Incorporating Dairy Cow Behavior into Management Tools

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Introduction

During the past few years, there has been a noticeable increase in publication of applied cow behavior research. Presently, many of the most active research groups in dairy cattle behavior are located in Europe and Canada. We need more dedicated research effort in the US on applied behavior, and greater collaborative efforts, with a goal of developing decision support tools that assist the producer and consultant in making profitable decisions by accurately modeling behavioral responses to facilities and management and associated changes in cow and herd performance.

We need to differentiate between individual cow behavioral response to a management routine and the economic return for adopting a management routine on a whole-herd basis. Figures 1a and b provide an example of this concept using the hypothetical or stylized response to stocking density on an individual cow or a herd basis. In this example, the limited published research demonstrates clear implications for under- and overstocking feed and stall resources. Most research has focused on cow response, but a comprehensively useful decision tool needs to consider herd response (as the integration of multiple pen responses) and the impact of stocking density on long-term enterprise profitability. An appropriate research target should be how to achieve the point of inflection in Figure 1b where economic return to the dairy is optimized. We can surmise that the optimal stocking density might vary among farms, and consequently "an optimal stocking density" can never be determined. But, we can identify the primary factors that most acutely influence optimal stocking density for any particular farm and then develop decision support tools that solve for the optimal solution (in this example, the stocking density that maximizes long-term economic return).

Beginning with an initial focus on cow behavioral response, the primary purpose of this paper is to review briefly the current knowledge base of selected factors that influence eating, resting, and rumination behavior. Specifically, major factors known to influence the cow's behavioral response within a herd setting will be addressed including stocking density and grouping strategies. Finally, a simple preliminary version of a spreadsheet to evaluate the cow's time budget will be presented. Longer-term, we need to consider how this behavioral information may be incorporated into tools such as the Cornell Net Carbohydrate Protein System (CNCPS) and CPM-Dairy models.

Dairy Cow's Daily Time Budget

Essentially, the 24-h time budget represents the net response of a cow to her environment. Deviations in any herd from these benchmarked behavioral routines represent departures from natural behavior and could serve as a basis for estimating the performance and economic loss due to poor management strategies. Table 1 illustrates a simplified daily time budget for lactating dairy cattle adapted from Grant and Albright (2000).

Albright (1993) measured the daily behavioral time budget for a cow (Beecher Arlinda Ellen) during the lactation in which she set a world record for milk production while housed primarily in a box stall. The data indicated that she spent 6.3 h/d eating, 13.9 h/d resting (lying), and 8 h/d ruminating (7.5 h/d while lying and 30 min/d while standing). Matzke (2003) compared the time budget of the top 10% of cows (by milk yield) in a group versus the average time budget for the entire group of cows. Table 2 compares the daily behavioral time budget for the highest milk production versus the average cows. It is interesting that these elite cows, as well as Beecher Arlinda Ellen (the first cow to produce >22,600 kg of milk in a lactation), both rested for 14 h/d. One could speculate that the actual requirement for resting is close to 14 h/d for the most productive cows, rather than 10 to 12 h/d as commonly proposed. An appropriate analogy might be the approach of formulating rations to meet the requirements of a cow above the average milk production level in a group of cows. Perhaps we need to consider designing facilities and developing management routines that allow the cows access to stalls for up to 14 h/d; cows requiring less than this amount will use the time for other behaviors whereas the highest producers will have adequate access to stalls. We have just completed the compilation of 7 years of behavioral data from a variety of experiments at the Institute and we hope to better define the relationship between resting and other behaviors and productivity.

It is clear that cows need to accomplish certain behavioral activities each day, and we cannot allow our management routines to interfere. If we tally up the required number of hours each day to satisfy the basic behavioral needs, it approaches 20 to 21 h/d: 5 to 5.5 h/d for eating + 12 to 14 h/d for lying/resting (includes 6 h of rumination) + 4 h/d for rumination while standing + 30 min/d for drinking. If we add in only 30 min/d for other activities such as grooming and other interactions, the total time required in the budget is 20.5 to 21.5 h/d (Grant, 1999). Given this time need, it is easy to see how our management practices can very easily perturb the cow's normal time budget. Improper grouping strategies that result in overcrowding and excessive time in holding pens are two common ways of upsetting the time budget and reducing herd productivity.

