presynch (Fricke and Welle, unpublished).

| Treatment group | Conception rate (%) Presynch TAI | Conception rate (%) Resynch TAI | Pregnancy loss[1] (%) |
|---|---|---|---|
| Day 19 | 46.0[a] | 23.3[a] | 27.8[a] |
| Day 26 | 42.1[a] | 33.9[b] | 27.7[a] |
| Day 33 | 32.6[b] | 37.8[b] | 11.7[b] |
| Overall | 40.2 | 32.0 | 23.4 |

[a,b]Within a column, percentages with different superscripts differ ($P$<0.01).

[1]Cows conceiving to Presynch TAI that subsequently were diagnosed nonpregnant at pregnancy recheck.

Differences in conception rate to the Presynch TAI and pregnancy loss can be accounted for because the pregnancy check was conducted 26 d post TAI for the Day 19 and Day 26 groups, whereas the pregnancy check for the Day 33 group was conducted on 33 d post TAI. Most important, the Day 19 group had a lower conception rate to Resynch than did the Day 26 and Day 33 treatment groups. Based on this preliminary data, the Day 19 scheme should not be used to resynchronize cows for second service, whereas the Day 26 and 33 groups resulted in similar conception rates to Resynch.

## Conclusion

Currently, use of controlled breeding protocols for initiating first postpartum AI service and use of transrectal ultrasound for determining nonpregnancy early post breeding are proven methods for improving dairy cattle reproduction. The ECF test, in its present form, is an unreliable method for determining pregnancy status on Day 6 after estrus in dairy cattle. The predictive value of a negative ECF test result would be less than 50% (i.e., no better than a guess) in dairy herds exhibiting a conception rate greater than 25%. Future research will lead to new and improved methods for assessing pregnancy status early post breeding and resynchronizing cows for second and subsequent AI services.

## References


Adams, C. S., and P. W. Jardon. 1999. Evaluation of the early conception factor tests in cows 3-7 days post-breeding. Proc. Am. Assoc. Bov. Pract. 32: 240-241.

Ball, P. J. H., and D. D. N. Logue. 1994. Ultrasound diagnosis of pregnancy in cattle. Vet. Rec. 134:532.

Baxter, S. J., and W. R. Ward. 1997. Incidence of fetal loss in dairy cattle after pregnancy diagnosis using an ultrasound scanner. Vet. Rec. 140:287-288.

Britt, J. S., and J. Gaska. 1998. Comparison of two estrus synchronization programs in a large, confinement-housed dairy herd. JAVMA 212:210-212.

Burke, J. M., R. L. de la Sota, C. A. Risco, C. R. Staples, E. J. P. Schmitt, and W. W. Thatcher. 1996. Evaluation of timed insemination using a gonadotropin-releasing hormone agonist in lactating dairy cows. J. Dairy Sci. 79:1385-1393.

Cordoba, M. C., R. Sartori, and P. M. Fricke. 2001. Assessment of a commercially available Early Conception Factor (ECF) test for determining pregnancy status of dairy cattle. J. Dairy Sci. 84:1884-1889.

Cordoba, M. C. and P. M. Fricke. 2001. Evaluation of two hormonal protocols for synchronization of ovulation and timed artificial insemination in dairy cows managed in grazing-based dairies. J. Dairy Sci. 84:2700-2708.

Cordoba, M. C. and P. M. Fricke. 2002. Initiation of the breeding season in a grazing-based dairy using synchronization of ovulation. J. Dairy Sci. 85:1752-1763.

Des Côteaux, L., P. D. Carrière, and M. Bigras-Poulin. 2000. Evaluation of the Early Conception Factor (ECF) dipstick test in dairy cows between days 11 and 15 post-breeding. Bov. Pract. 34:87-91.
Diskin, M. G. and J. M. Sreenan. 1980. Fertilization and embryonic mortality rates in beef heifers after artificial insemination. J. Reprod. Fert. 59:463-468.
Filteau, V., and L. DesCôteaux. 1998. Predictive values of early pregnancy diagnosis by ultrasonography in dairy cattle. Proc. AABP Annu. Mtg., Spokane, WA, Vol. 31:170-171.
Foote R. H. 1975. Estrus detection and estrus detection aids. J. Dairy Sci. 58:248-256.
Fricke, P. M. and M. L. Welle. Resynchronization of ovulation using Ovsynch to induce second timed artificial insemination service in lactating dairy cows. Unpublished.
Fricke, P. M. 2002. Scanning the future – Ultrasonography as a reproductive management tool for dairy cattle. J. Dairy Sci. 85:1918-1926.
Fricke, P. M., J. N. Guenther, and M. C. Wiltbank. 1998. Efficacy of decreasing the dose of GnRH used in a protocol for synchronization of ovulation and timed AI in lactating dairy cows. Theriogenology 50:1275-1284.
Galland, J. C., L. A. Offenbach, and M. F. Spire. 1994. Measuring the time needed to confirm fetal age in beef heifers using ultrasonographic examination. Vet. Med. 89:795-804.
Jobst, S. M., R. L. Nebel, M. L. McGilliard, and K. D. Pelzer. 2000. Evaluation of reproductive performance in lactating dairy cows with prostaglandin $F_2$_, gonadotropin-releasing hormone, and timed artificial insemination. J. Dairy Sci. 83:2366-2372.
Kastelic, J. P., D. R. Bergfelt, and O. J. Ginther OJ. 1991. Ultrasonic detection of the conceptus and characterization of intrauterine fluid on days 10 to 22 in heifers. Theriogenology 35:569-581.
Mee, J. F., D. P. Ryan, and T. Condon. 1994. Ultrasound diagnosis of pregnancy in cattle. Vet. Rec. 134:532.
Moreira, F., R. L. de la Sota, T. Diaz, and W. W. Thatcher. 2000a. Effect of day of the estrous cycle at the initiation of a timed artificial insemination protocol on reproductive responses in dairy heifers. J. Anim. Sci. 78:1568-1576.
Moreira, F., C. A. Risco, M. F. A. Pires, J. D. Ambrose, M. Drost, and W. W. Thatcher. 2000b. Use of bovine somatotropin in lactating dairy cows receiving timed artificial insemination. J. Dairy Sci. 83:1237-1247.
Moriera, F., C. Orlandi, C. Risco, F. Lopes, R. Mattos, and W. W. Thatcher. 2000c. Pregnancy rates to a timed insemination in lactating dairy cows pre-synchronized and treated with bovine somatotropin: cyclic versus anestrus cows. J. Dairy Sci. 83(Suppl 1):134 (Abstr.).
Morton, H., B. E. Rolfe, and A. C. Cavanagh. 1987. Ovum factor and early pregnancy factor. Curr. Topics Dev. Biol. 23:73-92.
Nancarrow, C. D, A. L. C. Wallace, and A. S. Grewal. 1981. The early pregnancy factor of sheep and cattle. J. Reprod. Fert. (Suppl.) 30:191-199.
Navanukraw, C., L. P. Reynolds, A.T. Grazul-Bilska, D. A. Redmer, and P.M. Fricke. 2002. Effect of presynchronization on pregnancy rate to a timed artificial insemination protocol in lactating dairy cows. J. Dairy Sci. 85(Suppl. 1):263.
Paisley, L. G., W. D. Mickelsen, and O. L. Frost. 1978. A survey of the incidence of prenatal mortality in cattle following pregnancy diagnosis by rectal palpation. Theriogenology 9:481-489.
Pieterse, M. C., O. Szenci, A. H. Willemse, C. S. A. Bajcsy, S. J. Dieleman, and M. A. M. Taverne. 1990a. Early pregnancy diagnosis in cattle by means of linear-array real-time ultrasound scanning of the uterus and a qualitative and quantitative milk progesterone test. Theiogenology 33:697-707.
Pursley, J. R., M. O. Mee, and M. C. Wiltbank. 1995. Synchronization of ovulation in dairy cows using $PGF_2$_ and GnRH. Theriogenology 44:915-923.
Pursley, J. R., M. R. Kosorok, and M. C. Wiltbank. 1997a. Reproductive management of lactating dairy cows using synchronization of ovulation. J. Dairy Sci. 80:301-306.

Pursley, J. R., M. C. Wiltbank, J. S. Stevenson, J. S. Ottobre, H. A. Garverick, and L. L. Anderson. 1997b. Pregnancy rates per artificial insemination for cows and heifers inseminated at a synchronized ovulation or synchronized estrus. J. Dairy Sci. 80:295-300.
Pursley, J. R., R. W. Silcox, and M. C. Wiltbank. 1998. Effect of time of artificial insemination on pregnancy rates, calving rates, pregnancy loss, and gender ratio after synchronization of ovulation in lactating dairy cows. J. Dairy Sci. 81:2139-2144.
Pursley, J. R., P. M. Fricke, H. A. Garverick, D. J. Kesler, J. S. Ottobre, J. S. Stevenson, and M. C. Wiltbank. 2001. NC-113 Regional Research Project. Improved fertility in anovulatory lactating dairy cows treated with exogenous progesterone during Ovsynch. J. Dairy Sci. (Midwest Branch ADSA Meetings, Des Moines, IA, Abstract 251 p. 63).
Szenci, O., G. Gyulai, P. Nagy, L. Kovacs, J. Varga, and M. A. M. Taverne. 1995. Effect of uterus position relative the pelvic inlet on the accuracy of early bovine pregnancy diagnosis by means of ultrasonography. Vet. Quarterly 17:37-39.
Senger, P. L. 1994. The estrus detection problem: new concepts, technologies, and possibilities. J. Dairy Sci. 77:2745-2753.
Smith, M. W., and J. S. Stevenson. 1995. Fate of the dominant follicle, embryonal survival, and pregnancy rates in dairy cattle treated with prostaglandin F2_ and progestins in the absence or presence of a functional corpus luteum. J. Anim. Sci. 73:3743-3751.
Spalding, R. W., R. W. Everett, and R. H. Foote. 1974. Fertility in New York artificially inseminated Holstein herds in dairy herd improvement. J. Dairy Sci. 58:718-723.
Stevenson, J. S., and E. P. Call. 1983. Influence of early estrus, ovulation, and insemination on fertility in postpartum Holstein cows. Theriogenology 19:367-375.
Stevenson, J. S., Y. Kobayashi, and K. E. Thompson. 1999. Reproductive performance of dairy cows in various programmed breeding systems including OvSynch and combinations of gonadotropin-releasing hormone and prostaglandin $F_{2\_}$. J. Dairy Sci. 82:506-515.
Vaillancourt, D., C. J. Vierschwal, D. Ogwu, R. G. Elmore, C. E. Martin, A. J. Sharp, and R. S. Youngquist. 1979. Correlation between pregnancy diagnosis by membrane slip and embryonic mortality. J. Am. Vet. Med. Assoc. 175:466.
Vasconcelos, J. L. M., R. W. Silcox, J. A. Lacerda, J. R. Pursley, and M. C. Wiltbank. 1997. Pregnancy rate, pregnancy loss, and response to heat stress after AI at two different times from ovulation in dairy cows. Biol. Reprod. 56(Suppl 1):140 (Abstr.).
Vasconcelos, J. L. M., R. W. Silcox, G. J. Rosa, J. R. Pursley, and M. C. Wiltbank. 1999. Synchronization rate, size of the ovulatory follicle, and pregnancy rate after synchronization of ovulation beginning on different days of the estrous cycle in lactating dairy cows. Theriogenology 52:1067-1078.
Weibold, J. L. 1988. Embryonic mortality and the uterine environment in first-service lactating dairy cows. J. Reprod. Fert. 84:393-395.

# Fertility Factors– Which Ones are Really Important?

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## Introduction

The goal of every dairy management team should be to maximize the efficiency of high producing dairy cows so that profitability will increase. The standards which define a high producing dairy cow will move upward as long as genetic progress continues to be made, management priority is placed on cow comfort and improving milk yield, nutrition is improved and new technology is developed and implemented.

Historically, dairy management teams, veterinarians and dairy scientists have promoted the concept that high milk production is related to cow stress, reduced cow health and poor reproduction. In fact, this notion started well before the use of AI, sire proving and rbST. For example, Hansen (31) reported the following quote from a Minnesota dairy bulletin published in 1929.

> *"In recent years the opinion has been held by a large number of dairymen that difficulties with breeding accompany high milk production. Dairymen have had the impression that difficulties with breeding have increased in recent years. As the level of production has also increased during the same interval, the conclusion has been drawn that the two bear the relation of cause and effect." (Eckles, 1929).*

From this historical perspective, it should be clear that modern genetic selection, nutrition and technology cannot be considered unique in receiving all of the blame for sub-optimal reproductive performance. From a physiologic standpoint, it is simply hard to imagine that we are selecting for higher and higher milk yields and susceptibility to higher and higher stress levels at the same time. Stress is generally a cause of poor production **NOT** the result of high production.

The goal of this paper is to present a reasonable case that successful reproductive management in high producing cows can be realized best by focusing on the right factors; the ones that impact fertility the most. This paper will not provide specific programs or recommendations for improvements. These are available from numerous other sources and specific programs must be custom-designed for each herd.

**Reproductive management is not easy**, regardless of whether cows are producing high or low quantities of milk!! It is complicated by numerous factors (we shall call them *Fertility Factors*), which may or may not be related. A list of *Fertility Factors* is presented below without regard to their relative importance to overall reproductive performance of the cow.

- Age of the Cow (Parity)
- Breed of Cow
- Calving Difficulty (dystocia)
- Environment – heat stress and footing
- Embryonic Death
- Estrous Detection Efficiency
- Estrous Detection Errors
- Fertility of the AI Bull
- Genetic Selection –(possible inbreeding)
- Inseminator Skill
- Milk Yield of the Cow
- Cystic Ovarian Disease
- Transition Cow Nutrition
- Reproductive Diseases (vaccinations)
- Retained Placenta
- Storage and Handling of Frozen Semen
- Uterine Infection
- Twinning

It should be emphasized that no other component of the dairy enterprise has this many variables to manage. Management of the above *Fertility Factors* can be overwhelming for the veterinarian, reproductive manager, workers and the overall dairy herd organization because on a whole herd basis they are “happening-all-at-once”, especially in large herds. For example, some cows are calving today, others are beginning to cycle, others are “ready to breed”, others are on the “preg check list” and still others need to be treated for something. All the *Fertility Factors* exert themselves in a constant mix of challenges that require a huge variety of management skill. This is further confounded by the fact that other management challenges, such as milk quality and cow comfort, are impacting herd performance at the same time.

Because of obvious economic incentives, management energy is almost always focused on high milk yield. These economic incentives far outweigh the incentives for reproductive management. For example, the results of changing nutrition (or giving bST) to improve milk yield can be observed almost immediately after the management change. However, the results of changing a heat detection program take weeks or months to see. Further, the effect and the financial gains with improved reproduction are often difficult to assess because they represent lost opportunities and are not directly “out-of-pocket.”

Given these inherent issues, there needs to be a model that partitions the many *Fertility Factors* into groups that reflect the relative effectiveness of management control points. For example, some *Fertility Factors* are easily controlled and others simply cannot be controlled no matter what the management team does. Often management teams place emphasis on *Fertility Factors* that cannot be controlled rather than focusing on *Fertility Factors* that can be significantly altered to improve reproduction. For example, management energy devoted to solving cystic ovaries may be better spent on improving heat detection efficiency and accuracy. Placing management emphasis on *Fertility Factors* that cannot be easily controlled insures management failure and frustration. This often causes something else to receive the blame, and blame often falls on high production. It would be inappropriate to consider that we might improve reproductive management by lowering milk yield.

In order to determine which *Fertility Factors* should receive the most management attention, we must first answer the following question: **Which *Fertility Factors* have the most influence and which can be managed so that positive change can be realized?** For example, if estrous detection efficiency is only 35%, there is huge opportunity for improvement. In contrast, if only 6% of the herd has cystic ovaries, there is not much room for improvement. Put quite simply, some *Fertility Factors* have a high probability for improvement and others do not. As in this example, management usually has the opportunity to improve estrous detection efficiency and accuracy but can have little effect on the incidence of cystic ovaries.

## Organizing the *Fertility Factors*

One way of organizing the *Fertility Factors* is with regard to who or what controls them. For example, we can subdivide the above list of *Fertility Factors* into three groups that reflect their primary control. These categories include *Fertility Factors*:

- **I. Controlled by man**
- **II. Controlled by the reproductive system of the cow**
- **III. Natural to any herd or cow**

Among these three categories, the most control can be exerted by those under the direct influence of man and the least control is exerted on *Fertility Factors* natural to any herd. *Fertility Factors* controlled by the reproductive system of the cow are intermediate and are moderately difficult to control. Figure 1 illustrates this method of organizing the many *Fertility Factors*.

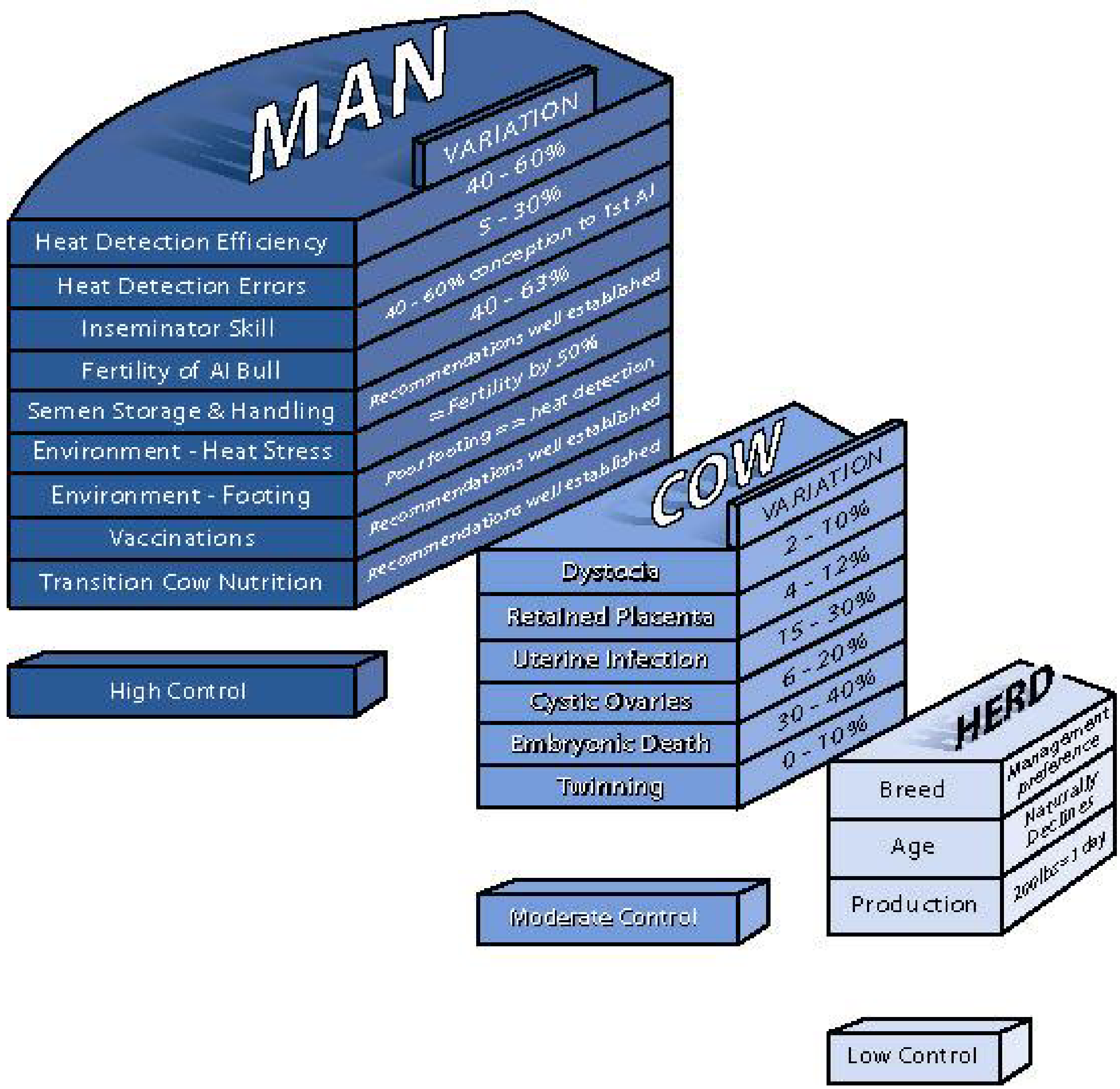


Figure 1. *Fertility Factors* are organized according to who/what controls them. High control can be exerted on factors that the management team can have a major influence on (MAN). Moderate control can be exerted on *Fertility Factors* under the influence of the reproductive tract of the cow (COW). Certain *Fertility Factors* are almost beyond management's control because they are natural (intrinsic) to every herd (HERD).

## I. *Fertility Factors* Controlled by Man

The *Fertility Factors* in the box below are almost totally controlled by the individuals performing a task or making a decision (assuming that a cow is healthy and functioning normally). Major improvements in reproduction can be made by managing each of these factors well. Each *Fertility Factor* is followed by an expected range derived from the scientific literature. Each of these *Fertility Factors* will be discussed briefly in the sections subsequent to the boxes.

**_Fertility Factors_ Controlled by Man**

| *Fertility Factor* | Expected Range |
| --- | --- |
| • Heat detection efficiency | 40-60% |
| • Heat detection errors | 5-30% |
| • Inseminator skill | 40%- 63% conception to first AI |
| • Fertility of the AI bull | 45% - 60% conception to first AI |
| • Storage and handling | adequate if recommendations of the frozen semen are followed |
| • Environment - heat stress and footing | 50% reduction in fertility |
| • Vaccinations | adequate if appropriate vaccination program is consistently maintained |
| • Transition cow nutrition | adequate if recommendations for lactating cow and dry cow nutrition are followed |

**Estrous Detection Efficiency**

Estrous detection efficiency is defined as the percentage of cows displaying estrus that are identified as being in heat. For example, if 100 cows are cycling normally and only 50% of these cows are detected in heat, the estrous detection efficiency is 50%. It is generally agreed that estrous detection efficiency in most dairy herds is less than 50% (3,7,22,37).

Estrous detection efficiency is almost totally controlled by the estrous detection program designed by the management team. Too often, estrous detection is performed “on-the-fly” (detection of estrous while performing other tasks). This is a problem because generally cows do not display a high degree of standing and mounting behavior when they are eating, resting or being milked. Also, crowded conditions in alleys and the milking parlor entrance cause errors in cow identification if mounting behavior occurs in these areas. Too often, dedicated estrous detection techniques (such as planned focused observation, chalking of tailheads, use of pedometers and electronic pressure sensors) are not used. Kinsel and Etherington (39) reported that estrous detection management accounted for the greatest use of prostaglandin in 45 dairy herds (10,742 lactations) in Ontario, Canada. Use of prostaglandin was not associated with significant improvements in reproductive performance. The researchers further reported that a 1% increase in estrous detection efficiency resulted in a .5-day decrease in days open. Therefore, a 20% improvement in estrous detection efficiency would reduce days open by 10 days. Of the variables they examined, estrous detection rate and conception rate were the dominant factors influencing days open. It should be emphasized that estrous detection efficiency is under the total control of the management team and significant improvements in overall herd reproductive performance can be achieved if estrous detection is improved. Programs designed to focus exclusively on detecting estrus must be implemented or replaced with effective timed insemination programs if this *Fertility Factor* is to be improved.

**The Take-Home Message**

- Less than 50% of heats are detected in most herds.
- Many estrous detection programs lack structure and focus and can be significantly improved.
- Implementing techniques such as "chalking" tail heads, timed AI programs or focused intense observation periods can significantly improve estrous detection.
- For most herds, improving estrous detection efficiency is the most important impactor of overall reproductive performance.

**Estrous Detection Errors**

Estrous detection errors are defined as the proportion of cows that are inseminated that are not in estrus. Research using milk and blood progesterone analysis has shown that between 5% - 30% of all inseminations take place in **cows that are not in heat**. (2,57,58). Estrous detection errors are brought about by identifying cows based on secondary signs of estrus rather than standing-to-be-mounted. Also, poor cow identification results in confusion on the part of the person identifying animals in heat and thus the "wrong cow" may be presented for insemination. Financial incentives paid to workers may promote errors, because there is a financial bias on the part of workers to submit cows for insemination that are not in heat.

Costs of heat detection errors may be large because cows are often inseminated during the luteal phase of the cycle when the reproductive tract is susceptible to uterine infection. Errors also result in wasted semen and wasted labor. Furthermore, they create record-keeping errors, via incorrect heat dates that further confuse the management team when trying to predict future heats or breeding dates or the timing pregnancy diagnosis.

Determination of the estrous detection error rate in a herd requires the use of a milk or blood progesterone assay at the time of breeding. Cows that have high progesterone at the time of insemination are not in estrus and represent an error. Every herd should periodically use progesterone tests at the time of insemination to monitor estrous detection error rate.

**The Take-Home Message**

- 5-30% of cows inseminated are not in heat!!!
- Errors can be monitored by conducting routine milk progesterone assays.
- The goal for estrous detection error rate should be less than 2% in any herd.

Efficiency and accuracy of estrous detection can almost always be improved if the management team implements focused, well-defined programs. A 20% improvement of estrous detection efficiency can result in a 4 to 1 return on investment (47). Estrous detection errors can be corrected by reviewing the primary and secondary signs of estrus with the labor team and insisting that only cows that stand to be mounted be presented for artificial insemination. The error rate goal should always be less than 2%. The principles and techniques for estrous detection programs have been reviewed extensively by O'Connor and Senger (46).

As individual dairy herds continue to increase in size, the problem of poor estrous detection efficiency and accuracy could be amplified because manpower input per cow often decreases.

## Environment – Heat Stress and Footing

### Heat Stress

The single most important environmental factor impacting reproductive performance is heat stress. A significant portion of the USA is confronted by seasonal heat stress which manifests itself in the following ways: 1) increased embryonic death; 2) decreased length of estrus; 3) decreased number of mounts per estrus period; and 4) decreased conception rate (31). Cooling cows during periods of heat stress improves conception rates (59, 60, 51, 63). Methods of managing heat stress are almost totally under the control of the management team. For example, decisions regarding improved ventilation, misting, shade, etc. are made exclusively by the management team.

### Footing

Estrous behavior is dramatically affected by the composition of the footing surface on which cows interact. Cows that interacted on a dirt surface had a more sustained estrus period (13.8 hr) than cows that interacted on a grooved concrete surface (9.4 hr) (9). Further, cows on dirt displayed over twice the number of stands (6.3 vs. 2.9) and mounts (7.0 vs. 3.2) during the observation period when compared to cows on concrete (9). There is little doubt that dirt surfaces provide more secure footing during mounting. While no data exists, there is probably a strong relationship between cow comfort and the composition of the surface on which cows move and interact. It should be emphasized that slippery concrete is a major factor influencing poor estrous behavior (standing and mounting) and cow safety and comfort. Scoring slippery concrete can have profound positive effects on estrous detection.

One problem accompanying a dirt surface for cow interaction is mud. Mud creates a host of problems including difficult mobility, poor mounting, poor foot health, injury and poor udder hygiene. Further, mud on the udder can dramatically increase udder and teat washing time. Mud undoubtedly reduces cow comfort, increases stress and compromises all aspects of production efficiency (including reducing worker comfort and efficiency). Steps should be taken to eliminate exposure to mud.

**The Take-Home Message**

- A heat abatement system (including adequate water supply, air exchange and evaporative cooling and shade) is a must for improving reproduction under heat stress conditions.
- Dirt footing enhances estrous behavior
- Mud should be eliminated from the dairy management environment

### Skill of the Inseminator

Many management teams erroneously assume that any person can artificially inseminate cows with a high degree of success. Thus, good AI technique is often overlooked as a crucial *Fertility Factor*. Research has clearly shown that skill of the artificial inseminator is a significant factor influencing fertility in dairy cattle (27, 48). Successful deposition of semen in the appropriate location of the cow's reproductive tract has been shown to be a major problem associated with insemination technique. (14, 27, 38, 43, 48, 62) In a carefully designed experiment comparing professional AI technicians with herdsman-inseminators, Peters, et al (48) demonstrated, using radiographic evaluation of insemination attempts, that only 39% of insemination pipette placement attempts were located in the desired anatomical location (the uterine body). In contrast, 25% were located in the cervix and 36% were located in the lumen of one uterine horn. Thus, 61% of placement attempts were erroneous when the uterine body was considered the target. Surprisingly, professional inseminators had error rates similar to herdsman-inseminators. In a field study (56) involving a total of 2,820 first services in four commercial Washington dairy herds utilizing a total of 11 herdsman-inseminators, the most skilled inseminator achieved 62.7% conception to first service while the least skilled inseminator in the study achieved only 40.1% first service conception. The within herd variation ranged from 7% to 10% among inseminators. In this study (56), data were statistically corrected for age of cow and level of production. Therefore, all technicians were statistically competing in cows of similar milk production levels. These data clearly demonstrate that there is a significant variation among inseminators.

The management team can keep accurate records and evaluate, on a continual basis, the conception rate of each inseminator within the herd and make changes or retrain inseminators when the data indicate such action is needed. Periodic review/retraining (at least every year) of inseminator technique will keep inseminators aware of the importance of placing the semen in the uterus and **NOT** the cervix. When semen is deposited in the cervix there is twice the retrograde loss of semen as when compared to deposition in the horns or the body of the uterus (25). Pregnancy failures are more likely with cervical deposition than with uterine deposition of semen.

**The Take-Home Message**

- There is 15-20% difference in 1st service conception rates among inseminators.
- Semen must be placed in the uterus to optimize conception.
- Routine review and retraining of inseminators can improve conception.

**Fertility of AI Bull**

Since the introduction of herdsman-insemination (herdsman performing the insemination technique) over 30 years ago, the use of non-return techniques for evaluating bull fertility (as well as AI technician performance) has been lost. It has always been known, that there is a significant fertility difference among AI bulls. Senger, et al, (56) have shown that there is about a 10-15-percentage point difference between the highest fertility bulls and the lowest fertility bulls when measured using palpated pregnancy to determine percent conception to first service. Also, Davidson and Farver (15) reported a range in percentage conception among AI bulls of 35% to 70%. Using heterospermic insemination techniques, differences in fertility among bulls were also shown (52). It should be emphasized that this difference is not due to over dilution of semen by the AI organizations. Extension rates used for frozen semen are well above the threshold for optimum fertility. The Dairy Records Management System (DRMS) at N.C. State University has developed the "Estimated Relative Conception Rate" based on large numbers of AI services in dairy cattle throughout the U.S.A. This approach has enabled producers to identify (and eliminate from use) the lowest fertility bulls. By selecting AI bulls, which are in the high fertility group, reproductive managers can maximize their chance of achieving pregnancy in dairy cows. Unfortunately, the pricing structure used by the artificial insemination industry does not penalize or reward a bull for low or high fertility. Therefore, the incentive for bull selection (and semen pricing) is based totally upon the genetic potential for milk yield, milk components, functional type and supply/demand. There is an urgent need to provide producers with accurate data about the relative fertility differences among bulls. If such information were available, then management teams could select high fertility bulls to improve their probability of success.

### The Take-Home Message

- All bulls are not created equal. Their fertility differs (by 15% or more).
- AI organizations **DO NOT** over dilute ("water-down") semen.
- Reproductive managers need access to accurate bull fertility data. Fertility estimates should be a mandatory part of the sire summaries in the future.

**Storage and Handling of Frozen Semen**

Recommendations for thawing and handling of frozen bull semen have been carefully researched and documented during the past 20 years (55). There is NO doubt that the recommendation for warm-water thawing (95° F or 35° C for 30-60 seconds) in French straws is appropriate. Prevention of post-thaw cold shock should be accomplished by wrapping the inseminating syringe with a warm clean paper towel and placing it inside the outer garment. Management of on-the-farm liquid nitrogen refrigerators has been well described. Research evaluating the possible damage to frozen semen stored in on-the-farm liquid nitrogen (LN) refrigerators clearly indicates that there is little risk associated with the potential for damage to semen stored in on-the-farm tanks (54). Regardless, periodic reviews of the principles and methods for handling semen should be done. It should be emphasized that failure of the LN refrigerator usually results in complete loss of sperm fertility and thus cow fertility will be zero unless tank failure is noted and the tank and semen are replaced.

Because herds continue to increase in cow numbers, there is increasing probability that several cows will display estrus on the same day. Furthermore, the use of programmed AI techniques increases the probability that multiple cows will be inseminated on the same day. These sets of conditions have resulted in the desire of inseminators to thaw simultaneously groups of straws as a convenience measure. Data regarding "batch thawing" is controversial. For example, laboratory data (12) indicates that up to 10 straws can be thawed at once without a demonstrable loss in spermatozoal viability. However, field studies (40, 26) indicate that fertility may be compromised when "batch thawing" is employed. A clear recommendation awaits further data from well-controlled fertility experiments.

### The Take-Home Message

- Semen handling (thawing) recommendations have been well researched and are easy to follow.
- There is no evidence that LN refrigerators are mismanaged on dairy farms.
- Periodic review (once per year) of LN refrigerator care and semen handling can maximize the chance of good technique
- More data is needed to clarify the efficacy of "batch thawing" of semen

**Vaccinations and Transition Cow Nutrition**

It is assumed in this paper that well designed immunization programs are in place. Further, transition cow nutrition programs and feedbunk management, if properly designed, should not be a factor limiting fertility. If these factors are limiting, they are totally under the control of management and can be corrected.

**Summary – *Fertility Factors* controlled by man**

*Fertility Factors* controlled by man, can be improved significantly with the appropriate management decisions and implementation of the well-focused programs. **The greatest improvement in reproductive performance can be made by improving estrous detection efficiency, estrous detection accuracy and skill of the inseminator. In addition, proper management of the environment, mainly heat stress and footing, can significantly improve reproduction**. The probability of implementing successfully and controlling these factors is much higher than attempting to control other factors, which cannot be totally controlled by the management team. Heavy management emphasis should be placed on these *Fertility Factors* controlled by man.

## II. *Fertility Factors* Controlled by the Cow's Reproductive Tract

These factors are under the direct influence of the reproductive system of the cow. These *Fertility Factors* are somewhat difficult to manage and to control because cow's reproductive system is the primary component influencing the outcome.

**Fertility Factors Controlled by the Cow's Reproductive Tract**

| *Fertility Factor* | **Expected Incidence** |
|---|---|
| Dystocia | 2%-10% |
| Retained placenta | 4%-12% |
| Uterine infection | 15%-30% |
| Cystic ovarian disease | 6%-20% |
| Embryonic death | 30%-40% of fertilized ova die before 50 days |
| Twinning | 0 – 10% |

**Dystocia**

Dystocia means "difficult birth." The major cause of dystocia is fetopelvic disproportion (calf too large for the birth canal). Birth weight of the calf and pelvic area of the dam are two of the most important factors that contribute to dystocia (1). Improper positioning of the fetus is also a major contributor. Reduction in incidence of dystocia can almost always occur when bulls are selected for a high degree of calving ease especially in heifers. Further, calvings should be accompanied by attendants with the appropriate obstetrical skills. Such focus can reduce the incidence of dystocia. Growing heifers to achieve 1250 – 1300 lb immediately after calving (24 months) coupled with the use of calving ease bulls can reduce the incidence of dystocia in first-calf heifers. Thus, management can exert a strong preventive influence by selecting calving-ease bulls for use in heifers and employing proper heifer management and maternity pen care. A certain amount of caution should be exercised because continued use of calving ease bulls can predispose a herd to smaller cows over time. Such a practice would amplify the dystocia problem during the same time frame. Regardless, there will always be a certain proportion of cows, which are afflicted by difficult birth. Almost without exception, cows that have difficult births have "downstream" reproductive problems including retained placenta, Metritis, delayed uterine involution and poor cyclicity.

**The Take-Home Message**

- Most dystocia is related to fetopelvic disproportion (calf too large for birth canal).
- Use of calving ease bulls can reduce dystocia in heifers.
- Some types of dystocia can be neither predicted nor prevented.
- Careful observation during parturition can reduce calving problems

**Retained Placenta**

The incidence of retained placenta varies from about 4% to about 12%. Retained placenta is defined as the retention of the fetal membranes beyond a 12-hour period. The cause of retained placenta is not understood. However, there is evidence that the lack of cotyledon proteolysis (breakdown of collagen) contributes to retained fetal membranes (19). Like cows afflicted with dystocia, cows with retained fetal membranes are almost always characterized by delayed return to estrus, increased services per conception, lengthened calving interval, higher culling rate, reduced milk production and increased days open (19). Reduction in the incidence of retained placentas has been associated with providing the cow with adequate selenium levels prior to parturition. However, cows with adequate selenium may still be afflicted by retained placenta, suggesting that other causative factors are associated with this abnormality. There is no conclusive evidence to indicate that treatment intervention of retained placenta provides the cow with a reproductive advantage when compared to cows with retained placenta that are not treated.

**The Take-Home Message**

- Proper nutrition (especially Selenium) can reduce the incidence of RP but cannot totally eliminate it.
- Cows with retained placenta almost always have uterine infection, delayed return to estrus, increased services per conception, lengthened days open and reduced milk production.

**Uterine Infection**

Most postpartum cows have intrauterine microbial contamination as a normal sequela to parturition. Most of these cows do not develop uterine infection that impairs reproductive performance (41). However, some cows develop more severe infections that compromise reproductive performance. Almost all cows that experience dystocia and retained fetal membranes develop uterine infection. In some herds, 40% of all postpartum cows may be treated for uterine infection (41). Such infections have been reported to cost over $100 per cow per lactation (4).

Uterine infection has two major effects on the cow's ability to become pregnant. First, it may delay the onset of cyclicity by delaying luteolysis. Second, it delays uterine involution and thus delays the time to first breeding. Treatment of uterine infection is controversial. In general infusions, draining uterine fluids and manipulation of the uterus is considered counterproductive both from a therapeutic and economic standpoint (41). Proper sanitation of the fresh cow, the maternity area and cow hygiene are most frequently indicated as good management steps for the prevention of uterine infection. Also, inducing estrus (with $PGF_{2\alpha}$) allows the uterus to be exposed to estrogen when the cow comes into estrus. Estrogen has a powerful therapeutic effect on the involuting uterus. It is important to recognize that poor uterine health can result from a cascade of negative events. The starting point may be dystocia or retained placenta. Either of these events can culminate in severe uterine infection. Any one or combination of these conditions delay pregnancies.

**The Take-Home Message**

- Up to 75% of all postpartum cows have postpartum uterine microbial contamination.
- Most cows with uterine infection "self-cure".
- Uterine infection <u>cannot</u> be totally eliminated.
- Intrauterine treatment is controversial but appears to be of limited value.

**Cystic Ovarian Disease (COD)**

The causes of cystic ovarian disease are not understood and therefore controlled prevention is not possible (6). Cows with uterine infections (8, 32, 21) and postpartum diseases (20) appear to have a higher risk of COD.

The effect of milk yield upon COD is controversial. Some studies (21, 13, 29, 35) indicate that high producing cows have a greater risk of COD than their lower producing contemporaries, while others (45, 16) indicate that COD is not related to milk yield.

The incidence of ovarian cysts in dairy herds has been reported to vary between 6 and 20% (49). Between 10 and 14% of all dairy cows will develop ovarian cysts at least once in their productive lifetime (6). Approximately 80% of cows with cystic ovarian disease respond to gonadotropin or GnRH treatment and 20% are non-responsive to hormonal treatment (11). It has been proposed (11) that these animals are characterized as having a genetic abnormality whereby the cystic structure has low receptor density to FSH and LH and therefore is incapable of responding to treatment. Such animals probably should be culled from the herd since they may represent a genetic predisposition for COD. In general, treatment of cows with cystic ovarian disease with gonadotropins or gonadotropin releasing hormones is effective. In this context, cows that are properly diagnosed and treated will have acceptable fertility. It should be emphasized again that in most herds, the incidence of COD is relatively low (<10%). Thus, COD is a *Fertility Factor*, which imposes only moderate impact

**The Take-Home Message**

- Between 6 and 20% of cows have cystic ovarian disease (COD).
- About 20% of cows with COD will not respond to treatment
- There is evidence that COD is heritable.

