Economic Benefits of Improved Cow Comfort

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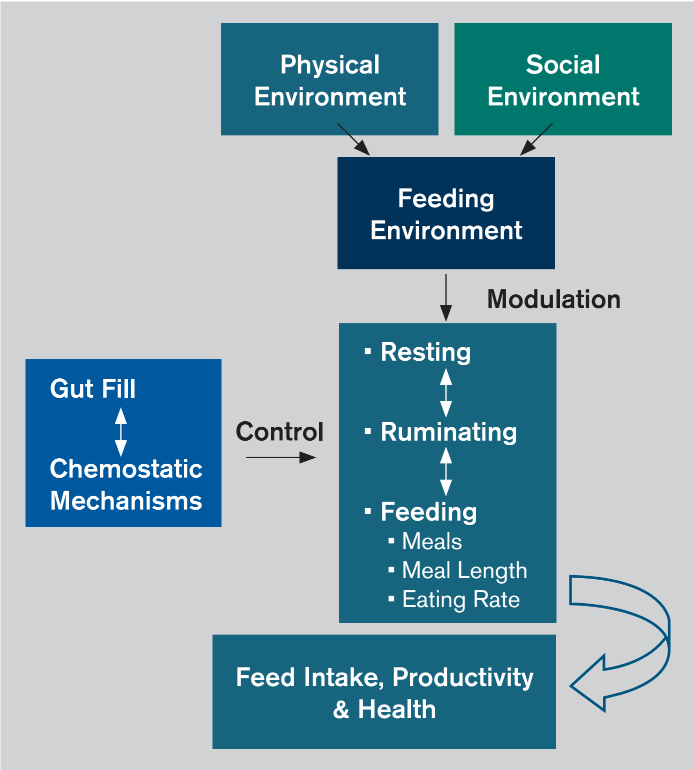
Figure 1. Cow Comfort: The “Big Picture”.



PURPOSE OF THIS REVIEW

The primary purpose of this review is to summarize what is known about the impact of improved cow comfort on economically important responses in dairy cattle such as feed intake, milk production, reproduction and health. Knowing the economic consequences of good or poor cow comfort should generate motivation for farmers and industry professionals to improve it.

Several sources of information have been used. When available, peer-reviewed literature has been referenced. However, considerable information is also found in scientific abstracts, conference proceedings and other non-peer reviewed publications. It is safe to say that much less is known about the short- and long-term health and productive responses than is known about behavioral responses to cow comfort. We can easily observe the negative effects of poor cow comfort on commercial farms every day, but in many cases scientifically controlled studies are lacking.

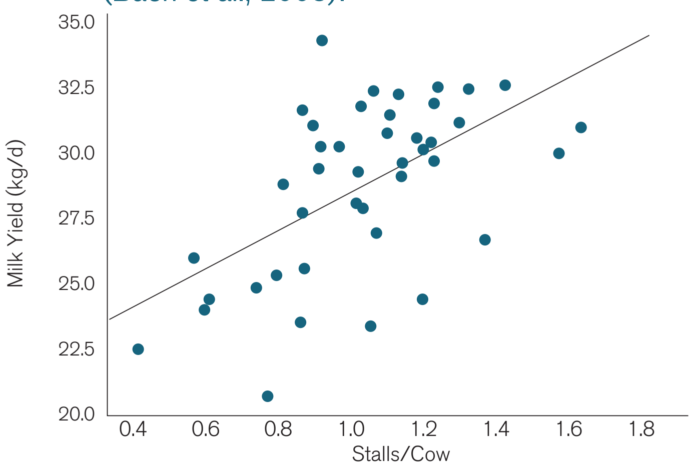
COW COMFORT: THE “BIG PICTURE”

Cow comfort is a function of the cow’s management environment. The management environment is comprised of both a physical and a social component which taken together define the feeding environment (Figure 1). The cow’s management environment influences her ability to practice her natural time budget behaviors. Ultimately, an optimal environment combined with proper nutrition will ensure that her time budget needs are met and that her feeding behavior and feed intake are optimized, resulting in greater productivity and health. The interactions among feeding, resting and rumination are critical to cow comfort. An integration of gut fill and physiological mechanisms control feed intake and productivity, but the management environment exerts a tremendously powerful modulatory effect on the cow’s behavioral and performance responses to diet.

MANAGEMENT ENVIRONMENT AND HERD PERFORMANCE

Quantitative measurement of the “management” environment: Bach et al. (2008) evaluated 47 dairy herds with similar genetics that were fed the same total mixed ration (TMR). Mean daily milk yield across these dairy farms was 65 pounds per cow with a range of 45 to 74 pounds per day. Non-dietary factors (i.e. management) explained 56 percent of the variation in milk yield not attributable to diet in this data set. The most important management factors were age at first calving, presence or absence of feed refusals, whether feed was pushed up or not and number of free-stalls per cow. Herds that fed for feed refusals averaged 64.1 versus 60.6 pounds per day, and herds that practiced routine feed push up averaged 63.7 versus 55.0 pounds per day of milk.

Figure 2. Relationship between milk yield (kg/d) and stall stocking density (stalls/cow) (Bach et al., 2008).



Milk yield = 20.4+(7.5 x stalls/cow) R^2 = 0.32

Stall stocking density alone explained about 32 percent of the variation in milk yield among these farms. Figure 2 illustrates the relationship between stalls per cow and milk yield observed by Bach et al. (2008). It is extraordinary that only one factor, such as stall stocking density, could explain this much of the variation in milk yield across these farms.

This study provides us with an excellent quantitative measure of the effect of the "management environment."

Cow Comfort Economics: Stalls per cow (1.7 pounds per 0.1 stall availability), feeding for refusals (+3.5 pounds per cow), and feed push-ups (+8.7 pounds per cow) are all positively related to herd milk production. Management environment is just as important as nutrition!

TIME BUDGET OF A DAIRY COW

The 24-h time budget (Figure 3) represents the net behavioral response of a cow to her social and physical environment (Grant, 2004). Deviations from benchmarked behavioral routines reflect departures from natural behavior and may serve as a basis for estimating DMI, performance, health and economic losses due to inadequate management strategies.