Feeding Behavior: Measurement in Competitive Feeding Environments

Feeding is the predominant drive in dairy cattle (Metz, 1985), and consequently any attempt to predict cow response to a particular environment must accurately describe feeding response. When a competitive situation exists at the feed bunk, dominant cows typically spend more total time eating than cows of lower social rank, resulting in greater feed intake. Some level of competition within a group of cows is inevitable; even under conditions of unlimited access to feed, cows interact in ways that give some an advantage over others (Olofsson, 1999). To date, the most comprehensive data base of feeding behavior has been compiled by Dado and Allen (1994) for cows in a noncompetitive environment. However, similarly detailed information of feeding behavior in competitive environments awaits advances in measuring systems. Conventional systems to measure feeding behavior and feed intake such as Calan Gates have supposed limitations regarding natural ingestive behavior. Recently, Canadian researchers have reported on a system that captures extensive feeding behavioral data, but not associated dry matter intake (DeVries et al., 2003). Consequently, meal size and rate of consumption cannot be determined. Figure 2 illustrates a typical 24-h chart of feeding activity for cows housed in a competitive environment using the behavior monitoring system reported by DeVries et al. (2003).

A recent report from Spain (Bach et al., 2004) validated the use of a computerized system for monitoring feeding behavior and individual feed intake for cows in a typical, competitive environment. The system was capable of measuring number of visits to the manger by each cow, length of each visit, amount consumed per visit by each cow, the total amount of feed consumed daily per cow, and the rate of feed consumption. In short, this system could generate crucial feeding behavioral data to allow measurement of cow response to varying management factors in competitive situations which has been impossible until now.

Swedish researchers (Olofsson, 1999) evaluated the effect of increasing competition from one to four cows per total mixed ration feeding station. As competition per feeder increased, cows exhibited shorter average eating times and accelerated eating rates. Similarly, visits to the feeding station increased in direct proportion to greater aggression during feeding. However, feed intake was unchanged. In contrast, when cows were fed limited amounts of feed, dominant cows consumed 14% more feed than submissive cows. This divergence increased to 23% as competition increased from one to four cows per feeding station. Under conditions of limited feed availability, competition escalates and feed intake of submissive cows suffers.

In addition, when competition increased from one to four cows per feeding station, a higher proportion of the feed consumption occurred during the night (1800 to 0600 h). The cows also spent a smaller proportion of time standing during the night with greater competition for feed. As level of competition increased, cows of low social rank tended to adjust behaviors to a greater extent than did the more dominant cows. Instead of eating, the subordinate cows were observed standing and lying more often around milking time, when eating would have been preferred. Additionally, as manger space is reduced, there may be a greater risk of increased feeding rate and associated risk of metabolic problems such as abomasal displacement and subacute ruminal acidosis (DeVries et al., 2004). The industry standard for feeding space has been approximately 60 cm/cow. With this amount of feeding space, 66 to 70% of cows in a group may eat simultaneously (DeVries et al., 2004). DeVries et al. (2004) evaluated the impact of increasing manger space from 50 to 100 cm/cow. These researchers observed a 60% increase in space between cows, 57% fewer aggressive interactions while feeding, and a 24% increase in feeding activity during the 90 min following fresh feed delivery. This research clearly raises the question of what constitutes optimal manger space for cows in a competitive environment. But, we also need to keep in mind the concept of cow response versus herd profitability illustrated in Figure 1.

The bottom line is that we need to be able to accurately model feeding patterns, meal consumption and timing, and size of meals throughout the day for models such as the CNCPS to best predict total feed intake and dynamic ruminal conditions. The assumption of steady-state conditions in the rumen clearly does not match reality, and we may now be entering a period where researchers can generate the needed feeding behavior data to make existing models more accurately reflect in vivo conditions.

Resting Behavior: Implications in Competitive Environments

As early as 1928, researchers were investigating the importance of resting and the implications of adequate lying time for cow comfort, health, and productivity (Fuller, 1928). Recognized benefits of adequate resting activity include: reduced stress on feet, reduced lameness, increased blood flow to the mammary gland, increased feeding activity, and greater overall cow health. The advantages of adequate rumination activity are obvious and involve maintenance of ruminal conditions conducive to efficient microbial fermentation. Although dietary physically effective fiber drives rumination activity, social stress, such as overcrowding and excessive competition for feed and stalls, can reduce rumination activity significantly (Batchelder, 2000).

Cows attempt to maintain a rather fixed amount of lying time, and their well-being is impaired when lying time is restricted for several hours (Metz, 1985). Within 10 h, approximately 50% of lost resting activity has been recouped in most cases (Metz, 1985). When lying and eating are restricted simultaneously, cows choose to rest rather than eat, with an additional 1.5 h/d standing time associated with a 45-min reduction in feeding time (Metz, 1985). A similar relationship was observed by Batchelder (2000) where cows with a stocking density of 130% preferred using free stalls versus eating post-milking and spent more time in the alley waiting to lie down than eating when compared with a stocking density of 100%.

Table 3 presents the potential relationship between improved lying time and greater milk production based on reported results in the scientific literature (Grant, 2003). Increased feed intake explained about 35% of the milk response to increased lying time using this data set.