**Embryonic Death**

A major contributor to pregnancy failure (loss) in dairy cattle is early (preattachment) embryonic death (36, 53, 61). Between 30% and 40% of embryos die between fertilization and day 50 of pregnancy. Unfortunately, the precise cause(s) of this loss are not understood and makes this costly *Fertility Factor* among the most difficult to manage. A recent review by Inskeep (34) implicates an imbalance of progesterone, estradiol, and prostaglandins as a cause of early embryonic death. Unfortunately, controlling the timing and balance of these hormones in the cow is beyond the scope of current daily management efforts. An encouraging finding was recently reported by Moriera et al. (44), who showed that lactating cows treated with bST in combination with timed AI (GnRH + 7 days; $PGF_{2\alpha}$ + 48 hr; GnRH + AI; 16-20 hr. later) had improved conception rates. These workers (44) speculated that the combination of bst, GnRH and $PGF_{2\alpha}$ may have improved embryo survival.

Cows exposed to heat stress are quite likely to have elevated body temperature. Elevated body temperature of the cow (above 41° C) especially during the first 1-3 days after insemination causes a marked increase in embryonic death (17, 18, 50). Cooling cows to prevent elevated body temperature prevents embryonic death and thus improves pregnancy rate (59, 57, 60, 63).

**The Take-Home Message**

- Between 30-40% of potential embryos die between fertilization and day 50 of pregnancy.
- Management control of embryo death is almost impossible except through cow cooling

**Twinning**

The physiologic factors controlling twinning in cattle are not well understood. However, the incidence of twinning can be genetically influenced (28) and influenced by parity of the dam (24). Recently, high milk yield, especially high peak milk yield, has been implicated as a cause for the increase rate of twinning. The scientific data are far from conclusive and this issue remains controversial. More research is needed to establish a cause and effect relationship. Regardless of the causes of twinning, however, its occurrence has a significant negative impact on reproduction of the dam. The estimated loss associated with each twin birth is $108 (5). These losses are related to elevated risks associated with periparturient problems such as dystocia, retained placenta, uterine infection and an increased incidence of metabolic diseases of the dam.

Early identification of cows with twin fetus should be accomplished by palpation per rectum (day 50-70) or by ultrasonography (day 40-55) (24). Fricke (24) has presented several options for management of cows with twin pregnancies. These are: 1) cull the cow with a twin pregnancy, 2) abort the twin pregnancy, 3) elevate the plane of nutrition during the last trimester of gestation, 4) earlier dry-off and transition diet adjustment, and 5) careful obstetrical observation/management of twin-bearing cows.

Until definitive data is available establishing the factors that control twinning, it will be difficult to manipulate this *Fertility Factor*. Recognition of the "downstream" postpartum problems associated with twinning is important so that appropriate management steps can be taken to minimize the risk associated with multiple births.

**The Take-Home Message**

- Management can expect little (if any) influence upon the incidence of twinning until definitive cause and effect relationships are established through controlled research.
- Cows with twins should be identified and managed according to the management scenario of Fricke (24).

## *III. Fertility Factors* Natural to any Dairy Herd

These factors are an inherent part of any dairy herd. Serious manipulation of these *Fertility Factors* would disrupt the very purpose of producing profitable quantities of milk. While these factors can influence reproduction, little can be done to alter them because of their intrinsic nature to the herd.

> ***Fertility Factors* Natural to any Dairy Herd**
> - Breed of cow
> - Age of cow (parity)
> - Level of milk production

**Breed of Cow**

Breed of cow within the herd is a management preference and favors breeds with the highest yields of milk. There appears to be some differences in fertility among the major dairy breeds. A recent study by Brown, et al (10) reported that Jerseys had fewer average days open (147 days) when compared to Holsteins (162 days). Aryshires, Guernseys and Brown Swiss averaged 173 days open. Services per conception were similar among breeds (about 3.1). Once the decision on herd composition (breed) has been made the inherent fertility of the breed constitutes the baseline around which management must operate.

> **The Take-Home Message**
> - Once the breed of cow is selected, management must operate within the characteristics of that breed.

**Age of Cow (Parity)**

Nuliparous heifers have the highest fertility among dairy animals followed by a decline in fertility with advancing parity (33, 23). The composition of any dairy herd includes first-calf heifers, second, third, and fourth (and beyond) lactation cows. This natural herd composition guarantees that there will be a declining fertility with advancing parity. It would be almost impossible to develop a strategy, which would alter this herd composition to improve fertility, while at the same time maintaining high levels of milk production.

> **Take-Home Message**
> - Fertility declines with advancing age (parity) but as yet no management scheme has been developed to alter this natural factor.

**Level of Production**

**Genetics**

The impact of level of milk production upon fertility continues to be a controversial and much discussed topic. The concept that elevated production results in increased stress on the cow, and negatively impacts reproduction and cow health had been promoted for decades. However, cows producing high levels of milk certainly cannot be under a high level of stress because stress reduces milk and does not promote it.

It is difficult to separate elevated production from genetics and the possible antagonism between production and reproduction. Hansen (30) points out that the heritabilities for reproductive traits are quite low (3% or less). Therefore, most of the variation in fertility is due to nongenetic factors and these have been presented earlier in this paper. Furthermore, if a genetic relationship between increased production and decreased fertility existed, fertility in virgin heifers would be expected to decrease over time. Such a decrease has not been observed. The possibility that the elevated incidence of inbreeding in U.S. Holsteins may contribute to reduced fertility has been presented by Lucy (42).

**Management**

Because the economic incentives are high and the results of managing for high production occur rapidly (and are often dramatic), every herd has a built-in (intrinsic) drive to improve milk yield per cow. There are fewer incentives for improved reproductive management and the results often lag far behind the steps implemented to improve milk yield. Therefore, the results of good reproductive management are camouflaged, become frustrating and the management emphasis declines. Unfortunately, high production often receives the blame for poor reproduction when, in reality, poor reproductive management should receive the blame. When incentives for both high milk yields and high reproduction are solidly in place it is possible (and even likely) that good reproduction and high milk yields can co-exist.

During the past decade, dairy production has been in a transition from managing cows for the maximum number of peak lactations per lifetime to managing for maximum persistence per lactation. This has created a marked departure from a reproductive management philosophy that has historically indicated that the cow should become pregnant as soon as possible after calving so that she can experience the maximum number of peak lactations in her lifetime. The modern dairy cow, coupled with new technology (more frequent milking, the use of bST, and sophisticated transition cow nutrition) has created higher milk yields through higher peaks and more persistent lactations. This persistence reduces the need for "rapid" pregnancies following parturition because the profit periods within the lactation curve are more sustained. Thus, if "old" measures of reproductive performance continue to be used and producers actually practice postponing pregnancies because of high persistence, it will appear that high milk yields result in poor reproduction. "Old" measures of reproduction were designed to maximize peaks, and may not apply to high persistence. There needs to be a critical evaluation and, if necessary, a "remodeling" of reproductive guidelines that apply to current conditions of management and production. Caution should be exercised when interpreting current data that might imply that high production damages reproduction when in fact, astute management practices will purposely postpone reproduction because of the obvious economic benefit of sustained high milk yield.

The data linking high production to poor reproduction are quite controversial and it would appear that there are many other factors which impact reproduction to a much greater degree than high milk production. These *Fertility Factors* fall into the category of *Fertility Factors* controlled by man. The appropriate economic strategy should be to manage for the highest possible milk yield while focusing reproductive management on *Fertility Factors* that have the greatest variation and a high probability of management impact.

**The Take-Home Message**

- Management efforts should be toward managing the efficiency of milk yields
- Reproduction should be managed by focusing on the *Fertility Factors* that have a high impact on reproduction and that can be effectively managed

## References

1. Anderson, K. J., J. S. Brinks, and D. G. LeFever, K.G. Odde. 1993. The factors associated with dystocia in cattle. Vet. Med. 88:764
2. Appleyard, W. T., and B. Cook. 1976. The detection of estrus in dairy cattle. Vet. Rec. 99:253.
3. Barr, H. L. 1975. Influence of estrous detection on days open in dairy herds. J. Dairy. Sci. 58:246.
4. Bartlett, P. C., J. H. Kirk, M. A. Wilke, J. B. Kanseene, and B. C. Mather. 1986. Metritis complex in Holstein-Friesian cattle: incidence, descriptive epidemiology and estimated economic impact. Prev. Vet. Med. 4:235
5. Beerepoot GMM, Dykhuizen AA, Nielen M, Schukken YH, 1992. The economics of naturally occurring twinning in dairy cattle. J. Dairy Sci 75:1044-1051.
6. Bierschwal, C. J. 1966. A clinical study of cystic conditions of the bovine ovary. J. Am. Vet. Med. Assoc. 149:1591
7. Bozwerth, R. W., G. Ward, E. P. Call, and E. R. Bonewitz. 1972. Analysis of factors affecting calving intervals of dairy cows. J. Dairy Sci. 55:334.
8. Bosu, W.T.K. and A.T. Peter. 1987, Evidence for a role of intrauterine infections in the pathogenesis of cystic ovaries in postpartum dairy cows. Theriogenology 28:725.
9. Britt, J.H., R.G. Scott, J.D. Armstrong, and M.D. Whitacre. 1986: Determinates of estrous behavior in lactating Holstein cows. J Dairy Sci. 69:2195
10. Brown, C.H., B.T. McDaniel, S.L. White, and S.P. Washburn. 2000. Reproductive trends among southeastern dairy herds. J. Dairy Sci. 83, suupl I:229.
11. Brown, J. et al 1986. Effect of FSH treatment on LH and FSH receptors in chronic cycstic-ovarian – diseased dairy cows. J. Anim. Sci. 62:1063
12. Brown, D. W. P.L. Senger and W.C. Becker. 1991. Effect of group thawing on post-thaw viability of bovine spermatozoa packaged in .5 milliliter French straws. J. Anim. Sci. 69:2303.
13. Casida L.E. and A.B. Chapman. 1951. Factors effecting the incidence of cystic ovaries in a herd of Holstein cows. J. Dairy Sci. 34:1200.
14. Cembrowics, H. J. 1964. Efficiency of inseminators. Proc. 5th Int. Cong. An Anim. Reprod. And Artif. Insem. 4:624.
15. Davidson, J. N., and T. B. Farver. 1980. Conception rates of Holstein bulls for artificial insemination on a California dairy. J. Dairy Sci. 63:621
16. Day, N. 1991. The diagnosis, differentiation, and pathogenesis of cystic ovarian disease. Vet Med; 86:753.
17. Dunlap, S.K., and C.K. Vincent. 1971. Influence of postbreeding thermal stress on conception rate in beef cattle. J. Anim Sci. 32:1216.
18. Ealy, A.D., J.L. Howell, V.H. Monterroso, C.F. Aréchiga and P.T. Hansen. 1995. Developmental changes in sensitivity of bovine embryos to heat shock and use of antioxidants as thermo protectants. J. Anim. Sci. 73:1401.
19. Eiler, H. 1997. Retained placenta in *Current Therapy in Large Animal Theriogenology – 2nd Ed.* Youngquist Ed. W. B. Saunders Co., Philadelphia, PA.
20. Erb, H.N. and S.W. Martin. 1980. Interrelationship between production and reproductive disease in Holstein cows: Data. J. Dairy Sci. 63:1911.
21. Erb, H.N., S.W. Martin and N. Ison. 1981. Interrelationships between production and reproductive diseases in Holstein cows: Path analysis. J. Dairy Sci. 64:282.
22. Esslemont, R. J. 1974. Economic and husbandry aspects of the manifestation and detection of estrus in cows. III. The detection of estrus. Agric. Dev. Advis. Serv. Q. Rev. 15:83.
23. Fonseca, F.A., J.H. Britt, B.T. McDaniel, J.C. Wilk and A.H. Rakes 1983. Reproductive traits of Holsteins and Jerseys. Effects of age, milk yield and clinical abnormalities on involution of the cervix and uterus, ovulation, estrous cycles, detection of estrus conception rate and day open. J. Dairy Sci. 66:1128.

24. Fricke, 2000; Twinning in Dairy Cattle. The Professional Anim. Sci., In Review
25. Gallagher G.R.; P.L. Senger, (1989). Concentrations of spermatozoa in the vagina of heifers after deposition of semen in the uterine horns, uterine body or cervix. J. Reprod. Fertil. 86, 19-25
26. Goodell, G. 2000. Comparison of A.I. pregnancy rates in dairy cattle by order of preparation of insemination straws. J. Dairy Sci, 83, Suppl :229.
27. Graham, E. F. 1966. The use of dye as an indicator for testing, training and evaluating technicians in artificial insemination. Proc. 1st Tech. Conf. On Artif. Insem. And Bovine Reprod. Pp 57-60.
28. Gregory K.E., Bennett G.L., Van Vleck L.D., Echternkamp S.E., Cundiff L.V, 1997. Genetic and environmental parameters for ovulation rate, twinning rate, and weight traits in a cattle population selected for twinning. J. Anim Sci 75:1213-1222.
29. Grohn, V.T., J.A. Hertl and J.L. Herman. 1994. Effect of early lactation milk yield on reproduction disorders in dairy cows. Am. J. Vet. Res. 55:1521.
30. Hansen, L. B. 2000. Consequences of selection for milk yield from a geneticist's viewpoint. J. Dairy Sci. 83:1145.
31. Hansen, P. J. and C. F. Arechiga. 1999. Strategies for managing reproduction in the heat-stress dairy cow. J. Anim. Sci. 77: Suppl.2:36.
32. Hardie, A.R. and R.L. Ax. 1981. A 40-year survey of cystic ovaries in dairy cows. J. Dairy Sci 64 (suppl.1): 149.abst.
33. Hillers, J.K., P.L. Senger, R.L. Darlington and W.N. Fleming. 1984. Effects of production, season, age of cow , dry days and days in milk on conception to first service in large commercial dairy herds. J. Dairy Sci 67:861.
34. Inskeep, F. K. 2000. Factors that affect embryonic survival in the cow: application of technology to improve calf crop, Proceedings of the 49th Annual Beef Cattle Short Course, Gainesville, FL, Fields, M.J. and R.S. Sand, ed.
35. Johnson, A.D., J.E. Legates and L.C. Ulberg. 1966. Relationship between follicular cysts and milk production in dairy cattle. J. Dairy Sci 49:865.
36. Kidder, H. E., W. G. Black, J. N. Wiltbank, L. C. Ulberg, and L. E. Casida. 1953. Fertilization rates and embryonic death rates in cows bred to bulls of different levels of fertility. J. Dairy Sci. 37:691
37. King, G. J., J. F. Hurnik, and H. A. Robertson. 1976. Ovarian function and estrus in dairy cows during early lactation. J. Anim. Sci. 42:688.
38. King, G.J. and J.W. Macpherson. 1965. Observations on retraining of artificial insemination technicians and its importance of maintaining efficiency. Can. Vet. J. 6:83.
39. Kinsel and Etherington. 1998. Factors affecting reproductive performance in Ontario dairy herds. Therio. 50:1221.
40. Lee, C.N. et al. 1997. Conception rates in dairy cattle is affected by the number of semen straws thawed for breeding. J. Dairy Sci. 80: Suppl. 1:151.
41. Lewis, G. S. 1997. Health problems of the postpartum cow – uterine health and disorders. J. Dairy Sci. 80:984
42. Lucy, M.C. 2000. Reproductive loss in high-producing dairy cattle: where will it end? J. Dairy Sci. In Press.
43. Milk Marketing Board. 1960. Report of the production division, No. 11. pp 113-115
44. Moriera F, Risco CA, Pires FA, Ambrose JD, Drost M, Thatcher WW, 2000. Use of bovine somatotropin in lactating dairy cows receiving timed artificial insemination. J Dairy Sci 83:1237-1247
45. Nanda A.S., Ward W.R., Dobson H. 1989. The relationship between milk yield and cystic ovarian disease in cattle. BR Vet J;145:39
46. O'Connor, M. L. and P. L. Senger. 1997. Estrus Detection in *Current Therapy in Large Animal Theriogenology.* Ed. Youngquist. W.B. Saunders Co. Philadelphia PA.
47. Oltenacu, P. A., T. R. Rounsaville, R. A. Milligan and R.H. Foote. 1981. Systems analysis for designing reproductive management programs to increase production and profit an dairy herds. J. Dairy Sci. 64:2096

48. Petesr, J. L., P. L. Senger, J. L. Rosenberger and M. L. O'Connor. 1984. Radiographic evaluation of bovine artificial insemination techniques among professional and herdsman – inseminators using .5 and .25-ml French Straws. J. Anim. Sci. 59:1671.
49. Peter, A.T. 1997. Infertility due to abnormalities of the ovaries. *Current Therapy in Large Animal Theriogenology*. P. 349-354. W.B. Saunders Co., Philadelphia PA.
50. Putney, DJ, M Drost and WW Thatcher, 1988. Embryonic development in superovulated dairy cattle exposed to elevated ambient temperature between days 1 to 7 post-insemination theriogenology. 30:195.
51. Roman-Ponce H., W. W. Thatcher, D. E. Buffington, C. J. Wilcox, and H. H. Van Horn. 1977. Physiological and production responses of dairy cattle to a shade structure in a subtropical environment. J. Dairy Sci. 60:424-430
52. Saacke, R. G., W. E. Vinson, M. L. O'Connor, J. E. Chandler, J. Mullins, R. P. Amann, C. E. Marshall, R. A. Wallace, W. N. Vincel, and H. C. Kellgren. 1980. The relationship of semen quality and fertility: A heterspermic study. Pages 71-78 *in* Proc. 8th Tech. Conf. Artif. Insem. Reprod.
53. Screenan, J. M. and M. G. Diskin. 1986. The extent and timing of embryonic mortality in cattle. *Embryonic Mortality in Farm Animals* pp 1-11 Ed. J. M. Screenan and M. G. Diskin. Martinus Nijhoff, Dordrecht.
54. Senger, P. L., W. C. Becker. and J. K. Hillers. 1980. Quality of semen stored in on-the-farm semen tanks. J. Dairy. Sci. 63:646
55. Senger, P. L. 1986. Principles and procedures for storing and using frozen bovine semen in *Current Therapy in Theriogenology –2nd Ed.* W. B. Saunders Co., Philadelphia, PA.
56. Senger, P. L., J. K. Hillers, J. R. Mitchell, W. N. Fleming and R. L. Darlington. 1984. Effects of serum treated semen, bulls and herdsmen-inseminators on conception to first service in large commercial dairy herds. J. Dairy Sci. 67:686
57. Senger, P. L., W. C. Becker, S. T. Davidge, J. K. Hillers, and J. J. Reeves. 1988. Influence of corneal insemination on conception in dairy cattle. J. Anim. Sci. 66:3010.
58. Smith, R. D. 1982. Presenting heat detection as "A" in the A. I. Alphabet. Page 104 *in* Natl. Assoc. Anim. Breeders 9th Tech. Conf. Artif. Insem. Reprod. 104.
59. Stott, G. H., F. Wiersma, and J. M. Woods. 1972. Reproductive health program for cattle subjected to high environmental temperatures. J. Am. Vet. Med. Assn. 161:1369-1375
60. Thatcher, W. W., F. C. Gwazdauskas, C. J. Wilcox, T. Toms, H. H. Head, D. E. Buffington, and W. B. Fredricksson. 1974. Milking performance and reproductive efficiency of dairy cows in an environmentally controlled structure. J. Dairy Sci. 57:304-307
61. Thatcher, W. W., C. R. Staples, G. Danet-Desnoyers, B. Oldock and E-P. Schmitt. 1994. Embryo health and mortality in sheep and cattle. J. Anim. Sci. 72(Suppl. 3):16-30.
62. Webb, J. H. 1976. Use of dye for technician training and retraining. Proc. 6th Tech. Conf. On Artif. Insem. And Reprod. Pp 69-72
63. 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

# Managing Herd Bulls on Large Dairies

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## Introduction

Despite the proven genetic (and other) advantages of A.I., natural service (NS) bulls are not a rarity on U.S. dairies. Here, a number of scenarios appear to exist. One is the widespread use of NS bulls on large dairies, especially those newly established, such as in south-west Kansas. Another involves the use of NS bulls in conjunction with pastured females. These options may be combined on the same operation. Another option is to use NS bulls for specific purposes, such as with heifers to reduce dystocia or to produce dairy beef. Dairies employing NS bulls often purchase their replacement heifers, rather than raise them. On newly established large dairies, NS bulls may be exclusively employed initially, and then at decreasing levels as improvements occur in both management and facilities. From the evidence available, it would appear that NS dairy bulls are seldom subject to close scrutiny or monitoring, especially when compared with procedures commonly accepted in the cow-calf sector. In addition, their general level of management seems to be lower in comparison with those associated with other facets of the dairy industry. As a consequence, many dairies are failing to adequately exploit an often underrated resource - the natural service bull.

## Natural Service Bull Usage

Estimates from large dairy herds in Florida, and Texas indicate that the use of NS is widespread particularly in those using rotational grazing management systems. One survey (NAAB, 1995) showed that less that twenty per cent of dairies used artificial insemination exclusively. It has been estimated that 60 percent (or more) of large dairy herds in Florida and California employ some degree of natural breeding (Risco, pers. comm). A recent survey (Champagne et al, 2002) showed that nearly 90% of California dairies employed NS bulls, with 12% of herds using NS for more than 60% of breeding. Here, confirmed pregnancies were similar for both AI and NS, regardless of herd size or cow lactation number. Despite evidence of such widespread usage of NS bulls on U.S. dairy farms, there is little information available re. the optimal management of such bulls.

## Natural Service Bull Advantages

Bulls may be used in dairy management schemes for a number of reasons, as shown in a recent California survey (Champagne et al, 2002 ). Here, producers could select more than 1 category.
Problem/hard breeders - 51%
To get cows pregnant - 32%
Clean-up following A.I. - 27%
Heifer breeding - 13%
“No-heat” cows - 13%
Reduced labor - 8%
No heat detection – 6%

A common theme involves problems with heat detection or getting cows bred. The lack of trained, motivated personnel to adequately perform essential tasks such as heat detection can be a major concern on large dairies, especially those that are newly established and those situated in more isolated rural areas. Poor heat detection rate (HDR) is, in turn, a major cause of lowered reproductive performance, production and profitability on dairies (Tables 1-3).

**Table 1.** Estimated long-term (10 yr) effects of heat detections rates (47, 57, & 67%) on milk production & net revenues/cow/yr at a seasonally adjusted conception rate of 30% (Chenoweth and Larsen 1992)

| Heat detection rate | Annual milk production/cow (10 yr avg) | Excepted change per +10% HDR | Net revenues/ cow/year (10yr avg.) |
|---|---|---|---|
| 47 | 14,914 lb | | Base |
| 57 | 15,284 lb | +370 lb | Plus 6% |
| 67 | 15,476 lb | +192 lb | Plus 10% |

This problem can be exacerbated by lack of trained personnel and reduced female heat activity in hot weather. Here, it is a common perception that a motivated bull will detect more heats than will humans, particularly if the latter are poorly trained and motivated. In other words, NS bulls circumvent human errors in heat detection.

Improvement in areas such as cow cull and retention rates are also associated with improved HDR.

**Table 2.** Culling/replacement rate and average months in the herd/cow when conception rate averages 30% and heat detection rate is varied (47, 57, & 67%) (Chenoweth and Larsen 1992)

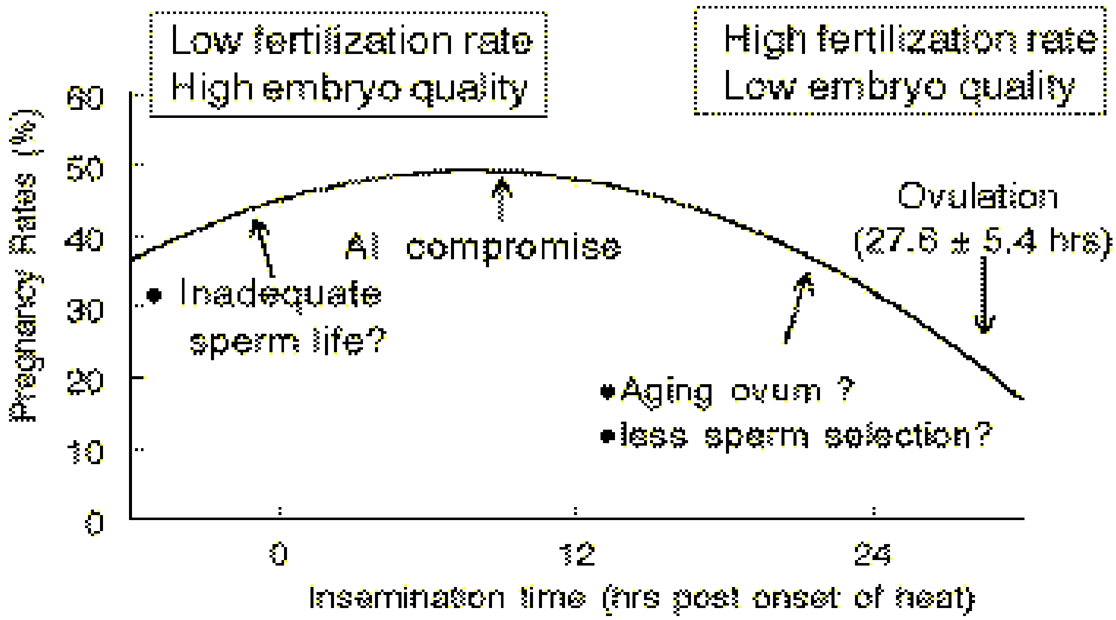
| | Heat Detection Rate (HDR) | | |
|---|---|---|---|
| | 47% | 57% | 67% |
| Replacement rate | .41 | .35 | .33 |
| Avg. mo in herd/cow | 25.06 | 28.08 | 29.54 |

**Table 3.** Effective pregnancy rate (conception rate x heat detection rate) influence on milk/cow/yr, net income/cow/yr, and replacement rate (Chenoweth and Larsen 1992)

| Effective pregnancy rate | Milk/cow | Net $/cow | Replacement rate |
|---|---|---|---|
| .15 | 14,826 | Base | .38 |
| .25 | 16,127 | Plus 20% | .27 |
| .27 | 16,110 | Plus 20% | .27 |
| .35 | 16,482 | Plus 26% | .26 |
| .45 | 16,726 | Plus 30% | .25 |
| .63 | 16,951 | Plus 34% | .27 |

From these estimates, it is apparent that CR and HDR exert their greatest effects on herd production, profit and cow replacement rate, when EPR is between 15 and 25%.

**Figure 1** (Saacke et al. 2000)




It is possible that a number of other advantages accrue from using NS bulls, although most are poorly documented. One is the so-called "male effect", or "biostimulation". This effect has been shown to influence female reproductive responses in a number of species. A widely accepted application of this phenomenon occurs with sheep. Here, rams introduced just prior to the normal breeding season will induce and part-synchronize estrus in ewes. This effect appears to be most effective when the females are in a "transitional" cyclicity state and the males have been excluded from the flock for some period before being reintroduced as a novel stimulus. More work needs to be done to fully exploit such effects in cattle where biostimulation is less dramatic. An apparent advantage has been described for natural breeding over AI (e.g. Pelissier 1976, Langley 1978) although this may be confounded with other effects associated with the timing of service, and multiple services (Saacke et al, 2000). NS bulls may improve herd fertility because multiple services of females can provide an improved balance between fertilization rate and embryo quality (Fig 1). However, this implies that NS bulls are fertile. A clear-cut advantage has been shown for post-partum return to estrus, whereas the evidence for the advancement of heifer puberty are more equivocal. It still remains uncertain whether or not other advantages, such as stimulating cyclicity in sub-cycling females, might accrue from the presence of bulls on dairy farms. An intriguing strand of anecdotal evidence suggests that herds employing NS bulls have a markedly lower prevalence of cystic ovaries than do herds without bulls.

Thus bulls continue to be used in dairy herds because heat detection and conception rates have important impacts on cow production levels and net returns, both annual and lifetime, as well as on replacement/culling rates within herds. This is despite indisputable advantages for A.I. in promoting genetic progress. However, in the case of large dairies which do not raise all or most replacement heifers, the genetic balance can be maintained by purchasing replacement heifers from breeders who are using A.I. with semen from proven bulls.

## Bull Selection

Natural service bulls representing dairy, beef or dual-purpose genotypes may be reared on-farm, purchased, leased or borrowed. In the recent California survey (Champagne et al,2002) 64% of bulls were home-grown, 30% came from multi-sources (e.g. sale barns, contractors), 29% came from a single source and 3% were leased.

Reasons for selecting bulls were as follows (note, more than 1 category could be selected):
Dams milk production - 74%
Bull conformation - 36%
Bull BCS - 35%
Bull age - 22% (with the emphasis on early pubertal bulls)
Bull cost - 12%

Whatever their origin or purpose, the primary mission of the NS bull is to detect and breed estrous females as quickly and efficiently as possible. The ability of the bull to perform this task is influenced by a number of factors including:

- Semen quality (and quantity),
- Libido and mating ability,
- Social “status” (both with other bulls and also with females in the breeding pasture).
- Freedom from reproductive disease

Thus, selection of bulls for natural service duty in dairies should pay particular attention to physical (and reproductive) soundness, sex-drive (libido), mating ability and health. It is highly recommended for all NS bulls to first pass a breeding soundness examination (BSE), as recommended by the American Society for Theriogenology. This should be repeated on working bulls on an annual basis at least. This topic is discussed in more depth later.

Younger bulls (i.e. less than 2 to 2.5 years of age) are preferable to older bulls for the following reasons:

1. They are more tractable and pose less danger to humans.
2. They can be used in multi-sire groups with less danger of the more serious aspects of social dominance being manifest (e.g. injured bulls, broken fences).
3. They have less chance of having developed degenerative or other age-related pathological or psychological problems which might lower their reproductive performance.
4. Although their full reproductive potential is not yet attained, this is probably less important than in beef operations where higher mating loads over shorter periods are more common.

Although younger bulls are preferred, they should be pubertal and not of disparate physical size (larger or smaller) compared with females. For young Holstein bulls being used with mature cows, this would preclude bulls less than approximately 1000 lb body weight The safety aspect is a very important consideration which will be revisited. However, bulls of any age which have bad temperament should not be tolerated on dairy farms. In the recent California survey (Champagne et al, 2002), bull size (73%) and health (65%) were the most common reasons for culling bulls, with bull temperament (53%) and age (37%) also being important.

Care should be taken when buying bulls from sale barns, or other situations in which animals from diverse sources are commingled (approximately 30% of dairy bulls in California). Here, appropriate biosecurity measures should ensure that the diary form is not purchasing unwanted problems, and that on-farm quarantine measures help to reinforce biosafety. Contract bull raisers should adhere to similar health and nutrition protocols as those which have been tried and tested in the beef cattle industry.

The presence of mature bulls on a dairy poses particular concerns and obligations. Facilities should be suitable for bull restraint and handling to minimize the possibility of human or animal injury. A sobering statistic shows that dairy bulls cause more human fatalities in the U.S. than do beef bulls (even though the latter are far more numerous). Working facilities need to be more robust and more safety-oriented than those used just for females. Alleys and chutes suitable for safely moving and working bulls are often lacking on dairies. In addition, fencing around pens and pastures should be sufficiently secure to prevent bulls either from cohabiting with the wrong females or from disrupting other activities or programs. In general, the presence of bulls on dairy farms necessitates a higher level of facilities, stockmanship and caution.

## Breeding Soundness Evaluation

The Breeding Soundness Evaluation (BSE) is a relatively quick and economic procedure for screening bulls prior to sale or use. Its objective is to establish a baseline, above which bulls would be regarded as satisfactory potential breeders. Using this system, bulls are placed into the categories of satisfactory, unsatisfactory and classification deferred. Most developmental work on the BSE has been done with beef bulls. It has received less atention on dairy farms, and this was illustrated in the recent California survey (Champagne et al, 2002). Here 67% of bulls had not received an evaluation of breeding soundness, even though many producers recognized that it might be useful.

### BSE Procedures

Breeding soundness evaluation should be performed on any bull before placing him in the breeding pen or pasture.

The routine BSE includes the following steps:
1. Physical examination.
2. Reproductive examination (including measurement of scrotal circumference* ).
3. Collection and examination of semen..

In addition, a libido/serving capacity test may be included, as may special tests for diseases (e.g. vibriosis or trichomonosis). These procedures will add predictive value to the assessment process and may be specifically indicated at times, but they are not part of the routine BSE.

*Measurement of scrotal circumference at 12-15 months of age provides an indication of normal development. Bulls with small scrotal circumferences (e.g.. less than 30 cm at 15 months of age) should be considered as questionable prospects, not only because of reduced sperm production but also because the scrotal circumference in bulls is genetically associated with age at puberty in heifers. Bulls with larger scrotal sizes will tend to sire daughters which reach puberty earlier than the daughters of lesser bulls.

### BSE Thresholds.

Assuming that a bull is free of physical or pathological problems which would render him otherwise unfit for breeding, to be classified as “satisfactory” on the BSE, he must equal or exceed the following thresholds:
1. Individual (progressive, %) sperm motility - 30%
2. Normal sperm morphology - 70%
3. Scrotal circumference. As follows -

| | |
|---|---|
| < 15 months | - 30 cm |
| >15<18 months | - 31 cm |
| >18<21 months | - 32 cm |
| >21<24 months | - 33 cm |
| >24 months | - 34 cm |

## Problems With Natural Breeding

Apart from issues of safety and security, natural breeding can pose extra problems. These include those associated with bull infertility. Reasons given for culling bulls in California (Champagne et al,2002) did not mention fertility per se, even though health (65%) was a major cause for culling.

A host of factors can contribute to bull infertility, and a full description of all is beyond the scope of this presentation. Much of the risk, however, can be obviated with bull breeding soundness evaluations (initially and regularly thereafter), combined with astute observation of the breeding pen or pasture, as well as attention to herd health aspects.

Particular bull problems on dairy farms occur with lameness (see case report below), much of which may be attributed to dietary factors. Rations formulated for middle to high producing dairy cows contain higher energy, protein and calcium levels than those required by the bull. This excessive energy intake, can predispose bulls to acidosis, laminitis and lameness, especially when they are acutely introduced to such diets. High levels of dietary calcium can also cause lameness in conjunction with bone lesions in the spine and hip regions. Mature bulls have similar dietary requirements to those of a dry dairy cow.
Another determinant for lameness in dairy bulls is type of flooring and its surface. Bulls confined to hard unstable surfaces for long periods of time are more likely to develop lameness problems, whereas slick or unstable surfaces can cause injury and sexual tentativeness.

**To minimize such problems, the following guidelines can be used:**
1. Introduce bulls to lactating cow rations (.78-.80 NE1) gradually (preferably over a period of weeks).
Do no move DMI more than 1 lb in 2 days
Do not move both intake and energy at the same time
Adjust intake, roughage and energy in steps
2. Periodically remove bulls from hard flooring surfaces and lactating cow rations.
3. Minimize physical obstacles that interfere with bull movement (e.g. insufficient space behind free stalls, as well as protruding objects). Also avoid situations where bulls are jammed together.
4. Regularly monitor bulls, and remove those requiring foot care and/or showing early signs of lameness.

The importance of such precautions is illustrated in the case report, below.

**A Case Report**
Bulls were examined on a large, newly established, 2500 cow dairy in SW Kansas in January of 2000. This was a new facility where the management procedures and personnel were still evolving as the dairy was growing in size and attempting to achieve production goals. All breeding was exclusively performed by NS bulls. It was evident, however, that natural breeding was not as successful as it should be, with a large number of cows (more than 500) remaining open after more than 200 DIM.

NS bulls were obtained under contract by a supplier and varied in age. The bull to female ratio (BFR) was approximately 1:40. Female herds consisted of approximately several hundred females. The cow groups included varying numbers of open and pregnant females at any given time. Bulls spent much of their time in free-stalls, on concrete, although access had recently been provided to outside dirt lots. In the free-stalls, the “working” area consisted of the concrete alley-way behind the stalls, which was periodically flushed with water. Bull groups comprised mixed ages of bulls and these were generally kept intact, although they were rotated between cow groups at approximately 1 week intervals. Bulls were fed the same diets as their respective cow group. Both cows and bulls were vaccinated for Leptospirosis (5 way) and vibriosis. A total of 98 bulls were subjected to a physical examination, 66 of which were electro-ejaculated for semen assessment. Approximately 30 bulls were subject to sampling for Trichomonosis. An additional 20 young bulls were subjected to visual appraisal only.

**Results and Discussion:**
During examination it was observed that many of the bulls were “tentative” in their footing on concrete. Twenty-one of the 98 bulls were classified as poor breeding prospects and they were recommended to be culled. An additional 7 bulls had problems which might compromise breeding success, but which could improve with time. Screening for Trichomoniasis was negative for all samples. No obvious problems were detected in the young replacement bulls which were subjected to a visual appraisal only. The major problems encountered in bulls were as follows:
Lameness - 23/98 (23%).
Of these, 13 were severely lame (13.3%)
Accessory genital disease (“seminal vesiculitis”) - 17/98 (17.3%)
Penile problems (inflammation, injury) - 7/98 (7.1%)
Poor semen quality - 4/98 (4%)
Other problems - cryptorchid (1), lumpy jaw (1), eye cancer (1), respiratory infection (3)

The most common bull problem encountered was lameness. Lame bulls were recommended for culling only if the problem was severe and probably irreversible. Lameness in the hind limbs was regarded as being more detrimental to reproductive success than was forelimb lameness. Severely lame bull problems included a dislocated hip, a dislocated knee cap, a number of swollen joints (particularly of the lower limbs) and acute foot soreness. There was little evidence of severe laminitis, although it is probable that subclinical laminitis was present. With bulls being fed the same rations as lactating dairy cows, it is probable that some bull lameness problems would be caused by excessive energy and calcium in their rations. However, it was considered that a large number of the lameness problems observed in this herd were due to trauma - e.g. from loss of footing or fighting with other bulls.

The relatively high prevalence of seminal vesiculitis/accessory genital disease observed (17.3%) was of concern, although only 2 bulls had this in severe form . Active vesiculitis will adversely affect semen quality. Often the infection will spread to other parts of the genital tract where it may lead to irreversible problems. The factors leading to increased seminal vesiculitis in a group of bulls are not all known. This problem is often encountered in young beef bulls on performance test, when there is a combination of high energy rations and intensive rearing (and perhaps increased homosexual behavior). Without further observations and tests, it would be difficult to determine the cause in this case. However, managerial options such as rotating bulls, reducing cattle density in pens, and perhaps feeding chlortetracycline (CTC) should help to reduce this problem

### Transmission of Venereal Disease.

Venereal diseases of importance in cattle include vibriosis (or campylobacteriosis) and trichomoniasis. Ureaplasmosis, under certain conditions, may also be problematical. Natural service presents a very real risk of the transmission of venereal disease. Reputable A.I. organizations ensure that bulls are free of such diseases by regular sampling and preventive treatments, and also by safeguarding semen with the addition of appropriate antibiotics. The important disease entities in question are as follows:

### Vibriosis

This is caused by a bacteria (Campylobacter fetus) which localizes within the bull's penis and prepuce. Older bulls (>3 yrs) are more likely to become carriers. No clinical signs are seen in the infected bull. However, when he services a susceptible female, the transmitted organism multiplies in her cervix and then ascends the reproductive tract during diestrus. If the original ovum is fertilized, it is destroyed early giving a normal or slightly prolonged return to estrus. Subsequent breedings are infertile, probably due to interference with gamete transport. Spontaneous recovery in cows occurs after approximately 4 months, with some degree of convalescent immunity being conferred after this time. Bulls, however, do not appear to develop immunity from natural infection, probably because the organism does not truly infect the bull, but colonizes on the surface of the penis. Some abortions may occur particularly in the second trimester. The herd picture, where a number of susceptible females are exposed to infection, is primarily one of repeat breedings with irregular estrous cycles being a common sign. Both cows and bulls may be sampled for diagnosis of vibriosis although female sampling is generally more successful. A positive finding in any of the sampled females is indicative of herd or group infection. Vaccination of females affords best protection with best timing within several weeks of breeding. Some success has also been obtained with vaccinating bulls against vibriosis, both to afford protection, and to effect a cure.