Dairy cows at approximately100 percent stocking density in free-stall housing spend 3 to 5 hours per day feeding, consuming 9 to 14 meals per day. In addition, they ruminate 7 to 10 hours per day, spend approximately 30 minutes per day drinking, 2 to 3 hours per day outside the pen for milking and other management practices and require approximately10 to 12 hours per day of lying time (Grant and Albright, 2001). There are three important management considerations regarding time budgets:

- Approximately 70 percent of the cow's day is spent eating and/or resting, so we cannot afford to screw it up
- There are only 24 hours in a day
- Consequently, the cow only has, on average, 2.5 to 3.5 hours per day to spend outside the pen and away from the feed, water and stalls. If we force the cow to spend more than this time outside the pen, then she will need to give up something – typically feeding and/or resting. *Every farmer should know how long their cows spend outside the pen in a free-stall barn.*

Figure 3. 24-hour time budget of a dairy cow.

- 5.0 h/d eating
- 12-14 h/d lying (resting)
- 2.0-3.0 h/d standing, walking, grooming, agonistic, idling
- 0.5 h/d drinking
- 20.5-21.5 h/d total needed
- **2.5-3.5 h "milking" = 24 h/d**

Recently, Gomez and Cook (2010) have shown how time outside the pen during milking and lameness interact to affect the cow's daily time budget. For example, lameness score 3 cows (1 to 3 scale) with a mattress stall base may only be outside the pen for approximately 0.5 to 1.5 hours per day and still meet their requirement for 11-12 hours per day resting time (based on Figure 3 with mattress systems in Gomez and Cook, 2010). In contrast, lameness score 1 (healthy) cows can stay outside the pen from 2 to 4+ hours per day and meet their resting requirement. At some point, it becomes impossible to meet time budgeting requirements with lame cows. If they can only be outside the pen for 0.5 hours per day, for instance, then realistically there is not enough time for milking even twice daily.

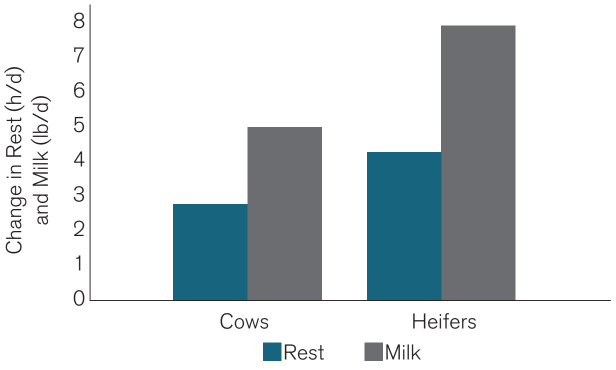
Common ways to disturb time budgets on-farm include:

- excessive time outside the pen
- mixing primi- and multiparous cows
- overcrowding and resulting excessive competition
- greater than 1 hour per day in headlocks, especially fresh cows
- short pen stays during transition period – i. e. "social turmoil"
- inadequate exercise
- uncomfortable stalls
- inadequate feed availability

And the list could continue further…

Time budgeting as a concept is easy to grasp. But, farmers often ask if time away from the pen really matters to the cow in any measurable way? In an on-farm case study, Matzke (2003) observed the effect of 3 versus 6 hours per day outside the pen. Pen size was adjusted versus parlor capacity to manipulate time outside the pen for milking. Mixed primi- and multiparous cows (30:70 ratio) at 100 percent stocking density of stalls and feed bunk were observed for 14-day periods. As much as possible, factors other than time outside the pen were kept constant. Figure 4 shows that cows gained over 2 hours per day of rest and nearly 5 pounds per day of milk when they were outside the pen for only 3 versus 6 hours per day. Incredibly, first-calf heifers gained 4 hours per day of rest and 8 pounds per day more milk. So, there appear to be short-term effects of time budgeting on milk yield that are associated with changes in resting activity. Failure to meet time budget needs may also affect longer term health status of the cow, such as lameness. In fact, the long term economic consequences of poor time budgeting may outweigh any shorter-term changes in milk yield. Espejo and Endres (2007) found that prevalence of lameness in 53 high-producing pens on 50 dairy farms was most highly associated with greater time outside the pen.

Figure 4. Changes in resting time (h/d) and milk yield (lb/d) when time spent outside of the pen was 3 h/d versus 6 h/d (Matzke, 2003).

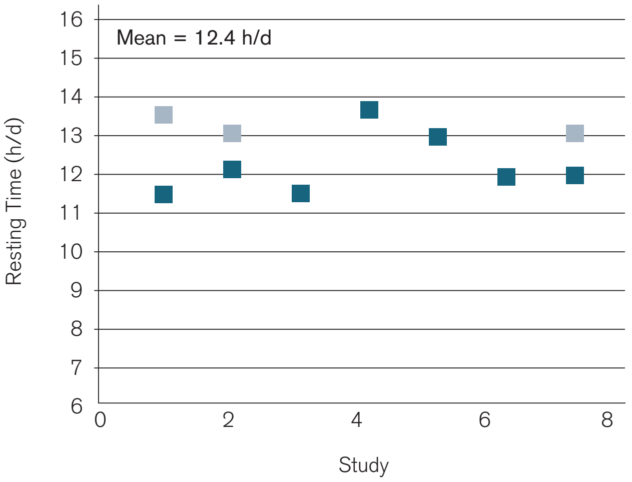


Cow Comfort Economics: Minimizing time outside the pen is the key to optimal time budgeting. Meeting the time budget requirement for resting may result in greater milk yield (5 to 8 pounds per day more) and lower incidence of lameness.