On-farm measurement of resting time is difficult because most producers will not have the luxury of observing their cows throughout 24 h to directly determine resting activity. It is worth noting that recently several producers have inquired about installing video cameras in their barns to monitor resting and other activity. What a tremendous development! For some producers, use of video monitoring equipment will help them solve behavioral and production problems on their dairy. Also, we need to recognize that this approach merely attempts to convert known short- and long-term responses to varying resting times into realistic milk yield changes. A more accurate and mechanistic approach to predicting economic consequences (long and short-term) of variable resting times for a dairy herd must await further research on the impact of housing and management routines on health status of a herd (notably lameness), reproductive performance, and lactational performance. Likely, this needed research will be collaborative because no single research station possesses the resources needed to accomplish it, and it will involve a combination of smaller-scale, more controlled research and larger-scale on-farm studies.

Grouping Strategies and Behavioral Responses

Recently, Boe and Faerevik (2003) published an excellent review of grouping and social responses in calves, heifers, and mature cows. Previously, Grant and Albright (2001) published a review specifically on effects of grouping strategy on feed intake in dairy cattle. A fundamental consideration for any decision tool on grouping strategies is the difference between conventional concepts in dominance hierarchies and grouping and what may be closer to reality. Conventionally, it is assumed that 1) cows fight to establish social hierarchy, 2) fighting stops once hierarchy is established, 3) dominant cows regulate access to the resources, 4) group size should not exceed number of cows an individual can recognize, 5) dominance hierarchy is rapidly established – 50% within one hour, and 6) the hierarchy is stable (only 4% are reversed). Contrast this rather static depiction of group interactions with the following more dynamic and likely realistic scenario: 1) continued and fluctuating levels of fighting/aggression, 2) formation of subgroups within larger pens, 3) inability to recognize all peers when group size exceeds approximately 100 cows, 4) some individuals thrive, not by winning fights, but by not participating, and 5) stable hierarchy formed within 2 d for cows with previous social experience and within 4 d for cows with no previous experience.

Figure 3 illustrates achievement of social stability in a group of cattle, defined as when nonphysical agonistic interactions among group members predominate, and the ratio of physical to nonphysical interactions remains comparatively stable (Kondo and Hurnik, 1990). Various social behaviors and locomotor activity will return to a baseline level within 5 to 15 d following a grouping change such as regrouping or commingling (Boe and Faerevik, 2003). Essentially, this figure represents the major challenge inherent in grouping cattle. We need to manage a group of cows such that the rate of decline in physical interactions is as rapid as possible, and that the period of social stability is maximized. Realistically, animals move into and out of pens continuously on many farms, and so the challenge becomes managing the magnitude of increase in the physical interactions that accompany any regrouping and introduction of new animals into a pen. A reasonable analogy would be steady state conditions in the rumen – they are never truly achieved, just assumed.

Early tools to help with grouping decisions may assume that social stability is reached and then is maintained, but this would clearly be simplification of reality. Monitoring and then devising means to control the physical:nonphysical interaction ratio would be a valuable tool for producers and consultants. Classic data such as that reported by Krohn and Konggard (1980; cited in Grant and Albright, 2001; Table 4) provides useful information for modeling changes in resting, feeding, and other activity that occurs over time with regrouping. We need similar data from cows managed in larger groups.

A useful tool to assist with proper grouping decisions would need to consider competition for resources, stocking density, group size (and can it become too large?), group composition (especially primi- and multiparous cows commingled), and degree of commingling and movement between groups, particularly during the transition period when feeding behavior is naturally depressed. A tool that would accurately predict the net effect of these factors on the time budget, assuming deviations from a natural time budget can be related to changes in health and performance, would be a logical research goal.

Stocking Density and Behavioral Responses

Stocking density will affect the time budget of dairy cattle. To-date, few experiments have evaluated stocking density, and some were conducted using small numbers of animals per pen. Consequently, the real effect of stocking density on larger group sizes remains unknown. A key difference between small group sizes and larger (more realistic) group sizes is the amount of time that an animal will spend outside the pen for milking and other management procedures. When cows spend too much time away from the pen (basically more than 3.5 h/d), resting time will be reduced (Matzke et al., 2002). Additionally, when primi- and multiparous animals are commingled, resting time is reduced much more for the heifers than for older cows (-2.6 h/d for multiparous cows and -4.2 h/d for primiparous cows; Matzke, 2003).