### Trichomoniasis

Tritrichomonas foetus, a protozoan, also causes infertility as well as abortions. The clinical manifestations of vibriosis and trichomoniasis can appear very similar. Again, the organism is carried within penile and preputial crypts of bulls with older bulls more likely to be chronic carriers. Infectivity is high, with the protozoan then localizing within the vagina, uterus and oviduct of infected females. Embryonic or fetal wastage following the initial fertilization occurs due to inflammatory changes to the uterus and fetal membranes with abortion often resulting around 3 months gestation (range 1 to 9 months) following the infective, fertile service. A typical picture is one of an increased calving interval of 90 to 100 days. Some degree of convalescent immunity follows although this varies. Abortions of 3- to 4-month-old fetuses may go unnoticed. Thus, the major signs of infection may be infertility (with prolonged or erratic return to estrus) along with some pyometras (pus in the uterus) and perhaps later, more apparent, abortions.

Diagnosis is best done with samples from bulls although female sampling is useful. Bulls may be treated for trichomoniasis although there are no approved products for this purpose. A vaccine is available for female use only and which has been shown to reduce the abortion losses associated with trichomoniasis.

**Ureaplasmosis**
A bacteria, Ureaplasma diversum is a common inhabitant of the respiratory and reproductive tracts of cattle. It has been implicated in a number of reproductive tract disorders including granular venereal disease, early embryonic loss, weak calf syndrome, abortion and seminal vesiculitis in bulls. Following experimental inoculation, granular vulvovaginitis resulted in 3-6 days followed by endometritis and salpingitis. U.diversum strains differ in pathogenicity as does female susceptibility. Heifers appear to be particularly susceptible. Although U.diversum may be cultured from prepuberal heifers, breeding activity appears to disseminate it more rapidly, suggesting that venereal transmission may occur. There is no vaccine available although evidence suggests that feeding of chlortetracycline (CTC), at 1.1 mg/kg for several weeks coinciding with the start of the breeding season helped to constrain the adverse reproductive effects of U.diversum.

## Environmental Stressors

**Heat Stress**
High environmental temperatures can adversely affect bull fertility. Adverse reproductive effects will occur before bulls show overt signs of hyperthermia (e.g. hypersalivation, rapid open-mouth breathing, shade seeking). Holstein bull fertility has been shown to be lowest during the hot summer months in subtropical regions with most effect apparently due to depressed semen quality. Bulls in bull studs in all regions of the U.S. generally show lowered semen quality over the summer months. It is important to realize that there is a delayed effect of excessive heat upon spermatozoa with the damage often occurring a month or two before major changes are observed in the ejaculate.

Both scrotal and testicular configuration are important in helping to maintain an optimal temperature for sperm production with poor conformation and/or fat in the scrotal neck acting to compromise this ability. Studies in Oklahoma have shown that provision of shade during the hot months afforded some protection against decreased semen quality in young bulls.

**Nutritional Considerations.**
Some relevant nutritional considerations have been previously addressed.

In general, the natural breeding bull should be neither overfat or overthin, but in good working condition. Overfatness can lead to premature mating fatigue, greater susceptibility to heat stress and a compromised testicular thermoregulatory system. There is evidence that overfeeding of young bulls decreases both semen quality and libido. In addition, an excessive paunch can prevent proper intromission during mating.

Recently, there has been considerable interest in the possible deleterious effects of cottonseed products on bull fertility. In many dairy regions of the United States as much as 8 pounds (15% of ration dry matter) of whole cottonseed is fed in total mixed rations balanced for high producing dairy cattle. In surveyed California dairies (Champagne pers comm), 59% fed cottonseed products. A mature Holstein bull with an dry matter intake of 13 kg could consume as much as 13 g of free gossypol per day. Whether or not gossypol intake at this level has a detrimental effect on bull fertility is not definitively known. An increase in sperm midpiece abnormality and a reduction in sperm production per gram of testicular tissues in Brahman bulls fed 2.75 kg of cottonseed meal (8.2 g of free gossypol per day) has been reported. In contrast, Hereford bulls ingesting 7.6 to 19.8 g of free gossypol daily from whole cottonseed showed no significant sperm abnormalities. A number of factors can contribute to such differences. These include the type of cottonseed product (e.g. meal vs whole seed). The CSM processing method employed (e.g. pressure vs solvent extraction), the particular gossypol enantiomers present, and the rate of ingesta passage, which is influenced by the amount of roughage in the diet. In addition, the feeding of relatively high levels of antioxidants may counter the deleterious reproductive effects of gossypol in bulls.

Recommendations in terms of gossypol intake in the total diet for bulls used for breeding is 200 mg/kg for diets composed of cottonseed meal and 900 mg/kg for diets composed of whole cottonseed. However, the relevance of gossypol studies to commercial cattle operations needs to be carefully considered. The free gossypol content in the cottonseed meal study rations cited above, were obtained from solvent extraction methods, which accounts for less than 2 per cent of the oil extraction method used today.

**Behavioral Aspects**
Social effects can strongly influence reproductive behavior in many species and cattle are no exception. Thus, bulls which are lower in dominance rank may be inhibited in their reproductive behavior by more dominant bulls. In general, older bulls are more dominant than younger ones while body-size and presence of horns play a lesser, although not insignificant, role in establishing and maintaining dominance. Breed differences also occur. Older females can also inhibit young bulls, particularly if age and inexperience are confounded. Such inhibition can occur even from a distance, for example from dominant animals in an adjacent pen or pasture. Dominant bulls attempt to monopolize the female herd or group in the breeding pasture or corral. As bull dominance appears to be a different trait from either sex-drive or sperm production, a dominant bull which is either infertile or impotent can depress herd reproduction rates.

Bulls may also be inhibited in their sexual function by their physical surroundings, for example by being within a totally enclosed building or by loose or unstable flooring. Wet or slick concrete as well as muddy conditions can lead to feet and leg problems in bulls and cows alike while unsure footing can cause bulls to become "shy" breeders.

In general conservative bull-to-female ratios (BFRs) are recommended for NS bulls on dairies, as many variables exist. These include constant changes in the numbers of available females, and various constraints to optimal bull performance as described elsewhere. Conservative BFRs are within the range of 1:15 to 1:25. This is reflected in actual bull usage (Champagne et al, 2002), where 60% of surveyed California dairies using bulls employed them at a BFR of <1:30.

Rotation of bulls, and the provision of “rest” periods are both important managerial considerations. Nutritional aspects have already been discussed. However, of interest are findings from the California survey (Champagne et al, 2002) which showed that 47% of dairies did not ever move bulls from the breeding pen once they were admitted. A further 22% moved bulls once a year, or less. Movement of bulls appeared to be mostly because of necessity (e.g. lameness, injury) than by design. Here, the following observation is relevant: “the length of time a bull stays in the breeding corral is a major determinant re. the success or failure of bull breeding management” (Champagne et al 2002).

## Biosecurity and Health Recommendations

Natural breeding bulls should, in general, be subjected to similar biosecurity and health programs as the female herd, with several exceptions. Venereal disease protection is of particular importance. Despite this, 71% of California dairies using NS bulls took no special precautions against venereal diseases (Champagne et al,2002). Vibriosis vaccination is recommended for both bulls and females. Vaccination of females for trichomoniasis may be considered if this disease is suspected to be a problem. This vaccine can reduce abortion losses associated with trichomoniasis. It is possible that diseases such as ureaplasmosis will be shown to cause significant reproductive problems, leading to recommendations for either vaccination or prophylactic antibiotic treatments. Special attention should be directed to both endo- and ecto-parasite control.

Bulls, and females, on dairies are often in a state of flux, with constant changes in group sizes, composition and dynamics. This poses problems in terms of biosecurity. Here, a veterinary protocol for ensuring that such movements pose minimal risk to herd health and biosecurity is highly recommended

## Summary and Recommendations

Natural service (NS) bulls are widely employed on large dairy farms despite the well-proven genetic progress achievable through AI. The reasons for using NS bulls are many. It is apparent that gaps often occur in both selection and management of dairy NS bulls. The following recommendations are would help optimize bull usage on dairy farms.

1.All virgin bulls should be subjected to a breeding soundness evaluation (BSE) before admittance to the herd.

2. All bulls should be given a physical exam every 6 months and a full breeding soundness exam every 12 months.

3. Adequate handling facilities should be provided for the working and handling of bulls to reduce the risk of injury to both animals and personnel.

4. Bulls in freestall housing should be given access to dirt lots.

5. All working bulls should be monitored daily.

It is important for personnel to be especially alert for signs of lameness. Early detection of lame bulls is critical and employees should be trained to observe common lameness signs, as well as other problems associated with breeding bulls. Lame or otherwise injured bulls should be treated and/or replaced as soon as possible.

6. It is beneficial to rotate bulls in and out of the breeding herd.

7. Bulls ideally should be less than 2.5 years of age. Aggressive, older and large, heavy bulls should not be retained on the dairy.

8. A suitable bull to female ratio is approximately 1 bull to 15-25 open cows.

9. If a dairy has large breeding pens (i.e. containing large groups of females) it may be beneficial to distribute open cows over more pens to reduce the number of bulls in any given pen.

10. Avoid drastic changes in diets fed to bulls. Don't put bulls abruptly onto the same diets as lactating cows without increasing intake and energy in steps.

11. Minimize heat stress by providing shade and cooling systems.

12. Bulls should be subjected to the same vaccination and preventive health program as the cows (with the exception of vaccinations for brucellosis, trichomoniasis and MLV IBR).

## Selected References


Brinks JS (1994). Relationships of scrotal circumference to puberty and subsequent reproductive performance in male and femal offspring. Ch. In Fields MJ and Sand RS (Eds). Factors Affecting Calf Crop.CRC Press, Boca Raton.pp 363-370

Champagne JD, Kirk JH, Reynolds JP. (2002). Bull management practices on California dairies: Implications for education and veterinary services University of California, Davis, 15th Annual Fall Symposium. Sept. 15, 2002.

Chenoweth PJ (1986). Reproductive behavior of bulls. In Morrow DA (Ed) "Current Therapy in Theriogenology". W.B. Saunders Company, Philadelphia.

Chenoweth PJ and Larsen RL (1992). Selection and management of natural service bulls. Ch. in Van Horn HH and Wilcox CJ (eds), Large Dairy Herd Management. American Dairy Science Association.

Chenoweth PJ, Risco CA. Larsen RE et al (1994). Effects of dietary gossypol on aspect of semen quality, sperm morphology and sperm production in young Brahman bulls. Theriogenology 42:1-13.

Chenoweth PJ, Spitzer JC and Hopkins FM (1992). A new bull breeding soundness evaluation form. Proc. Society for Theriogenology AGM, pp63-70.

Chenoweth PJ and Smith JF (2001). Management of natural service bulls on large dairy farms. Proc. KSU Dairy Day Report

Chenoweth PJ and Spitzer JC (1995). Biostimulation in livestock with particular reference to cattle. Assisted. Reprod.Technol/Androl. (ARTA) 7:271-275.

DeLorenzo MA, Spreen TH, Bryan GR, Beede DK. and Van Arendonk JAM (1992). Optimizing Model: Insemination, Replacement, Seasonal Production, and Cash Flow. J. Dairy Sci. 75:885-896.

Langley OH (1978). Conception rate to artificial insemination and natural service. Irish vet. J. 32,4:4-8.
O'Farrell KJ (1977). A comparison of natural service and artificial insemination in seasomnally calving dairy herds. Ir.J.agric.Res. 16:251-257.
Pelissier CL (1976). Dairy cattle breeding problems and their consequences. Theriogenology 6,5:575-583.
Saacke RG, Dalton JC, Nadir S, Nebel RL and Bame JH (2000). Relationship of seminal traits and insemination time to fertilization rate and embryo quality. Anim. Reprod. Sci. 60-61:663-677.
Rae DO, Chenoweth PJ, Brown MB, Genho SA, Moore SA and Jacobsen KE (1993) Reproductive performance of beef heifers: Effects of vulvo-vaginitis, Ureaplasma diversum and prebeeding antibiotic administration. Theriogenology 40:497-508.
Risco CA, Chenoweth PJ, Smith BI, Velez JS and Barker RD (1998). Management and economics of natural service bulls in dairy herds. Compendium, March, pp385-390
Smalley SA (1981). Management problems of large dairies. Vet. Clinics of N. America: Large Animal Practice. 3,2:289-305.
Smith JF, Harner JP,Brouk MJ, St Pierre N, Stokes SR, Cole WJ, Goff JP, Boomer G, Bethard G, Armstrong DV and Gamroth MJ , (2001). Recommendations for special needs facilities. Proc. 5th Western Dairy Management Conference, pp31-40.
Velasquez-Pereira J, Prichard D, Mcdowell LR, Chenoweth PJ, Risco CA, Staples CR, Martin FG, Calhoun MC, Roxas LX, Williams SN and Wilkinson NS (1998). Long-term effects of gossypol and Vitamin E in the diets of dairy bulls. JDairySci. 81:2475-2484.

# Selecting and Managing Your Milking Facility

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## Introduction

Decisions concerning the milking center are some of the most complicated decisions a dairy producer has to make. Milking procedures, herd size, expansion plans, milking interval and the equity position of a producer influence these decisions. One parlor will not meet the needs of all dairy producers. Producers will have to make the following decisions before they can select or develop management protocols for a milking parlor:

1. How many cows will be milked through the parlor?
2. Will the parlor need to be expanded in the future?
3. What milking procedure will be used (minimal or full)?
4. If a full milking routine; how much contact time do you want (strips per teat)?
5. Which milking routine will be used (sequential, grouping, territorial)?
6. Are you willing to train teams of milkers to operate large parallel or herringbone parlors?

This paper will discuss the factors to consider when selecting a new parlor or managing an existing parlor. It is essential that dairy producers develop accurate time budgets for the milking procedures and routines they select.

## Options for Milking Procedures and Routines in Parallel and Herringbone Parlors

Before the options for milking procedures and routines can be discussed the following terms must be defined:

**Prep time**–time taken to manually clean and dry the teat surface

**Contact time**–the actual time spent manipulating/touching teats and is the source of stimulation for oxytocin release.

**Prep-lag time**-time between the beginning of teat preparation to the application of the milking machine.

**Milking Procedures**–the individual events (i.e. strip, pre-dip, wipe, attach) required to milk a single cow.

**Milking Routines**–define how an individual milker or a group of milkers carry out a given milking procedure (minimal or full) over multiple cows. In parallel and herringbone parlors; there are three predominant milking routines (grouping, sequential, and territorial). These individual milking routines are drawn in Figure 1.

**Grouping Milking Routine**–In a grouping routine the operator will perform all the individual tasks of the milking procedure on 4-5 cows. Once they have completed a group of cows they move to the next group of available cows.

**Sequential Milking Routine**–Operators using a sequential routine split up the individual tasks of the milking procedure between operators and work as a team. Operators work as a team following each other performing their individual tasks.

**Territorial Milking Routine**–Milkers are assigned units on both sides of the parlor and only operate the units assigned to them. When a territorial routine is used milkers are not dependent on other milkers to perform specific tasks.

The predominant milking procedures are minimal (strip or wipe and attach) and full (pre-dip, strip, wipe and attach). Full milking procedures impact the number of cows per stall per hour in parallel, herringbone and rotary parlors. In large parallel and herringbone parlors cows per stall per hour are 5.2 when minimal milking procedures are used and 4.4 when full milking procedures are used. In rotary parlors cows per stall per hour decline from 5.75 to 5.3 when a minimal routine is used as compared to a full routine (Armstrong et al. 2001). In large parlors milking procedures have a dramatic impact on the number of units one operator can handle in parallel and herringbone parlors. In 1997, Smith et al. published guidelines for the number of units that one operator could handle using a minimal and a full milking procedures. When a full milking procedure was used a milker could operate 10 units per side and 17 units per side when using minimal milking procedures. These recommendations were based on allowing 4-6 seconds to strip a cow and attaching all the units on one side of the parlor in 4 minutes. In recent years several milking management specialists have been recommending 2-3 squirts per teat (8-10 seconds) when stripping cows to increase stimulation and promote better milk letdown. Some of these management specialists believe that increasing the amount of stimulation reduces unit on times. At this time a strong data set supporting this theory does not exist. An AABP research update reported by Rapnicki, Stewart, and Johnson (2002) indicates that milk flow rate was decreased when cows that had been previously stripped were no longer stripped. If this is implemented, producers will have to reduce the number of units one operator can manage per side (Table 1). The sequencing of the individual events of the milking procedure is critical. Work completed by Rasmussen et al. (1992) would indicate an ideal prep-lag time of 1minute and 18 seconds. Prep-lag times of 1-1.5 minutes seem to be accepted as optimal for all stages of lactation. Producers will have to decide which milking procedure they will use and the amount of stimulation. Some of the advantages and disadvantages of minimal and full milking procedures are listed in Tables 2 and 3.

Table 1. Time (seconds) Required for Individual Events of the Milking Procedure.

| | Procedure | | |
|---|---|---|---|
| Event | Minimal* | Full | Full with 10 sec Contact Times |
| Strip | 4-6 | 4-6 | 10 |
| Pre-dip | | 6-8 | 6-8 |
| Wipe | 6-8 | 6-8 | 6-8 |
| Attach | 8-10 | 8-10 | 8-10 |
| Total | 12-18 seconds | 24-32 seconds | 30-36 seconds |

*Strip or wipe and attach

Table 2. Advantages and Disadvantages of a Minimal Milking Routine

Compromises teat skin sanitation
Successful when cows enter the milking parlor clean and dry
"Machine on-time" may be prolonged
Steady state throughput is increased.
Time required to milk the herd may be decreased (total milking time).
May require milkers to decide when extra cleaning of dirty teats is required
Can cause lower milk quality and higher mastitis when compared to "full hygiene"

Table 3. Advantages and Disadvantages of a Full Milking Procedure

Maximizes teat sanitation and milk letdown
Use 4 separate procedures or can combine into two or three procedures
Use when maximum milk quality results are the goal
Minimizes "machine on-time"
Results in lower cow throughput or higher labor cost compared to "minimal" or "none"
Requires milker training to maximize results

Three predominant milking routines are used in parallel and herringbone parlors (sequential, grouping, and territorial). These milking routines are presented in Figure 1. The use of territorial routines will reduce throughput 20-30% when compared to sequential routines (Smith et al. 1997). Grouping routines seem to be an alternative to sequential routines without sacrificing throughput. Sequential and grouping routines are demonstrated in Figures 2-7. Both full and minimal milking procedures in rotary parlors are presented in Figure 8.

**Impact of Automatic Take-offs**
A study published by Stewart et al. (2002) would indicate that when automatic cluster remover settings were increased, average milking duration was reduced 10.2 to 15.6 seconds per cow. Higher automatic cluster remover settings did not have a negative impact on milk production per cow. Average milk flow per minute increased .11 to .42 lb/minute. Increasing automatic cluster remover settings represents an opportunity to increase parlor performance.

**Selecting Parlor Type**
Dairy owners usually have a personal preference for a certain parlor type. Many times this personal preference conflicts with the number of cows to be milked, length of the milking shift, anticipated milk quality, udder health results and financial resources. The selection of a milking parlor should be influenced by the initial herd size, expansion plans, economic impact on the dairy, and the ability to train and manage employees. Dairy producers should visit as many types of parlors as possible and make a final decision after having an opportunity to review all types, not just the fastest or newest.

**Total Hours of Use**
A milking parlor sized for use only 4 to 6 hours a day will be more expensive to build and operate per cow than if the parlor operates 20 to 21 hours per day. For example, a 250-cow dairy, milking two times a day could be milked in a double-4 herringbone parlor in a 6-hour shift, or milked in a double-10 herringbone in a 3-hour shift. The cost of a double-4 is approximately $90,000, while a double-10 is $180,000. Fewer hours of use may be desirable if farm personnel also have other duties, such as crop production, feeding, animal health, and raising replacements. However, a larger return on investment will be realized if the milking parlor can be used 20 to 21 hours a day to milk cows. Producers are often caught making a choice between the number of cows they can milk and which milking procedure they can use under these conditions. If they are not careful milk quality and udder health may suffer.

**Number of Operators**
The number of operators may be influenced by the availability of personnel, milking procedure or herd size. Most small herringbone and parallel parlors (D-4 to D-12) are operated by one operator. One-person parlors are more efficient in the number of cows per labor hour. Two-or-more-operator parallel or herringbone parlors have the advantage of continuous operation even during group change, when one operator is late for the milking shift, or when a short emergency requires one operator to leave the parlor. The disadvantage is that is it more difficult for the owner to assess operator performance or quality standards, and the number of cows per labor hour will be less. However, many producers are able to achieve the same labor efficiency in multiple operator parlors as single operator parlors with training and monitoring programs.

## Initial Herd Size and Expansion Plans
Dairy producers will want to consider their current herd size along with plans to increase herd size in the future. If a producer wants to grow in steps, parallel or herringbone parlors can be constructed to allow for expansion as herd size increases. Parallel and herringbone parlors have an advantage over rotary parlors that can not be expanded in steps.

**One vs Two Parlors**
Some research indicates that two smaller parlors are more efficient than one larger parlor (Thomas et al. 1993, 1994, 1995). One study compared two double 20 parallels versus one double 40 parallel (Thomas et al.1995). The net parlor return over 15 years was $908,939 greater in the two smaller parlors vs. one large parlor. The initial cost of constructing two double 20 parallels was $22,227 higher than constructing one double 40. Constructing 2 parlors also allows producers to construct the dairy in phases and increase the number of groups of lactating cows.

**Training and Monitoring Milkers**
Providing training and monitoring milkers is a constant challenge for dairy producers. In parallel and herringbone parlors with multiple milkers it becomes very important to train teams of milkers to work together to improve parlor performance. In parallel and herringbone parlors operators are mobile and able to perform multiple tasks (i.e. strip, pre-dip, wipe, attach) as compared to rotary parlors where operators are fixed in one location and only perform one or two tasks in this location. If the performance of multiple operator parallel and herringbone parlors is to be maximized, operators will have to work together to perform the milking procedures over multiple cows using a grouping or sequential milking routine. After milker training has been completed producer will have to monitor the performance of individual milkers and parlor performance.

**Evaluating Parlor Performance**
Milking parlor performance has been evaluated by time and motion studies (Armstrong and Quick, 1986) to measure steady-state throughput (cows per hour). Steady-state throughput does not include time for cleaning the milking system, maintenance of equipment, effects of group changing, and milking the hospital strings. These studies also allow us to look at the effect of different management variables on milking parlor performance. Historically this information has been used to size milking parlors to meet dairy producer needs.

## Sizing Milking Parlors
As the size of dairies increases the sizing of milking parlors becomes more complicated. Many producers are choosing to use hospital parlors reducing pressure on the main parlor. Some producers are also milking healthy cows through the hospital parlor so additional cows can be milked through the main parlor or parlors. Some dairies are increasing the number of milkings to 4, 5, or 6 times a day for the first 21-42 days of lactation and returning to 2 or 3 times a day milking at 21-42 days in milk (Dahl 2002). These factors will have a dramatic impact on how the milking parlor is sized. Sizing parallel, herringbone, and rotary parlors is discussed below. In the discussion below it is assumed that all groups of cows will be milked through the main parlor.

**Sizing Parallel and Herringbone Milking Parlors**
The design criteria for parallel and herringbone parlors are presented in Table 4.

Table 4. Design Criteria for Parallel and Herringbone Parlors

| Milking Frequency | Shift Length* | Turns per Hour | Time to Milk One Group (min) |
|---|---|---|---|
| 2x | 10.0 | 4.0 | 60 |
| 3x | 6.5 | 5.0 | 40 |
| 4x | 5.0 | 6.0 | 30 |

*Hours of Steady State Throughput

Typically, milking parlors are sized so that the herd can be milked once in 10 hours when milking 2x per day; 6.5 hours when milking 3x per day; and 5 hours when milking 4x per day. Using these criteria, the milking parlor will be sized to accommodate the cleaning and maintenance of the parlor. The facilities or cow groups are determined based on milking one group in 60 minutes when milking 2x, 40 minutes when milking 3x, and 30 minutes when milking 4x. Group size is adjusted to be divisible by the number of stalls on one side of the milking parlor. Having as many occupied stalls as possible per cycle maximizes parlor efficiency. The number of cows that will be milked per hour can be calculated using the following formulas:

Total # of stalls x turns per stall per hour = cows milked per hour (CPH)

Number of milking cows = CPH x milking shift length (hours)

**Sizing Rotary Parlors**

Entry time (seconds/stall), number of empty stalls, number of cows which go around a second time, entry and exit stops and the size of the parlor (number of stalls) influence the performance of rotary parlors. The entry time will determine the maximum number of cows that can be milked per hour. For example if the entry time is 10 seconds, the maximum throughput will be 360 cows per hour (3600 seconds per hour / 10 seconds per stall = 360 cows per hour). This is referred to as theoretical throughput.

Theoretical throughput assumes that the parlor never stops, cows are milked out in 1 rotation and a new cow occupies every stall at entry. In reality, there are empty stalls, cows that go around a second time and times when the rotary table is stopped. Table 5 shows rotary parlor performance at different percentages of theoretical throughput. As the number of empty stalls, cows making a second trip around, and number of stops increases the percent of theoretical throughput is decreased.

Table 5. Rotary Parlor Performance (Cows per hour)

| | | | % of Theoretical cows/hr | | |
|---|---|---|---|---|---|
| Time (sec/stall) | 100% | 90% | 80% | 70% | 60% |
| 8 | 450 | 405 | 360 | 315 | 270 |
| 9 | 400 | 360 | 320 | 280 | 240 |
| 10 | 360 | 324 | 288 | 252 | 216 |
| 11 | 327 | 295 | 262 | 229 | 196 |
| 12 | 300 | 270 | 240 | 210 | 180 |
| 13 | 277 | 249 | 222 | 194 | 166 |
| 14 | 257 | 231 | 206 | 180 | 154 |
| 15 | 240 | 216 | 192 | 168 | 144 |
| 16 | 225 | 203 | 180 | 158 | 135 |

The number of stalls or size of the rotary parlor affects the available unit on time. Table 6 lists available unit on time for different sizes of rotary parlors at different rotation times. A rotary parlor must be large enough to allow approximately 90 percent of the cows to be milked out in one trip around the parlor.

Table 6. Available Unit on Time Calculated for Rotary Parlors at Different Rotation Times*

| | | Revolution Time | | Available Unit on Time | |
|---|---|---|---|---|---|
| # of Stalls | Entry time sec/stall | Seconds /Revolution | Minutes/ Revolution | Seconds/ Revolution | Minutes/ Revolution |
| 40 | 8 | 320 | 5:20 | 240 | 4:00 |
| 40 | 10 | 400 | 6:40 | 300 | 5:00 |
| 40 | 12 | 480 | 8:00 | 360 | 6:00 |
| 40 | 15 | 600 | 10:00 | 780 | 7:30 |
| 60 | 8 | 480 | 8:00 | 400 | 6:40 |
| 60 | 10 | 600 | 10:00 | 500 | 8:20 |
| 60 | 12 | 720 | 12:00 | 600 | 10:00 |
| 60 | 15 | 900 | 15:00 | 750 | 12:30 |
| 72 | 8 | 576 | 9:22 | 496 | 8:16 |
| 72 | 10 | 720 | 12:00 | 620 | 10:20 |
| 72 | 12 | 864 | 14:24 | 744 | 12:24 |
| 72 | 15 | 1080 | 18:00 | 930 | 15:30 |
| 80 | 8 | 640 | 10:40 | 560 | 9:20 |
| 80 | 10 | 800 | 13:20 | 700 | 11:40 |
| 80 | 12 | 960 | 16:00 | 840 | 14:00 |
| 80 | 15 | 1500 | 20:00 | 1050 | 17:30 |

*Assumes 5 stalls for entry and exit, 3 stalls for pre-milking hygiene, 2 stalls to detach

In reviewing the data available today, rotary parlor should be sized at an 11-12 seconds per stall rotation and 81% of theoretical throughput. The parlor should be large enough to allow 9 minutes of available unit on time. If you want size to rotary parlors on a steady state throughput basis, parlors below 54 stalls milk 5 cows/stall/hour and parlors 60 stalls or larger milk 5.8 cows/stall/hour (Table 7). The parlors with 60 stalls or larger are able to increase the number of rotations per hour and still maintain adequate time to milk cows out with out sending them around a second time. It is critical that rotary parlors be sized to accommodate some expansion because they are very difficult to expand.

Table 7. Performance of different size rotary milking parlors using a full milk procedure.

| | Number of Stalls | | |
|---|---|---|---|
| | 24-40 | 48-54 | 60-80 |
| Number of Parlors | 8 | 5 | 7 |
| Number of Stalls (Avg) | 36 | 51 | 72 |
| Cows/hour (Avg)* | 181 | 258 | 420 |
| Number of Operators (Avg) | 2.6 | 2.7 | 5.41 |
| Cows Labor/hour (Avg) | 82 | 98 | 77 |
| Milk Production (lbs) (Avg) | 70 | 77 | 74 |
| Rotation/stall/hour (Avg) | 5.42 | 5.42 | 6.16 |
| Cows/stall/hour (Avg) | 5.01 | 5.06 | 5.82 |

*Steady state throughput

## Which Parlor is Right for Me?

The decisions that a dairy producer makes concerning the milking parlor can have a dramatic impact on their ability to meet their goals. One parlor type will not meet the needs of all dairy producers. Producers will need to carefully evaluate all options. The milking parlor is the center of the dairy. If a producer wants to grow in steps and expand the milking parlor as cows are added, constructing a parallel or herringbone parlor with the ability to add stalls in the future would be a logical choice. If the goal is to build a parlor to its final size and fill it full of cows, any of the milking parlor types could be used. Room could be allowed in the site plan to add a second milking parlor and additional cow housing. Whatever type and size of parlor is selected, it is absolutely critical that a financial evaluation is completed.

## References

Armstrong, D.V., M.J. Gamroth, and J.F. Smith. 2001. Milking Parlor Performance. Proc. of the 5th Western Dairy Management Conference, pp 7-12. Las Vegas, NV.

Armstrong, D.V. and A.J. Quick. 1986. Time and motion to measure milk parlor performance. J. Dairy Sci. 69(4): 1169-1177.

Dahl, G. 2002. Milking frequency effects in early lactation. Proc. of the Dairy Summit. Minnetonka, Minn.

Rapnicki, P., S. Stewart, and A. Johnson. 2002. Personal Communication.

Rasmussen, M.D., E.S. Frimmer, D.M. Galton and L.G. Peterson. 1992. Influence of premilking teat preparation and attachment delay on milk yield and milking performance. J. Dairy Sci. 75:2131.

Smith, J.F., J.P. Harner III, M.J. Brouk, D.V. Armstrong, M.J. Gamroth and M.J. Meyer. 1999. Relocation and Expansion Planning. Proc. of the Western Herd Management Conference, pp 73-85. Las Vegas, NV.

Smith, J.F., D.V. Armstrong, and M.J. Gamroth. 1997. Labor Management Considerations in Selecting Milking Parlor Type & Size. Proc. of the Western Dairy Management Conference, pp. 43-49. Las Vegas, NV.

Stewart, S., S. Godden, P. Rapnicki, D. Reid, A. Johnson, and S. Eicker. 2002. Effects of Automatic Cluster Remover Settings on Average Milking Duration, Milk Flow, and Milk Yield. J. Dairy Sci. 85:818-823.

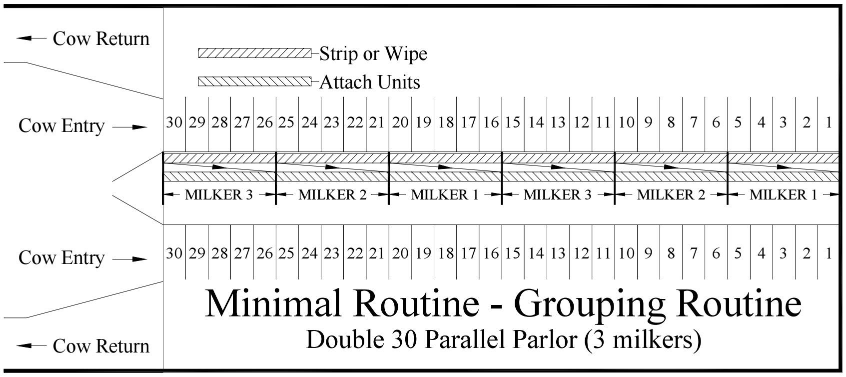
Thomas, C.V., D.V. Armstrong, J.F. Smith, M.J. Gamroth, and D.R. Bray. 1995. Managing the Milking Parlor for Profitability. Proc. of the 2nd Western Large Herd Dairy Management Conference, pp. 139-146. Las Vegas, NV.

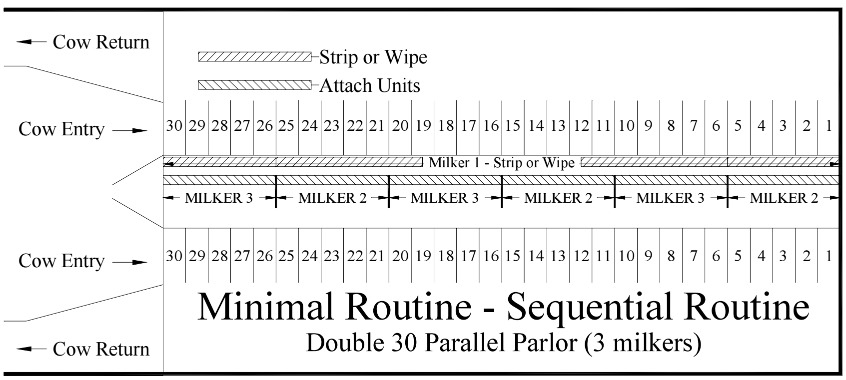
Thomas, C.V., M.A. DeLorenzo, R.N. Weldon, and D.R. Bray. 1994. A stochastic economic analysis of large herringbone and parallel milking parlors. J. Dairy Sci. 726(Supp. 1): 129(Abstr).

Thomas, C.V., M.A. DeLorenzo, and D.R. Bray. 1993. Prediction of individual cow milking time for milking parlor simulation models. J. Dairy Sci. 76(8):2184-2194.

Thomas, C.V., M.A. DeLorenzo, and D.R. Bray. 1993. Capital budgeting for a new dairy facility. Circ. No. 1110. Gainesville, Fla.: Inst. of Food & Agric. Sci., University of Florida.