COWS HAVE STRONG BEHAVIORAL NEED TO REST

The dairy cow appears to have a strong behavioral need for adequate rest. Dairy cattle are highly motivated to lie down for approximately 12 hours per day (Grant, 2004; Munksgaard et al., 2005; Cook et al., 2005; Drissler et al., 2005; Fregonesi et al., 2007; Gomez and Cook, 2010). Additionally, Jensen et al. (2005) found an inelastic demand for rest of 12 to 13 hours per day for dairy heifers approximately 3 months pregnant. Figure 5 illustrates the measured average resting times for cows in these studies (mean 12.4 hours per day). The measured range in resting time for lactating Holstein cows of varying milk yield, days in milk, and body condition score was 4.1 to 17.1 hours per day (Bewley et al., 2010). The range reflects both cow and environmental factors.

Figure 5. Average resting times (h/d) of Holstein cows from 7 studies (adapted from: Jensen et al., 2005; Munksgaard et al., 2005; Cook et al., 2005; Drissler et al., 2005; Fregonesi et al., 2007; Bewley et al., 2010; Gomez and Cook, 2010).

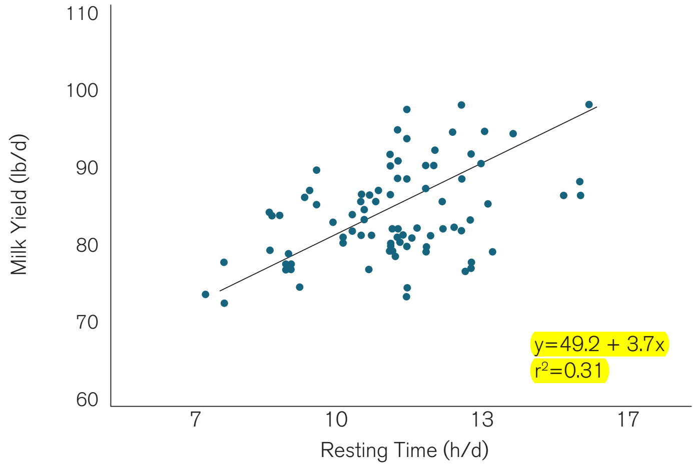


Lying behavior takes precedence over eating and social behavior when opportunities to perform these behaviors are restricted (Munksgaard et al., 2005). Physiological function, health and productivity are impaired when the resting requirement is not met. Cows with restricted lying time have greater serum cortisol and lower growth hormone concentrations, impaired hoof health and locomotion and sometimes lower milk yield (Munksgaard and Lovendahl, 1993; Singh et al., 1993; Grant, 2004; Cooper et al., 2007; Calamari et al., 2009).

This over-riding importance of rest to the productivity and health of the dairy cow has been termed "Vitamin R."

The data in Figure 6 are from a series of studies conducted at Miner Institute (Grant, 2007). The observations are primarily from healthy (non-lame) cows and we can see that there is a range in resting time from 7 to 17 hours per day. There is considerable

Figure 6. Relationship between milk yield (lb/d) and resting time (h/d) (Grant, 2007).



variation in milk yield versus resting time, but nonetheless there is a positive relationship. The slope of the best-fit line through this data indicates that, for every additional hour of resting time that a cow achieves, there is a milk response of approximately 3.7 pounds. Consideration of other studies would indicate that approximately 2 pounds per day would be associated with an hour extra resting time (Albright and Arave, 1997). It is important to point out that this response in milk yield will not be observed in every situation, although it appears to be reasonably consistent.

> Cow Comfort Economics: Proposed rule of thumb: there will be 2 to 3.5 pounds per cow more milk whenever cow comfort is improved resulting in one more hour of resting time.

RESTING AND FEEDING BEHAVIOR ARE CONNECTED

Lying behavior is a high priority for cattle after even relatively short periods of lying deprivation (Munksgaard et al., 2005). Cows will sacrifice feeding in an effort to recoup lost resting time. Consequently, environmental factors that interfere with resting may also reduce feeding behavior. Metz (1985) evaluated cow response when access to either resting stalls or the feed manger was prohibited. Cows attempted to maintain a fixed amount of lying time, and their well being was impaired when lying time was restricted for several hours daily. An additional 1.5 hours per day standing time was associated with a 45-minute reduction in feeding time. A similar relationship was observed by Batchelder (2000) where cows experiencing a stocking density of 130 percent of stalls and headlocks preferred lying in freestalls rather than feeding post-milking and spent more time in the alley waiting to lie down rather than feeding.

A review of published studies indicates that, for rest deprivation ranging between 2 and 4 hours per day, there was a 30 to 58 percent compensation following the rest deprivation. The associated reduction in feeding time has ranged between 32 and 45 minutes per day (Metz, 1985; Hopster et al., 2002; Cooper et al., 2007). Lying-deprived cows had reduced time spent feeding during the actual period of lying deprivation as well as after the deprivation.

From the data in these papers, it appears that cows sacrifice approximately 1 minute of eating time for each 3.5 minutes of lost rest. If this relationship represents a long-term, chronic behavioral adaptation to environments that restrict resting time, then we need to adjust expected feeding time and its predicted effect on DMI.

> Cow Comfort Economics: When cows are chronically deprived of adequate resting opportunity, they will also lose feeding time and potential for feed consumption in a 3:1 ratio.

STALL COMFORT AND COW COMFORT

A clean, dry and comfortable resting place is associated with greater resting time, better health and improved productivity. The effect of stall comfort on productivity is illustrated by the study of Calamari et al. (2009) who compared 4 free-stall bases: sand, straw, rubber mat and mattress. Over the 8 weeks of the study, cows resting on the sand stall maintained milk yield while cows resting on the other three alternative beds steadily lost milk yield with an 11.6 pounds per day advantage for sand during the final 3 weeks of the study. This lost milk yield was associated with a loss in resting time. Another study (Ruud et al., 2010) evaluated 305-d milk production and stall softness in 1,923 dairy farms in Norway. For all parities (1, 2, 3 and >3) softer stalls were associated with higher milk production. Table 1 summarizes these data with the 1 to 5 (5 is softest) scoring of the stalls based on a standard method for measuring stall softness.