**Figure 1.** Different Milking Routines for Parallel and Herringbone Parlors



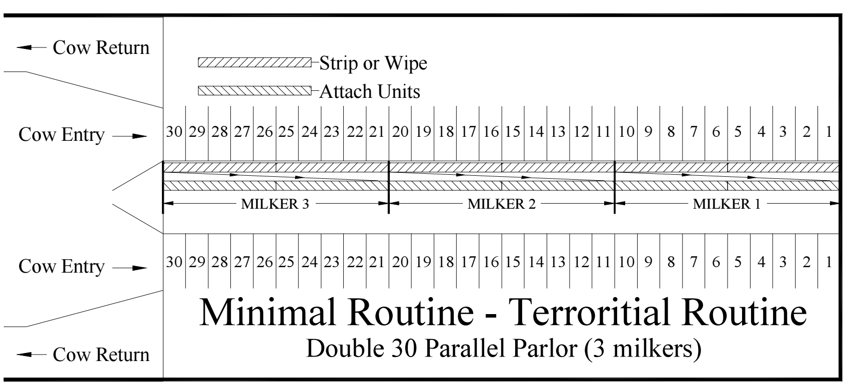
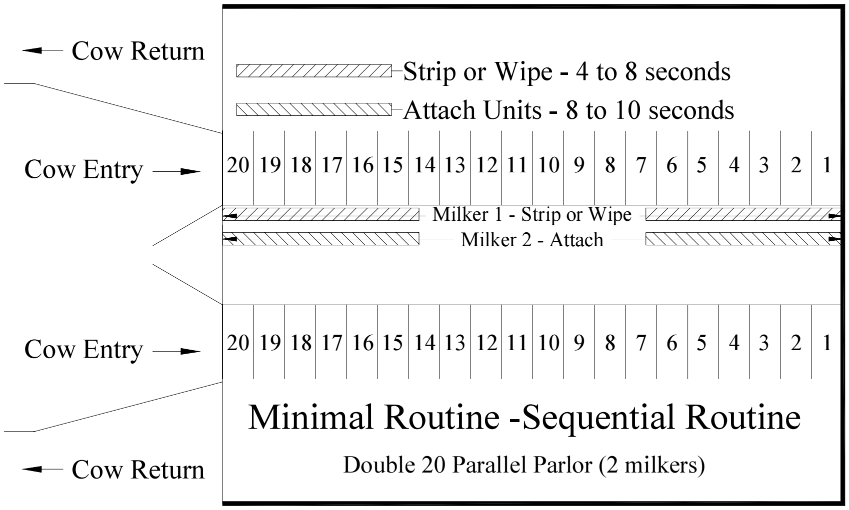



**Figure 2.** Sequential Milking Routines for Double 20 Parallel Parlors Using Minimal or Full Milking Procedures



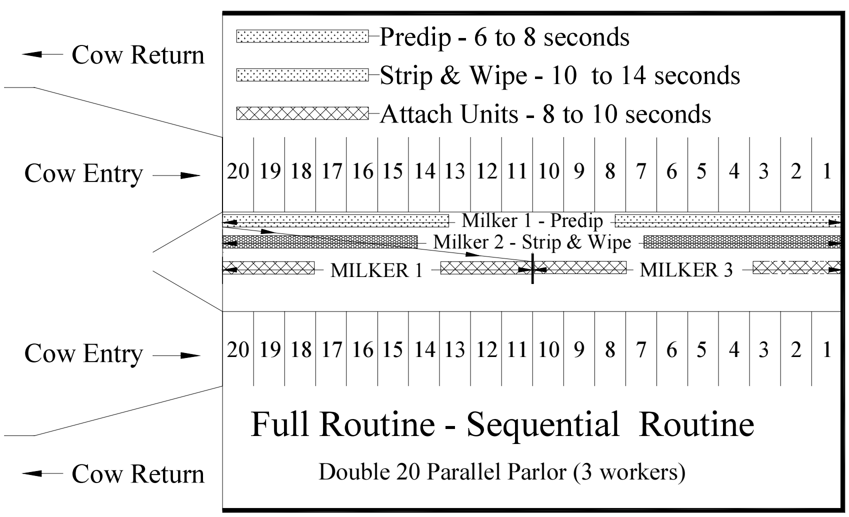
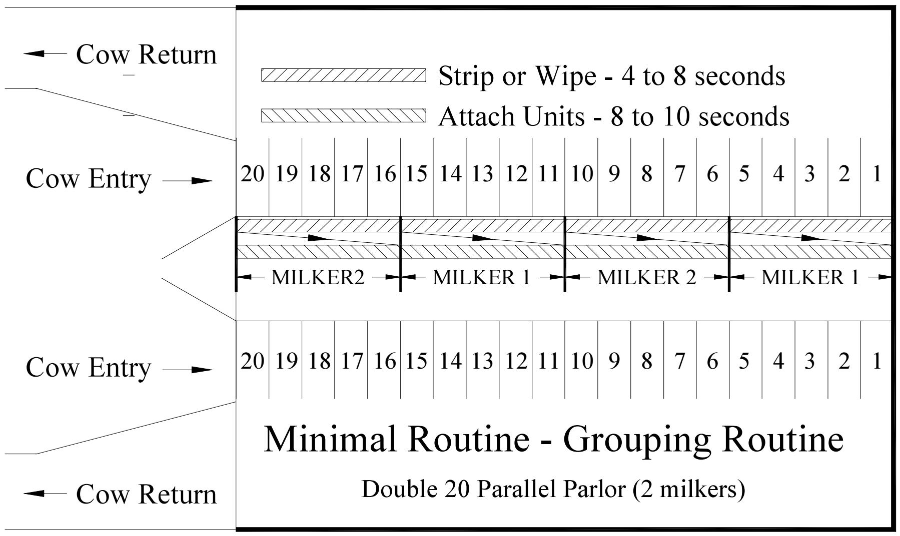



**Figure 3.** Grouping Milking Routines for Double 20 Parallel Parlors using Minimal or Full Milking Procedures



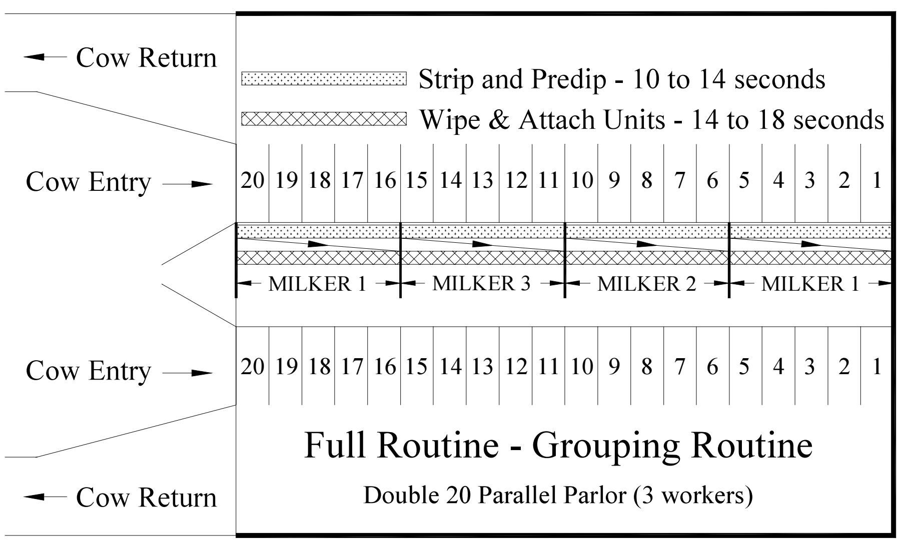
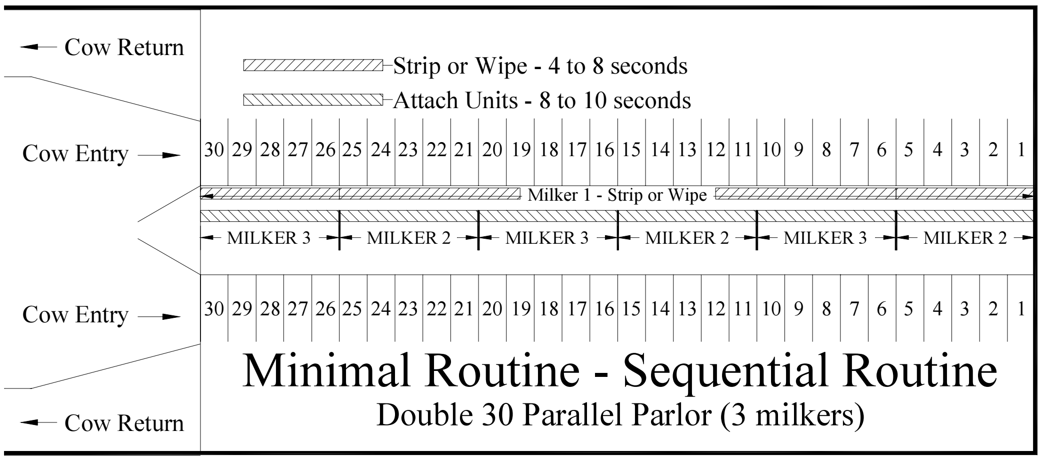



**Figure 4.** Sequential Milking Routines for Double 30 Parallel Parlors using Minimal or Full Milking Procedures



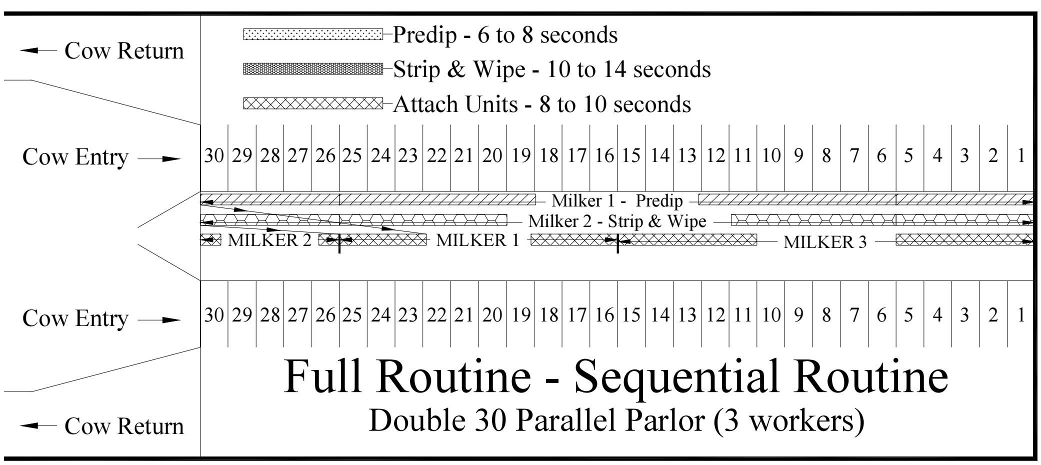
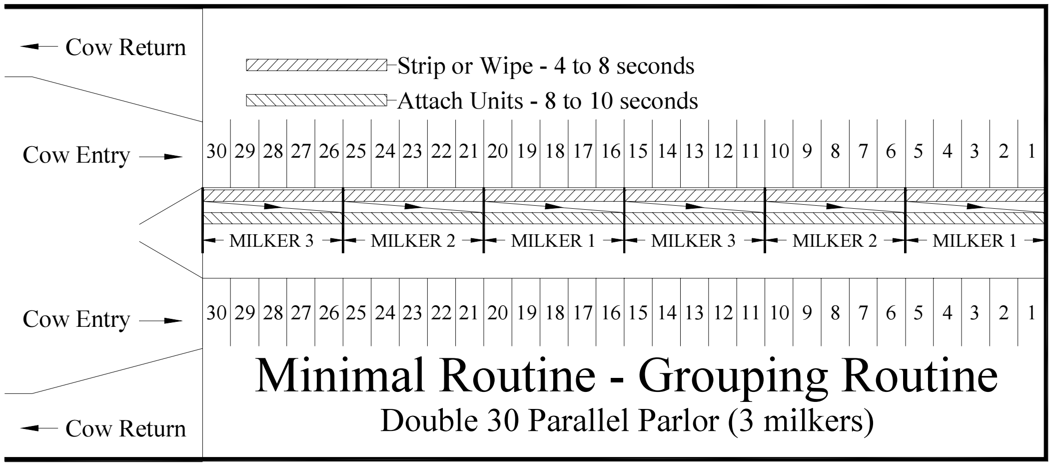



**Figure 5.** Grouping Milking Routines for Double 30 Parallel Parlors using Minimal or Full Milking Procedures



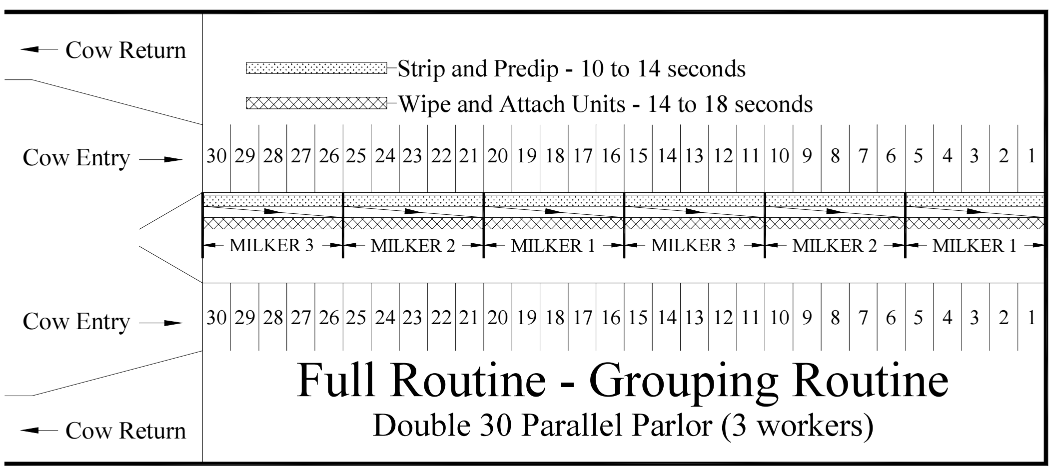
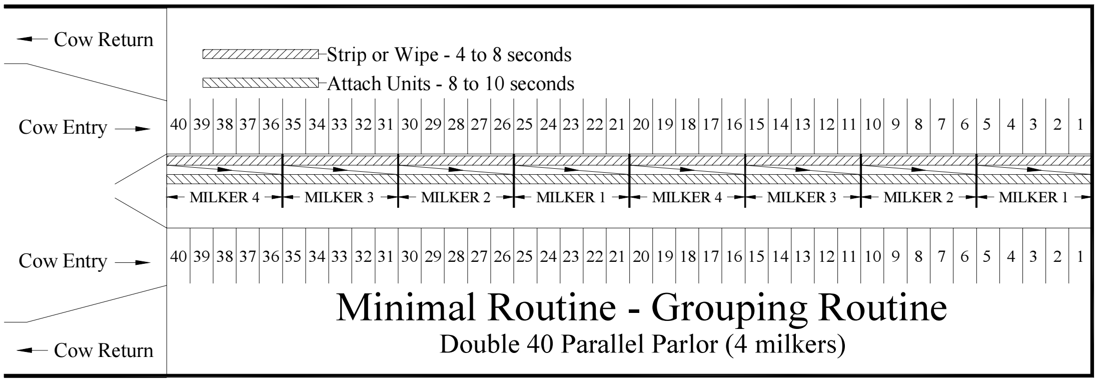



**Figure 6.** Grouping Milking Routines for Double 40 Parallel Parlors using Minimal or Full Milking Procedures



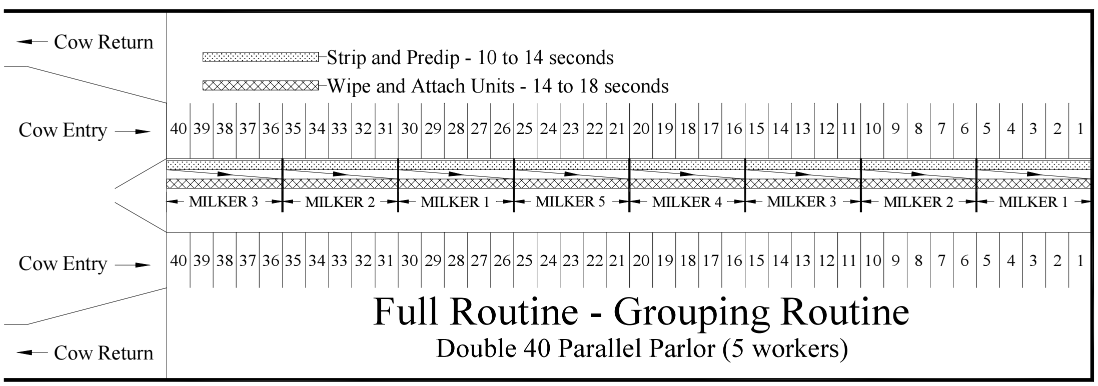
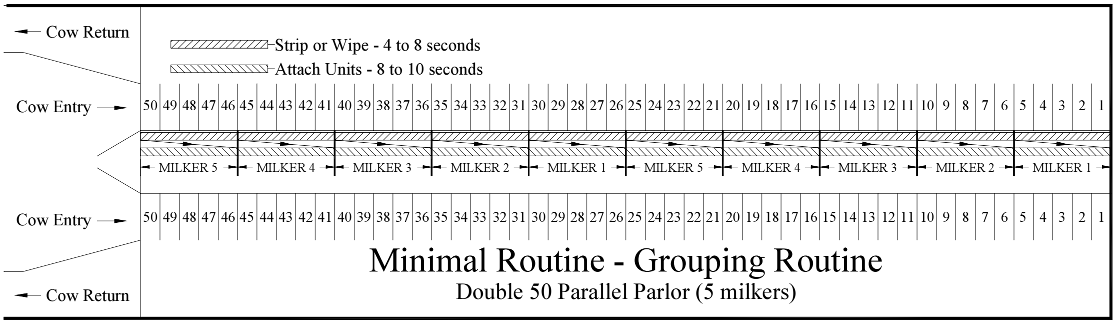



**Figure 7.** Grouping Milking Routines for Double 50 Parallel Parlors using Minimal or Full Milking Procedures



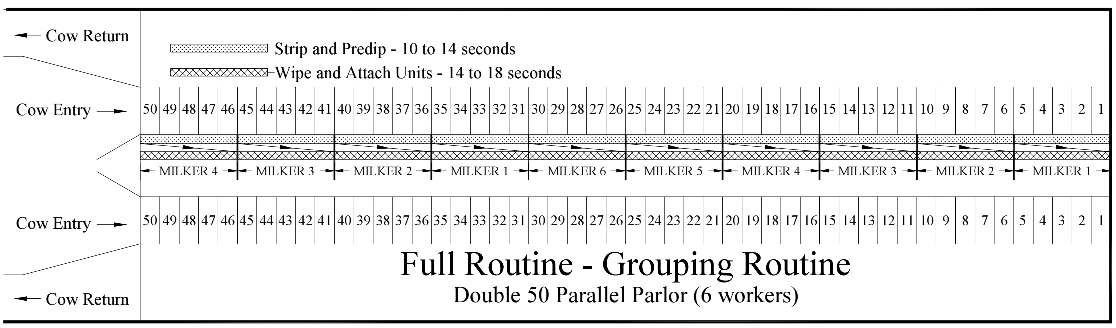
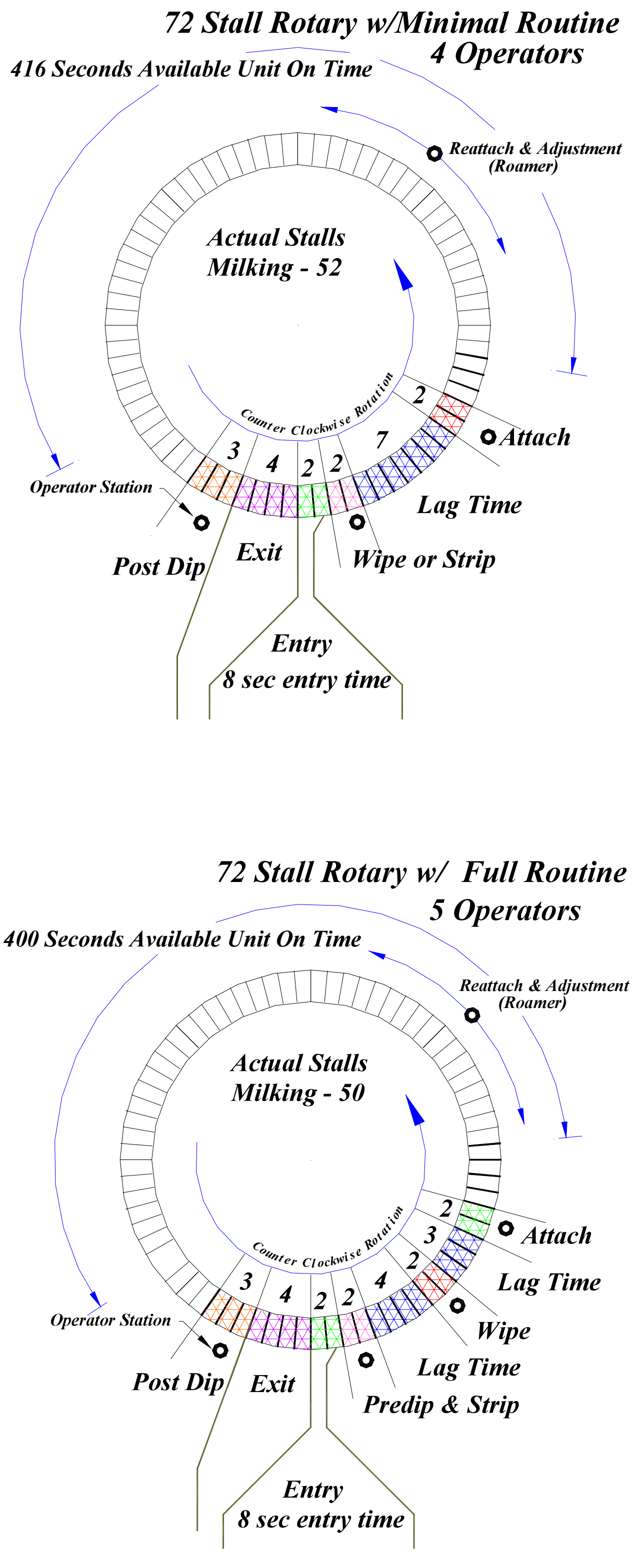



**Figure 8.** Minimal and Full Milking Procedures in Rotary Milking Parlors



# Managing Mastitis in Today's Parlors

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Mastitis is still the most costly disease facing dairymen. This is a complex disease resulting from many causes and is affected by many factors. When a herd has a mastitis problem, it is important to look at the entire picture on the dairy. The most important areas are the cows' environment, the milking system and the people milking the cows. Rarely is one single cause responsible for a herd mastitis outbreak.

Today's modern dairies continue to get larger with many hired employees. Managers and owners have much less time to spend with details of managing mastitis and milking performance. It is important for owners and managers to understand what needs to be done with mastitis management and also how to direct and monitor employee performance in this regard. This paper will outline the 3 key areas of mastitis management; cow comfort and environment, milking systems, and milker performance. In addition, recommendations for monitoring these areas will be discussed.

The level of mastitis is directly related to the new infection rate and the cure rate. A mastitis control program must focus on reducing the new infection rate. Cure rates are often dependent on the cow's own immune system and the type of infecting organism, therefore, treatment protocols cannot be relied upon to have a high rate of cure. The new infection rate is directly related to the number and type of bacteria present on teat skin when units are attached to the cows, and therefore, can be managed. The key factors for reducing the new infection rate are:

- minimize the contamination of the skin and teat ends between milkings
- keep bacteria from entering the teat canal during milking
- reliably dip all 4 teats completely with an effective product after milking
- keep teat skin and teat ends healthy

Teat skin contamination is related to the cow's environment. Whether cows are housed in free stalls or dry lots, the bedding must be clean, dry and comfortable. Cows should be relatively clean. Udders and legs should be free from large areas of dried manure and bedding. A scoring system can be utilized which evaluates the number of cows with clean udders and legs versus cows with obvious manure and dirt. For example, Pharmacia has provided a scorecard system in their Q-Max Quality Plan for producers, which has photographs and descriptions of cow cleanliness levels. A score of 1 is a clean cow with no observable dirt on the udder, thigh or body, while a score of 4 shows a cow with very large areas of dirt and manure over the udder, legs and thighs. A goal should be set by managers regarding the acceptable number of cows having a score of 3 or greater, with the vast majority of cows scoring a 2 or less. Monthly or regular scores should be collected and employees involved in bedding care should be informed of the results. When results do not reach desired goals, action should be taken in the form of a procedure review, with discussion involving the people performing the work, and revision of procedures as needed.

Managing milking systems is important because milking machine function directly affects teat end health and entry of mastitis pathogens while the machine is attached. Teat end condition is directly related to milking duration. Milking duration is affected by udder preparation, vacuum level and take-off settings. Goals should be set for vacuum level and vacuum stability. Vacuum stability in the receiver jar and milk lines should be within .6" at all times during normal milking. Recommended peak flow claw vacuum levels should be between 11.5" to 12.5" Hg when measured between the 1st and 2nd minute after unit attachment. It is important for producers to understand that lower vacuum levels result in longer machine on-time and slower milk out. Increased machine on-time will cause significant wear and tear on teat ends causing teat end hyperkeratosis lesions. Hyperkeratosis lesions greatly inhibit the cow's ability to naturally exclude bacteria from entering the teat end, and also make cleaning these teat ends very difficult. Automatic take-offs (ATO's), if used, should be adjusted to minimize machine on-time. With properly adjusted ATO's, and good pre-milking preparation, cows can be trained to milk out completely and quickly resulting in greater throughput and greater milk yield. A qualified professional should thoroughly evaluate milking machine function at least monthly in accordance with established National Mastitis Council guidelines.

A large dairy parlor can be managed more efficiently when cows enter with clean, dry legs and udders, and are milked with properly adjusted and maintained milking equipment. Many of today's larger milking parlors are typically run by hired personnel with little training or cow experience. Milker education and strict adherence to established protocols is of utmost importance in mastitis prevention and control. Regular evaluation of milking employee performance and additional follow-up coaching and training is absolutely required to prevent unwanted variation in routine and the development of unacceptable milking habits. It is natural for employees to drift from procedure and modify habits when owners and managers are rarely available to show an interest in their activities.

Milking routine and procedures should be customized for individual dairies. The size, style of parlor and number of employees available will determine what routine and procedures are necessary to arrive at the goal of milking clean, dry, stimulated teats at every milking. Milking routine refers to the positioning, timing and movement of people milking the cows. Milking procedures refer to the actual tasks performed during the routine. The most efficient types of pre-milking routines that will maximize milk quality as well as cow throughput, involve pre-milking hygiene and forestripping choreographed in a way that allows time for the cow to achieve proper milk let down. Management's goal should be to bring cows to the holding pen as clean as practically possible at every milking and in as calm a manner as possible. Cows handled in a calm manner move slower and have less manure splash on the front of their feet and lower body than do cows that are pushed aggressively to the parlor. Calm cows will more willingly enter the parlor and will have better primary oxytocin letdown during the pre-milking period, resulting in efficient throughput and improved milk yield.

Udder preparation is the key factor to reducing the new infection rate. The number of bacteria present on teat skin dictates the new infection rate. There is no one right way to prep cows. However, there are certain physiological principals that hold true for all cows. Manipulation of cows' teats during the pre-milking period is achieved by forestripping and toweling activities. This stimulation results in a nervous impulse that travels to the brain of the cow very quickly. The pituitary gland located below the brain then releases oxytocin after stimulation of the teats. This occurs very rapidly, within one to two seconds after the nerve impulse reaches the brain. The oxytocin is carried within the bloodstream and from there it is dispersed through the cow's body. It takes approximately 20 seconds for the oxytocin to reach the mammary gland and an additional 20 to 30 seconds to have full milk letdown affect. Renau and Chastain have reviewed and analyzed research data concerning oxytocin letdown and proper milking procedures. They state that a teat cleaning and drying process with a stimulation time on the teats of ten to twenty seconds is adequate to consistently achieve milk letdown while effectively sanitizing teats. In addition, a prep lag time of 60 seconds, which is the length of time between first stimulation to machine attachment, reduced average milking time per cow by .6 minute, increased mean milk yield by .7 pounds per milking and increased the average milk flow rate by .7 pounds per minute per cow. Therefore, the goal of any pre-milking protocol is to effectively stimulate and sanitize teat ends of several cows before the first machine is attached to the first cow stimulated approximately one minute later.

The actual milking period when machines are attached is extremely important because this is the time when most cows are infected with mastitis bacteria. A major goal is to limit the number of audible liner squawks, a sign of outside air entering the system from around the base of the teats. Liner squawking, audible or not, may directly result in high velocity impacts of milk and bacteria back against teat ends, resulting in penetration of the canal by bacteria causing mastitis. Cows with adequate oxytocin letdown, dry and clean teat skin and properly positioned milking units will have few liner squawks, fewer units kicked off and, therefore, decreased new infection rates. In addition, properly stimulated cows will decrease flow rate abruptly at the end of milking allowing for rapid unit detachment. Adjustments should be made to equipment and management practices that are geared to milking cows as quickly, as gently, and as completely as possible. Milking cows quickly, gently and completely will minimize the machine effects on teat end and skin condition.

As soon as practically possible after the units are removed from the cows, teats should be dipped with a sanitizing, post milking teat dip. The primary purpose of post milking teat dipping is to flush off the milk film present on teats when units are removed and to leave a germicide on the teat skin. Application of post milking teat dips is important also to maintain soft, healthy teat skin, which is more resistant to colonization by bacteria. It is recommended to use non-return dip cups for applying dip rather than spraying. It is more difficult to quickly and adequately cover the entire teat surface with product from sprayers. Spray mechanisms also require a significant increase in dip consumption as compared to the dip cup. Remember to never return used dip to an original container and to clean dip cups after every milking.

Consistent cow handling, effective pre-milking stimulation, proper machine function and adjustment, and post milking teat dipping will reduce the new infection rate. Most dairymen are already well aware of these principles. However, these same dairymen are increasingly tempted to omit as many of the steps as possible in an effort to increase cow throughput. Because first calf heifers have lower overall SCC scores, when a new dairy begins with mostly first calf animals, the SCC will likely be acceptable regardless of the udder preparation or lack of udder preparation protocols adopted. If the same management and milking procedures are followed for the next several years, the dairy will likely have significant issues of both high somatic cell count and high levels of clinical mastitis.

Managing mastitis requires the monitoring of clinical case rates and somatic cell counts; however, in order to interpret the results of your monitoring effort, it is necessary to Know Your Enemy. Mastitis causing organisms are very different and have different prognoses for cure and varied potential for causing devastating outbreaks, therefore samples must be collected for culture. Mastitis bacteria are divided into two main groups, the contagious bacteria and the environmental bacteria. Contagious bacteria include *Strep. ag*, *Staph. aureus* and Mycoplasma species. These organisms are generally classified as parasites of the udder not typically found in the cow's environment and, therefore, infected quarters are the primary source of new infections in the herd. *Staph. aureus* and mycoplasma are considered to be chronic or permanent infections, generally not responding to treatment. The second group of bacteria is the environmental bacteria, which are typically found outside of the cow with very high numbers occurring in moist and soiled bedding areas. The most common types of environmental organisms are Streptococci bacteria (or Strep species bacteria) and coliforms. Coagulase negative staph species (CNS) are also common but are normally found on teat skin and hair, not soiled bedding. Staph species infections are also typically less severe than strep and coliform infections, but under certain circumstances may significantly contribute to elevated somatic cell counts and clinical mastitis. Any mastitis causing bacteria, whether considered to be contagious or not, can contribute to contamination of the milking environment via infected cow's milk and lead to an infection of another cow.

Mastitis prevention programs were first developed to control the contagious mastitis organisms of *Strep ag* and *Staph aureus*. The most effective control program for contagious mastitis involves sample collection and culture of all animals, followed by the identification and segregating of infected animals for treatment, permanent segregation and/or culling. It is critical to identify any and all cows that are infected with these organisms because remaining infected animals are usually sub-clinical which means the milk appears normal even though they are infected. These animals will continue to contaminate the milking environment and spread infection to other animals, thereby, indefinitely perpetuating the problem. In the case of *Strep. ag*, the vast majority of animals can be treated successfully and recover or, in the case of chronic *Strep ag* cows or *Staph aureus* cows, the animals can be segregated and milked last until they are removed from the herd. Additional management procedures primarily used to limit the spread of these two organisms are effective post milking teat dipping, blanket use of dry cow therapy and milking procedure hygiene such as wearing gloves and single use towels. To prevent re-introduction of contagious pathogens, it is essential to establish an on-going system for sampling all new replacements and new clinical quarters. Consideration for sampling all fresh cows should be made if there is evidence of lingering infection within the herd. Mycoplasma control programs are fashioned very closely to those for controlling *Staph aureus*. Mycoplasma infections may become latent which means the cow will culture negative but may begin to shed contagious organisms again at a later time. Mycoplasma culture is performed as a separate process from the other organisms and likely will require a special culture request at most labs.

Many dairies have eliminated *Strep ag* and may have a very low prevalence of *Staph aureus* due to the successful implementation of such programs. On the other hand, clinical mastitis from environmental organisms is now the primary problem on many well-managed dairies. Additionally, mycoplasma infections will tend to appear sporadically due to the fact that the organisms can be carried in the respiratory or reproductive tract of normal healthy cows. Therefore, it is recommended that large dairies continually culture new clinical cases and monitor these organisms routinely. The best monitoring program consists of having individual somatic cell count data available on all cows on a monthly basis as well as bacteriological examination of both tank milk and clinical mastitis cases. Clinical mastitis records are very important for identifying repeat cases, problem cow groups, and treatment results. Minimal records should consist of the cow id, the quarter infected, and the date. On many dairies this information can be recorded in the herd's management software. Routine evaluation of this information is essential to determine the herd's current status and trends that are occurring in the herd over time.

Most new environmental infections occur at the time of dry off if dry cow therapy is not properly practiced. Dry cow bedding should be kept equally as clean and dry as the lactating herd. Another major source of new environmental intramammary infections is the period just before or right after calving. Sanitation practices must be optimized to minimize the new infection rate at this critical time. On some dairies the use of bedded pack areas for calving can essentially make it impossible to control these organisms even with good milking procedures after cows calve. The environmental bacterial load on the teats must be reduced before calving to reduce the new infection rate during the subsequent lactation.

Routine bulk tank culturing is one of the best ways to monitor the overall herd mastitis level and milking procedures. When quantitative bulk tank cultures are performed, high levels of environmental streptococci, environmental staphylococci and coliform organisms indicate breakdowns in the udder preparation process. The majority of these organisms present in bulk tank milk is coming from teat skin contamination but may also be significantly elevated in the case of chronic Strep non-ag infections.

Coliform infections in cows rarely result in elevated bulk tank coliform counts, while *Strep ag* and non-ag infections may elevate bulk tank plate counts to illegal levels. Bulk tank cultures also are important to demonstrate the presence of contagious organisms such as *Strep ag, Staph aureus*, or Mycoplasma species. However, a certain percentage of animals need to be infected and shedding bacteria for a bulk tank culture to report back as positive. A contagious mastitis problem may not be identified based on bulk tank monitoring alone until there are literally dozens of animals infected in a large herd. Therefore, large dairies should culture individual heifers and cows at freshening and segregate these animals until the cultures come back negative.

In conjunction with recommendations from the herd veterinarian, treatment protocols should be established and adhered to based on the organisms found. It is not always necessary to delay treatment until results are known but this may be something to consider. Some large dairies will segregate animals with contagious or otherwise non-treatable chronic infections such as *A. pyogenes*. *A. pyogenes* causes abscessation in the udder and is very difficult to treat. These cows tend to have recurring mastitis in the affected quarter. Dairy managers may also decide not to treat animals with mild coliform infections since most coliform infections do not respond more favorably when standard mastitis tubes are used. The results of whatever treatment protocol adopted should be regularly evaluated and changed if necessary. An important reason for culturing all clinical cows routinely is that one of the main causes for treatment failure could be mycoplasma or other opportunistic organisms such as yeast or Nocardia, which is introduced during treatment procedures when strict infusion hygiene is not adhered to. If dairy managers wait until an outbreak occurs before identifying a disaster such as this the dairy will likely lose many more animals than necessary.

If a routine bulk tank culture shows a positive mycoplasma result, the first place to look is the hospital treated group. Mycoplasma can be dynamite in a large dairy barn with many animals presented for intra-mammary treatment in close proximity. Collect samples from all animals currently undergoing treatment, or at least a sample of co-mingled waste milk from these animals. If no animals are found that have the infection and a follow-up bulk tank culture is still positive for mycoplasma, then it is necessary to culture samples from strings of cows to determine where the mycoplasma problem exists on the dairy. Occasionally, on every dairy that monitors bulk tank samples for mycoplasma, sporadic positive results will occur with no positive animals found. String samples are collected directly from the cold side of milk transfer lines and should represent only milk from animals of a particular group or corral. When sampling strings, milk filters should be changed between groups. Dairies can monitor for contagious pathogens, somatic cell counts and other parameters routinely using this technique with much greater sensitivity. This is especially important for operations of several thousand animals.

Individual cow cultures will be necessary for entire herds or strings of cows when contagious mastitis becomes a persistent problem on the dairy. Sampling technique is especially important in herd cultures to insure the results are meaningful and will yield a benefit for the dairy. If herd cultures or string cultures are necessary, additional personnel should be in the parlor when samples are taken. These individuals must be properly trained and understand the principles of collecting aseptic milk samples rapidly. Under no circumstances should samples be collected from an in-line system or milk metering devices for culture. Milk samples should be chilled immediately and kept frozen or on ice until brought to the lab for culture. Be sure the laboratory has a good reputation in your area and that they can be ready to handle large amounts of samples before you collect them. An ideal lab will provide information and materials for collection and will be able to report results back in a practical and timely manner. Two days for contagious Staph or Strep and seven days for mycoplasma should be sufficient.

Several other bacterial tests are currently run on bulk tank milk. Milk plants will run a standard plate count, which is the number of bacteria after incubation of 48 hours at 90 degrees Fahrenheit. Elevated standard plate counts (SPC) may be due to many different causes. High SPC can be due to poor or inadequate pre-milking hygiene, equipment cleaning and sanitation, or incubation of bacteria in the milk handling system. Mastitis may contribute to elevated SPC in the case of *Strep ag* and environmental Strep infections. If a lab pasteurized count (LPC) is run in conjunction with a normal standard plate count, a much better diagnosis of high bacteria counts is available for the dairymen. A lab pasteurized count is the number of bacteria per milliliter of milk, which survived laboratory pasteurization at 143 degrees Fahrenheit for 30 minutes. The LPC test typically kills the normal mastitis causing bacteria leaving only those organisms from the environment, which can survive the elevated temperatures. Normally LPC counts should be below 100. An LPC below 10 indicates excellent equipment hygiene. Another routine test on bulk tank milk is the coliform count. An ideal coliform count would be less than 10 organisms. Coliform counts between 100 and 1000 are generally an indication of poor milking hygiene. When these tests are available, it becomes easier to diagnose bacterial problems in the bulk tank milk. If equipment sanitation problems are present, there will be an elevated LPC count. When there is incubation of bacteria in the milking system, there can be both a high coliform count and/or high LPC count. Inadequate milking hygiene may result in elevated coliform counts but not high LPC counts.

Bulk tank culture (mastitis organisms and bacteria counts) can be very useful to monitor the effects of milking practices and changes to milking protocols and management changes when counts are taken before and after the changes are made. Charts and graphs of sequential bulk tank culture results from a dairy are most valuable for looking at the trends on the dairy. If only one bulk tank culture is available, be very cautious of making a diagnosis based on that information. The trends over time in bulk tanks are much more important than individual bulk tank cultures.

In summary, managing mastitis in today's parlors requires a system to measure and monitor all three areas of critical control, which are the cow's environment, the milking system, and the milking team. By setting goals and measuring results in specific areas, such as cow hygiene scores, bulk tank bacteria counts, presence of contagious pathogens in milk cultures, or somatic cell counts, the producer can monitor the success of the various programs on the dairy. When the results do not match the goals, then the program undergoes review and revision by the dairy management team.

# Effectiveness of Cow Cooling Strategies Under Different Environmental Conditions

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## Introduction

Thermal stress in cattle results in major decreases in dairy production each summer. These decreases have been documented in many studies and reviews (Armstrong, 1994, Collier, et.al., 1982, Ravagnolo, et.al., 2000 and Ray, et.al. 1992). Igono and others (1992) proposed that the Temperature Humidity Index (THI) could be used to evaluate the thermal stress of the environment. This index combines relative humidity and temperature into a single value to estimate the potential environmental heat load. An environment is generally considered stressful for cattle when the THI exceeds 72. When THI is above this level, adverse affects are expected in cattle. Others have suggested (Hahn, et al., 1992) that feed intake of cattle will be reduced when temperatures exceed 75 °F. Production losses can be minimized by proper heat abatement measures. However, the measures must also be cost effective and provide an economic return to the dairy operation.

## Heat Exchange Mechanisms

Dairy cattle produce large amounts of heat from both ruminal fermentation and metabolic processes. As production increases, the total amount of heat produced increases. A high producing lactating cow will produce about 4,500 British Thermal Unit (BTU)/hr. In order to maintain body temperature within the normal range, cows must exchange this heat with the environment. Cattle exchange heat through the mechanisms of convection, conduction, evaporation and radiation. It is important to remember that heat exchange is a two-way street; the cow gives and receives heat energy from the environment depending upon the condition. For example, if the air temperature is lower than the body temperature of a cow standing in the sun, heat is transferred by conduction, convection and radiation to the environment while the environment is transferring heat to the cow by radiation from the sun. Protection from solar radiation by providing adequate shade is the first step in reducing heat stress in dairy cattle. University research station scientists recognized summertime stress as a major dairy production problem in the 1940's. Extensive work at the Missouri experiment station sought to describe and define the heat loss mechanisms of dairy animals (Kibler and Brody, 1949, 1950, 1952 and 1954). One of the most significant findings was an accurate accounting of heat loss for dairy cattle by various mechanisms over a wide range of environmental temperature (Figure 1). At temperatures above 70° F, the heat loss is primarily due to moisture evaporation from the skin and lungs. As temperatures exceed 90° F, over 85% of the total heat dissipation is due to vaporization of water from the body surface and lungs. It is important to note that cattle in these studies were not cooled. Researchers were simply trying to establish the mechanisms of heat loss and the relative importance of each. Brody and others (1954) would later suggest that at a temperature of 95° F, wetting the hair and skin would greatly increase heat dissipation due to the large surface area of the hair allowing for greater vaporization of the water.

## Cooling Inspired-Air

Zone cooling or "snout" cooling has been utilized in the swine industry and a few studies have evaluated this method for dairy cattle. Kleiber and Regan (1935) reported cooling inspired-air 40 to 50 ˚F below ambient conditions (90 to 99 ˚F) reduced respiration rates. A later report (Hahn, et al., 1965) showed that cows in an 85 ˚F environment benefited from inspired-air cooled to 50 to 60 ˚F. Researchers observed increased feed intake and milk production coupled with decreased rectal temperature and respiration rates when cows were given access to cooled air for breathing. Further research (Roussel and Beatty, 1970) showed that cooling inspired-air 15 ˚F below daytime (95 to 91 ˚F max temperature) and 5.5 ˚F below nighttime ambient (74 to 71 ˚F minimum temperature) temperature increased milk production 19 percent as compared to control cows. Air conditioning was utilized in this study and no report was available on the relative humidity of the control and cooled cows. If differences in relative humidity existed between the treatments, some of the response could have been due to relative humidity and not temperature alone. Other researchers (Canton, et al., 1982) reported that when cattle were exposed to black globe temperatures of 86 ˚F (shade) and 104 ˚F (no shade) with inspired-air cooled to 46 to 70 ˚F, inspired air needed to be cooled below 70 ˚F to reduce respiration rates and below 60 ˚F to reduce both respiration rate and rectal temperature of cattle without shade. The authors concluded that a well-designed shade structure was more beneficial and economical in reducing heat stress than inspired-air cooling without shade. It is interesting to note that in most of these studies inspired-air needed to be cooled to below 70˚F to reduce heat stress in dairy cattle. Brody had concluded that environmental temperature must be maintained 25 ˚F below body temperature to prevent heat stress.

## Soaking and Airflow

Researchers in Louisiana conducted several experiments in the late 1940's to determine the effects of utilizing sprinkling, shade and supplemental air movement to cool dairy cows (Seath and Miller 1947 and 1948). They reported that sprinkling cows prior to entering a shade reduced respiration rates by 65-81% and body temperatures by 46-59% over shade alone. They also found that using sprinkling in combination with supplemental airflow resulted in a rapid change in body temperature and respiration rate and was superior to either a fan or sprinkling alone.

Wetting frequency and level of supplemental airflow have been shown to have a dramatic impact upon the heat exchange rate of dairy cattle. Hillman and coworkers (2001) showed that increasing airflow and wetting frequency had a dramatic effect on the evaporative heat loss from the skin of dairy cows (Figure 2). Heat loss increased 2 to 8 fold when wetting frequency was increased from 0.4 to 4.9 mph.

In a study conducted at Kansas State University, several different cooling treatments were evaluated (Table 1). Body and surface temperature of the rear udder and thurl were monitored every 5 minutes during the study. Body temperature (Figure 3) dropped the fastest with soaking the cow every five minutes in addition to providing supplement airflow. Just the fan alone did not significantly reduce body temperature. Increasing sprinkling frequency reduced body temperature, but not to the same degree when used in conjunction with supplemental airflow. The surface temperatures of the rear udder and thurl showed a similar pattern as body temperature.

**Evaporative Cooling**

When choosing heat abatement measures, it is important to remember these concepts. There are two general approaches to cooling dairy cattle. One must either modify the environment to prevent heat stress or utilize methods that increase heat dissipation from the skin of cattle. Air conditioning is the ultimate method to modify a warm environment. It reduces air temperature and relative humidity greatly lowering the THI of the environment. On a commercial basis, this is not an economical choice for modifying the environment of dairy cattle. A more economical method to reduce air temperature is by evaporative cooling. When water evaporates it absorbs heat, reducing the temperature, but when water evaporates it also increases the relative humidity due to the increased level of water vapor present.

The combination of tunnel ventilation with evaporative cooling systems has been used in swine and poultry operations for many years to cool the environment. Recently, these systems have been installed in some Midwest dairy facilities. It has been reported (Huhnke, et. al. 2001) that evaporative cooling could reduce the number of hours at higher level of temperature-humidity index (THI) in some environments. Evaporative cooling has been used very successfully to cool dairy cattle in hot arid climates. Under arid conditions and high environmental temperatures, there is a great potential to reduce temperature and THI (Figures 2 and 3). However, as relative humidity increases and or temperature decreases, the potential of evaporative cooling to modify the environment decreases. Data presented in Figures 2 and 3 are based on a 100% efficiency of evaporation to 90% relative humidity. The efficiency of evaporative cooling equipment ranges between 50 and 80% reducing the effect of the systems. In the Midwest, high relative humidity reduces the potential of evaporative cooling. As relative humidity increases above 70%, the potential reduction in THI is less than 10%.

Very few studies have been reported in the literature concerning the effects of evaporative cooling on the stress level of dairy cattle housed in humid environments. Brown and others (1974) evaluated the effects of evaporative cooling in tie stall housing at Mississippi State University during the summers of 1970, 1971 and 1972. Milk production was significantly increased in one of the three summers and respiration rates were significantly lowered in two of three summers by evaporative cooling as compared to the controls. The study showed that evaporative cooling could reduce peak daytime temperatures however the authors questioned the long term benefits of the system.

As dairy producers have adopted evaporative cooling systems, the K-State Dairy Team has had the opportunity to monitor several systems beginning in the summer of 1999. The two barns evaluated in 1999 were both modified systems utilizing roof peak ventilation fans (Brouk, et al. 2001). Air was drawn through the sidewall with either cellulose evaporation pads or a narrow slit equipped with a high-pressure mist system. Temperature and relative humidity were monitored and recorded every fifteen minutes at various points in the building from late July until early September. In addition, naturally ventilated freestall barns located in the area were also monitored. Respiration rates of cattle under heat stress were evaluated and recorded in each of the barns. As compared to the ambient conditions, evaporative cooled barns were cooler in the afternoon hours but warmer during the late evening and early morning hours. When the data were averaged by day average temperature was less than 2 ºF different than ambient conditions. Average THI were actually higher than ambient conditions. Cattle housed in the evaporative cooled barns had greater morning respiration rates as compared to cattle housed in a naturally ventilated freestall barn, indicating a greater level of environmental stress associated with greater THI in those barns. The system designs did not effectively alter the environmental conditions enough to reduce heat stress. It should be noted that both of these systems utilized roof exit fans and were not tunnel ventilated but rather roof ventilated.

During the summer of 2000, two barns with tunnel ventilation and evaporative pads were evaluated. The level of THI was reduced during the afternoon hours as compared to ambient conditions. However, the degree of reduction was greater for one barn than the other. Data indicated that the evaporative cooled tie stall barn was cooler than either the two-row or four-row naturally ventilated freestall barn. This was due to differences in ambient conditions and barn design. This tie stall had an excellent design and provided an airflow of 500-600 ft/sec and a small cross-sectional area. The other barn was much larger and reductions during the afternoon hours were less than the smaller barn and offset by increases during the evening and night hour. It was also noted that air temperature increased and relative humidity decreased at greater distances from the air intake at the evaporative pads. The effects of barn and system design are important factors in determining the efficiency of evaporative cooling on Midwest dairy facilities.

Data from the 1999 and 2000 studies were summarized by hours above and below a THI of 75 (Table 2). The researchers observed a reduction in total hours above a THI of 75 with ranges from –10.3 to +3.5%. Factors critical to the correct design of the system include airflow, air turnover, cross-sectional area, and evaporation potential. When using evaporative cooling systems, one is trying to reduce the environmental stress level. Evaporative cooling is only effective if the THI is actually lowered as compared to ambient conditions. It is important to recognize that as air temperature is lowered due to water evaporation the potential to evaporate moisture from the skin of cattle is also reduced. The net effect of evaporative cooling of air must be greater than the loss of cooling from moisture evaporation from the skin of cattle or cattle stress will increase rather than decrease under heat stress conditions. As a result of questionable system design, some evaporative cooled barns may be more stressful than conventional freestall barns that are naturally ventilated as was observed in the 1999 studies.

During the summer of 2001 six tunnel ventilated tie stall barns in northeastern Missouri and southeastern Iowa were evaluated. Three of the barns were equipped with cellulose evaporative pads and three were not. Temperature and relative humidity were recorded continuously for 11 weeks from July 1 to September 15, 2001. On three consecutive days under stress conditions, respiration rates, rectal temperature, and skin temperature of three sites were evaluated on 20 cows in each barn (Table 3). Cattle housed in tie stall barns equipped with evaporative cooling had lower average respiration rates (65.7 vs 70.3 breaths/min) than those housed in barns without evaporative cooling. However, rates observed in the morning and at night were not different, only the afternoon rates differed significantly. Average rectal temperatures were also lower for the cows housed in evaporative cooled barns. Similar to respiration rates, the greatest differences existed during the afternoon. Skin temperatures followed respiration rates and rectal temperatures and were significantly lower for the cattle housed in the barns equipped with evaporative cooling with the greatest differences observed during the afternoon.

Greatest changes from ambient conditions are noted during the 1:00 pm to 8:00 pm period. During this period temperature decreases up to 8.25 ºF, relative humidity increases up to 30% and THI decreases up to 3.25 units as compared to the ambient conditions. There is considerable variation in the response over the 11 wk trial. During the period from 9:00 pm to 4:00 am and the period from 5:00 am to 12:00 pm, the evaporative pads were not utilized due to the ambient humidity level reaching about 85%. Thus the systems had little effect upon the barn environment during these periods.

As compared to the barns with only tunnel ventilation, barns with evaporative cooling had a greater percentage of July and August hours at a THI level below 70 and eliminated the hours in the 85-90 THI category (Figure 6) during the hours of 1:00 pm and 8:00 pm. Evaporative cooling reduced the heat stress during the afternoon hours without increasing the stress during the evening and night hours as compared to the tunnel ventilated barns. This study showed significant advantages for the evaporative cooled and tunnel ventilated barns in terms of respiration rates, rectal temperatures and barn environment.

**Conclusions**

Can evaporative cooling be utilized in combination with tunnel ventilation to reduce heat stress of dairy cattle housed in the Midwest? It depends upon several factors. First, what is the temperature and evaporation potential of the environment? In many locations, the afternoon relative humidity may be too great to take advantaged of evaporative cooling. In the 2001 study area, nighttime relative humidity was near the saturation point, limiting the systems. However, afternoon relative humidity dropped to a level that allowed for evaporation potential making the systems effective in reducing the severity of the stress. In hot arid conditions, the system would work well. However, in high humidity locations its effectiveness would be limited by evaporation potential.

If the environment will allow for evaporation potential, one should then consider barn design. The barns studied in 2001 were well designed and had a small cross-sectional area. This allowed for high levels of air exchanged with minimal fan horse power. These barns were also less than 300 ft in length and approximately 40 ft wide with ceiling heights of less than 9 ft. All barns also had a correct pad area. These systems were utilized during the afternoon hours and were shut down during the high humidity evening and night hours. The net effect was a reduction in animal stress as compared to tunnel ventilation only. When sound design criteria are not followed, problems arise as was noted in the 1999 study. Based on the 2000 data, there may be some advantages of the evaporative system in smaller barns as compared to large freestall barns. Smaller barns (tie stall) have a much smaller cross-sectional area than a large freestall barn. If one builds a barn with 12 ft side-walls and a 4/12 roof pitch, over 25% of the cross-sectional area is the rafter area. One approach is to utilize a ceiling or false ceiling along underside of the rafters to reduce the cross-sectional area that is tunnel ventilated and evaporative cooled. It would also be possible to lower the sidewall height and roof pitch. Choosing to do this results in a structure that must always be mechanically ventilated. This approach has been taken in the swine industry. Trying to mix natural and mechanical ventilation systems has had limited success in the swine industry and the same is likely in the dairy industry. To work effectively, evaporative cooling and tunnel ventilation systems must be correctly designed. Suggested guidelines to tunnel ventilation have been made by Tyson and others (1998).

The third thing to consider is the effectiveness of evaporative cooling with other heat abatement methods. Work at KSU has shown the effectiveness of soaking cattle and then evaporating the water from skin. This has been shown to be highly effective in reducing respiration rates and skin temperatures. However, to date no study has evaluated in a head-to-head comparison the effect of evaporative cooling verses soaking and evaporation from the skin surface. It would be more efficient to dissipate heat from the skin via evaporation rather than exchange via convection. However additional research is needed to determine the effects of tunnel and evaporative cooling systems on milk production as compared to conventional methods of cow cooling.

**Recommendations for dairy cow cooling strategies.**

1. Consider the temperature of the location. If ambient temperatures are greater than 100 ˚F for a significant amount of the day and for a period of several weeks, consider evaporative cooling to reduce environmental temperature.

2. Consider the relative humidity of location. High relative humidity limits evaporative cooling. Consider the afternoon potential to reduce afternoon stress. In some cases, afternoon relative humidity is lowered enough to allow evaporative cooling to be effective.

3. Consider cooling mechanism of the cow. Evaporation of water from the surface of the cow's body effectively cools the cow

4. Increase soaking frequency at feedlane as temperature increases. Soaking will require .35 gallon of water per headlock per soaking cycle.

   a. 75 - 82° F once every 15 minutes

   b. 83 - 87° F once every 10 minutes

   c. >87° F once every 5 minutes

5. Provide minimal supplemental airspeed of 6-7 mph over feedlane and 3-3.5 mph over freestalls.

6. If utilizing evaporative cooling systems, consider adding feedline soakers to increase cow cooling during peak feeding periods.

**References**


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

Brouk, M.J., J.F. Smith and J.P. Harner, III. 2001. Efficiency of modified evaporative cooling in Midwest dairy freestall barns. Pages 412-418 *in* Livestock and Environment VI: Proceedings of the 6th International Symposium May 21-23, 2001, Louisville, KY. ASAE.

Brown, W.H., J.W. Fuquay, W.H. McGee and S.S. Iyengar. 1974. Evaporative cooling for Mississippi dairy cows. *Transactions of the ASAE* 17(3):513-515.

Brody, S., A.C. Ragsdale, H.J. Thompson and D.M. Worstell. 1954. Environmental physiology and shelter engineering with special reference to domestic animals. XXV. The effect of wind on milk production, feed and water consumption and body weight in dairy cattle. Missouri Agr Exp Stat Res Bul 545:1-20.

Canton, G.H., D.E. Buffington and R.J. Collier. 1982. Inspired-air cooling for dairy cows. Transactions of the ASAE 25:730-734.

Collier, R.J., D.K. Beede, W.W. Thatcher, L.A. Israel and C.J. Wilcox. 1982. Influences of environment and its modification on dairy animal health and production. J. Dairy Sci. 65:2213-2227.

Hahn, G.L., Y.R. Chen, J.A. Nienaber, R.A. Elgenberg, A.M. Parkhurst. 1992. Characterizing animal stress through fractal analysis of thermoregulatory responses. Thermal Biology, 17(2):115-120.

Hahn, L., H.D. Johnson, M. Shanklin and H.H. Kibler. 1965. Inspired-air cooling for lactating dairy cows in a hot environment. Transactions of the ASAE 8:332-334 and 337.

Hillman, P.E., K.G. Gebremedhin, A. Parkhurst, J. Fquay and S. Willard. 2001. Evaporative and convective cooling of cows in a hot and humid environment. Pages 343-350 *in* Livestock and Environment VI: Proceedings of the 6th International Symposium May 21-23, 2001, Louisville, KY. ASAE.

Huhnke, R.L., L.C. McCowan, G.M. Meraz, S.L. Harp and M.E. Payton. 2001. Determining the frequency and duration of elevated temperature-humidity index. ASAE Meeting Paper No. 01-4111. St. Joseph, MI. ASAE.

Igono, M.O., G. jotvedt and H.T. Sanford-Crane. 1992. Environmental profile and critical temperature effects on milk production of Holstein cows in desert climate. Int. J. Biometerol. 36:77-87.

Kibler, H.H. and S. Brody. 1949. Environmental physiology with special reference to domestic animals. VII. Influence of temperature, 50° to 5° and 50° to 95° F, on heat production and cardiorespiratory activities of dairy cattle. Missouri Agr Exp Stat Res Bul 450:1-28.

Kibler, H.H. and S. Brody. 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 body surfaces of Jersey and Holstein cows. Missouri Agr Exp Sta Res Bul 461:1-19.

Kibler, H.H. and S. Brody. 1952. Environmental physiology with special reference to domestic animals. XIX. Relative efficiency of surface evaporative, respiratory evaporative, and non-evaporative cooling in relation to heat production in Jersey, Holstein, Brown Swiss and Brahman cattle, 5° to 105° F. Missouri Agr Exp Sta Res Bul 497:1-31.

Klieber, M. and W. Regan. 1935. Influence of temperature on respiration of cow. Proceedings of the Society for Experimental Biology and Medicine. 33:10-14.

Ravagnolo, O., I. Mistzal and G. Hoogenboom. 2000. Genetic component of heat stress in cattle, development of a heat index function. J. Dairy Sci. 83:2120-2125.

Ray, D.E., T.J. Halback and D.V. Armstrong. 1992. Season and lactation number effects on milk production and reproduction and reproduction of dairy cattle in Arizona. J. Dairy Sci. 75:2976-2983.

Roussel, J.D. and J.F. Beatty. 1970. Influence of zone cooling on performance of cows lactating during stressful summer conditions. J. Dairy Sci. 53:1085-1088.

Seath, D.M. and G.D. Miller. 1947. Effects of shade and sprinkling with water on summer comfort of Jersey cows. J. Dairy Sci. 30:255-261.

Seath, D.M. and G.D. Miller. 1948. Effect of water sprinkling with and without air movement on cooling dairy cows. J. Dairy Sci. 31:361-366.

Tyson, J.T., R.E. Graves and D.F. McFarland. 1998. Tunnel ventilation for dairy tie stall barns. Northeast Regional Agricultural Engineering Service publication 120.

**Table 1.** Experimental treatments of KSU study.

| Treatment | Soaking frequency* | Supplemental Airflow |
|---|---|---|
| 0 | None | None |
| 0 + F | None | 700 cfm |
| 5 | Every 5 minutes | None |
| 5 + F | Every 5 minutes | 700 cfm |
| 10 | Every 10 minutes | None |
| 10 + F | Every 10 minutes | 700 cfm |
| 15 | Every 15 minutes | None |
| 15 + F | Every 15 minutes | 700 cfm |

*.35 gallon/headlock applied in 1 minute

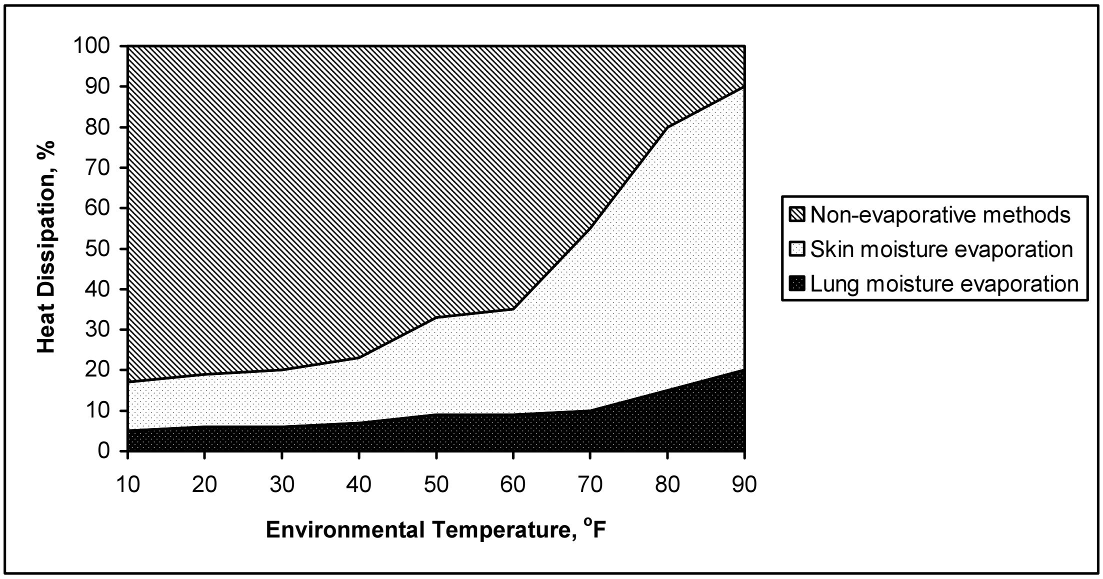
**Table 2.** Effect of evaporative cooling on the percent of summer hours below and above Temperature-humidity index (THI) of 75 in four Midwest dairy facilities.

<table>
<tr><th rowspan="2">Barn</th><th rowspan="2">Summer</th><th rowspan="2">System</th><th rowspan="2">Location</th><th colspan="2">Percentage of Hours</th></tr>
<tr><th>THI<75</th><th>THI=>75</th></tr>
<tr><td rowspan="3">A</td><td rowspan="3">2000</td><td rowspan="3">Pads/Tunnel</td><td>Barn</td><td>67.5</td><td>34.3</td></tr>
<tr><td>Ambient</td><td>55.4</td><td>44.6</td></tr>
<tr><td>Change</td><td colspan="2">-10.3</td></tr>
<tr><td rowspan="3">B</td><td rowspan="3">1999</td><td rowspan="3">Pads/Roof Exit</td><td>Barn</td><td>79.2</td><td>20.8</td></tr>
<tr><td>Ambient</td><td>75.7</td><td>24.3</td></tr>
<tr><td>Change</td><td colspan="2">-3.5</td></tr>
<tr><td rowspan="3">C</td><td rowspan="3">1999</td><td rowspan="3">High Pressure/Roof</td><td>Barn</td><td>73.3</td><td>26.7</td></tr>
<tr><td>Ambient</td><td>76.9</td><td>23.1</td></tr>
<tr><td>Change</td><td colspan="2">3.6</td></tr>
<tr><td rowspan="3">D</td><td rowspan="3">2000</td><td rowspan="3">Pads/Tunnel</td><td>Barn</td><td>76.5</td><td>23.5</td></tr>
<tr><td>Ambient</td><td>70.5</td><td>29.5</td></tr>
<tr><td>Change</td><td colspan="2">-6.0</td></tr>
<tr><td colspan="4">Average Change</td><td colspan="2">-4.05</td></tr>
</table>

**Table 3.** Effect of tunnel ventilation with and without evaporative cooling on the average respiration rate, rectal temperature and skin temperatures of lactating Holstein cows at three different time periods of the day.

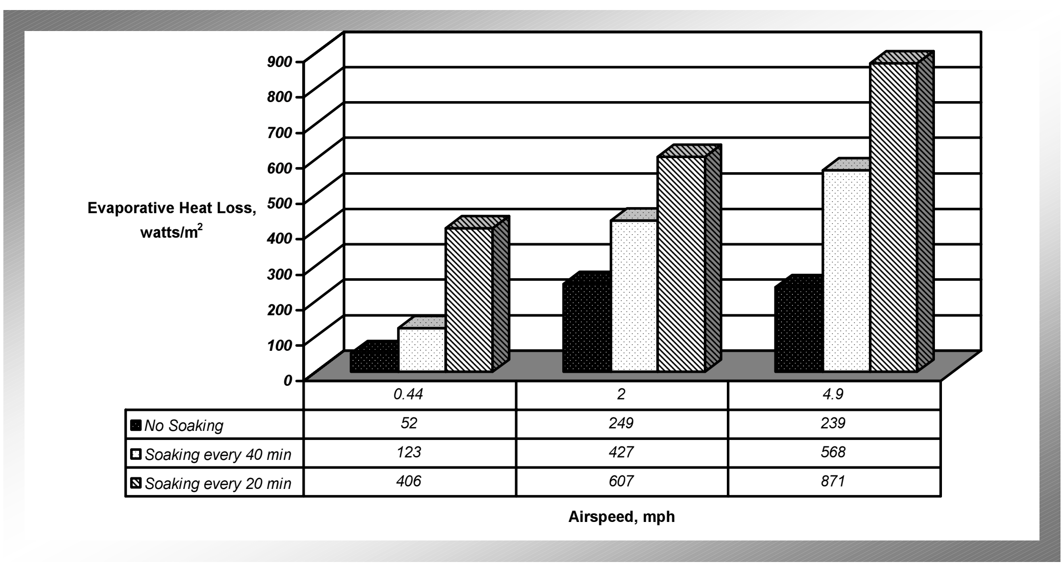
| Measurement | Barn | Period of Day | | | Average of Day | Cooling System Effect |
|---|---|---|---|---|---|---|
| | | Morning | Afternoon | Night | | |
| Respiration rate, breaths/min | Tunnel + Evap | 55.0 | 73.5[a] | 68.7 | 65.7[a] | |
| | Tunnel | 56.5 | 83.8[b] | 70.6 | 70.3[b] | P<.01 |
| Rectal Temperature, ºF | Tunnel + Evap | 101.4 | 102.3[a] | 102.5 | 102.1[a] | |
| | Tunnel | 101.6 | 103.0[b] | 102.7 | 102.4[b] | P<.01 |
| Thurl Skin Temperature, ºF | Tunnel + Evap | 90.0 | 93.2[a] | 93.4[a] | 92.2[a] | |
| | Tunnel | 91.8 | 97.5[b] | 94.6[b] | 94.6[b] | P<.01 |
| Rear Udder Skin Temperature, ºF | Tunnel + Evap | 92.4 | 95.4[a] | 95.0 | 94.3[a] | |
| | Tunnel | 92.5 | 98.3[b] | 95.4 | 95.4[b] | P<.01 |
| Ear Skin Temperature, ºF | Tunnel + Evap | 90.3 | 93.3[a] | 93.2 | 92.2[a] | |
| | Tunnel | 90.4 | 96.3[b] | 93.2 | 93.3[b] | P<.01 |

[ab]Measurement means within the same column with different superscripts differ.




Adapted from Kibler and Brody, 1950.

**Figure 1.** Partition of total heat loss of dairy cattle without supplemental cooling.




Adapted from Hillman, et.al. 2001

**Figure 2.** Effect of soaking and airflow on evaporative heat loss from the skin of cattle.

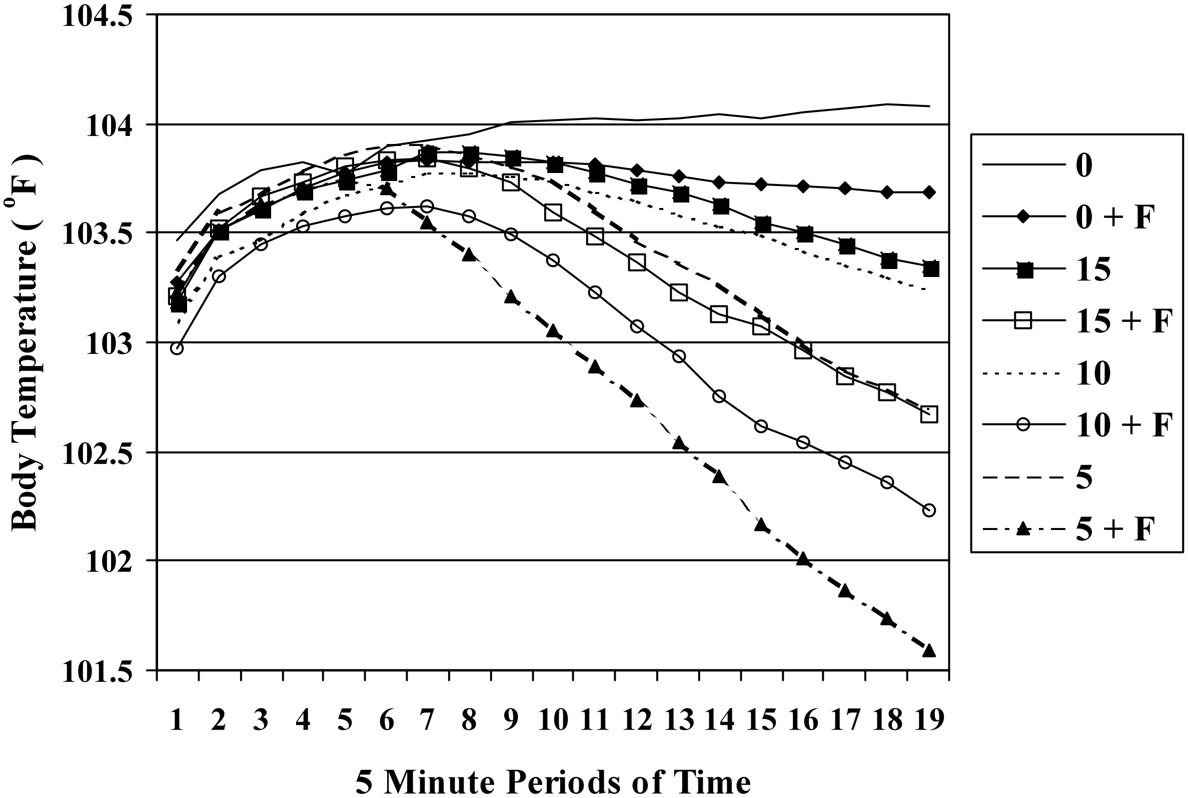



**Figure 3.** Effect of Cooling Systems Upon Body Temperature Over 95 Minutes of Cooling.

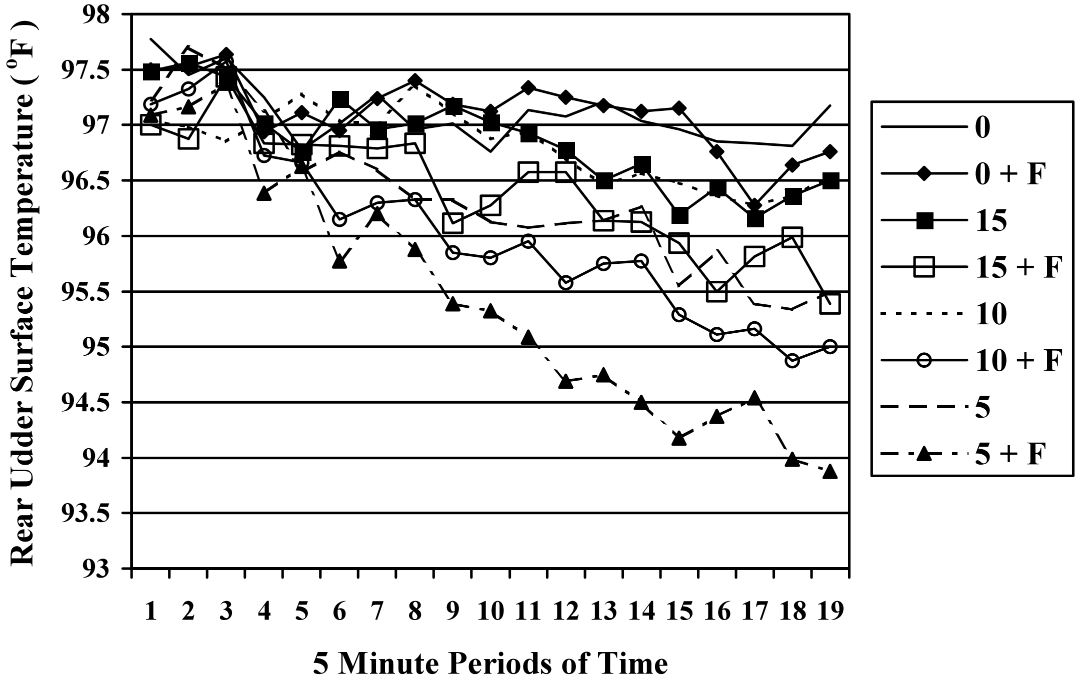



**Figure 4.** Effect of cooling systems upon rear udder surface temperature over 95 minutes of cooling.

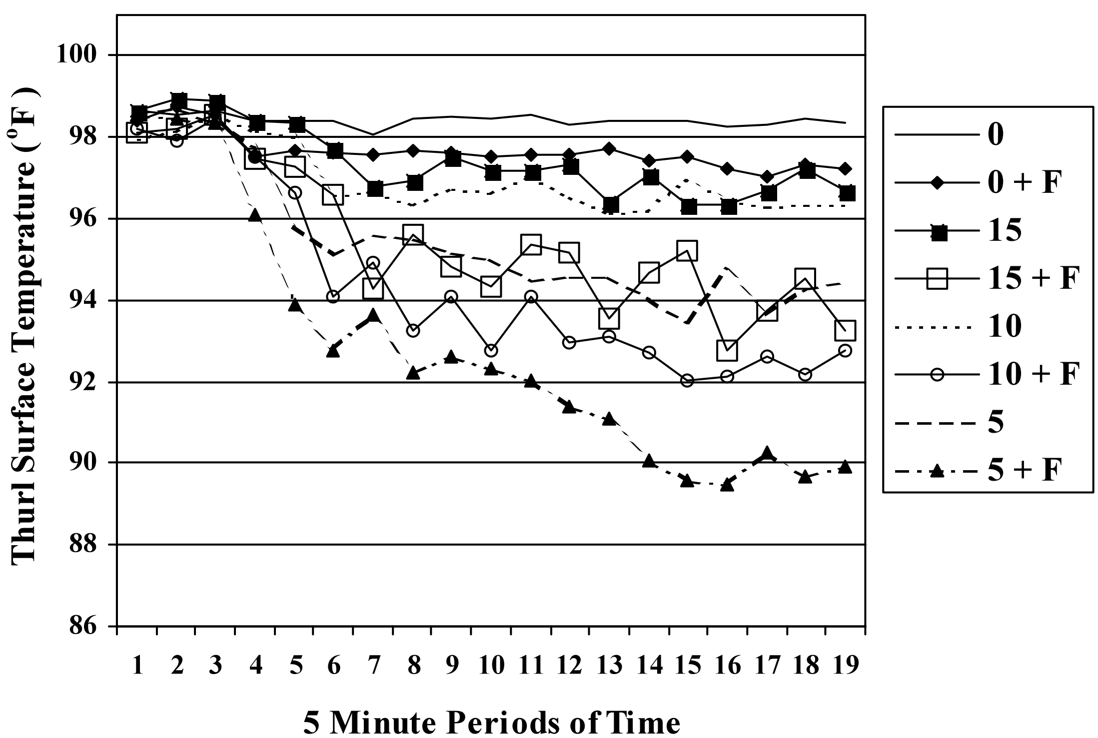



**Figure 5.** Effect of cooling systems on thurl surface temperature over 95 minutes of cooling.

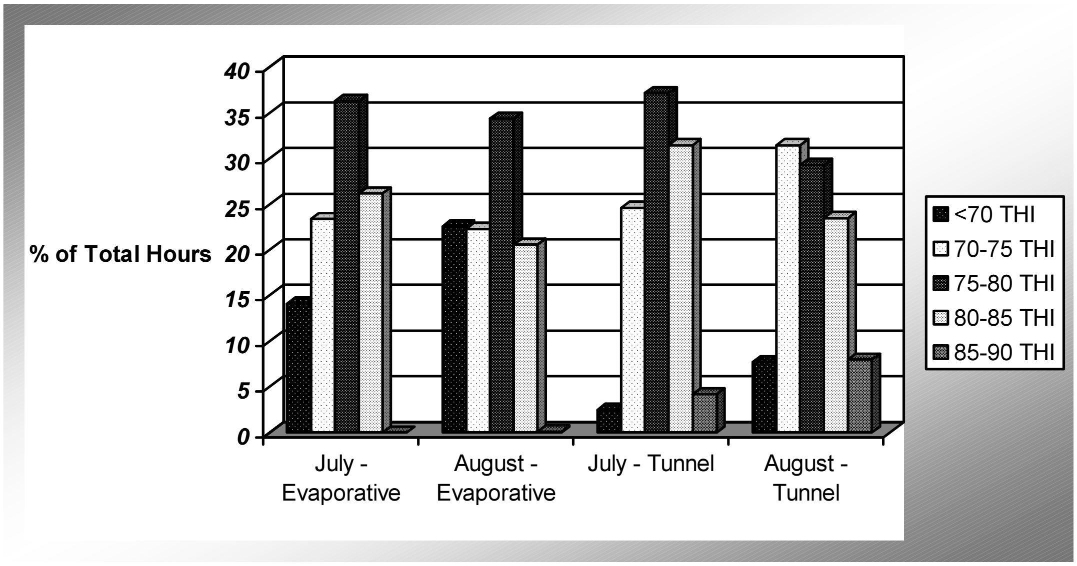



**Figure 6.** Percentage of hours at different levels of temperature-humidity index of tunnel ventilated tie stall barns with and without evaporative cooling during the hours of 1:00 pm to 8:00 pm during July and August of 2001.

# Diagnosis and Control of Bovine Leptospirosis

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## General Introduction

Leptospirosis is an economically important zoonotic bacterial infection of livestock that causes abortions, stillbirths, infertility, and loss of milk production. The disease occurs worldwide and is caused by infection with the spirochete *Leptospira*. The pathogenic leptospires were formerly classified as members of the species *Leptospira interrogans;* the genus has recently been reorganized and pathogenic leptospires are now identified in 7 species of *Leptospira*. Leptospiral serovars are recognized and approximately 200 different serovars of pathogenic *Leptospira* have been identified throughout the world. Serovars are identified based on antigens on the surface of the organisms.

In particular regions, different leptospiral serovars are prevalent and are associated with one or more maintenance host(s), which serve as reservoirs of infection (Table 1). Maintenance hosts are often wildlife species and, sometimes, domestic animals and livestock. Transmission of the infection among maintenance hosts is efficient and the incidence of infection is relatively high. Incidental hosts are not important reservoirs of infection and the incidence of transmission is low. Transmission of the infection from one incidental host to another is relatively uncommon.

Transmission of the infections among maintenance hosts is often direct and involves contact with infected urine, placental fluids, or milk. In addition, the infection can be transmitted venereally or transplacentally. Infection of incidental hosts is more commonly indirect, by contact with areas contaminated with urine of maintenance hosts. Environmental conditions are critical in determining the frequency of indirect transmission. Survival of leptospires is favored by moisture and warm temperatures and under these conditions the organism may persist for days to weeks outside of the animal; survival is brief in dry soil or at freezing or sweltering temperatures. Therefore, leptospirosis occurs most commonly in the spring, autumn, and early winter in temperate climates.

Table 1. Maintenance hosts of leptospiral serovars commonly found in the United States

| **Leptospiral Serovar** | **Maintenance Host(s)** |
|---|---|
| Hardjo | cattle |
| Pomona | pigs, cattle, skunks, opossum |
| Bratislava | pigs, horses(?) |
| Canicola | dogs |
| Icterohaemorrhagiae | rats |
| Grippotyphosa | raccoons, skunks, opossum |

Leptospires invade the body after being deposited on mucous membranes or damaged skin. After a variable incubation period (3 to 20 days), leptospires circulate in the blood. During this period, leptospires enter and replicate in many tissues, including the liver, spleen, kidneys, reproductive tract, eyes, and central nervous system. Agglutinating antibodies can be detected in serum soon after the leptospires are in the bloodstream. Appearance of circulating antibodies coincides with the clearance of leptospires from blood and most organs. Leptospires can remain in the kidney and urinary shedding may occur for weeks to many months after infection. In maintenance hosts, leptospires also may persist in the genital tract and, less commonly, in the cerebrospinal fluid and vitreous humor of the eye.

Bovine leptospirosis in the U.S. is most commonly caused by infection with leptospires belonging to serovar Hardjo. The prevalence of infection with other serovars of *Leptospira* in cattle varies with different husbandry conditions; serovars Pomona and Grippotyphosa are the other relatively common causes of bovine leptospirosis in the U.S.

## Leptospirosis caused by infection with serovar Hardjo

***Prevalence*—**The most common cause of leptospirosis among cattle throughout much of the world is infection with leptospires belonging to serovar Hardjo. Two serologically indistinguishable but genetically distinct types of serovar Hardjo have been identified: *Leptospira interrogans* serovar Hardjo (type hardjoprajitno) and *L borgpetersenii* serovar Hardjo (type hardjo-bovis). Serovar Hardjo type hardjo-bovis is common in cattle populations throughout the world; type hardjoprajitno is isolated primarily from cattle in the United Kingdom.

Reliable estimates of the prevalence of serovar Hardjo infections have not been available in the US because of the difficulty in establishing the diagnosis. In a recent study, we tested urine and serum from 15 cows in each of 44 dairy herds from four different regions of the U.S. Overall, at least one infected cow was detected in 59% of the herds tested and, in most cases, serologic results indicated that the likely infecting serovar was Hardjo. When serovar Hardjo infection becomes endemic within a herd or region, it is common to have 30 to 40% of the animals infected and shedding the organisms in their urine at any one time.

***Clinical Signs*—**Infection by serovar Hardjo generally results in no or relatively mild acute clinical signs but produces a renal carrier state associated with long-term urinary shedding. Persistent infection of the male and female genital tract is also a prominent feature of serovar Hardjo infections. Clinical signs of serovar Hardjo infection in dairy cattle are subtle and generally involve decreased reproductive efficiency and milk production.

Abortions, stillbirths, or birth of weak calves occur as a result of serovar Hardjo infection but generally, are only seen when a cow is infected for the first time when she is pregnant. Abortions may occur many weeks after infection of the dam and are usually not associated with any obvious illness in the cow. Infected, but apparently healthy, calves also may be born and retention of fetal membranes may follow Hardjo abortion. Abortions due to serovar Hardjo infection tend to occur sporadically as opposed to abortion 'storms' which may occur as a result of infection with serovars Pomona or Grippotyphosa, for example.

Perhaps the most economically significant manifestation of serovar Hardjo infection is the result of persistent infection of the reproductive tract. Infertility which results in increased services per conception and prolonged calving intervals is associated with this infection. The precise pathogenesis of these events is not clearly understood but presumably the presence of leptospires in the uterus and oviducts of infected cows interferes with implantation of the embryo or other early pregnancy events.

## Diagnosis of leptospirosis

Diagnosis of leptospirosis is dependant on a good clinical and vaccination history and the availability of diagnostic testing at a laboratory with experience in the diagnosis of leptospirosis. Coordination between the diagnostic laboratory and the veterinarian is required to maximize the chances of making an accurate diagnosis. It is advisable to contact the diagnostic laboratory prior to submission of samples to assure that appropriate samples are collected and that the samples arrive at the diagnostic laboratory in suitable condition. In addition, in problem situations, it may be necessary to consult reference or regional diagnostic laboratories, which have expertise in the diagnosis of this infection.

Diagnostic tests for leptospirosis can be separated into those designed to detect antibodies against the organism and those designed to detect the organism or its' DNA in tissues or body fluids of animals. Each of the diagnostic procedures, for detection of the organism or for antibodies directed against the organisms, has a number of advantages and disadvantages. Some of the assays suffer from a lack of sensitivity and others are prone to specificity problems. Therefore, no single technique can be recommended for use in each clinical situation. Use of a combination of tests allows maximum sensitivity and specificity in establishing the diagnosis. Serological testing is recommended in each case, combined with one or more techniques to identify the organism in tissue or body fluids.

***Serologic tests*—** The microscopic agglutination test (MAT) is the most commonly used technique for diagnosing leptospirosis in animals. Serology is inexpensive, reasonably sensitive, and widely available. The MAT involves mixing appropriate dilutions of serum with live leptospires of serovars prevalent within the region. The presence of antibodies is indicated by the agglutination of the leptospires.

Detection of high titers of antibody in animals with a disease consistent with leptospirosis may be sufficient to establish the diagnosis. This is particularly true in the investigation of abortions caused by incidental host infections in which the dam's agglutinating antibody titer is $\geq$800-1600. However, in maintenance host infections, particularly serovar Hardjo infection, infected animals often have a poor antibody response to infection. Often at the time of abortion, antibody titers may be quite low or negative against serovar Hardjo. In these cases, the herd serologic response to infection or detection of the organism in tissues or fluids are often more helpful than is the individual's antibody titer in establishing the diagnosis.