Although sand is considered the "gold standard" for a stall base, there is considerable variability in acceptability and comfort among alternative beds. The best comparative work was done by Wagner-Storch et al. (2003) who compared sand stalls with a foam mattress, rubber crumb mattress, waterbed, solid rubber mat or concrete with sawdust (Table 2). All of their studies were carried out in understocked conditions to allow cows unimpeded access to the stall of their choice. As expected, sand was most preferred and had the greatest cow comfort index (CCI), but note how close the foam mattress was to sand. Rubber crumb mattresses and waterbeds were intermediate. The point here is that, if sand is not an option, then do not assume that all other beds will be equivalent. There are meaningful differences among alternative stall bases in comfort, acceptability and also how quickly they compress and become hard with time.

Recommended dimensions for free stalls have generally increased over the past 5 to 10 years with Canadian, and later Wisconsin, researchers leading the way (Cook and Nordlund, 2004). Table 3 summarizes the current recommendations of the University of Wisconsin veterinary group who are leaders in this area. Note the larger dimensions recommended compared with the traditional, and much smaller, recommended dimensions.

TABLE 1.

305-d milk production (lb) by parity from 1923 Norwegian farms with different stall softness (Ruud et al., 2010).

Parity	Concrete (1)	Rubber (2)	Soft Mat (3)	Multi-Layer (4)	Mattress (5)
1	13,338^{a}	13,369^{a}	13,572^{b}	14,106^{d}	13,746^{c}
2	15,255^{b}	15,048^{a}	15,649^{c}	16,139^{e}	15,893^{d}
3	16,086^{a}	15,997^{a}	16,498^{b}	16,744^{c}	16,788^{c}
>3	15,767^{a}	15,811^{a}	16,221^{b}	15,943^{a}	16,500^{d}
Mean	14,799^{b}	14,749^{a}	15,149^{c}	15,464^{e}	15,382^{d}

TABLE 2.

Comparison of sand stalls with other stall base types as % occupied, % lying, and Cow Comfort Index (CCI) (Wagner-Storch et al., 2003).

Stall Base Type	Percent Occupied (Ranking)	Percent Lying (Ranking)	CCI (Ranking)
Sand	79% (3)	69% (1)	88% (1)
Foam mattress	88% (1)	65% (2)	85% (2)
Rubber crumb mat	84% (2)	57% (3)	68% (4)
Waterbed	62% (5)	45% (4)	74% (3)
Solid rubber mat	65% (4)	33% (5)	51% (6)
Concrete & sawdust	39% (6)	23% (6)	59% (5)

TABLE 3.

Current recommendations for free-stall dimensions (University of Wisconsin-Madison School of Veterinary Medicine).

Dimension (in)	1st Lac (1399 lb)	Mature (1599 lb)	Prefresh (1799 lb)
Total stall length facing wall	108	120	120
Head to head platform	204	216	216
Stall length (rear curb to brisket locator)	68-70	70-72	72
Stall width	48	50	54
Height of brisket locator	4	4	4
Neck rail height	48	50	50
Rear curb height	8	8	8

Make smart bedding decisions: Tucker et al. (2009) summarized results of several studies that had measured the lying response to varying amounts of bedding. Certainly, cows prefer more compressible (i.e. softer) lying surfaces. Figure 7 summarizes the relationship between resting time and additional bedding material for sawdust, chopped straw and sand. Using this information, we can begin to fine-tune our recommendations for adjusting bedding strategies on-farm and prediction of potential change in lying time if more bedding is added to the stall. If we can predict the expected increase in lying time, then we can also estimate the potential change in milk production or possible feed intake.

Figure 7. Relationship between resting time and additional bedding material for sawdust, chopped straw, and sand.

- **Cows prefer more compressible (softer) lying surface**
- +3 min/d lying time for each additional 2 lb sawdust shavings
  - 6-52 lb/stall: +1.1 h/d lying
- +12 min/d lying time for each additional 2 lb straw
  - 2-15 lb/stall: +1.2 h/d lying
- +12 min/d lying time for each additional 1/2 inch of sand

Impact of free stall renovations: What is the cost of stall renovation – what is the cost of not renovat-

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ing? Despite the data that demonstrate a positive relationship between cow comfort and productivity and health, often farmers are reluctant to remodel existing facilities or to build new facilities with larger stall dimensions. Why? It is likely related to the fact that the costs are known, but the potential cow response on any given farm is not.

At this point, no truly controlled research exists that quantifies the performance response to stall comfort (dimensions, bedding, maintenance of resting surface). One abstract (Cummins et al., 2005) described a study that compared 48 inches wide by 66 inches curb-to-brisket locator by 45 inches neck-rail height versus 50 inches wide by 70 inches long by 50 inches neck-rail height stall design (so-called 50-50 stall). The CCI was 50 percent for the smaller stall and 95 percent for the larger stall. Milk response averaged 3 pounds per cow per day more for cows using the larger stalls.

University of Wisconsin veterinary researchers have conducted a number of case studies in recent years designed to measure the response to improved cow comfort. Generally, baseline performance and health information was collected on a herd, a stall renovation was made to improve cow comfort and then herd response was followed for up to 3 years. Case studies have included converting mattress to sand or upgrading a mattress system. The commonality has been creating softer, larger stalls (Cook, 2006). A summary of these case studies indicates that payback on investment ranged from 0.5 to 3 years (average 1.9 years). Most renovations were done at a reasonable cost and in most cases the farmers provided some or all of the labor. The observed benefits (across four case studies described by Cook, 2006) of stall improvement were:

- Greater milk yield (3 to 14 pounds per cow per day)
- Lower turnover rates (-6 to -13%)
- Lower somatic cell count (-37,000 to -102,000)
- Less lameness (-15 to -20%)

Cow Comfort Economics: Improving the comfort of a stall should improve milk yield, reduce culling rate, lower somatic cell count and improve lameness status of the herd. Little controlled research exists, but we cannot ignore the consistently positive case studies.

FEEDING ENVIRONMENT AND COW COMFORT

When cattle are grouped, some competition at the feed bunk is inevitable. Even with unlimited access to feed, cows will interact in ways that give some an advantage over others (Oloffson, 1999). Consequently, the management goal is not to eliminate competition, but rather to control it. Three characteristics describe the natural feeding behavior of dairy cows (Albright and Arave, 1997):

- Allelomimetic: cows like to feed together
- Crepuscular: cows like to feed early in the morning and early in the evening
- Competitive: competition at the feed bunk is inevitable, with the 60 minutes following fresh feed delivery being a time of greatest competition for feed

Cows have a naturally aggressive feeding drive and will willingly exert greater than 500 pounds of force against the feed barrier while eating in an attempt to reach the feed (Hansen and Pallesen, 1998). To put this in perspective, 225 pounds of force is enough to cause tissue damage. The best working definition of "aggressive feeding drive" – cows will injure themselves in an attempt to eat if we do not properly manage the feeding system to ensure feed accessibility. Factors that must be optimized to encourage aggressive feeding activity and optimal dry matter intake include:

- Adequate bunk space or manger space per cow
- Feed barrier and headlocks
- Manger surface and height
- Accessibility of feed to cow (reach distance and time available)
- Alley width, floor behind the feed manger

- Stall comfort and adequate resting time

Based on several recent surveys of management practices in the US, the "typical" feeding environment would be characterized as follows (Caraviello et al., 2006; Espejo and Endres, 2007; Schefers et al., 2010):

- 3-row pens more common than 2-row pens
- Once daily feeding more common than multiple deliveries of TMR
- Post-and-rail feed barriers more common than headlocks
- Approximately 18 inches of bunk space per cow
- Feed push-ups approximately 4 to 6 times per day
- Feed refusal rate approximately 3.5 percent more common than feeding to a clean bunk
- Mixed parity pens more common than grouping by parity

What stimulates feeding behavior? The big three factors are:

- Delivery of fresh feed
- Feed push-up with pushing up being more important during the day rather than at night
- Milking

TABLE 4.
Summary of recent research on frequency of TMR delivery (FF/d) and cow response.

Reference	FF/d	Eating Time %	DMI %	Milk %	Rest %
DeVries et al. (2005)	1 vs 2x	+3.5	-2.0	NR	-.08
	2 vs 4x	+4.6	-3.0	NR	0
Mantysaari et al. (2006)	1 vs 5x	+7.0	-4.8	-1.0	-12.1
Phillips and Rind (2001)	1 vs 4x	+11.0	-6.3	-4.7	-8.6
Nikkhah et al. (2011)	1 vs 4x	NS	-5.2	-2.5	NS

The biggest driver of feeding is delivery of fresh TMR according to the University of British Columbia research group (DeVries et al., 2005). Table 4 summarizes recent research on frequency of TMR delivery and cow response. Greater feeding frequency may improve ruminal fermentation, rumination time and feeding time, but it also seems to reduce lying time and dry matter intake. So, do not over-do feeding frequency of TMR. It is likely safe to say that delivery of feed twice a day is an improvement over once daily in some circumstances, but greater feeding frequency may not improve response, and the data would indicate that intake and resting will actually be reduced. Diets with large amounts of water added would either dry out or begin to heat in warm environments, which may reduce intake. Time of day that feeding occurs, especially in hot climates, clearly changes intake patterns and totals. Equipment and labor availability may need to be adjusted to reduce feeding frequency. Some of the positive reports related to increasing feeding frequency may be over-coming some of these other limitations. For example, diets that are very dry and subject to sorting and heating (from added water) may result in increased feed intake when fed multiple times per day. Once or twice daily feeding is preferred. In hot environments twice daily feeding (40% in early morning, 60% in evening) is warranted and recommended.

In summary, here are several feeding factors that could translate into one additional pound of dry matter intake (Grant and Albright, 2001):

- Resurface a pitted manger surface
- Adjust manger height to approximately 6 inches above standing surface if it is too low
- Ensure accessibility of feed with timely push-ups and availability at least 21 hours per day
- Bunk space of 24 to 30 inches per cow
- Alley width behind the feed manger of 14 feet

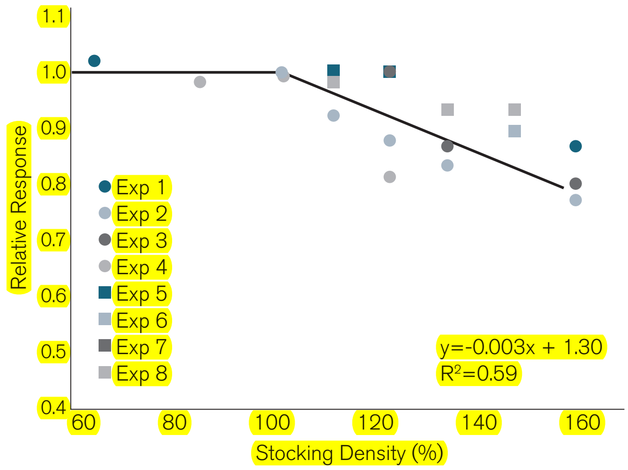
Cow Comfort Economics: Optimizing the feeding environment will promote aggressive feeding behavior and greater dry matter intake which translates into more milk production (for Holsteins, 1 lb of dry matter intake translates into 2 lb of milk).

STOCKING DENSITY AND COW COMFORT

Overstocking reduces the cow's ability to practice natural behaviors. But, overstocking improves economic returns on facility investments. We know that social and group dynamics along with facility design influence the cow's response to stocking density.

Feeding behavior: Dry matter intake is a function of the number of meals x meal length x feeding rate. Ordinarily, the management goal is to encourage more meals with a slower feeding rate. But, with limited access to feed and the resulting increased competition, cows actually consume fewer meals with a greater rate of feeding. In a chronic situation, this feeding pattern may lead to poor rumen health and reduced feed efficiency.

Figure 8. Relationship between stall stocking density (%) and resting time (Wierenga and Hopster, 1990; Matzke and Grant, 2002; Winkler et al., 2003; Fregonesi et al., 2007; Hill et al., 2009; Krawczel, 2008, 2009, 2010).