Interpretation of leptospiral serologic results is complicated by a number of factors. These factors include: cross-reactivity of antibodies, antibody titers induced by vaccination, and lack of consensus about what antibody titers are indicative of active infection. Antibodies produced in an animal in response to infection with a given serovar of *Leptospira* often cross-react with other serovars of leptospires. Therefore, a cow infected with a single serovar is likely to have antibodies against more than one serovar in an agglutination test. Patterns of cross-reactive antibodies vary widely between species of animals and between individuals within a species. However, in general, the infecting serovar is assumed to be the serovar to which that animal develops the highest titer.

Widespread vaccination of cattle with leptospiral vaccines also complicates the interpretation of leptospiral serology. In general, vaccinated cattle develop relatively low agglutinating antibody titers (100 to 400) to the serovars in the vaccine and these titers persist for one to three months after vaccination. However, some animals develop high titers after vaccination (particularly those vaccinated several times each year) and although these high vaccination titers decrease with time, they may persist for six months or more after vaccination. Introduction of new vaccines may also change the typical pattern of post-vaccination antibody titers.

The third complication of interpretation of leptospiral serological testing is caused by a lack of consensus as to what titer is "significant" for the diagnosis of leptospiral infection. An agglutinating antibody titer of >100 is considered significant by many. However, this cut-off level may be exceeded in vaccinated animals and may not be reached in cattle infected with serovar Hardjo. Therefore, diagnosis of leptospirosis based on a single serum sample must be made with caution and with full consideration of the clinical picture and vaccination history of the animal. In cases of acute leptospirosis, a fourfold rise in antibody titer is often observed in paired serum samples. However, cattle are commonly actively infected and shedding serovar Hardjo with antibody titers $\leq$ 100. Leptospiral antibody titers are often steady or decreasing at the time of abortion and up to 50% of cows aborting due to serovar Hardjo will be seronegative at the time of abortion. Therefore, a low antibody titer does not necessarily rule-out a diagnosis of leptospirosis.

***Detection of leptospires***—Other techniques available for the diagnosis of leptospirosis in livestock involve procedures to detect leptospires or leptospiral DNA in tissues or body fluids. Commonly used techniques include: Immunofluorescence (fluorescent antibody tests or FA) and polymerase-chain-reaction (PCR) assays. Organisms can also be cultured from infected animals but culture is expensive, takes many weeks, and is generally only available in reference laboratories.

Immunofluorescence can be used to identify leptospires in tissues, blood, or urine sediment. The availability of this test is increasing, and the test is rapid, has good sensitivity, and is very useful for screening urine samples or fetal tissues for leptospires. Interpretation of immunofluorescence tests may be difficult and some diagnostic labs may be more experienced with this test than others. The fluorescent antibody conjugate currently in general use is not serovar-specific; serologic examination of the animal is still required to identify the infecting serovar.

Polymerase chain reaction (PCR) tests can be used to detect leptospiral DNA in clinical samples. These tests rely on the PCR amplification of DNA in tissues or body fluids. A number of PCR procedures are available and each laboratory running the test may select a slightly different procedure that works well for them. In general, PCR testing of urine is more reliable than testing of tissues. PCR assays are able to detect the presence of leptospires but are not able to determine the infecting serovar. PCR can be a sensitive and specific technique for the diagnosis of leptospirosis. Unfortunately, the process is exquisitely sensitive to contamination with exogenous leptospiral DNA and, therefore, may be prone to false-positive reactions. It is very important that PCR results be interpreted with full knowledge of the quality control procedures used in the laboratory.

## Control of leptospirosis

An optimal program to control bovine leptospirosis will prevent clinical disease and urinary shedding in animals exposed to a variety of leptospiral serovars. The most common approaches to the control of leptospirosis in cattle are based on prevention of exposure, vaccination, and selective treatment.

In all cases, efforts should be made to limit direct and indirect contact between cattle and carriers of leptospirosis (for example, by rodent control around buildings, fencing swampy ground or streams). In addition, adequate quarantine procedures should be undertaken to prevent introduction of Hardjo into a herd through purchase of infected animals. However, given the ubiquitous nature of wildlife that may be carriers of leptospirosis and the prevalence of serovar Hardjo infection in cattle, prevention of all exposure to leptospirosis is virtually impossible in most dairy and beef operations. Therefore, vaccination is relied upon to enhance resistance of the animals to infection with the serovars of *Leptospira* in the region.

Leptospiral vaccines currently available for use in cattle in the U.S. are all 5-way, killed, whole-cell vaccines containing serovars Pomona, Canicola, Icterohaemorrhagiae, Grippotyphosa, and Hardjo. These antigens are also available in combination with various other viral and bacterial vaccines. In general, these leptospiral vaccines provide good protection against disease induced by each of the serovars except serovar Hardjo.

A series of experimental studies and field data from the United States showed that vaccination with leptospiral vaccines typical of those available in the United States, does not prevent renal infection, urinary shedding, or fetal infection with serovar Hardjo isolates from the U.S. (type hardjo-bovis). Field data on the prevalence of serovar Hardjo infection, even in well vaccinated herds, provides further evidence that the currently available vaccines are not providing good protection against serovar Hardjo. Many of the Hardjo vaccines available were licensed many years ago and were not subjected to rigorous efficacy trials using virulent strains of serovar Hardjo, routes of challenge which mimic natural exposure, and modern methods of determining if challenged cattle became infected with serovar Hardjo.

Recently, however, two serovar Hardjo vaccines have been extensively investigated using appropriate challenge strains and methods. In contrast to many other serovar Hardjo vaccines, these two products were shown to provide excellent protection against infection and shedding of serovar Hardjo. The studies establishing the efficacy of Leptavoid (Schering-Plough) were reported by Dr. Bill Ellis (Veterinary Science Division, Stormont, Northern Ireland) and those regarding Spirovac (CSL, Inc) were reported from my laboratory. One of these vaccines will soon be available for use in the United States (Spirovac, marketed by Pfizer) and will provide additional options for veterinarians and dairy producers in the U. S.

Why these two vaccines protect so well against serovar Hardjo and others do not is not entirely clear. Based on recent studies, it appears that Hardjo vaccines that do protect cattle from serovar Hardjo induce a strong and long lasting cell-mediated immune response in vaccinated animals. The cell-mediated immune response in vaccinated cattle is demonstrated by high levels of production of gamma-interferon by lymphocytes exposed to serovar Hardjo antigen in culture. Cattle naturally infected with serovar hardjo and cattle vaccinated with non-protective serovar hardjo vaccines do not demonstrate this cell-mediated immune response. These data suggest, but do not prove, that it is the cell-mediated immune response induced by these efficacious serovar Hardjo vaccines that is responsible for protection of cattle from serovar Hardjo. Clearly, more studies are needed to prove this hypothesis and to determine which antigens induce the cell-mediate immune response.

Traditional vaccination regimens for leptospirosis include 2 initial doses of vaccine, followed by annual vaccination of all cattle in a closed herd with 5-way vaccines, or twice yearly vaccination in an open herd. This regimen provides good protection against serovars Pomona, Grippotyphosa, Icterohaemorrhagiae, and Canicola—but not serovar Hardjo. At this time there is little evidence to indicate that use of the 5-way vaccines multiple times per year increases the protection against serovar Hardjo and vaccination 3 -5 times a year for leptospirosis has the potential to cause hypersensitivity problems in some animals. If the veterinarian and producer elect to use the new serovar Hardjo vaccine, it will still be necessary to use a 5-way vaccine as before. The new serovar Hardjo vaccine will require two initial doses followed by yearly boosters.

Antibiotics can be used to treat individual animals and will, in general, eliminate persistent Hardjo infections. Antibiotic treatment stops urinary shedding and is likely to improve clinical signs associated with persistent colonization of the reproductive tract with serovar Hardjo. However, it is not clear how long a 'cured' animal resists reinfection. Therefore, antibiotic therapy should not be relied upon as an overall control program for leptospirosis—usually antibiotic treatment is matched with a good vaccination program. Likewise, there is no evidence that vaccination (even with the new vaccines), will cure an already infected animal. Therefore a combination of approaches should be considered to efficiently bring the infection under control in a herd infected with serovar Hardjo. Long-acting oxytetracycline (20 mg/kg, IM, two doses 10 days apart) has been shown to be effective in the treatment of serovar Hardjo infections and is recommended.

# Mycoplasma: Calf to Cow

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## Introduction

Mycoplasma has, in the past few years, gone from what seemed to be relatively rare occurrence to an issue that any dairy regardless of size or location needs to consider. In addition, there is an increasing awareness that Mycoplasma is not just an udder health problem but often has more widespread clinical manifestations. A more complete perspective on what Mycoplasma is, where it hides out, and how it potentially gets to be a problem of clinical significance allows for the development of much more effective prevention and control measures.

## Mycoplasma: What are They?

Mycoplasma are small organisms that are related to bacteria but also have some fundamental differences. The major difference is that they do not have a cell wall, as do bacteria. This has good and bad consequences. Many of the antibiotics we use work by attacking the cell wall of the bacteria we are trying to control. In the case of Mycoplasma these antibiotics are not effective. On the other hand, not having a cell wall makes them much more sensitive to their surrounding environment such that they do not survive well outside animal hosts. This also makes them fairly easy to kill with heat or disinfectants. Finally, not having a cell wall makes them somewhat more of problem for an animal's immune system to recognize such that we generally do not see a very effective immediate response or good long-term immunity develop with exposure. In fact, some of the clinical signs we see with infection seem to result because the organism confuses the immune system into reacting against the host itself.

Mycoplasma is actually quite widespread both in the environment as well as being associated with essentially all warm-blooded animals. Many types do not seem to cause disease and most that are associated with animals seem to be specific to the species of animal they associate with.
In cattle, there have been somewhere around 11 different species of Mycoplasma that have been reported. Of these, only three really seem to cause much in the way of disease, these are M. bovis, M. bovigenitalia, and M. californicum. Of these, M. bovis appears to be the most common as a cause of clinical problems. Another, name you might see associated with Mycoplasma would be Acholeplasma. This organism can be confused with Mycoplasma when cultured in milk samples. It is generally considered to be a contaminant and not able to cause disease. This means that, particularly in bulk tank samples, growth alone without typing the organism may result in a wrong diagnosis.

## What Kinds of Problems do They Cause?

Generally, we have been pretty focused as an industry on the mastitis problems that Mycoplasma causes. While this seems to be the most frequent way the disease shows up there are a number of other conditions that effect both cows and calves. In fact, when mastitis shows up on a dairy we can frequently find evidence of these other disease processes going on at the same time. Recognizing some of these related conditions may also be the "early warning" sign that alerts you to the possibility of developing more serious problems.

The following gives a short description of some of the more common related conditions one might see.

Eye infections (pinkeye) can be caused by Mycoplasma. The signs may involve anything from simple weeping and reddening to more serious swelling and erosion of the cornea. Poor response to antibiotic treatment should make one suspicious that you are not dealing with typical "pinkeye". While it is more common to see in calves, cows can sometimes be affected as well.

Occasionally, Mycoplasma can cause brain infections (meningitis) in calves. These can sometimes be difficult to recognize, as calves may just appear to have fevers and be depressed. Signs of apparent neck pain and abnormal eye movements may also be evident. Signs are usually severe and response to treatment poor. It is not uncommon to see ear infections in young calves associated with Mycoplasma. Calves with head tilts, droopy ears, fevers, and eye signs should be suspect.

Mycoplasma has been implicated as a cause of respiratory problems in feedlot cattle, dairy calves, and cows. When Mycoplasma alone is involved the signs are usually mild enough that they are not noticed. In fact, it is commonly thought that for Mycoplasma to cause significant respiratory problems there has to be other pre-disposing factors involved. These could include other respiratory pathogens, poor ventilation and air quality, and immune suppression.

Arthritis is another common sign of Mycoplasma infection. This can be a problem in both young and adult cattle. In young calves one might be suspicious that Mycoplasma is involved when you see joint problems occurring without infected navels. Adult cows tend to be extremely lame and multiple joints may be involved. Often other signs of Mycoplasma are present in addition to the lameness if one looks closely.

Mycoplasma has been implicated in breeding and abortion problems as well as fertility problems in bulls. The significance of Mycoplasma in these types of problems, however, is thought to be low.

### Where do They Come From?

While it may be somewhat of an over-statement it is probably safe to say that one can find Mycoplasma on most dairies if one looks hard enough. Mycoplasma is isolated from the upper respiratory tract and the reproductive tract of apparently normal animals. This is true both for cows and calves.

Certainly we also see some level of animals in the population (probably low) that have chronic unapparent infections. This is true for both respiratory and udder infections and these animals are a potential reservoir for exposure of other animals within a herd.

Finally, in some situations, Mycoplasma is capable of surviving in the environment for fairly extended periods of time. It has been found to survive well in the environment in wet bedding or wet corral conditions particularly during warm or mild weather. It addition, it survives quite nicely in environments that are contaminated with milk and uterine fluids. It will also survive well in contaminated medications, etc.

### How Does a Clinical Mycoplasma Problem get Started?

Understanding the basic relationships that predispose to clinical disease problems in a herd is extremely helpful when thinking about how to prevent, control, and/or eradicate a specific problem such as Mycoplasma. Basically if we know something about the potential source of the organism, how that source gets started and spreads through the herd, and something about the ability of the animals to resist a challenge we can be pretty effective at addressing the problem. Multiple factors are important in most disease outbreaks and more commonly than not there are multiple factors that have come together to create a problem. Unless we have a systematic way to identify, determine the significance, and address all factors involved we run the risk of investing significant money and time for a mediocre result.

The source of Mycoplasma as was stated earlier tends to be other animals although there does appear to be some ability to survive in the environment. When thinking about source it is important to not only think about location but also about level of challenge. For example, we know that some percentage of an apparently normal group of calves will have Mycoplasma in their upper respiratory tract. In herds where we do not have Mycoplasma problems in the cows and we are careful about feeding potentially contaminated milk to calves the level of these healthy carriers is very low. The level of carrier calves is much higher in a population where they are being exposed to the organism through the milk they drink. This does not necessarily mean that these calves will get clinical Mycoplasma. What it does mean is that if other predisposing factors develop that enhance spread or lower resistance (such as poor air quality or marginal nutrition) the organism is much more likely to be present and able to take advantage.

In the case of Mycoplasma mastitis the same relationship exists. The initial source could be another animal with mastitis, an animal that develops the respiratory form that spreads through the blood to the udder, or the environment. The ability for significant spread to occur through the herd usually depends, however, on the addition of other factors that enhance challenge levels, enhance number of animals exposed, or lowers a herd's resistance.

Animals with clinical Mycoplasma will generally go through stages where they shed extremely high numbers of organisms so in addition to thinking about the levels of carrier animals in a herd it is important to think about the levels of challenge created by any one infected animal. The levels of cleanliness associated with hospital, fresh cow, milking time, and calf feeding practices is critical to increasing the chances that an infected carrier animal does not have the opportunity to expose significant numbers of other animals. This relationship is so key to good control that it cannot be stressed strongly enough. Many herds experience episodes of clinical Mycoplasma but herds that have breaks in basic hygiene in these areas tend to have much worse problems when they occur.

The resistance of a population of animals to infection with Mycoplasma also seems to play a role in the initiation and spread of a problem. Vaccination specifically for Mycoplasma does not seem to fundamentally change the course of the disease in a population and, in fact, there have been some reports of increased severity of clinical signs with vaccination. Suffice it to say that vaccination certainly will not replace the need for good screening and control practices.

There does appear to be some potential relationship between other diseases that tend to cause immune suppression and the ability of Mycoplasma to become clinical within a herd. Specifically, there has been some work done in feedlot animals that seems to indicate that BVD may play a role in some Mycoplasma outbreaks through its immune suppressive effects. Good control strategies for BVD could be a factor in preventing Mycoplasma outbreaks.

Another area that is often overlooked is the nutritional status of young calves. Many calf-hood infectious problems have a nutritional component to them and Mycoplasma would be no exception.

## Managing Mycoplasma on the Dairy

From the above discussion it is evident that virtually any dairy has some risk of experiencing Mycoplasma problems and therefore should include this as a consideration in the development of farm-level bio-security protocols.

There are four basic questions, which need to be addressed in this regard.

**First:** What are we doing to minimize the introduction of Mycoplasma carriers into the herd?

**Second:** What control measures are critical to controlling spread if it is introduced?

**Third:** How would we know if we begin developing a Mycoplasma problem?

**Fourth:** If we had a problem what steps can we take to address the problem?

To address these questions there needs to be some ongoing screening strategy in place. Since there is no one perfect test, it is extremely important that one is able to recognize clinical signs that make one suspicious that Mycoplasma could be involved. Groups of calves that show ear, eye, or joint problems should be highly suspect. In addition, respiratory infections, which occur around 3-6 weeks of age, often have a Mycoplasma component.

In adult cattle we tend to recognize mastitis as a predominate clinical sign. Groups of animals that have clinical mastitis that does not respond to treatment and seems to jump aggressively from quarter to quarter should be suspect. Milk from effected quarter tends to be slightly discolored and contain garget that may be "sandy" or gritty in consistency. In addition to mastitis, if a herd seems to experience animals with joint problems or periodic outbreaks of pneumonia there is likelihood that Mycoplasma is involved.

Mycoplasma types, which are most commonly involved in clinical mastitis problems, tend to show fairly obvious clinical signs, particularly with newly acquired infections. This is not necessarily the case with other species or with chronically infected animals. Because of the high likelihood that some infections will be sub-clinical or inapparent, a good screening program will not rely on clinical signs alone. Animals with Mycoplasma mastitis tend to run significantly elevated SCC's so individual SCC can be helpful in determining whether a cow is truly infected or not.

Some level of milk culturing is probably necessary as part of a sound preventative screening program. At the least, one should be screening the bulk tank on a regular basis. In addition, clinical cows probably should be cultured. It is also probably worth culturing all new additions to the herd (including first calf heifers) either as they freshen or as lactating animals are added to the herd.

Use of milk culturing for Mycoplasma as part of an effective screening and control program is dependant on a number of considerations. First, there needs to be a clear plan of what to do with the information generated. Second, samples need to be collected and handled properly. One of the characteristics of clinical Mycoplasma is that enormous levels of the organism are shed. This not only increases the risk of spread but also significantly increases the chances that samples can be contaminated during collection causing false positive results. On the other had, some types of Mycoplasma seem to be very sensitive to freezing and thawing so it is possible to have samples from positive cows that show up as no growth. A certain portion of chronically infected animals seem to vary significantly in the levels of Mycoplasma they shed at any one time so this can further confuse the issue. Growing Mycoplasma in the lab is not particularly difficult, however not all labs are created equal. If there is reason to be suspicious of Mycoplasma, it is really important to work with a lab that has experience with the organism. Finally, simply growing Mycoplasma, particularly from the bulk tank, without further typing of the organism is probably not acceptable.

There are other tests available to screen for Mycoplasma. One that is relatively new is termed PCR. PCR has the advantage of being very sensitive as well as specific for a particular Mycoplasma species such as Mycoplasma bovis. It also is much faster to yield a result. Currently, PCR is fairly expensive. The sensitivity of the test potentially makes it much more susceptible to contamination and the fact that is specific, means other types of Mycoplasma would not be picked up.

## Managing for Control

Despite best efforts at screening the reality is that there is still the risk of exposure from carrier animals as well as the environment. This means that understanding and addressing the critical modes of spread is important not just when you know it is present. Sound basic control measures can be the difference between culling the odd positive cow or having it rapidly spread to a group of other animals in the herd.

Control for calves needs to be focused on excellent hygiene practices around feeding as well as feeding Mycoplasma free milk. Pasteurization of milk is effective, but as with any other management process it needs to be done correctly and it also needs to be monitored to make sure we are consistently getting a desirable product.

Air quality is also a factor in how easily spread can occur through a group of animals. This is probably true for susceptible adult populations as well as for calves.

Control for cows tends to focus on mastitis. The initial challenge that starts a mastitis outbreak may be another animal with mastitis. It may be an animal with respiratory disease that ends up with a septecemia and resulting mastitis. It may even be contaminated bedding or environment.

While it is important to be aware of these potential sources and address them effectively, it is also important to remember that most if not all serious outbreaks have some component that really facilitated spread beyond the initial infected animal.

Poor or inconsistent milking, hospital, and fresh cow practices are critical in creating potential for an actively shedding animal to challenge other cows. As an example, housing fresh and hospital cows in the same pen will increase the probability for spread.

Finally, the quality of these practices is critical to control during an outbreak. No amount of culture and culling or segregation will help if new cases are being created faster than we can find them.

While mastitis is by far the most common clinical problem associated with Mycoplasma, there does appear to be an apparent increase in herds that experience the respiratory/joint syndrome in adult cows. Environmental stresses, air quality, and possibly other types of infections, particularly those associated with immune suppression, probably play a role in how aggressively infections spread through a herd.

## Managing a Mycoplasma Outbreak

Finding out you have Mycoplasma mastitis in your herd is serious. How extensive the actual impact is, however, is strongly dependent on good screening and basic control strategies as outlined above. This means that the first step in dealing with news of Mycoplasma in the herd is to ensure that basic critical control measures are in place and being effectively practiced. It is also probably a good idea to step back and look for related signs of Mycoplasma on the dairy.

Given that we have our basic control measures in place, the next step is to identify and manage the existing Mycoplasma positive animals. This can be approached with differing levels of intensity. There

is obviously a strong correlation between level of intensity, efficacy, and cost. These need to be considered in each particular situation.
The least intensive approach would be to do nothing except ensure that basic control measures are in place. Basic screening of bulk tank and hospital samples as well as aggressive culling of non-responsive clinical case might be added as additional strategies. Culturing clinical, fresh, and incoming cows as well as bulk tanks would add to effectiveness. One might consider string sampling and culture to focus individual cow sampling efforts to certain sub-populations within the herd. Finally, an aggressive program of whole herd culture with culling and/or segregation of positive cows may be desirable based on herd status and management goals.

While it is fair to say that both cost and probability of quick resolution increase with more aggressive control programs it is also important to remember that without consistent basic control measures (particularly in the parlor, hospital and fresh pen) no program has much likelihood for success.

## Summary

No herd is completely risk free when it comes to the possibility of clinical Mycoplasma problems and in fact, there seems to be an increase in the frequency with which Mycoplasma problems are being reported. While we tend to think of Mycoplasma as mainly a mastitis problem it is associated with other disease processes on the dairy. These other types of Mycoplasma infections not only cause problems in their own right but may be significant as the source of eventual mastitis problems as well.

Basic screening procedures as well as good basic control procedures in the parlor, fresh and hospital pens are the basis for preventing Mycoplasma from becoming a serious issue. In fact, these same screening and hygiene producers are equally important to the success of any attempt to control or eradicate an existing Mycoplasma problem.

# Managing Lameness for Improved Cow Comfort and Performance

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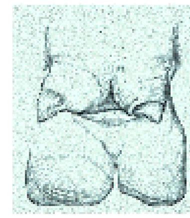
## Introduction
Lameness is clearly one of the most important health and welfare issues on today's dairy farms. This is in part a consequence of the increase in size of herds, higher levels of feeding and management intensity, and a greater concern for the potential environmental impact of large scale dairy operations which has led to regulations for the containment of waste, and a gradual shift from pasture to confinement-type housing. While there are advantages, confinement housing can result in reduced cow comfort from increased exposure to hard flooring surfaces. Therefore, it should come as no surprise that the incidence of lameness continues to increase. The cow's foot was not designed for prolonged exposure on concrete and in housing conditions that subject claws to constant contact with wet manure slurry. Present-day housing and management practices common to intensive dairy production present tremendous challenges to foot health.

## Normal Gait in Cattle
The cow's stride consists of the stance phase (standing position) and the swing phase (movement from, and back to, the standing position). The swing phase is divided into a retraction (contraction or shortening) and protraction (extension or lengthening) phase. The retraction phase of the stride starts with the cow in standing position. The cow begins her stride by shifting body weight to the sole of the weight-bearing surface of the claws which also provides traction as the cow enters the retraction phase of the stride. As the body moves forward and weight is applied to the soles of each claw, the foot is retracted (or lifted upward) toward the body, thus ending the retraction phase. Once the foot leaves the ground it is extended forward thus entering the protraction phase (forward swing and placement of the foot on the ground surface) of the stride. The heels strike the ground first with the soles resuming a normal weight-bearing position as the cow completes the protraction phase and reaches the standing position. In a sense, the rear legs propel the cow's body forward while the front legs act more like props or supports for the body weight.

Gait characteristics are altered by conditions which make the surfaces of floors more or less slippery. For example, on wet manure slurry covered concrete floors cows will alter their gait by lowering walking speeds, changing limb angles and reducing the length of their step, all in an effort to increase stability on the less secure surface. It is interesting to speculate on what effects, if any, this has on claw horn wear rates. In recent years the occurrence of thin soles from excessive claw horn wear has become a major problem in herds throughout the southeastern United States.

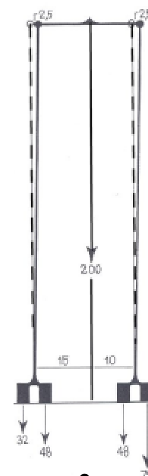
## The Dynamics of Weight-Bearing in Cattle: Anatomical and Biomechanical Factors
The anatomical and bio-mechanical characteristics of weight-bearing in cattle are well described in "Cattle Footcare and Claw Trimming" by the late Dr. E. Toussaint Raven from the Netherlands (Raven, 1989). Following years of study and observation, his insight on weight-bearing and the likely effect of housing conditions (hard floors) on foot problems has added much to our current understanding of lameness, particularly as it relates to claw disorders.



1

The sole of the inner claw of rear feet in cattle slopes toward the axial (inside) side of the claw (in other words, it slopes toward the interdigital space). This differs from the outer claw which tends to be flatter and more stable. As the cow steps forward and places her foot down, weight shifts (or rolls over) from the inside to the outside claw. The result is greater weight-bearing on the outside claw that over time (particularly on hard surfaces) leads to irritation of the corium and accelerated hoof horn formation on the outside claw (See Figure 1).


2




3

At the hip the hind legs of the cow are connected to the pelvis through a ball-and-socket joint. This creates a fairly rigid skeletal structure for support of the rear quarters and legs of the cow. In an animal standing squarely on its feet, weight is distributed equally over all 4 claws of the rear feet (Figure 2, from Raven). However, during movement the distribution of weight within and between the claws changes displacing more weight to the outside claws. Despite movement, load-bearing on the inside claws is more even (more stable). Outside claws automatically and continuously correct for ever-changing weight load (Figure 3, from Raven). This circumstance of ever-changing weight distribution is believed to be a major reason for accelerated hoof growth and a higher incidence of claw disorders involving the outside claw.

The situation for front feet differs in that both stability of the weight bearing surfaces and size of the claws is similar. Furthermore, there appears to be greater flexibility in the anatomical arrangement of the skeleton and soft tissues of the shoulder. Front legs are not connected to the upper body through a ball-and-socket joint. Instead, front legs are connected to the torso by tendons and ligaments that tend to cushion the effects of variable weight distribution between the claws. As a result the bio-mechanical forces associated with variable weight distribution are less pronounced in front feet and disorders leading to lameness less frequent. Despite similarities between each of the front claws, weight bearing is greater for inside claws. Consequently, when lesions do occur they are more commonly associated with the inside claw.

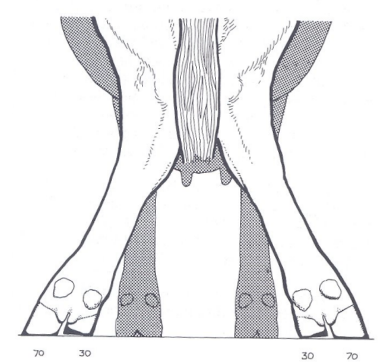
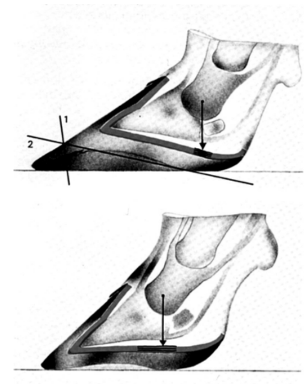



**Figure 4**

Confinement on concrete or other hard surfaces enhance the physical effects of load-bearing on feet, whereas housing on earthen surfaces tends to reduce these effects. The practical significance of which is the observation of cattle (especially heifers) moved from pasture to confinement that experience lameness due to a physical/mechanical form of laminitis. These physical effects are further complicated by the fact that the unyielding nature of hard-flooring surfaces tends to irritate the corium thereby increasing its blood flow and accelerating the growth of claw horn. Excessive hoof growth (particularly of the outside claw of rear feet) leads to overgrowth and eventually overloading of the affected claws. This causes the cow discomfort which she attempts to alleviate by taking a base wide or cow-hocked posture (Figure 4, from Raven). Despite changing her posture she continues to bear excess weight on the outside claws. The end result is an increased risk of claw disease in these overgrown/overloaded claws.

## Weight-Bearing Forces in Overgrown Claws

Most overgrowth occurs at the toe. When the toe is long the sole at the toe is thick. This forces the weight-bearing axis backward toward the heel often concentrating weight bearing forces over the sole and heel ulcer sites. By reducing length and sole thickness at the toe one is able to move the weight bearing axis forward and away from the sole and heel ulcer sites thereby decreasing the potential for ulcer development (See Figure 5, from Raven). Studies by Raven and others indicate that proper length of the front wall of the inside claw of the rear foot is approximately 3 inches in mature average sized Holstein cows. This front wall length corresponds to a sole thickness of about 1/4 of an inch which is believed to be the minimum sole thickness required to protect the corium. When front walls measure less than 3 inches, sole thickness at the toe is less than a 1/4 of an inch and potentially unable to support the weight of the cow on hard flooring surfaces.



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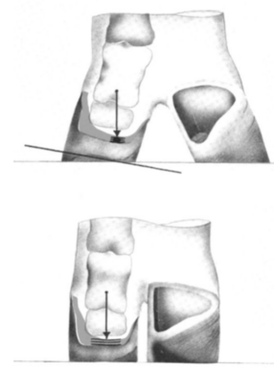
Since horn of the wall is harder and grows faster than the sole, overgrowth of the abaxial (outside) walls is a natural occurrence in overgrown claws (See Figure 6, from Raven). Similar to that described earlier for overgrowth occurring at the toe, overgrowth of the abaxial walls shifts weight bearing forces onto the sole ulcer site. The combined effect of overgrowth of the abaxial wall and toe exaggerate weight bearing over this area and significantly increase the potential for a sole ulcer to occur. Correction of abaxial wall overgrowth displaces the weight bearing forces laterally thereby reducing the potential for sole ulcer development.



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It is for these reasons (overgrowth, overburdening and altered weight bearing) that the claws of dairy cattle require regular evaluation and trimming. In some cases the rate of horn wear is in balance with the rate of horn growth despite the effects of weight bearing and trimming is not required. In other cases, horn growth exceeds the rate of wear and trimming is required to correct weight bearing disparities. In free stall housed dairy cattle, the rate wear often exceeds the rate of claw horn growth and trimming only exacerbates an already serious problem. Proper foot care and claw trimming requires an understanding of the anatomy of the foot and the dynamics of claw horn growth.

## Claw Trimming: 2 Approaches

*"If there is no lameness problem, trimming can produce it"*
from Cattle Footcare and Claw Trimming, by E. Toussaint. Raven

Although footcare and claw trimming have an important role in the management of lameness conditions, experience has shown that claw trimming can be a cause for lameness. The most common error in the US is over-trimming. It is important to remember that one of the primary purposes of the claw horn capsule is to protect the corium. When excess claw horn has been removed and the sole is no longer able to properly support the cow's body weight, the underlying corium becomes subject to damage from bruising. In herds with abrasive flooring surfaces cows may develop thin soles from excessive wear. Thin soles in dairy cattle represent one of the most difficult of foot problems to manage. The functional and corrective trimming method as described by Raven provides important guidelines for the maintenance of proper toe length and sole thickness. These guidelines are useful to prevent trimming-related lameness.

***The Traditional Approach to Claw Trimming.*** Traditional claw trimming techniques applied to cattle are based largely on procedures used by farriers and others trimming the hooves of horses whereby weight is transferred primarily to the hoof wall. Application of this same technique to the cow would consist of shortening the axial wall and sloping or "cupping out" the sole in order to place the majority of weight on the abaxial (outside) wall. This is problematic in that underdevelopment of the axial wall and sloping of the sole toward the axial (inside) wall are primary reasons for instability of the medial claw of the rear foot under natural conditions. Removal of the axial wall in both claws only exacerbates instability in the foot. Furthermore, transfer of weight-bearing to the abaxial walls naturally increases shearing forces on the walls. One might speculate that this could increase the risk of white line separation and thus white line disease. Based on the work of Raven, sloping of the soles in an axial direction may also encourage the development of sole ulcers by shifting weight-bearing within the claw onto the "typical site" for sole ulcers (See Figure 6, from Raven). Also, when the soles of claws are sloped axially, claws are encouraged to splay apart when weight is borne on the foot. This causes stretching and irritation of the interdigital skin and is believed by some to contribute to interdigital fibromas (corns) in cattle. Finally, traditional trimming techniques generally make little or no attempt to balance weight-bearing within or between the claws of each foot. Studies on the pathogenesis of sole ulcers and white line disease clearly show that claw overgrowth leads to disproportionate weight-bearing and eventually claw disease. Therefore, the re-establishment of appropriate weight-bearing within and between claws would seem to be an important objective in hoof trimming.

***Functional and Corrective Claw Trimming.*** Functional claw trimming is the method described by Raven. Readers are advised to consult this book for a more in-depth review of this topic.

According to Raven the objectives of preventive hoof (claw) trimming are:

1. Correction of the relative overgrowth that leads to overburdening of the claw (overgrowth is most significant for the outside claw of rear feet and the inside claw of front feet).

2. Restoration of the appropriate weight-bearing surface within each claw.

3. Correction of claw lesions at an early stage.

The following describes a 4-step functional trimming procedure based on the Raven method. The trimming procedure and claw parameters described herein are intended for application on average sized Holstein-Friesian cows. They should be adjusted for larger framed cows or bulls. Although Raven's technique is described as 3-step procedure, the authors prefer the 4-step procedure as described below because it permits greater emphasis on heel balance (Step 4).

## Step-wise procedure for the trimming of rear feet:

***Step 1.*** Begin by making an assessment of the cow's size and length of her claws. The front wall of the medial claw should be a minimum of 3 inches (3 1/4 inches in a very large cow or bull) in length. The point of measurement is from just below the skin-horn junction where the hard horn starts to the tip of the toe. Three inches is accepted as the minimum front wall length for the average Holstein-Friesian cow. Minimum sole thickness should be 1/4 of an inch.

The bearing surface is "stabilized" on the inner hind claw sparing as much of the heel as possible. In other words, the bearing surface of the toe and wall is pared flat so that it will be at right angles to the long axis of the shin (cannon) bone in the standing position. This will ensure that the cow has a flat and stable supporting weight-bearing surface.

***Step 2.*** Using the medial claw just trimmed as a guide, trim the toe of the outer claw (rear foot) to the same length. Next, pare the weight-bearing surface of the outside claw to the same level as that of the medial claw. When the front walls of each claw are held at the same level the weight bearing surfaces at the toe should be flat and level with each other.

***Step 3.*** Shape and slope the sole so that the innermost back portion of the sole slopes toward the center of the claws. Care should be taken to avoid paring away important weight-bearing surface at the toe. Excessive cupping or sloping of the sole should be avoided because it reduces the weight-bearing surface area to the outside walls. Proper sloping of the sole in this region is designed to reduce pressure in the sole-ulcer site and open the interdigital space between the claws. Overgrowth of the sole which occludes the interdigital space causes dirt and manure to be entrapped between the claws. This increases the likelihood of interdigital disease.

***Step 4.*** Balance the heels by laying the handle of the hoof knife across the heels and making the weight bearing surfaces perpendicular to the long axis of the leg. When trimming is complete the weight-bearing surfaces should be flat at the toes, along the walls, across the heels and perpendicular with the long axis of the leg. This assures an appropriate distribution of weight within and between the claws and completes the trimming process in feet where further corrective trimming procedures are unnecessary.

***Corrective Trimming:*** Steps 5 and 6 are characterized as "therapeutic and curative trimming procedures". They are applied as needed.

***Step 5.*** *Remove loose horn and trim away hard ridges.* In the presence of claw horn lesions, further corrective trimming is necessary. Remove all loose horn irrespective of how extensive it is (sole separation) and pare away hard ridges (heel horn erosion). Only healthy hoof horn should be left in place. Always slope horn away from the lesion. For example, carefully trim the loose necrotic horn around sole ulcers and slope the remaining horn axially (toward the inside). Likewise, remove the adjoining lateral wall when trimming out white line lesions. Trim carefully and DO NOT remove new healthy horn. Avoid damage to the corium (i.e. stop when trimming leads to bleeding of the corium).

***Step 6.*** *Adjust weight bearing in damaged claws.* Pare the damaged claw lower toward the heel to increase weight-bearing on the healthy claw. In most cases the damaged claw will be the outside claw of rear and the medial claw of front feet. Specific indications for this trimming procedure would include conditions in which overgrowth has led to overloading (i.e. hemorrhage at the sole ulcer site) and pain resulting in postural or gait abnormalities. Lowering the damaged claw reduces weight-bearing and thereby permits recovery and eventual return to normal function and health. In some cases it is necessary to apply a foot block to the healthy claw in order to reduce weight-bearing in the damaged claw.

Part of fixing a foot is trimming a foot. In other words, unless the defect that created the problem is corrected the benefits from curative procedures are short-lived. The step-wise procedure as outlined above should be applied to the healthy as well as the lame foot in a lame cow. Quite often, similar problems can be found in the other foot. Cows that do not respond or get worse within a couple of days should be re-examined.

## Claw Checking and Trimming as Needed

Cows should have their claws checked at least twice per year for the presence of claw horn overgrowth and early lesions. Both abnormalities should be corrected as needed. However, in many situations today, cows are trimmed 2 or 3 times per year whether they need it or not. Trimming normal feet is costly and jeopardizes foot health, especially for cows on concrete where subsequent wear may create thin soles that could lead to serious problems. On the other hand, cows with corkscrew claws or laminitis would likely benefit from trimming as much as 3 or even 4 times per year because of the accelerated rates of claw horn growth that accompany these conditions.

## Foot Blocks for Relief of Weight-Bearing in Diseased Claws

The application of corrective trimming procedures as described in Step 6 above will often provide a sufficient difference in height between the two claws to relieve weight-bearing and promote recovery of claw lesions. However, when pain is severe or one is unable to create sufficient difference in height between the two claws, additional elevation of the diseased claw can be achieved by means of a block attached to the sound claw. Proper application of foot blocks requires attention to the following:

1. Start by properly trimming the claws according to the step-wise procedure outlined above. Before attaching a block to the healthy claw, the claw must be pared flat and in the proper plane. This will provide a bearing surface that is at right angles to the long axis of the cannon bone.

2. Prepare the claw with a rasp or grinder so that the adhesive will properly adhere to the wall and sole of the claw being fitted for the block.

3. Mix the adhesive to the proper consistency and apply to the block and claw as needed.

4. Apply the block and position it so that it lies flat on the sole and provides proper support of the heel. Failure to provide adequate heel support is one of the most common mistakes in applying blocks.

5. Be sure that adhesive is cleared away from the area between the block and the heel. Heel horn is very soft and can easily be damaged by the hard and sometimes very sharp edges of fully cured adhesive material.

6. Remove blocks after a period of 4-6 weeks. Blocks that cause discomfort prior to then should be removed sooner.

7. After removing a block, always re-trim the foot and adjust weight-bearing as needed.

## Application of Bandages or Wraps to Lesions of the Claw Capsule

Correction of horn lesions often results in small or moderate exposure of the corium. In general, most would agree that minor lesions or injuries to the corium are best left untreated and without a bandage. More severe lesions in which there may be large areas of the corium exposed may benefit from topical treatment with a mild disinfectant or antibiotic under a bandage with the proviso that it be removed within 3-5 days. The direct application of caustic or particularly irritating treatment materials on open lesions with exposed corium should be avoided. If it is the practice of the dairy to allow bandages to fall off on their own it is the opinion of these authors that they are better left without a bandage from the start. The environment of most cows is such that bandages become very contaminated within a couple of days. It is doubtful that they offer significant therapeutic benefit beyond this point. Indeed, results from a Cornell study comparing cows with claw lesions with a wrap verses no wrap indicate no advantage to the application of a bandage.

On the other hand, a bandage is advised for hemostasis in cases where corrective trimming has led to there is severe hemorrhage of the corium or other tissues. Bandages are also advised for postoperative care of surgical cases such as claw amputation. As suggested above, these should be changed every 2 days depending upon the degree of environmental contamination. Every attempt possible should be made to house animals having had such procedures in a clean dry environment.

## Training Employees in Foot Care and Claw Trimming Procedures

It is the opinion of these authors that all dairies (regardless of size) should have appropriate handling and restraint facilities for the treatment of lame cows. Herds of 250 or more cows should have not only handling and restraint facilities (i.e. tilt table or stand-up trimming type chute), but in addition proper equipment (knives, sharpening devices, hoof nippers, and angle grinders) and trained personnel to examine and treat lame cows on a daily basis. Routine maintenance trimming may be left to the services of a commercial trimmer or conducted by on-farm employees at the discretion of the dairy.

Proper skills in foot care and claw trimming require supervised training and practice. Training programs such as that described below are advised. Estimated initial investment for dairies who choose to employ an on-farm trimmer (including chute, foot care equipment and training) may range from $5000 to $20,000 (in US dollars). Considering present-day replacement cow costs in the US (greater than $2000/replacement), a foot care program that will reduce the loss of cows to irreversible lameness is easily justified.

***The Master Hoof Care Technician Program.*** Training programs in foot care and claw trimming are available from various sources including those who market restraint systems. Some of those teach traditional methods of claw trimming. The Florida Master Hoof Care Program teaches the method of Toussaint Raven described in this paper. Part I of the course consists of 4 days (3 days of trimming on cadaver specimens and live cows) of intensive training on foot care and claw trimming. Part II consists of continued study and practice of the techniques learned in Part I of the course. After a period of 3 to 6 months of study and practice, the student is eligible to return to the University of Florida to take a written, oral, and laboratory practical examination. Successful completion of these examinations qualifies the candidate as a “Master Trimmer” in the Master Hoof Care Technician Program. This qualification is the employer’s assurance that his employee is performing the task of foot care and claw trimming in accordance with accepted procedures.

The purpose of the Master Hoof Care Program is to provide training for health technicians responsible for foot care and claw trimming duties on dairy farms. The basis for the program comes from a strong belief that timely (i.e. daily) foot care and treatment of lame cows will reduce the number of cows lost from irreparable foot disease. Unfortunately, many dairies simply turn lame cows out into a lot where they remain until a commercial hoof trimmer or veterinarian can attend to them on their weekly or monthly visit. In these situations, cows go untreated for several days or weeks depending upon when the hoof trimmer or veterinarian is scheduled to visit the dairy. The time lag from original insult to examination and treatment permits treatable lameness conditions to progress to the point of irreparable damage that often results in premature culling of affected animals. This is costly and inhumane. Reducing losses in performance and involuntary culling from lameness has the potential to save the dairy industry millions of dollars to say nothing of the tremendous impact from improvements in animal welfare from providing prompt relief to suffering animals.

## Treatment of Infectious Diseases of the Skin of the Foot

Infectious claw disorders represent some of the most important causes of lameness in dairy cattle. However, unlike the lesion associated with a sole ulcer or white line disease which specifically affects the claw, these diseases affect the "skin" of the interdigital space, heel bulbs, and interdigital cleft (on the back of the foot above the interdigital space). Treatment consists of systemic therapy, footbaths, foot spraying or bandaging.

***Digital Dermatitis (Mortellaro's Disease).*** Although digital dermatitis (DD) was first reported in the US around 1980, the disease was not a widespread problem until the early 1990s. Although the precise cause remains to be determined, the organisms observed in lesions most consistently are bacterial spirochetes belonging to the genus *Treponema sp*. Approaches to therapy include: 1) surgical excision, 2) footbaths 3) topical treatment with various disinfectants, and antibiotic solutions, 4) cryosurgery, and electrocautery, 5) topical treatment under a bandage, and 6) systemic antibiotic therapy. With the possible exception of cryosurgery and electrocautery, most of these treatments have a place in the management of this condition.

Topical spray-on treatment with antibiotic and some non-antibiotic preparations (Victory$^{TM}$ by Westfalia-Surge) have been shown to be very effective when used in a scheme of consistent daily treatment for a period of 8-10 days over a 2-week period. The major disadvantage to topical treatment is that lesions occurring in the interdigital space are missed. Topical antibiotic treatment under a bandage is particularly effective with most cows showing remarkable improvement within 24-48 hours. Furthermore, when properly applied this approach to treatment has the potential advantage of reaching lesions affecting the interdigital skin. Footbaths containing various compounds including 3-5% formalin, 5-10% copper sulfate, 20% zinc sulfate, oxytetracycline 1-4 g/l, lincomycin 1-4 g/l, or lincomycin/spectinomycin 1-4 g/l have been recommended. Results vary widely. Footbaths are discussed in greater detail below.

Response to topical antibiotic treatment (topical spray or bandage) is also influenced by the anatomic location of lesions. Lesions occurring on the plantar interdigital cleft were less likely to respond compared with lesions occurring on the heel bulbs or dewclaws. Limited evidence also suggests that response to therapy may be influenced by lesion maturity and possibly antibiotic resistance patterns of etiologic agents. These factors should be considered in evaluating treatment responses as well as the development of new treatment strategies.

***Interdigital dermatitis (Slurry Heel).*** Interdigital dermatitis (ID) is an acute or chronic inflammation of the interdigital skin, extending to the dermis. It is extremely common in free-stall housing or other situations where the feet of cows are continuously exposed to wet manure slurry or muddy corral conditions. The disease is likely caused by a mixture of bacteria: *Fusobacterium necrophorum*, bacterial spirochetes, and possibly *Dichelobacter nodosus*. Unlike digital dermatitis because of their location in the interdigital space, most lesions of ID are not accessible to treatment by topical spray. Footbaths are the only practical treatment for ID in cows.

***Foot Rot (Interdigital Phlegmon) and Super Footrot.*** Foot rot is an infectious disease of the interdigital skin characterized by the presence of an interdigital lesion, swelling, and moderate to severe lameness. Fever ranging from 103-105$^{o}$F (occasionally higher) is a consistent finding during the acute stages. A recent study conducted at the University of Florida found that foot rot was associated with a 10% decrease in milk production in affected cows. This was greater than the milk loss observed for cows with claw disorders or digital dermatitis. Most cows developed the disease in early lactation as they were approaching peak milk yield which suggests that the occurrence of this disease in early lactation may inhibit a cow's ability to achieve peak milk yields.

In recent years, clinicians from the United Kingdom and the United States have observed a more extreme form of this disease referred to as “Super Footrot“. It is characterized by acute onset of lameness and swelling of the foot that progresses rapidly to an ascending cellulitis. The interdigital lesion associated with “Super Footrot” is especially severe and successful treatment particularly challenging.

Footrot is responsive to most antibiotics in common use for cattle. In fact, it is the opinion of these authors that dose and duration of treatment are more important in most cases than antibiotic selection. The key to achievement of a successful therapeutic outcome is dependent upon prompt recognition and early implementation of treatment procedures. Systemic therapy plus topical treatment of the interdigital lesion have long been the preferred methods of treatment. In uncomplicated cases, improvement is noticeable within 24-48 hours with good recovery attainable in 3-4 days from the onset of treatment. Treatments of choice are Naxcel (Ceftiofur Sodium), Penicillin, Albon (Sulfadimethoxine), and tetracyclines (extra-label in dairy cattle). Some prefer to simultaneously treat the interdigital lesion as well. Various antiseptic-type products may be used as topical treatments. Bandaging of the foot is unnecessary. Regardless, the secret to success is early detection of the disease.

## Footbaths and Environmental Considerations

Most operations design facilities for placement of footbaths in parlor exit lanes, however, in some operations cows tend to loiter in lanes exiting the parlor. In general, it is best to locate footbaths in pathways or areas where cows tend to keep moving. Ideally, after traversing through the baths, cows should be kept in a clean dry area for approximately 30 minutes. This allows time for drainage of the excess fluid and for the medications to exert their antibacterial action. Contaminated footbath solutions are discharged into manure holding systems. Here they are diluted with other waste material from the dairy operation and eventually applied to crop fields. Until recently, most have considered the contribution of footbaths to chemical load in the environment to be insignificant and just a part of sound foot care management. However, a recent article in the July 2001 issue of Hoard’s Dairymen demonstrated that the use of copper sulfate at the rate of 100 lbs per day equates to 18 tons per year. Considering the typical number of crop acres for an 800 cow dairy, that amounts to an application rate of 5 lbs per acre.

The article cites 2 important problems: 1) phytotoxicity, and 2) Environmental Protection Agency (EPA) guidelines on cumulative loading capacity of soils for heavy metals, including copper. Although copper is a potentially toxic for dairy cattle, the more significant problem relates to phytotoxicity. In high concentrations, copper damages the plant’s root system. In some locations crop yields have been greatly reduced as a result of copper toxicity. At current rates of application many dairy operations will achieve the lifetime accumulative load within a period of 10-15 years. Clearly, all operations need to assess the amount of copper sulfate being applied per acre to determine if they are in danger of reaching lifetime accumulative loads. This assessment may be made by multiplying the pounds of copper sulfate purchased annually by .25 to determine the actual amount of copper; then divide this amount by the number of acres that are receiving manure applications.

## Conclusions

Claw disorders are the predominant causes of lameness in dairy cattle. They can only be managed by the establishment of a foot care program that addresses lameness on a daily basis. Appropriate claw health management requires proper foot care and claw trimming techniques. From an international perspective, the functional trimming method as described by Toussaint Raven is the most widely recognized and accepted claw trimming procedure. In the US, however, there are other approaches some which are based on trimming techniques applied to horses. The most common trimming error is over-trimming. To learn proper foot care and claw trimming requires proper training in the "science" as well as the "art" of claw care and trimming. Infectious claw disorders are in large part a consequence of continual exposure to wet manure slurry. Treatment generally involves some form of topical treatment including topical spray, footbath, or topical treatment under a wrap. Foot rot generally requires systemic antibiotic therapy. The value of vaccination for control of infectious claw disorders is unknown at this time. Prompt treatment in combination with effective waste management are the best bets for keeping these diseases to a minimum.

### Selected References

Argaez-Rodriguez, RJD, Hird W, Hernandez J, Read DH, Rodriguez-Lainz A (1997) Papillomatous digital dermatitis on a commercial dairy farm in Mexicali, Mexico: incidence and effect on reproduction and milk production. Prev Vet Med 32, 275-286

David GP (1993) Severe foul-in-the-foot in dairy cattle. Vet Rec, 133, 567-569

Hernandez J, Shearer JK, Elliott JB (1999) Comparison of topical application of oxytetracycline and four non-antibiotic solutions for treatment of papillomatous digital dermatitis in dairy cows. J Am Vet Med Assoc 214, 688-690

Hernandez J, Shearer JK, Webb DW (2002) Effect of lameness on milk yield in dairy cows. J Am Vet Med Assoc, Vol 220, No 5, 640-644

Hernandez J, Shearer JK (2000) Efficacy of oxytetracycline for treatment of papillomatous digital dermatitis lesions on various anatomic locations in dairy cows. J Am Vet Assoc, Vol 216, No 8, 1288-1290

Hoblet KH, Weiss W (2001) The Veterinary Clinics of North America, Food Animal Practice, Vol 17, No 1, 111-127

Hoblet KH (2002) Footbaths - separating truth from fiction and clinical impressions. Proc of the 12th International Symposium on Lameness in Ruminants, Jan 9-13, Orlando, Florida, 35-38

Paulus N, Nuss K (2002) Claw measures at defined sole thickness. Proc of the 12th International Symposium on Lameness in Ruminants, Jan 9-13, 428-430

Phillips, CJC and Morris, ID (2000) The locomotion of dairy cows on concrete floors that are dry, wet, or covered with a slurry of excreta. J Dairy Sci, 83:1767-17772.

Raven T (1989) Cattle Footcare and Claw Trimming. Farming Press Ltd

Shearer JK, Elliott JB (1998) Papillomatous digital dermatitis: treatment and control strategies - Part I. Compend Cont Educ Pract Vet 20, S158-S166

Shearer JK, Hernandez J, Elliott JB (1998) Papillomatous digital dermatitis: treatment and control strategies - Part II. Compend Cont Educ Pract Vet 20, S213-S223

Shearer JK, Hernandez J (2000) Efficacy of two modifiec non-antibiotic formulations of (Victory™) for treatment of papillomatous digital dermatitis in dairy cows. J Dairy Sci, 83, 741-745

Shearer JK (2002) The standardization of input codes for the capture of lameness events in dairy records. Proc of the 12th International Symposium on Lameness in Ruminants, Jan 9-13, 346-349

Shearer JK, Van Amstel SR (2001) Functional and Corrective Claw Trimming. The Veterinary Clinics of North America, Food Animal Practice, Vol 17, No 1, 53-72

Thomas, ED (2001) Foot Bath Solutions may Cause Crop Problems. Hoard's Dairymen, July, 458-459

Van Amstel SR, Shearer JK (1998) Approach to improve claw trimming in the Southeastern United States. Proc of the 10th International Symposium on Lameness in Ruminants, Sept 7-10, Lucerne, Switzerland, 17

Van Amstel SR, Palin FL, Shearer JK (2002) Claw trimming: an adaptation of the Dutch method. Proc of the 12th International Symposium on Lameness in Ruminants, Jan 9-13, Orlando, Florida, 127-130

White EM, Glickman LT, Embree C (1981) A randomized field trial for evaluation of bandaging sole abscesses in cattle. J Vet Med Assoc, 178, 375-377

# Jejunal Hemorrhage Syndrome in Adult Dairy Cows

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## Introduction

Jejunal hemorrhage syndrome (JHS), also referred to as "hemorrhagic bowel syndrome" or "acute hemorrhagic enteritis of the small intestine", has been reported with increasing frequency in adult dairy cows over the past three years by veterinary diagnostic laboratories in many dairy states including Minnesota, New York, Pennsylvania, Washington, Wisconsin, Colorado, Illinois, and Iowa. While the occurrence of JHS is often sporadic many cases have presented as part of a syndrome causing the death of significant numbers, or clusters, of adult dairy cows in affected herds.[5] Hemorrhagic enteritis has been reported in other species and in calves, but published information describing JHS in adult dairy cows is limited.[2,5,6,7,13,18] The purpose of this paper is to present a short review and a description of JHS cases presented to the University of Minnesota Veterinary Diagnostic Laboratory, and to discuss theories for causes, risk factors, and some suggested methods for control and prevention of the disease.

**Clinical Syndrome and Treatment.** Affected cows are often found dead (sudden death). Alternatively, they may be found recumbent and semi-conscious, or still standing, but very weak, shocky, and pale. Affected animals may exhibit sudden complete anorexia, a severe drop in milk production, signs of colic or abdominal pain, and abdominal distension. Cows may show decreased fecal output, bloody stool, or diarrhea containing either frank blood or blood clots. Affected cows usually do not have an elevated rectal temperature. Treating affected cows with antibiotics and supportive therapy (e.g. anti-inflammatories, fluids, dextrose) has generally been reported to be unsuccessful. Treatment with calcium has reportedly resulted in temporary improvement in the animal's general condition, but this is short lived and death ensues shortly after.[5, 18] There is an extremely high case fatality rate, with reports of 85 to 100% of affected animals dying within 24 to 36 hours of the onset of clinical signs.[5] On exploratory surgery or necropsy, there are distinct sections of jejunum (a section of the small intestine) which are distended by a large amount of blood. Affected sections of intestine are sometimes three feet or longer. The intestine may contain either bloody or brown fluid or a large solid blood clot that obstructs the lumen, preventing any passage of ingesta or intestinal contents. Some veterinarians have reported limited success by surgically opening the intestine and removing the clot, or by massaging the clot through the small intestine. However, the prognosis is still grave. Spontaneous development of new clots, following removal of the original clot, has also been reported.[5]

**Pathology.** There are currently no studies published describing the cause of JHS in adult dairy cows. A review of 23 cases presented to the Veterinary Diagnostic Laboratory at the University of Minnesota between 1999 and early 2000, that showed typical gross lesions of either blood clots or bloody fluid in the jejunum, yielded the following diagnostic findings: 100 % of 22 cases tested were negative for *Salmonella* spp., 100% of 9 cases tested were negative for gastrointestinal parasites, and 100% of 18 cases tested were negative on virus isolation for bovine virus diarrhea virus (BVDV). Retesting using blood PCR, a DNA test, have found only three cases positive for BVD. While the following additional tests were performed on only a small subset of these cases, those tested have also consistently been negative for *Yersinia* sp., *Lawsonia intracellularis*, and Corona Virus (the cause of Winter Dysentery). One finding that has been common to the vast majority of these cases (86%, or 19 of 22 cases tested) is the isolation of *Clostridium perfringens* Type A. This has been recognized in cows submitted live that were then euthanized and fresh tissues collected, as well as in tissues submitted from animals that had died on the farm (i.e. tissues were collected by veterinarian several hours after death occurred).

**Causes and Risk Factors for JHS?** The importance of isolating *Clostridium perfringens* Type A in cases of JHS in adult dairy cows is unclear. Because *Clostridium* spp. are normal inhabitants of soil, live in the intestine of normal healthy animals, and are known to replicate rapidly in the intestinal tract after death, it is not clear if this bacteria is the primary cause of JHS, if it arises secondary to other predisposing changes in the intestine environment, or if it is simply an incidental finding.[1,15] One theory as to the cause of JHS is a model similar to hemorrhagic enteritis caused by *Clostridium perfringens* Type C in fast-growing suckling calves, lambs, or piglets.[1,7,8,11,12,15,19] *Clostridium perfringens* Type C will multiply rapidly and produce toxins under conditions of high carbohydrate and protein substrate availability in the small intestine. It is possible that this scenario could arise in the adult dairy cow in association with those same factors that also lead to ruminal acidosis (i.e. feeding excess amounts of rapidly fermentable carbohydrates, insufficient effective fiber and/or inadequate rumen fiber mat, or ration sorting by cows).[7]

A second theory is that poorly fermented ensiled feeds, such as haylage (e.g. in the case of poor silo or bunker management), may accumulate harmful molds, clostridial or other harmful bacteria, and possibly their toxins. These bacteria or their toxins may then be fed directly to the cow. Kirkpatrick et al. sought to investigate the possible role of both ruminal acidosis and clostridial contamination of poorly fermented forages in a case study of a 140-head herd of Brown Swiss that had experienced multiple cases of JHS.[5] Reported effects of the toxins produced by *Clostridium perfringens* type A in mammals have included illness, diarrhea, accumulation of fluid in intestinal loops, and death from shock.[10,14] Additional effects of the toxins may possibly include reduced gut motility.[17]

## Results of Surveys of Minnesota Veterinarians on the Occurrence of, and Potential Risk Factors for, Jejunal Hemorrhage Syndrome

**Frequency of Diagnosis of Jejunal Hemorrhage Syndrome by Minnesota Dairy Vets.** Given that dead cows are not routinely necropsied on many dairies, this disease may be underreported. Two small surveys were administered to two largely different groups of Minnesota bovine veterinarians in March 2000 and in February 2001. 50% to 59% of respondents indicated that they had diagnosed one or more cases of JHS in the previous 12 months (range 1 to 30 cases diagnosed per veterinarian), and that a median number of two client herds had been affected (range 1 to 8 client herds per veterinarian). Forty to fifty-six percent of respondents indicated that they had diagnosed more than one case on a single farm. When considering all respondents (those having and not having diagnosed JHS), the median number of cases of JHS was only one case diagnosed per veterinarian in the previous 12 month period (mean = 2.4, range = 0 to 30 cases per veterinarian).

**Potential cow risk factors**. In the first survey, vets were asked to describe the cow and herd-management for the most recent JHS case they had seen. Holstein cows accounted for 94% (n = 17) of JHS cases, with the remaining 6% (n = 1) being Jersey. As an aside, while none were reported in the mail survey, Brown Swiss cases have been submitted to the Veterinary Diagnostic Laboratory and have been reported by others.[5] A total of 61% of JHS cases were reported to have occurred within the first 100 days of lactation, 22% occurred in mid-lactation (101-200 DIM) and 11 % occurred in late lactation (> 200 DIM). One case was reported during the close-up dry cow period. A significantly greater number of cases (94%) occurred in second lactation and older animals than did in first lactation heifers (6%). These findings are consistent with a case study of a single herd of 140 Brown Swiss cows that had experienced multiple cases of JHS, in which it was reported that the syndrome had affected only older cows.[5] The authors of that study speculated that this apparent association could be due to higher milk production or higher dry matter intakes in the older animals.[5] We suggest this could also relate to different feeding behaviors (e.g. sorting, meal size and frequency). However all of these theories require investigation.

**Potential season, region and herd management risk factors.** While no statistically significant relationship existed, there was a trend for an increased rate of occurrence in the fall and winter months. JHS was reported in all dairy regions in Minnesota and in herds managed under a wide variety of systems typical of the Midwest: large (>500 cows) and small (<50 cows) herds, free stall and tie stall facilities, and in herds feeding typical Midwest forages (dry hay, corn silage, haylage) and using a variety of fermented forage storage systems (tower silo, bunker silo, or plastic bags). When compared to the average distribution of all Minnesota dairy herds by herd size, chi-square analysis showed a significantly higher risk for JHS in herds with ≥ 100 cows.[9,20] Also, a significantly higher percentage (83%) of affected herds fed a total mixed ration (TMR), as compared to herds using component feeding.[16] However, given that this was only a small preliminary survey and given the relatively small numbers of cases used in the analyses, readers should be cautious in their interpretation of these preliminary results since there is ample room for introduction of bias and confounding in the study. For example, it may be that larger herds are more likely to have adopted TMR feeding programs and also are more likely to routinely have the veterinarian necropsy all dead animals. Thus, they might simply find more of the disease because they are looking. Also, they have more cows to be at risk of developing the disease.

## Strategies for control and prevention of Jejunal Hemorrhage Syndrome.

**Ration balance and feeding management.** One theory suggests that JHS may occur in situations where an inadequate rumen fiber mat and/or high dietary levels of rapidly available carbohydrate result in an overflow of excessive quantities of carbohydrates into the small intestine. This could provide enough nutrients to allow for rapid multiplication and production of toxin by Clostridial organisms that are natural inhabitants in the gut. If this theory is true, then producers experiencing cases of JHS should work with their nutritionist to investigate ration fermentable carbohydrate and fiber levels, evenness of mixing, and shaker box analysis of particle size for both of fresh TMR and refusals (e.g. evaluate for sorting by the cows). Additional useful information may include evaluation of manure consistency, rumenocentesis to measure rumen pH, milk component data, and health data. Producers should strive to feed a ration balanced with adequate effective fiber to maintain good rumen health and integrity of the rumen mat. Even if we eventually learn that this theory has nothing to do with causing JHS, adequate dietary fiber and good rumen health are still something that we should strive for because they have other health and production benefits.

**Forage Quality.** A second theory for the cause of JHS is that poorly fermented ensiled feeds may accumulate harmful molds, clostridia or other harmful bacteria, and possibly their toxins that are then fed preformed to the cow. No scientific studies have confirmed this association. However testimonials from some producers state that the occurrence of JHS decreases or disappears if they stop feeding poor quality, poorly fermented forages. Producers experiencing JHS should work with their nutritionist to evaluate forages, including chemical analysis of nutrients, moisture, temperature and pH, as well as visual assessment for obvious spoilage or inadequate fermentation. Producers should discontinue feeding poorly fermented or spoiled forages to close-up and milking cows if another source of higher quality forages can be located. This will be most important for close-up, just fresh and high producing groups. Another strategy, if alternate forage sources are limited, may be to dilute the poorer forage out with higher quality forages. Again, even if we eventually learn that this theory has nothing to do with causing JHS, we all know that feeding high quality forages is the surest and cheapest way to get good production from our cows.

**Vaccination.** Before beginning this discussion, readers should be reminded that it is not conclusive whether *Clostridium perfringens* Type A is the causative organism, or, if it is, which specific toxin produced by this organsim is responsible for JHS. This said, one approach some producers have tried is using an autogenous vaccine. However there are serious concerns in adopting this approach because of a lack of answers to important questions such as: What is the causative organism? What is the correct toxin? What is the yield of toxin needed for protection? What is the correct immunogen dose? What adjuvant should be used? How is enough adjuvant introduced to induce protection without inducing adverse reactions? How pure is the end product? What quality control and testing is done before release? How consistent are different batches? Is any animal testing done? Additionally, autogenous vaccines can be expensive and adverse reactions have been reported including tissue reactions, milk drop, abortion and premature calving. These risks must be weighed against the risk for a disease that is infrequent in nature.

There are no commercial vaccines currently approved for JHS, nor are there likely to be in the near future, until the cause of the disease is understood. Testimonials report no protection from commercial 7 or 8 way clostridial vaccines. This may be because they don't contain the correct bacterial strain or toxin type, or because they contain inadequate yields to be protective. The Type C and D vaccines may give some protection against Type B because the toxins produced by Types C and D organisms are the same as for Type B. Otherwise, there is no cross protection among the other identified *Clostridium perfringens* toxins. Anecdotally, one C and D type vaccine has been reported to give some short-term protection against JHS in some affected herds. The suggested explanation for short-term immunity (3 to 4 months) is that it might also contain some small amount of free alphatoxin from the pathogenic strain. Producers should keep in mind that these reports of protection are only testimonials and are not proof of efficacy. It is very possible that producers experiencing one or two cases of JHS may have responded by changing several factors at the same time in addition to vaccinating, such as discontinuing feeding bad feed and reviewing and tightening up the ration. If the occurrence of JHS seemed to stop for several months, it is difficult to know whether this was due to these other management changes, the sporadic nature of the disease, or whether the vaccine truly helped.

## Summary

Jejunal hemorrhage syndrome has been diagnosed with increasing frequency in the past few years. In two surveys of Minnesota bovine veterinarians it was reported to have been diagnosed by 50 to 59% of veterinary respondents, of whom 40 to 56% reported multiple cases in the same herds. While there is probably a low annual incidence rate of JHS for the entire population of adult dairy cows at risk, a large number of dairy veterinarians dealing with this disease in multiple client herds, and multiple cases occurring in many herds make this an economically important disease in affected herds. Possible risk factors for JHS that deserve investigation in future studies include parity, stage of lactation, season, herd size, forage quality, ration nutrient and fiber composition, and feeding management. While the exact cause of JHS is not yet known, producers may try to prevent it by working with a nutritionist to ensure that rations include only high quality well fermented forages and include adequate levels of effective fiber so as to ensure a healthy rumen mat and good rumen health. Feeding management should prevent slug feeding and sorting by cows. While there is no science yet to prove efficacy of vaccination against this disease, herds are encouraged to use commercial clostridial vaccines (e.g. 7-way or 8-way), as a matter of routine management, in the adult herd, to protect against other clostridial diseases.

**References:**


1. Fleming S: Enterotoxemia in neonatal calves, in Vet Clin North Am (Food Anim Pract). Philadelphia, WB Saunders Co. 1:509-514, 1985.

2. Godden, S., Frank, R., and Ames, T. 2001. Survey of Minnesota dairy veterinarians on the occurrence of and potential risk factors for jejunal hemorrhage syndrome in adult dairy cows. The Bovine Practitioner. 35:97-103.

3. Guard C: Obstructive intestinal diseases: Intussusception, in Smith BP (ed). Large Animal Internal Medicine. Second edition. St. Louis, Mosby-Year Book, Inc. Pp. 881-882, 1996.

4. Herholz C, Miserez R, Nicolet J, Frey J, Popoff M, Gibert M, Gerber H, Straub R: Prevalence of ∃2-toxigenic *Clostridium perfringens* in horses with intestinal disorders. J Clinical Microbiol, 37:358-361, 1999.

5. Kirkpatrick M, Timms L, Kersting KW, Kinyon J. 2001. Jejunal hemorrhage syndrome of dairy cattle. The Bovine Practitioner. 35:104.

6. Lentz L: Small intestinal obstruction due to an intraluminal blood clot in the jejunum of 4 Holstein cattle, in Proc Annual Minnesota Dairy Health Conference. St. Paul, MN. May 25-27, Pp. 177-178, 1999.

7. Maddox CW, Hattel AL, Drake TR, Weinstock D: *Clostridium perfringens* Type A strains recovered from acute hemorrhagic enteritis of adult dairy cattle, in Proc 42nd Annual Meeting of the American Association of Veterinary Laboratory Diagnosticians. San Diego, CA. Oct. 8-11. Pg. 51, 1999.

8. Michelsen P: Diseases caused by toxins of *Clostridium perfringens*, in Smith BP (ed). Large Animal Internal Medicine. Second edition. St. Louis, Mosby-Year Book, Inc. Pp. 885-890, 1996.

9. Minnesota DHI 1999 Annual Summary. Minnesota Dairy Herd Improvement Association. Buffalo, MN. Pp. 8-9, 2000.

10. Niilo L: The effect of enterotoxin of *Clostridium welchii* (*perfringens*) on the systemic blood pressure of sheep. Res Vet Sci, 13:503-505, 1972.

11. Niilo L: *Clostridium perfringens* in animal disease: a review of current knowledge. Can Vet J, 21:141-148, 1980.

12. Niilo L: Experimental production of hemorrhagic enterotoxemia by *Clostridium perfringens* Type C in maturing lambs. Can J Vet Res, 50:32-35, 1986.

13. Niilo L: *Clostridium perfringens* Type C enterotoxemia. Can Vet J, 29:658-664, 1988.

14. Niilo L, Dorward WJ: The effect of enterotoxigenic *Clostridium welchii* (*perfringens*) Type A on the bovine intestine. Res Vet Sci, 12:376-378, 1971.

15. Radostits OM, Gay CC, Blood DC, Hinchcliff KW (ed): Veterinary Medicine. Diseases caused by bacteria, in A Textbook of the Diseases of Cattle, Sheep, Pigs, Goats and Horses. 9th edition. New York, WB Saunders Co. Pp. 769-773, 2000.

16. Rudstrom, M. Survey of feeding management practices in Stearns County, MN (*in progress*). 2001.

17. Senda T, Sugimoto N, Horiguchi Y, Matsuda M: The enterotoxin of *Clostridium perfringens* type A binds to the presynaptic nerve endings in neuromuscular junctions of mouse phrenic nerve-diaphragm. Toxicon, 33:499-506, 1995.

18. Shirley GN: Clostridial enteritis in cattle. Vet Rec, 70:478-480, 1958.

19. Smith DH: Enterotoxemia (*Clostridium perfringens*), in Howard JL (ed.). Current Veterinary Therapy 2. Food Animal Practice. Philadelphia, WB Saunders Co. Pp. 573-576, 1986.

20. Stewart S: Summary of Minnesota dairy herd size statistics for 2000 - unpublished. Source: http://www.mda.state.mn.us/dairyfrm/dairy . 2001.

# Manure Technologies for Today and Tomorrow

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Large dairy herds are continually faced with decisions related to manure management. What is the best method to collect, store, treat, and utilize manure nutrients? Is there any management tool that works universally throughout the United States? Are there any technologies required by law? If I change my herd size, housing type or bedding, will that effect my manure management system?

All dairy producers know there are a few universally accepted truths about manure. Dairy cattle fed for optimum or maximum production will yield plenty of manure daily, and this material must be handled regularly. The increased attention to large animal operations has triggered yet another opportunity for entrepreneurs to market products and goods to dairy producers. **There were NO Federally required treatment technologies adopted during the revision of the Federal Clean Water Act (Dec 16, 2002). There are no Federally required treatment technologies associated with obtaining cost share funds for dairy operations.** For individuals seeking financial assistance through Environmental Quality Incentive Program (EQIP) funds available through the Natural Resources Conservation Service (NRCS) individuals may need to complete a Comprehensive Nutrient Management Plan (CNMP). A well written CNMP will address manure management and land application of manure nutrients at appropriate rates.

## Establish a Job Description

Manure treatment technologies utilized on a dairy should be assigned duties and responsibilities. Additionally, it is critical to have a method in place to do performance evaluations on these technologies. What are the expectations? What are the consequences of using the technology? Are there additional ramifications that must be addressed? Each of the major categories of treatment technologies will be reviewed to describe the associated advantages and detriments.

If you are considering the installation of a technology to assist in reducing the footprint of the facility on the environment it will be useful to determine if the technology can potentially address the issues of concern. The usual concerns related to water quality are total solids, phosphorus, and nitrogen. Odor is the usual nuisance issue related to air quality. There are specific compounds that may be of concern depending on the state (ammonia, hydrogen sulfide, reactive organic gases).

## Anaerobic digestion

The key objective of anaerobic digestion is to collect and degrade organic material (solids) in an anaerobic environment, capture the methane gas and convert it to electricity. The chemical composition of methane is $CH_4$. The other major gas that is yielded during anaerobic digestion is carbon dioxide ($CO_2$). Anaerobic digestion in a controlled environment can be beneficial to reduce odor. Gases are formed within a structure (not released to the atmosphere) and at a pH near 7. At pH 7 methane production should be near optimum and there should be minimal formation of malodorous compounds. Gases formed are burned in the combustion process. Anaerobic digestion is not beneficial for a treatment technology if you need to reduce total nitrogen (N) or phosphorus (P) at a facility.

Anaerobic digestion systems can be designed to use slurry material or a covered dairy retention pond. The type of system depends on the method of manure collection (scraping versus flushing). The size of the system is based on the volume of material collected daily multiplied by the number of days material should be retained for digestion. For liquid systems this size can be considerably large. The volumes of water used to flush freestall lanes increases with decreasing slope of the lanes (less than 2%). It should be noted that the retention pond used as an anaerobic digestion cell is not considered part of the liquid storage capacity. This pond will be managed at capacity and after it is filled, the daily inflow will equal the daily outflow.

Environmental benefits of anaerobic digestion: For manures that are initially left on feed alleys and pushed into corrals there is potentially a net emission of methane if the manure is collected and digested anaerobically. These materials will usually be collected in a semi-solid form and be fed into a sequencing batch reactor or plug flow digester. In the original form materials are maintained in an aerobic environment (presence of oxygen). Since the removal of methane from digested manure is not complete there will be some residual methane in the digester effluent. Once exposed to the atmosphere (post digestion) there is probably off-gasing of methane to the atmosphere. Manures that are normally collected into an anaerobic retention pond should yield fewer emissions to the atmosphere if the retention pond is covered and methane is collected and either flared or converted to electricity.

Typically, anaerobic digestion is used to reduce odor while providing income through electrical generation and use or sale. Anaerobic digestion to yield methane is most productive at pH near 7. The United States Environmental Protection Agency (US EPA) AgStar program has promoted anaerobic digestion on animal facilities for many years. To date 31 digester systems are in operation at commercial livestock farms. Of these, 15 are at swine farms, 14 are at dairy farms, and 2 are at caged layer farms. For a listing of details associated with these facilities go to http://www.epa.gov/agstar/operation/bystate.htm

If you are considering installation of anaerobic digestion treatment technology on your dairy do your homework first. Identify appropriate vendors and determine if your facility is able to accommodate this type of technology. The US EPA maintains a website for location of vendors, equipment, etc. http://www.epa.gov/agstar/tech/index.htm. Another great source of information is On-Farm Biogas Production- NRAES-20. It can be ordered from the Northeast Regional Agricultural Engineering Service, 154 Riley-Robb Hall, Cornell University, Ithaca, NY 14853.

Legget et al. prepared an extension publication on anaerobic digestion. They identified the following questions to ask prior to considering anaerobic digestion: Is manure currently handled as a liquid? Are little amounts of bedding or frozen manure handled? Is the manure in the handling system free from high levels of copper sulfate and antibiotics? Is odor control a major concern? Is there space on the farm to expand the manure handling system with the possibility for gravity flow from a barn to an anaerobic digester or from a digester to a manure storage structure? Does someone on the farm have the interest, time, and technical skills to learn about the anaerobic digestion process, make repairs, and perform general maintenance on equipment? Are resources available to finance an anaerobic digestion system? Can you adhere to the recommended safety practices?

Important questions to address related to anaerobic digestion.

| Parameter | Anaerobic digestion technology |
|---|---|
| Odor control | Do you currently have an odor problem? If not, there is little opportunity for benefit. If you currently have an odor problem identify how you will monitor changes in odor after installation and operation begins. |
| Energy use/production | Will you flare the methane or convert it to electricity? |
| Nutrient content | Similar to that of original material |
| Fertilizer value | Conversion of some organic N to ammonium N (plant available form) |
| Nutrient stability | More stable after digestion |
| Total solids | Reduces organic material to some extent |

Initial costs may be costly depending on the volume of material and method of digestion. Estimated costs associated with anaerobic digestion installation for liquid collection systems can vary significantly. Through a program in California applicants have estimated cost of technology installation ranging from $350,000 to over $3,000,000. The huge variation is due to method of digestion and herd size (ranging from 200 to over 3,500 cows). Applications related to building and covering liquid manure storage ponds were from herds ranging in size from 525 to over 5,000 milking and dry cows. General summary statistics are provided. Some facilities use such incredibly high volumes of recycled wash water to flush lanes that the retention pond size needed to hold sufficient number of days of material (retention time) is BIG! NOTE: If you think you will ever consider anaerobic digestion and methane recovery from a liquid manure system SLOPE the freestalls.

Estimated costs (2001-2002) associated with installation of covered lagoons with the intent of capturing methane and generating electricity.

| Parameter | Low | High | Average |
|---|---|---|---|
| Head (Milking and dry cows) | 525 | >5,000 | 2,400 |
| Influent (gal/day/milking and dry cows) | 87 | 510 | 315 |
| Estimated capital cost (investment/milking and dry cows) | $ 232 | $ 711 | $ 420 |
| Estimated annual maintenance expenses | $ 2,400 | $ 87,600 | $ 15,800 |

- As with any technology, there will be a learning curve for facility managers and operators. A maintenance schedule will be necessary and at least two people at the facility will need to know the intricate details associated with proper digester and engine function. Since a greater amount of nitrogen will now be in the ammonium form, nutrient managers will need to consider the potential to loss more ammonia during land application. It is also important to establish appropriate Occupational Safety and Health Association (OSHA) hazard protocols and training for employees.

### Chemical or biological additives

There is an abundant supply of products available on the market with claims to reduce or eliminate solids and/or odors from manure storage structures. Products may be added to feed, animal facilities, or manure storage facilities. Products can be classified by mode of action. Before agreeing to buy a product you might want to consider the answers to a few questions. What is the mode of action? What kind of conditions are necessary for the product to work effectively? How reliable is the product? Are there undesirable outcomes from using the product?

Typically, there are five categories of products (Ritter, 1989): 1) Masking agents have strong odor characteristics of their own. This is designed to cover up the undesirable odor from the manure. 2) Counteractants consist of a mixture of aromatic oils that have a neutralizing effect on the offending odor. 3) Digestive deodorants contain a mixture of enzymes and/or bacteria that eliminate the undesirable odor through biological degradative processes. 4) Adsorbents are products with large surface areas used to adsorb targeted odors before volatilization. 5) Chemical deodorants act as oxidizing agents or germicides to alter or eliminate microbial activity responsible for odor production or chemically oxidize compounds that are components of the offending odor. This classification system was proposed as the mechanisms by which commercial additives would alter odor. All but the first class requires that the offending odorants/compounds be known. This is not always the case, particularly with odor. However, if ammonia is the target, a better assessment of the effectiveness of a specific product may be made, provided sufficient information on product content is supplied. In most situations, this is not the case.