As stocking density within a pen increases, the frequency of aggressive interactions increases, cows spend less time lying down and more time standing outside the free-stall, they consume feed up to 25 percent faster and take less time to lie down after milking (Fregonesi et al., 2007; Hill et al., 2009). Competition at the feed bunk is responsible for 88 percent of displacements indicating that gaining access to feed is a high priority for cows. Competitive success by dairy cows at the feed bunk varies according to each cow's motivation to eat. In addition to altered feeding behavior, overstocking may also suppress rumination activity, lower milk fat percentage and increase somatic cell count under some conditions (Batchelder, 2000; Krawczel et al., 2008; Hill et al., 2009).

Resting behavior: Figure 8 illustrates the relationship between stall stocking density and resting time based on a summary of published data (Wierenga and Hopster, 1990; Matzke and Grant, 2002; Winkler et al., 2003; Fregonesi et al., 2007; Hill et al., 2009; Krawczel, 2008, 2009, 2010). Although there is considerable variation among studies, it appears that, beyond 120 percent stocking rate, every study found a reduction in resting time.

Milk composition and quality: Hill (2006) found that as stall stocking density increased from 100 to 142 percent milk fat percentage was reduced and somatic cell count increased (summarized in Table 5). In fact, overstocked cows ate 25 percent faster and ruminated 1 hour per day less which explained the reduction in milk fat test. Overstocked cows also experience a greater pathogen load in the environment, have greater teat end exposure to pathogens and may experience immune suppression. All of these responses could explain the observed effect on milk quality. Stocking density does not cause a change in milk components in all studies and we need to better understand under what conditions it will alter milk characteristics. It is possible that there is a diet to stocking density interaction. One could easily imagine that a diet that is higher in unsaturated fatty acids or marginal in peNDF would more readily result in changes in milk components at higher stocking densities.

TABLE 5.
Effect of increasing stall stocking density on milk fat (%) and somatic cell count (SCC; x1000ml) (Hill, 2006).

	100%	113%	131%	142%
Milk fat (%)	3.84	3.77	3.77	3.67
SCC (x 1000/mL)	135	114	169	236

Reproduction: Caraviello et al. (2006) evaluated data from 153 farms in an effort to identify factors of greatest significance in influencing reproductive performance. Surprisingly, bunk space in the breeding pen rose to the top. These researchers found that as bunk space decreased from 24 to 12 inches per cow, percent of cows pregnant by 150 days in milk decreased from 70 to 35 percent. Additionally, Schefers et al. (2010) noted reduced conception rates with higher stocking densities. Given the value of a pregnancy of approximately $278 this is an important, and overlooked, effect of overstocking on dairy cattle.

TABLE 6.
Observed changes in cow behavior and the economic losses that may result due to overstocking.

Changes in these behaviors:	May result in these economic losses:
▪ Greater aggression & displacements at feed bunk ▪ Greater feeding rate ▪ Reduced resting time ▪ Increased idle standing in alleys ▪ Decreased rumination ▪ Subordinate (i.e. primiparous and lame cows) most affected	▪ Less milk yield ▪ Lower milk fat ▪ Greater SCC ▪ More health disorders ▪ Increased lameness ▪ Fewer cows pregnant

Table 6 summarizes the observed changes in cow behavior and the economic losses that may result due to overstocking.

Cow Comfort Economics: The greatest economic consequence of overcrowding may be the long-term health and reproduction consequences, although under some conditions changes in milk yield, milk quality and milk composition may occur. Approximately 120 percent stocking of stalls and feed bunk space appears to be a critical point beyond which resting is reduced and reductions in performance should be expected.

GROUPING CATTLE BY PARITY

There are numerous natural differences between primi- and multiparous cows. Heifers take smaller bites, eat more slowly and spend more time feeding. They are also typically less dominant and more easily displaced from the feed manger, stalls or water tank (Grant and Albright, 2001). Additionally, preliminary work at Miner Institute (Krawczel, 2007, unpublished) indicates that heifers that are forced to lie in a stall known to be preferred by a dominant cow will actually ruminate up to 40 percent less than a heifer lying in a less preferred stall (see Table 7).

TABLE 7.
Rumination behavior of heifers lying in preferred vs. less preferred stall by a dominant cow (Krawczel, unpublished).

	Preferred	Less Preferred	*P* Value
Rumination time (min/d)	81.4	147.8	0.09
Percent resting time spent ruminating	35.2	58.4	0.05

What are the possible long-term implications for this depression in rumination activity relative to sub-acute ruminal acidosis and its related consequences? Perhaps this effect of grouping strategy and natural cow preferences for certain stalls constitutes an overlooked reason why first-calf heifers do not perform up to their genetic potential when they have to compete with older cows.

Lactating primiparous cows may benefit from separate grouping (Grant and Albright, 2001; Østergaard et al., 2010). They have greater growth requirements, smaller body size, greater persistency of lactation and frequently a lower position in the group's dominance hierarchy (Grant and Albright, 2001). Phelps (1992) reported that separately grouped primiparous cows produced 1604 pounds more milk per lactation than those that had to compete with older cows in commingled groups. Grant and Albright (2001) reviewed the research on grouping dairy cattle by parity and concluded that when primiparous cows were separated from mature cows:

- Feeding time increased by 11.4 percent
- Meals per day increased by 8.5 percent
- Silage DMI increased by 11.8 percent

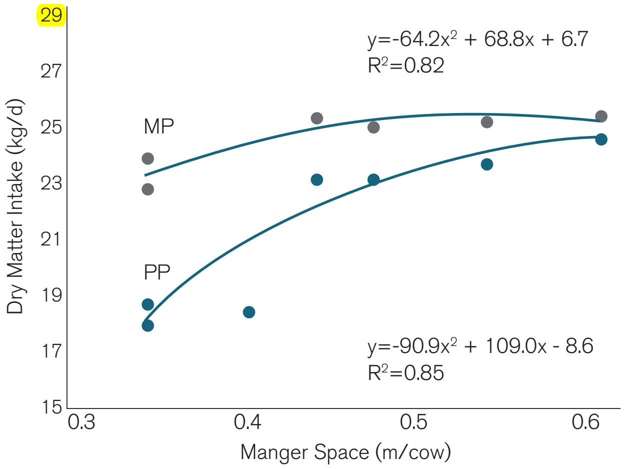
- Lying time increased by 8.8 percent
- Lying periods increased by 19 percent per day
- Milk yield increased by 9 percent

More recently, Bach et al. (2006) assessed primi- versus multiparous cows housed together in a robotic parlor system such that there was little competitive pressure for the feed and stall resources. Nonetheless, primiparous cows experienced greater loss of bodyweight and lower efficiency of fat-corrected milk production (FCM/DMI) during the first 30 days in milk. In a follow-up report, the same research group found that primiparous cows had less drinking time, lower rumination activity and reduced milk fat percentage when commingled with older cows.

As manger space is reduced, dry matter intake (at least in the short term) is relatively unaffected for multiparous cows, but it is reduced for primiparous cows in commingled groups. Feeding rate increased as manger space was reduced for both parities, but the feeding rates were lower for primiparous cows and they did not increase to the same extent as for multiparous cows resulting less intake (Figure 9; Grant et al., 2010).

Hill (2006) evaluated the impact of overcrowding commingled pens of primi- and multiparous cows (30:70 ratio) on milk production. The milk yield results are shown in Table 8. The main point here is that a modest increase in stocking density of stalls and headlocks from 100 to just 113 percent increased the difference in milk yield between multiparous and primiparous cows from 5.9 to 13.8 pounds per day. The loss in milk production with greater stocking density by the primiparous cows reflected reductions in resting and rumination activities.

Figure 9. Influence of manger space (m/cow) on dry matter intake (kg/d) for multiparous (MP) and primiparous (PP) cows (Grant et al., 2010).



Cow Comfort Economics: Commingling primiparous cows with older cows leads to loss of resting activity, rumination and milk yield. Plan on approximately 10 percent loss in milk. When stocking density is increased, the negative effect is even more pronounced even at low levels of overcrowding (such as 113% of stalls and headlocks).

TABLE 8.
Impact of overcrowding on milk yield (lb/d) of multiparous vs. primiparous cows (Hill, 2006).

	Stocking Density			
	100%	113%	131%	142%
Multi-primiparous response				
Milk (lb/d)	+5.9	+13.8	+21.1	+14.9

PHYSICAL ENVIRONMENT AND COW COMFORT

Components of the physical environment that influence cow comfort include: temperature, humidity, wind speed, degree of lot muddiness, standing time and distance walked (details in Tylutki et al., 2008). The effect of temperature and humidity (i.e. THI and heat stress) on lactating cow and growing heifer response has been extensively reviewed by West (2003). The primary goal of heat stress abatement is to allow the cow to practice normal feeding, resting and rumination behaviors in order to maintain, as nearly as possible, expected feed intake and productivity.

The impact of heat stress abatement on lactating cow comfort and productivity is well known. More recently, however, researchers have realized that heat stress abatement during the dry period improves cow comfort during the transition period and subsequent lactational performance. Table 9 summarizes the influence of dry cow cooling on milk yield.

Dry cow cooling is clearly an overlooked opportunity to improve cow comfort and subsequent productivity.

Heat stress is associated with several important changes in cattle behavior. As air temperature increased from 78 to 104°F, feeding decreased by 46 percent, ruminating decreased by 22 percent, standing increased by 34 percent, drinking increased by 30 percent, and locomotion decreased by 19 percent (Tapki and Sahin, 2006). Higher producing cows (>70 pounds per cow per day) were more sensitive to heat stress than lower producing cows, especially for resting and standing activity.

Body temperature mediates the cow's standing and lying response to varying conditions of heat stress. During heat stress conditions, core body temperature appears to control whether the cow lies down or stands, with the cow standing once core body temperature reaches approximately 102.0°F and then lying back down again once the temperature reaches approximately 100.9°F (Hillman et al., 2005).

TABLE 9.

Summary of current research on the influence of dry cow cooling on milk yield (lb/d).

Study	Method	Milk (lb/d) of cows not cooled	Milk (lb/d) of cows cooled
Avendaño-Reyes et al., 2006 (Mexico; 56 DIM)	Fans and water spray (mist ring)	55.9[a]	71.5
Urdaz et al., 2006 (CA; 60 DIM)	Add fans/shades to sprinklers over feed bunk	84.9[c]	88
do Amaral et al., 2008 (FL; 42 DIM)	Fans and sprinklers	55.9[c]	73.0
do Amaral et al., 2009 (FL; 140 DIM)	Fans and sprinklers	67.8[b]	78.3
Adin et al., 2009 (Israel; 90 DIM)	Fans and foggers along feed bunk	86.2[c]	90.9
Tao et al., 2010 (FL; 147 DIM)	Fans and sprinklers	69.5[b]	80.3

$^{a}P \leq 0.15$, $^{b}P \leq 0.10$, $^{c}P \leq 0.05$

The quickest way to get a heat-stressed cow to lie down is to cool her body temperature!

Recent research from Arizona (Collier et al., 2011) indicates that high-producing dairy cows begin to be negatively affected by heat stress at THI = 68 which is substantially less that traditionally thought. These authors have calculated an expected gain in milk yield of 2.5 to 5 pounds per cow per day for high-producing cows if heat stress abatement begins at 68° rather than 72°F (article in 2/11/11 issue of Dairy Herd Management magazine). Cook et al. (2007) observed that, as THI increased from 56 to 74, lying time decreased from 10.9 to 7.9 hours per day, standing in alley increased from 2.6 to 4.5 hours per day, and drinking increased from 0.3 to 0.5 hours per day. Lameness score and claw lesions increased markedly and were associated with greater standing time, sporadic feeding and slug feeding. Lameness peaked approximately 2 months after temperatures peaked. Similar to Collier et al. (2011), they reported that activity of the cows shifted around a THI of 68 which supports the use of more aggressive heat stress abatement strategies than traditionally used.