One of the challenges in evaluating the effectiveness of these products is that there are few independent research trials available to glean results and information. What can products potentially do? Potentially, they can reduce odor. Potentially, they can make odor worse. Potentially they can reduce solids. Potentially they can do nothing to the solids. Most independent studies associated with evaluation of commercial products have focused on products associated with treating odors from swine manure. Studies done in laboratory settings use odor panels or analysis of gaseous compounds. Many of these studies were funded by the National Pork Board and were conducted by scientists at North Carolina State University, Purdue University or Iowa State University. Go to the National Pork Board (http://www.porkscience.org) if you are interested in detailed information on these testing procedures.

There have been a few studies related to dairy manure. One such study was conducted in Washington State in 1992 (Bierlink et al., 1993). They evaluated eleven commercially available treatments with claims to control odor. Products consisted of plant extracts, plant growth regulators, microbes with nutrients and/or enzymes and lime and zeolites. Twenty six, 5 gallon buckets were filled with 4 gallons of the manure and treated according to manufacturers recommendations. Buckets were agitated biweekly and 100 ml samples were removed for sniff analysis. None of the treatments significantly improved the olfactory rating (probability $< .10$). One treatment had a tendency for slight improvement while another treatment made the olfactory rating significantly worse (probability $<.10$). All of the companies representing these products could honestly advertise that their product was University tested. As an informed reader you would quickly differentiate that having an unbiased test does not equate to proven product claims. This test was done on slurry manure. One may or may not anticipate different results if the products were added to commercial retention ponds.

When additives, enzymes, and chemicals do work in liquid manure systems they typically fit into either the third or fifth category. Either they serve to degrade the undesirable volatile acids or serve to alter or eliminate microbial activity responsible for odor production. One of the greatest challenges with additives is trying to determine if the product will work under the conditions at a specific dairy.

Theoretically, the products have the potential to work. However, they do not all work. Some only work during part of the year.

Before trying a product identify a method and process to evaluate the effectiveness of the product. Keep in mind that the use of the product will be confounded in time. You will need to determine conditions and normal activities and odors before and after the product is introduced. It is important to select a time period when climate is going to be relatively consistent for the comparison period.

Important questions to address related to chemical and biological additives.

| Parameter | Chemical and biological additives |
|---|---|
| Odor control | Is there a beneficial result from use of the product? |
| Reliability | Does the product work consistently during different weather conditions and through changes in animal diet and housing? |
| Nutrient content | Does the product promote ammonia volatilization (undesirable from an air quality point of view)? |
| Total solids | Is the concentration of total solids reduced? If so, what air emissions occur? |

## Aeration

The objective of aeration is to add oxygen into a manure storage system to effectively change the microbial population from those that thrive without oxygen to those that use oxygen. Changing the microbial population to aerobic microbes changes the end products of digestion. The end products of anaerobic microbes are methane and volatile organic acids. The end products of aerobic digestion are carbon dioxide and water.

Normal liquid manure collection systems contain manure (feces and urine) and potentially bedding. Contribution of bedding to the liquid waste stream must be calculated when considering aeration. Separation of solids from the liquid waste stream is helpful prior to aeration. This reduces the volume of solids that are available for digestion. However, a competent solids separation system does not guarantee effective aeration.

The use of aeration as a treatment technology in municipal waste treatment plants is designed to match the horsepower to the daily volatile solids loading rate. For many of the aeration technologies generally used on dairy retention ponds the number of units is based on the number of cows. Some companies suggest one unit for each 100 or 125 cows. This may or may not consider the volatile solids loading rate.

One of the key indicators of the effectiveness of aeration is to measure the dissolved oxygen concentration. It is generally accepted that the oxidation-reduction potential (ORP) value is an indirect measure of dissolved oxygen at concentrations that cannot be measured directly with oxygen probes (Kjaergaard, 1977). At relatively low or not measurable oxygen concentrations it is necessary to monitor ORP. Charpentier et al., 1987, provided a table to describe the relationship between ORP, treatment conditions, and carbon, nitrogen, and phosphorus removal. They listed ORP values of –500 mV with fermentative pathway to yield methane and enhanced reduction to yield ammonium. At this

ORP, phosphorus is released into the interstitial liquid. For ORP values of –300 mV the only change was the fate of carbon from methane to volatile acids (these may have offensive odor). For both of these categories there is an absence of dissolved oxygen and there is clear anaerobic zone fermentation. At ORP of 0 mV, nitrate can be measured even through there is no dissolved oxygen. Anaerobic respiration occurs and an oxidative pathway yields carbon dioxide and water. Denitrification of nitrate to dinitrogen gas can occur. Phosphorus is trapped in the sludge. Sludge would need to be removed to yield any benefit to phosphorus concentrations. At positive ORP (+100 mV) dissolved oxygen is present, and aerobic respiration occurs. Carbon end products are similar to 0 mV. There is sufficient amount of oxygen for nitrification to occur (ammonium converted to nitrate). Phosphorus uptake can occur as phosphorus is trapped in the sludge. The sludge would need to be removed to get any type of phosphorus credits.

If you select this technology, be sure to evaluate effectiveness in your operation. Work with a private laboratory to compare ORP values before installation of the technology and after. Work with someone from your local land grant university to establish a reasonable protocol for ORP evaluation. It is important to sample enough locations and under different circumstances (before technology, after infusion of irrigation water, etc.).

In the summer of 2002 we had the opportunity to evaluate ORP concentration on dairy ponds in California. Consistently, we found considerable variation over the surface of a pond. For many of the ponds, the least negative value was the inlet water entering the pond. This water usually was recycled water from the same pond or from another pond. Ponds were sampled at multiple locations and depths. Three of the five dairies did not use aeration devices on their retention ponds. The average ORP and standard deviations for the primary pond at these facilities was –339 ± 159, -230 ± 132, -215 ± 78. Two of the dairies had multiple aerators on the primary ponds. The average and standard deviations for these ponds was -387 ± 26 , -238 ± 98.

Important questions to address related to aeration technology.

| Parameter | Aeration Technology |
|---|---|
| Dissolved Oxygen (DO) Concentration or Oxidation Reduction Potential (ORP) | What are the DO and ORP concentrations in your current system (measure at many locations) ?<br>How will you test the technology?<br>Will you be able to detect measurable concentrations of oxygen?<br>Will you be able to detect changes in ORP? |
| Energy use | How will you document energy use? |
| Nutrient content | How will you sample to determine if there is a change in nutrient content of the retention pond water? |
| Fertilizer value | The nutrient sampling protocol should be developed to determine if there are changes in organic N. |
| Total solids | Sufficient number of samples need to be obtained to determine if total solids are changed as a result of the technology (many locations and depths). |

- As with any technology, there will be a learning curve for facility managers and operators. A maintenance schedule will be necessary and at least two people at the facility will need to know the intricate details associated with proper aerator maintenance. Any individual going in a boat to provide maintenance to the aerator should wear a life preserver. Lifelines should be connected to the individual and the boat and the opposite end of the lifelines should be in the skilled hands of someone directly at the shore of the pond. Swimming in manure ponds is NOT a pleasant activity and can be dangerous. Because retention ponds classify as confined spaces, there are worker safety rules from the Occupational Safety and Health Association.

### Solid liquid separation

Probably the largest number of questions dairy producers ask relates to defining the best method to remove solids from a liquid waste stream. Dairies that change housing from corrals to freestalls must consider the consequences of this decision on the liquid storage pond. There are at least four standard methods used to separate solids from a liquid stream: 1) single screen separation; 2) double screen separation; 3) settling basins; and 4) weeping wall separation.

Traditional inclined screens have a straight slope or are slightly concave. The screen openings are usually 1.5 mm (1500 microns) or roughly 60/1000 of an inch. Various screens were evaluated on commercial dairies in California between 1995 and 1997. The work evaluated the effectiveness of the screens at removing total solids and also looked at the nutrient content of the screen influent, effluent and removed solids. In all of these systems recycled liquid manure from the retention pond was used to flush lanes. Therefore, the total solids concentration of the influent started with solids and nutrients before coming in contact with manure in the freestalls. The simple efficiency of total solids removal was either less than 5% (water went from flush lanes into the retention pond and then was pumped over the separator from the pond) or between 9 and 15% (flush water came from lanes, into a sump, and then was pumped over the screen). Removal of water soluble or small particulate form nutrients (ammonium, phosphorus, potassium, calcium, magnesium, and sodium) was a function of the high water content of the removed solids (83 to 85% moisture).

A few years ago there was a trend for dairy producers to install a double screen system where the second screen was much smaller 30 or 20 thousandths (roughly 760 or 510 microns). The initial advertisements indicated that the total solids removal was anywhere from 86 to 95%. One set of tables provided by the scientists conducting the research indicated that there was a 60.2% and a 94.4% reduction of solids retained on their sieves from samples taken at the dairy. These data are on a percent of solids retained and did not include the percent of total solids in the samples or the number of samples processed. Their small screen size was 0.25 mm. Clearly, the advertisements were a bit misleading as they were reporting solids removed when compared to large particles and not on a total solids basis.

A California dairy with the double screen system was evaluated in August and again in October, 2001. Recycled manure water was used to flush the freestall lanes. The two screens were initially sampled at 10 to 15 second increments (influent and effluent). Based on the data, the sampling protocol was extended for the second screen to 30 second intervals as there was little variation in the influent or effluent concentrations. Efficiency of total solids separation was determined as the difference in the concentration of total solids in the influent water entering the first screen and the concentration of total solids in the effluent of the water exiting the second screen. At this dairy, there was a temporary storage basin between the screens so some settling of heavier materials did occur. The combined system efficiency was 34.5 and 35.2%. Samples were taken to evaluate the total solids concentration in the flush water as it entered the flush lanes. An adjusted efficiency was calculated by subtracting the concentration of the original flush total solids from the values obtained at the sampling sites. The adjusted values for total solids removal OVER ESTIMATED the solids removal with a value of 50.4% of total solids removed. The magnitude of the over estimation is unknown. In subtracting out the flush water concentration we are not accounting for that percent of total solids in the manure in the lanes. The actual total solids removal during the sampling trips was between the measured value of 34.5 and the adjusted value of 50.4%. We did not obtain data on bedding use.

Traditional settling basins have appeared in pairs at dairies. One is filled. Then it is dewatered while the second one is filled. An evaluation of basins on two separate dairies was conducted in 1997 and again in 1998. The smaller of the two dairies had 250 milking cows. The larger facility had 700 milking cows. Influent samples were taken at 15 second increments as water fell into the basins. Samples were analyzed for total solids and non-settleable solids. They fill and dewater cycle was one month filling and one month dewatering at both facilities. Daily samples were taken once per week for an eight week period. Efficiency of total solids removal was very variable. For the small dairy, the first summer weekly data were 46.6, 43.7, 9.2 and 17.4%. During the second summer the weekly sampling data were 25.7, 45.6, 22.3, 53.2, and 17.1%. The data for the larger dairy the first summer were 75.3, 75.2, 54.3 and 46.3%. Between the first and second summer an additional freestall was installed for cattle already housed at the dairy and two additional basins were installed. Weekly total solids removal was 27.7, 27.9, < 5, 27.3 during one cycle and 40.7, 40.8, 9.9, and 17.2% during the second cycle.

Settling basins did remove more total solids than did mechanical separators. Performance was inconsistent and could potentially be improved by reducing the number of days each basin was filled (reducing cycle duration to 3 weeks instead of 4) and by changing the inlet to be lengthwise opposite the outlet. In both instances the inlet and outlet were on the same surface. Basins performed differently at the same dairy at different times. Animal use of the freestalls and bedding amount were probably contributors to these differences. Percent of TS removed was 63.4, 59.6, 63.1 and 49.3 % for each of the trips. The higher values obtained during the March trips corresponded to observations made at the dairy that the structure filled faster (roughly eight weeks) in March than in July (roughly 12 weeks).

Through all of these sampling occasions nutrient analyses of some influent and effluent samples have been run. Although there was some benefit in the removal of organic N, other nutrients were not removed in large enough quantities to conclude that the separation devices would be useful in reducing ammonium, phosphorus or potassium in the liquid waste streams. Keep in mind that at all of these dairies, animals were fed commodity feeds, mixed rations, and some supplemented with long hay.

Important questions to address related to solid liquid separation technology.

| Parameter | Solid liquid separation technology |
|---|---|
| Total solids | What percent of the total solids in the liquid stream can be removed? How will you determine if this is achieved? |
| Energy use | How will you document energy use? What additional resources (labor, equipment) are necessary to manage solids? |
| Labor use | How much labor will you need for maintenance (daily, weekly, monthly)? |
| Nutrient content | How will you sample solids to achieve credits for nutrient removal if this is necessary? |

| | |
|---|---|
| Liquid retention pond | Will you overload the retention pond and prevent it from biological activity if the separation technology is not functioning properly? |
| Bedding | How much bedding do you use?<br>Can you at least recover the equivalent weight of the bedding with the technology? |

- As with any technology, there will be a learning curve for facility managers and operators. A maintenance schedule will be necessary and at least two people at the facility will need to know the intricate details associated with proper solid liquid separation technology maintenance. Maintenance individuals need to understand operational aspects of the technology that may put them at risk during routine activities. Appropriate precautions need to be posted and employee training should occur.

## Summary

It is anticipated that with the new Federal CAFO rule there will be even more people targeting their wares to dairy operators. There are a variety of technologies and products available to dairy operators to assist in manure management. Be advised that these merely ASSIST in manure management. The key to the actual management IS the manager. Identify where you can get reliable information. Be sure you ask to see research results from an independent party before investing in products. Check the results to be sure they back the claims. Ask others who are using the technology what they like and don't like. See if there are commonalities between your facility and theirs. The appropriate technology for you may not be the same thing for your neighbor. Identify what you want the product/technology to accomplish BEFORE you write a check.

## For Future Reading


Bierlink, H. B., W.J. Mathews, D.C. Grusenmeyer. 1993. Fertilizer and olfactory management of dairy manure nutrients. J. Dairy Sci. 76 (suppl 1):258.

Charpentier, J., M. Florentz, and G. David. 1987. Oxidation-reduction potential (ORP) regulation: a way to optimize pollution removal and energy savings in the low load activated sludge process. Wat. Sci. Tech. 19: 645-655.

Kjaergaard, L. 1977. The redox potential: Its use and control in biotechnology. In: *Advances in biochemical engineering*. Springer-Verlag, Berlin, pp. 131-150.

Leggett, J., R.E. Graves, and L.E. Lanyon. Anaerobic Digestion: Biogas Production and Odor Reduction from Manure. G-77.PA.

On-Farm Composting Handbook. 1992. NRAES-54. Northeast Northeast Regional Agricultural Engineering Service, 154 Riley-Robb Hall, Cornell University, Ithaca, NY 14853. http://www.nraes.org

On-Farm Biogas Production- NRAES-20. Northeast Regional Agricultural Engineering Service, 154 Riley-Robb Hall, Cornell University, Ithaca, NY 14853. http://www.nraes.org

Ritter, W.F. 1989. Odor Control of Livestock Wastes: State-of-the-Art in North America. J. Agric. Eng. Res. 42:51-62

US EPA. Guide to technology providers (this is for anaerobic digesters). http://www.epa.gov/agstar/tech/index.htm

US EPA. Guide to operational systems. http://www.epa.gov/agstar/operation/bystate.htm

Western United Resource Development, Inc. California Dairy Production Power Program. Money for Methane. http://www.wurdco.com/

# Farm Animal Welfare Assurance: Scientific and Retailer Perspectives

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## Introduction

For the first time in history, livestock and poultry producers in the United States are being asked by food retailers to provide assurance that animals raised for their markets are cared for, transported, and slaughtered in a humane manner. The emotional impact of this request initially launched mortar fire and has eventually led to deliberations on how to best address the logistics of ensuring a decent quality of life, and merciful death, of animals entering our food chain.

There is no doubt that differences exist between the animal industries concept of what constitutes a decent quality of life for our livestock and poultry, and those of a variety of specialized interest groups and the public. Why has quality of life become an issue? What is it about our systems of animal production that people find troublesome, so much so, that defenders/retractors often refuse to find common ground?

In general, entrepreneurs selling cheap efficiently produced animal products have not experienced massive consumer boycotts based on animal welfare. In this paper we will address why animal production practices have become problematic to the public, how science and ethics play a role in deciding their fate, and why an oversight process, if properly constructed, may assist in allaying public concern.

### Historical Context

Many authors have written about the development of the animal agriculture and corresponding changes in public perception. The need for mass production, economic efficiency, reduced labor costs under the intense competitive environments of the domestic and global marketplace have impacted animal agriculture. Similar to its plant-based sister, animal agriculture has morphed from a predominantly independent small family farm based economy, to a large integrated industry that employs a variety of strategies and technologies for producing food products to meet consumer demand.

The change in structure has brought social controversy regarding the preservation of the "family farm" along with the agrarian ethic that popularized it. The use of high tech methods of food production often generates debate and public/consumer concern for the environment, workers, communities and animals affected by these new technologies. Consumers are becoming more selective and vocal about what they desire and expect from food retailers.

### Modern Muckrakers of Corporate Agriculture

Public distrust of "corporate" America has a portion of its roots buried in the muckraking movement of the early 1900's. Historians acknowledge the careless regard with which some journalists wrote, but they also report this as the beginning of the Progressive Era (1901-1917) in the United States. Many legal reforms in labor, finance, insurance, government and even amendments to the U.S. Constitution occurred during this era. For example, Upton Sinclair's *The Jungle* (1906) documented the atrocious conditions at the Chicago stockyards and led to the passage of the Pure Drug and Food Act of 1906. Today, a new wave of journalists and special interest groups has focused on animal agriculture by documenting effects on animals, workers, the environment and rural communities. Should animal agriculture be immune from investigation? It seems to be an unavoidable consequence of becoming "big business" or in this case "Agri-business". There is nothing sacred about agriculture that prohibits investigative excursions into the business.

Modern consumers want a variety of low cost, but high quality, food products. Suppliers, like animal agriculture, actively pursue the most effective and efficient way to produce product. However, this also creates an inherent conflict of interest in their attempt to balance the bottom line against variables like animal welfare. As growth and concentration of the industry develops, special interest groups, government, media and even private citizens become vigilant of business activity. Social pressure tends to develop when the conduct of business falls seriously out of synch with a portion or the whole of society values. These values are often based in a social consensus concerning right and wrong actions and are not necessarily elucidated from consumer behavior. This process can be unnerving for industry, particularly when less than truthful accounts of industry behavior are used to persuade the public. However, social pressure can become functional in jolting the collective conscience of an industry into re-examination of its values and how well those values harmonize with greater public sentiment. Nike, Old Navy, K-Mart and others experienced intense social pressure to improve conditions at their factories overseas and to not use child labor in the manufacture of their products. Therefore social power becomes the primary mechanism for corporate accountability when there is no single entity required to govern their activity. In the United States there is no oversight process for monitoring animal care on farms or during transport (with the exception of slaughter horses).

## Science-Based Decisions: The Case of UEP

A recent example of a major change being tackled and implemented by a producer group is the cage space requirements for laying hens. The United Egg Producers (UEP) represents 210 members who own some of the largest and smallest egg layer operations in the United States. Their membership includes free range and barn raised egg producers. The UEP was the first producer group in the country to develop husbandry guidelines for their producers (UEP, 1983). In early 1998 UEP staff sought a University Department Head to chair a committee on hen welfare. The UEP Board of Directors approved the staff proposal and initiated a meeting with scientists to discuss welfare issues within the industry. From that meeting the Chair independently appointed a scientific advisory committee on hen welfare. The committee included: an avian veterinarian, an animal protection representative, three trained poultry ethologists, one stress physiologist, one producer, one food safety specialist, one poultry production specialist and one public policy specialist. The committee was given free rein to conduct a scientific review and to make specific recommendations for the revision of the existing UEP guidelines for caged laying hens. Cage space and the practice of induced molting were two of the highest profile welfare issues for egg layers. Cage space also involved considerable economic investment. However, the charge to the committee was to look at space requirements that caged hens needed and not to consider the immediate economic issues. Once the recommendations were completed, they were sent to the UEP Board of Directors for approval. After approval they were forwarded to the UEP appointed Producer Animal Welfare Committee to write a lay version of the guidelines, conduct the economic impact analysis, and develop a graduated phase-in for cage space.

In the case of cage space requirements, science provided a clear answer - - the existing UEP guidelines were out of synch with science and space allotments needed to be increased from the original recommended 48 sq in per hen to a range of 67 – 86 sq in based on bird size. Nearly 30 years of production and mortality data collected at different cage space allotments produced the new requirements. In hindsight UEP officials recognized the problem with their original strategy of formulating guidelines. "Experience has taught us that you can't first establish guidelines with a committee of producers [and what they are willing to accept] and hope the science will support it." said

Gene Gregory Executive Vice President of UEP (personal communication June 26, 2001). The strategy UEP developed assists them in negotiating hen welfare issues with buyers, government, the public and politicians.

In the case of cage space, science played a defining role in producing an answer for UEP. But not all issues of animal production practice are as cut and dry. When science fails to provide a concise answer to the public question ethical input is required.

## Ethical dilemmas

What happens when the science does not clearly lead to a conclusion? Had egg laying hens been housed singly, would the production and mortality data been as clear? Group housed hens enter into a different dynamic with cage space. The social activity occurring within cages contributes to producing distinct limits on productivity and contributes to mortality when out of synch with bird welfare. With those pressures controlled, productivity may not have shown the same dramatic drop nor mortality rise to the degree demonstrated under crowded cage conditions. In singly housed animals a more complex set of parameters come into play, such as deprivation of movement, minimized social contact, boredom and frustration. These parameters are not easily measured and require carefully planned research protocols and interpretation of results. Even then results can be inconclusive or heavily debated.

Ethical deliberation becomes even more important in practices that involve pain, distress or sensory deprivation. For example, the provision of social conditions for social animals (dogs and primates) is federally mandated for animals used in biomedical research except under qualified and scientifically justified circumstances. Like food animals, these animals are maintained under intensive conditions and used to produce information or products that are deemed beneficial to humans. A double standard of treatment exists for animal use in the United States.

Human experience also influences our values concerning animal treatment. Consider space allocation. We are impacted by space, and space represents a multitude of ideas to people. Space can mean status, comfort, punishment, etc. The restricting of space, mobility, or the deprivation of social and sensory contact with others, represents forms of punishment in most cultures. Solitary confinement constitutes a severe form of punishment. People easily relate to what it means to have restrictions placed on movement or space. Like-wise we may judge similar restrictions placed on animals that evolved to move and have social requirements, as punishing or unethical. The question becomes moral. For example, "Is it right to chronically house an animal in conditions where it has little mobility or social contact?" This question is not amenable to data that shows the animal still produces, or stays healthy, or even whether it completely understands the predicament in a cogent way. It does not matter that we have succeeded in keeping the animal productive under those housing conditions because that is not what is being asked. The question has to do with whether inflicting this housing practice on the animal is the correct action and is intimately tied to respecting the nature of the animal.

The agricultural animal industries have an interesting dilemma. The market places downward pressure that restricts profit margin and forces enterprise to become ultra efficient. Space, feed, labor, equipment, etc. all hack away at the margin. Consequently, targeted genetic selection has produced efficient and productive livestock who are pushed to their limit. Also, the effects of a high turnover low-to-no skill labor market further complicate animal care issues. Thus industry decisions on how best to raise livestock often reflect economic realities. This is precisely where the set of circumstances that drive their value system differs from the public at large.

Issues concerning animal welfare often link scientific information directly to cultural concerns and ethics. Scientists and producers must have appropriate knowledge of both to maneuver effectively when considering "What is the right course of action to take." The use of ethics to help resolve these dilemmas can be as stringent as any scientific review process. Also scientists must recognize that the same difference in value systems affects how they conduct their research into animal care and production practice. Even scientists working in the area of animal welfare have sharply differing opinions on how to weight different parameters considered important to animal welfare.

## Food Retailer Perspectives

Since 1999 McDonald's has audited beef, pork and poultry processors. In August 2000 McDonald's announced that standards of care for caged laying hens would be imposed on their suppliers of eggs. Burger King quickly followed McDonald's lead along with other quick service restaurants. Discussion among trade organizations, scientists, and animal producers led to the conclusion that maintaining consumer confidence with regard to agricultural animal treatment was important. However, a mechanism was needed to be certain standards were based on relevant and factual information and to provide an oversight process worthy of public support.

In January of 2001, at the request of their supermarket company members, the Food Marketing Institute (FMI) adopted a policy on animal welfare. In developing the policy, consumer focus group input was sought to define the supermarket role in this issue. The policy is based on five central points:

1) Animals must be raised, transported, and processed in a clean, safe environment free from cruelty, abuse or neglect.
2) The food industry must work together to help promote "best practices".
3) FMI will consult regularly with experts to elucidate best practice.
4) FMI will urge government to strictly enforce animal protection laws that pertain to animals used in the food chain.
5) FMI will communicate best practices to maintain consumer confidence.

In June 2001, FMI and the National Council of Chain Restaurants (NCCR) joined efforts to further develop and support industry policies to strengthen animal welfare. The specific goals of these combined efforts include:

1) Consistency across the food retail sector.
2) A measurable audit process.
3) Implementation of practicable and attainable guidelines based on science.
4) An ongoing advisory council of third party animal welfare experts.
5) Improved communications across the supply chain on animal welfare issues.

The central idea is to get in front of this issue before it elevates to the stage of crisis. The FMI and NCCR supermarket and restaurant members are sensitive and vulnerable to the loss of consumer confidence. Their members have the most direct relationship with the consumer and are often first to feel the tremors before the quake. Since June of 2001, FMI and NCCR have been meeting in person and by conference call with their respective members, advisors and producer organizations. Regular consultations are made with experts in animal and veterinary science and agricultural production to obtain objective and measurable indices for best practices in growing, handling, transport and processing of animals used in food production. Members of the respective organization's animal welfare councils constitute the council of experts advising the FMI and NCCR.

In December of 2001, the expert council produced guidance documents to assist in fostering uniformity of guidelines and to ensure integrity. The three primary objectives of the guidance documents were:

1) Producers are held to the same standard.
2) The guidelines are based on animal welfare and sound science.

3) Adherence to animal welfare guidelines is verified through an effective and measurable audit process.

The expert advisory council provides independent scientific counsel to FMI and NCCR on the process for writing animal welfare guidelines, interpretation of science, technical review, components and content of guidelines, and identifying the necessary components of an audit process. Legal counsel is employed to ensure sound and legal business practice is followed.

In principle, the goal is not an attempt to satisfy activist groups but to address a rapidly emerging issue of animal welfare assurance for our consumers. The FMI and NCCR are committed to working with producer organizations and our experts to a program in which the adoption of best practices will assure humane treatment of animals and maintain consumer confidence.

## Implications

As the public increases their focus on issues of farm animal care, scientists, retailers and producers must be prepared to tackle questions, and provide solutions for developing/identifying best practice. Also to develop an oversight process that will ensure farm animals a decent quality of life and to provide consumers peace of mind.

# Practical and Sensible Dairy Farm Biosecurity

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## Take Home Messages

Farm biosecurity strategy is very similar to financial investment strategy:

- Determine your risk level – What is your tolerance or intolerance to loss from disease?
- Develop your portfolio – Create a farm specific biosecurity program.
- Safeguard your assets – Protect the resident herd!

## Introduction

A disease outbreak in any herd could be financially devastating to the operation but it could be particularly devastating during an expansion program when debt load has increased substantially. A program designed to prevent disease is more than just a vaccination program. A tight biosecurity program is designed to maximize disease resistance and minimize herd exposure to infectious agents. By identifying some of the diseases that are likely to be of greatest risk, prevention and control measures can be developed and implemented to focus on ones that are most likely to create problems.

Here is a partial list of infectious diseases commonly found on U.S. dairy farms.

Bovine Leukemia Virus/Leukosis -- BLV
Bovine Respiratory Syncytial Virus -- BRSV
ovine Viral Diarrhea Virus -- BVDV
hlamydiosis
Costridial Diseases – Hemorrhagic Bowel, Black Leg, Enterotoxemia, etc.
Contagious Mastitis -- *Staphy aureus, Strep agalactiae* and *Mycoplasma bovis*
*Haemophilus somnus*
Infectious Bovine Rhinotracheitis -- IBR
Papillomatous Digital Dermatitis -- "Hairy heel warts"
Leptospirosis
Listeriosis
*Mycobacterium paratuberculosis* -- Johne's Disease
Mycoplasmosis – Respiratory form
Neosporosis
Parainfluenza-3 Virus -- PI3
Pasteurellosis
Rota/Corona Virus -- calf diarrheal agents
Salmonellosis
Winter Dysentery -- bovine corona virus?

All of these diseases can limit productivity--from lower milk production to reduced milk quality, from impaired reproduction to reduced calf survivability, from chronic debilitating infection to death. Any one of these diseases can become established in a naïve, resident herd when new cattle are introduced. Preventing the introduction of disease is often overlooked during an expansion due to the need for increased milk sales to maintain cash flow. Waiting until after the fact and attempting to control the spread of disease is a reactionary approach and doomed to fall short of expectations. If herd protocols are established, losses can be contained.

Establishing a practical and sensible farm biosecurity program involves rational risk assessment and careful planning to manage that risk. No two farms are identical. Certainly, there are external challenges (vermin, birds, wildlife, etc.) that make any biosecurity program difficult, if not impossible, to follow completely. The level of biosecurity implemented on your operation will depend on the goals and activities of your dairy operation (commercial herd versus show herd, death/disease risk averse versus death/disease tolerant).

**Levels of Biosecurity (1=low risk, 6=high risk)**

1. Closed herd (specific pathogen-free herd) and all bio-traffic strictly monitored.
2. No entry or reentry of cattle.
3. No entry of new cattle but reentry of existing cattle allowed (show cattle).
4. Entry of new cattle (known medical records) and isolation/quarantine.
5. Entry of new cattle (known medical records) and no/incomplete isolation/quarantine.
6. Entry of new cattle (no medical records) and no isolation.

**Steps to Develop a Farm Biosecurity Plan**

1. Determine your risk level for specific diseases and/or infectious diseases in general.
   -- Your herd veterinarian can help provide this information.
2. Assess the risk that the diseases of concern will be introduced or spread within your herd.
   -- Determine the method of infection and evaluate your operation for potential contaminations.
3. Target your program to address the highest risk activities or "loop holes" in your system.
   -- Manure management with Johne's disease/salmonella, persistently infected calves with BVDV, infected quarters with contagious mastitis, or all of the above!

## Strategies to Reduce the Risk of Impaired Productivity from Infectious Disease

**Raise the Level of Resistance in the Herd to Infectious Disease**

- Develop a strategic vaccination program with your herd veterinarian.
- Reduce environmental stress by:
  - providing clean, dry, comfortable housing for all animals on the farm,
  - using heat abatement strategies in summer, windbreaks in winter.
- Reduce nutritional stress by:
  - providing a transition between the dry period and early lactation,
  - supplying high quality forage to all lactating cows,
  - maintaining a balanced ration with adequate levels on trace minerals and vitamins.
- Maximizing colostrum intake of newborn calves.

**Prevent the Introduction of Infected Cattle**

- Consider the potential production losses from Johne's, BVD, and contagious mastitis.
- Only purchase cattle from uninfected herds or herds with known health status.
- Only purchase animals from herds with a known effective vaccination program.
- Avoid purchasing cattle from unknown sources or from commingled sources.
- Transport purchased animals in farm-owned trucks or require that hired transporters start with sanitized truck.
- Isolate and monitor purchased cattle for 30 days before allowing contact with the herd.
- Test new herd additions for infectious diseases before introduction to the herd.
- Embryo transfer recipients can be a source on infectious disease, test appropriately.
- Test all calves from purchased cattle for persistent infection with BVDV.

**Decrease the Herd Exposure to Infectious Disease**

- Isolate sick and diseased cattle with unusual clinical signs or cattle that do not respond to customary treatments.
- Have a veterinarian necropsy (autopsy) any animal that dies from undetermined causes and dispose of dead animals promptly.
- Control cattle and human movement patterns. Keep in mind that the maternity cows and young calves are most susceptible to disease.
- Utilize individual calf hutches for newborn calves. Thoroughly disinfect between uses.
- When selling cull cows and bull calves, identify a location outside of the barn for cattle buyers to pick up these animals without entering the barn.
- Reduce manure contamination of water sources, bunks, feeds and feeding equipment.
- Require hoof trimmers to sanitize their chutes, tables, knives, and other equipment before coming on the farm.
- Limit access to the dairy facilities from outside visitors.
    - Lock the doors to the barn.
    - Post a warning sign asking visitors to keep out. Leave a telephone number to call.
    - Provide clean coveralls and boots for all visitors.
    - Maintain a log book of all visitors -- date, time and origin.
    - Employ rodent and other pest control measures.

**Management of Isolation and Quarantine Facilities and Processes**

- Length of time - 30 days for cattle coming from commingled or unknown sources.
- The incubation period for most cattle diseases is two weeks or less.
- If cattle are reentering or coming from known sources, 14 days should be adequate.
- Exhibiting cattle at fairs presents a risk of disease transmission (a lower risk than others).
- If bringing in lactating animals, plan appropriately for milking these cattle.
    - Clearly identify all new arrivals to distinguish them from the resident herd.
    - Strictly control contact with these cattle (human and animal traffic, feeding, manure, etc.)
    - Obtain serum on arrival and test for risk averse diseases.
    - Maintain banked serum from new arrivals.
    - Vaccinate on arrival with standard herd protocol.
    - Re-vaccinate (booster) in 3-4 weeks prior to leaving quarantine facilities.

## Disease Prevention Practices for Specific Diseases

Diseases of the particular importance for which specific prevention protocols should be considered include: Bovine Virus Diarrhea Virus (BVDV), Johne's Disease, Leptospirosis, and contagious mastitis (*Staphylococcus aureus*, *Streptococcus agalactiae*, and *Mycoplasma bovis*).

## Bovine Virus Diarrhea

Bovine virus diarrhea virus (BVDV) is a systemic disease of cattle which has several clinical manifestations in cattle. Acute BVD is the most prevalent form of the disease in normal cattle. In healthy, unstressed, immunologically naive cattle, BVD usually varies from a clinically inapparent to mild disease. Infection with BVD can create a carrier state. When pregnant cows are infected with BVD while the developing fetus is between 40 and 125 days in gestation, the fetus can become persistently infected. The calves that survive to term are the Trojan Horse for introducing BVD virus into the herd. These calves will shed BVD virus from every pore of their bodies. If other pregnant cows or heifers are exposed to these carrier animals, more persistently infected calves will be born. Acute fatal BVD results when persistently infected cattle are exposed to another form of the virus. It appears that a sound vaccination program for BVD can prevent the acute form of BVD in herd mates exposed to the persistently infected animals. However, vaccination doesn't appear to prevent reproductive losses in the form of early embryonic death or abortion. If killed vaccines are used for primary immunization, two doses within 30 days are required. Frequent boosters every 4 to 6 months may also be necessary throughout the animals' lives. Modified-live vaccines may provide longer duration of immunity. Initial immunization with modified-live vaccines should occur between 4 and 12 months of age. Your veterinarian can help design a complete vaccination program tailored to your farm.

This raises the question of the value of implementing screening programs to identity carrier animals. Work with your veterinarian to determine which diagnostic laboratories have the proper tests to identify persistently infected animals. Obtaining blood from calves of purchased additions prior to receiving colostrum can be beneficial in identifying persistently infected neonates. Blood from persistently infected calves contains large quantities of virus. Passive transfer of antibodies from colostrum may bind much of the virus in the serum making detection difficult. Identification of carrier calves may not be possible again for up to two months.

## Johne's Disease

Recent surveys in Wisconsin have indicated that a third of the herds have one or more cows infected with Johne's disease. Johne's disease is chronic intestinal disorder of adult cattle caused by a *Mycobacterium avium subsp. paratuberculosis*. Chronic diarrhea and progressive wasting which leads to culling or death characterize clinical disease. The disease frequently becomes clinical at or near the time of calving and often at the time of third calving. Calves are either born with the infection if their dam is infected or acquire the infection early in life. The infection usually remains latent until the calves become adults. There is not currently a test that effectively identifies latent infections. Therefore, assume that herds undergoing major expansion and purchasing cattle also may be acquiring Johne's infected animals (even though the herd may already have latent carriers or clinical disease). Manage the herd as if Johne's disease is present.

Primary means of spread is through ingestion of manure containing *M. paratuberculosis*. Young calves are most susceptible to infection and heifers infected beyond a year of age are less likely to become infected. Some calves born to infected cows are born infected through intrauterine infections. The following list of management practices should be followed.

- Calve cows in clean environment
- Remove calves from cows **as soon as possible** after birth
- Don't feed pooled colostrum unless pasteurized
- Feed colostrum from negative dams
- Use milk replacer after colostrum
- Raise calves separate for adult cows
- Don't allow calves contact with manure from adult cows (buckets of skid loaders)
- Avoid contact with drainage from cow yard
- Avoid grazing lots or pastures where adult cows have grazed
- Cull offspring of any cow developing clinical disease
- Cull any adult cow with clinical signs
- Consider testing program if adult cows develop clinical signs

## Leptospirosis

Several types (serovars) of leptospiras infect cattle. Theses serovars can be divided into two categories. Host-adapted leptospirosis in cattle results from infection with *L. hardjo*. All other serovars that infect cattle are non-host adapted. Non-host-adapted leptospirosis is more likely to result in acute infection resulting in an epidemic of abortions and/or stillbirths. Non-infected herd mates become infected by contact with urine from infected herd mates. They transiently shed organisms in the urine and expose other animals in the herd. Host-adapted infections with *L. hardjo* are more likely to occur as subclinical infections resulting in abortions (10 percent of herd), stillbirths, and weak calves. *Leptospira hardjo* can be harbored in the kidneys of infected hosts for extended periods of time and shed in the urine. Urine from infected cattle is a source of infection for non-infected herd mates. Non-infected cattle can become infected by exposure through mucous membranes (urine splashing in the eye or cattle drinking pools of urine contaminated water) or breaks in the skin. Since there is no practical means of identifying chronically infected animals, it safest to assume that one of the new animals which was added to the herd is shedding leptospira in the urine. Herd mates can be protected through an effective vaccination program that means vaccination at least twice, once prior to breeding and once during gestation.

## Contagious Mastitis

If mature cows are purchased, a bulk tank milk sample from the herd of origin can be cultured to determine if *Staphylococcus aureus*, *Streptococcus agalactiae*, or *Mycoplasma bovis* mastitis exist in the herd. Either individual cow DHI somatic cell count records or if they are not available, the udder health of individual cows should be evaluated using the CMT test. Cows with SCC greater than 200,000 cells/ml for the previous two months should be examined by the CMT to determine which of the quarter(s) contributed to the elevated SCC. Quarters with a positive CMT score should be sampled for bacteriological culture. A decision on the acceptability of cows should be made on the basis of number of months of elevated SCC, number of quarters involved, and pathogens isolated from the quarters. As herd sizes increase, there is an increase association with mycoplasma mastitis. Monthly bulk tank cultures can be incorporated in a herd disease prevention program to monitor the herd for the presence of contagious mastitis pathogens.

Good hygienic practices during milking will help reduce the potential for these contagious mastitis pathogens to spread. Isolating known infected cows and those that are suspicious, then milking them last is a proactive step in controlling contagious mastitis. Milking personnel should wear latex gloves while milking. Contaminated milk can be rinsed from latex gloves much easier than rough calloused hands. Post-milking teat dipping with an effective germicide will kill residual bacteria that may remain on the teat surfaces once the milking units have been removed. It is essential that the entire teat surface be coated with the germicide. Inadequate coverage generally occurs when the product is sprayed on the teats. Dry treating every quarter of every cow will help eliminate *S. aureus* and *Strep. agalactiae* infections that have developed during lactation.

## Conclusion

Dairy farms considering expansion will have to respect sound biosecurity measures in order to maintain disease free herds and sustain maximum production. Most farm expansion requires an infusion of capital, which implies an increase in the debt load carried by the dairy enterprise. The variability in production (and subsequently cash flow) induced by disease cannot be tolerated. A five percent drop in production can be the difference between realizing a profit or enduring a loss. As dairy farm units become larger, the scope of the economic impact from disease magnifies. Infectious diseases can enter a herd through purchased additions or carried onto a farm by other animal species including humans. Strategies exist for increasing herd resistance against and decreasing herd exposure to infectious diseases.