Cow Comfort Economics: Heat stress abatement needs to begin at THI = 68, and to occur during the dry and the lactating phase. This will result in greater DMI and milk yield (average of more than 10 pounds per cow per day), less lameness and a better transition period. Cow comfort demands aggressive heat-stress abatement!

COW COMFORT AND LAMENESS

An economic analysis estimated that each clinically lame cow costs the dairy producer approximately $300 (Guard, 2002). Costs associated with lameness include:

- Decreased milk production (Warnick et al., 2001; Hernandez et al., 2002; Juarez et al., 2003)
- Reduced fertility (Spreicher et al., 1997)
- Increased culling risk (Booth et al., 2004)
- Treatment costs and increased labor requirements

Surveys indicate that incidence of lameness on dairies varies according to time of year, housing type and stall surface (Cook, 2003). Lameness prevalence was 21 percent during the summer and 24 percent during winter. Mean prevalence of lameness in free-stall herds with non-sand stall surfaces (33.7%) was higher than free-stall herds bedded with sand (21.2%). Tie-stall herds with sand as the stall surface had less lameness (12.1%) compared with tie stalls using a non-sand surface (21.2%). Hernandez et al. (2002) found

TABLE 10.
Effect of lameness on dry matter intake and milk yield shown as percent reduction of parameters relative to cows with locomotion score of 1 (Juarez and Robinson, 2002).

Score	Dry Matter Intake	Milk Yield
1	0	0
2	1	0
3	3	5
4	7	17
5	16	36

that lame cows averaged only 17,122 pounds per cow per year versus non-lame cows (19,007 pounds per cow per year). Warnick et al. (2001) found that cows lost between 1.8 and 2.6 pounds per day two weeks after becoming lame with the reduction in milk yield being worse for cows in second or greater lactation. Lame cows had a hazard ratio of leaving the herd two times that of a non-lame cow (Booth et al., 2004). Lame cows had a 59 percent reduction in 1st service conception rates, a 125 percent increase in ovarian cysts and an 8.2 percent decrease in pregnancy rate (Melendez et al., 2002).

Clearly, lameness is a costly disease and reducing its incidence will have a very favorable impact on dairy profitability.

One of the most widely cited studies is shown in (Table 10; Juarez and Robinson, 2002). The data are from commercial dairy herds in California. The one to five lameness scale was described by Spreicher et al. (1997). In general, we see that greater lameness score results in less mobility, presumably reduced feed intake, and therefore lower milk production. Juarez et al. (2003) found that both greater pen distance from the parlor and lameness reduced milk production.

Table 11 shows the impact of increasing stocking density of stalls and headlocks on milk yield of non-lame (score 1 and 2) versus lame (score 3 and 4) cows (Hill, 2006). At 100 percent stocking density, lame cows produced 9.4 pounds per day more milk than non-lame cows. But, when stocking density increased to only 113 percent of stalls and headlocks, there was a pronounced advantage for the sound cows. As stocking density increased further, the disparity in milk production became more dramatic. Clearly, lame cows are not competitive, and even modest overcrowding exacerbates the problem.

TABLE 11.
Impact of increasing stocking density on milk yield (lb/d) of non-lame vs. lame cows (Hill, 2006).

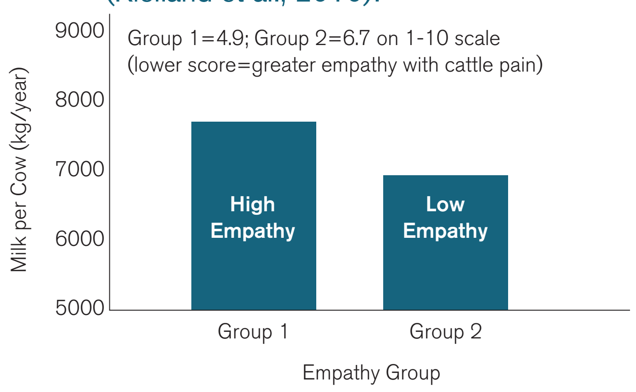
	100%	113%	131%	142%
Sound-lame				
Milk, lb/d	-9.4	+1.9	+16.7	+13.9

On the positive side, cows with locomotion problems can improve quickly when they are placed on better walking surfaces such as pasture. Hernandez-Mendo et al. (2007) found that the gait scores of lame cows improved by 0.22 units per week when they were kept on pasture compared with free-stall housing.

Cow Comfort Economics: Lameness results in a loss of at least 5 percent and as much as 36 percent milk annually, greater culling rate and reduced fertility.

COW-HUMAN INTERACTION

Figure 10. Effect of degree of empathy of the farmer on milk production (kg/cow/yr) (Kielland et al., 2010).



The most important factor in cow comfort is the human-cattle interaction (Berry, 2001), and the ideal personality type has been described as a confident introvert (Albright and Arave, 1997). Considerable research has shown productive benefits of more gentle handling and vocalizations when cows are being milked, in terms of more milk production or less residual milk. Seabrook (1984) observed that cows produced 13 percent more milk with gentle compared with aversive handling in the parlor. Later, dePassillé and Rushen (1999) found that just the presence in the parlor of someone who had previously treated the cows aversively (i.e. not the milker) was associated with a 47 percent increase in residual milk. Interestingly, Hanna et al. (2006) found a 3.6 percent increase in milk yield when the milking team had greater positive vocal and physical contact with the cows – both appeared to be important.

Figure 10 illustrates the effect of degree of empathy of the farmer on herd milk production (Kielland et al., 2010). When farmers were grouped into categories of either high or low empathy with cattle pain, amazingly there was nearly a 1,000-kg (2200 lb) difference in milk production per cow per year. More work needs to be conducted to determine what specifically caused this milk response, but it certainly is food for thought. Especially when we consider that empathy and avoiding aversive behavior around the cows does not cost a dime.

Cow Comfort Economics: Gentle treatment of cows, especially while in the parlor, results in 3.5 to 13 percent greater milk yield and greater empathy with cattle pain is associated with about 2000 pounds per year greater milk production. Gentle handling approaches do not cost any more than aversive handling.

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