Table 5 summarizes the influence of stocking density of dairy cow behavior from the few reports in the literature. Although there is clearly variation among studies, the few data reported thus far are surprisingly consistent. One point of difference is between Wierenga and Hopster (1990) and the other reports for the effect of stocking density on resting. They found relatively little impact of overstocking on resting, which differs substantially from other reports. Some tentative conclusions to draw from these studies are: 1) at 120% stocking density and beyond, resting time is reduced by 12 to 27% (may be a function of pen size with greater reduction for larger pens), 2) eating time is not affected greatly by stocking density (although meal patterns and feed intake could well be), 3) rumination may be reduced by as much as 25% at 130% stocking density, and 4) at 120% stocking density or greater, standing time will be increased by 15 to 25%. In general, the negative effect of overstocking beyond ~120% on resting and standing becomes more pronounced as the level increases, but there is insufficient data with larger group sizes to accurately model the effect at this point.

Time Budget Evaluator

Figure 4 shows the "Time Budget Evaluator" we have developed at the Miner Institute as an initial attempt at predicting the impact of management routines and stocking density on the time budget of dairy cows. The targets for resting and eating activity are based on data to-date from larger pen studies as well as more carefully controlled research with smaller group sizes. Although a range exists in measured eating time (3 to 6 h/d) we have chosen 5.5 h/d for this version, although this value can be changed by the user for any given situation. Time spent outside the pen for the milking process and any other activities may also be entered. Similar to eating time, commonly observed times for drinking and standing are incorporated into the spreadsheet, but the user may adjust these values if desired. These inputs allow calculation of time available for resting for a specific situation. This approach is simplistic because it forces the user to either measure, estimate, or accept standard values for eating, drinking, and other activities. As more research is generated, hopefully we will be able to better predict or more easily measure these inputs on-farm.

The spreadsheet also adjusts lying and standing time based on stocking density data presented in Table 5. Because there is very little data, particularly for larger group sizes, the current version of the spreadsheet simply adjusts lying and standing at 120% stocking density. This is an oversimplification of reality, but there is insufficient data to warrant a more detailed approach. The spreadsheet then subtracts the resting time available for the group from the requirement for resting for both average cows and the highest producing cows in the group (based on data by Matzke, 2003). If the difference is negative (i.e. resting time is deficient), then a predicted milk production loss is predicted using the relationship of one additional hour lying time beyond 7 h/d is associated with 1 kg/cow/d more milk (based on approach in Table 3). As previously discussed, this approach simplifies what may well be very complicated impacts on herd health into a single estimate of milk production loss. In field tests, in troubleshooting situations during the past year, the spreadsheet has proven remarkably accurate at predicting lost milk production on-farm. The final calculation of the spreadsheet simply converts the energy contained in the lost milk yield to the equivalent loss in body weight or condition score. Note that this is simply an equivalent energy calculation, and that there is no published research relating resting time directly to body condition score changes.

The Excel spreadsheet is available at the Miner Agricultural Institute web site:
http://www.whminer.com.

Summary

Considerably more research is required to develop accurate tools to evaluate management strategies to minimize negative effects on natural behaviors and time budgets. Key information would include measurement of feed intake and feeding behavior for cows that are group-housed in competitive situations. Resting and standing time play a major role in cow health and productivity and effects of management on these two variables must be understood. A simple spreadsheet is presented to assess the time budget for cows on-farm, both as a tool for cautious use and to determine areas requiring further research.

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Table 1. Daily time budget for lactating dairy cow.

Activity	Time devoted to activity per day
Eating	3 to 5 h (9 to 14 meals/d)
Lying/resting	12 to 14 h
Social interactions	2 to 3 h
Ruminating	7 to 10 h
Drinking	30 min
Outside pen (milking, travel time)	2.5 to 3.5 h

Table 2. Daily behavioral time budget for top 10% of cows by milk production and average milk production cows (h/d).[1]

Activity	Top 10%	Average
Eating at manger	5.5	5.5
Resting	14.1 [a]	11.8 [b]
Standing in alleys	1.1 [b]	2.2 [a]
Perching in stalls	0.5 [b]	1.4 [a]
Drinking	0.3	0.4

[ab]Means within a row differ ($P < 0.05$).
[1]Adapted from Matzke (2003).

Table 3. Milk responses related to increased lying time. Baseline (minimal) lying time is 7 h/d compared with recommended time of 14 h/d.

Putative benefit	Predicted milk response
Increased blood flow	0.7 to 1.0 kg/d more milk
Increased rumination (efficiency of digestion)	Up to 0.9 kg/d more milk
Less stress on hoof and lameness	1.4 kg/d more milk
Less fatigue stress	0.9 kg/d more milk
Greater feed intake	2.2 kg/d more milk

1 hour additional resting time associated with 1 kg/d more milk

Table 4. Shifting cows between groups and associated behavioral responses. [1]

Item	Day 0	Day 1	Day 6
Eating, min/d	295	271	302
Eating bouts, /d	5.2	4.6	5.2
Lying, min/d	580	336	537
Confrontations	19	163	20

[1]Krohn and Konggard (1980) cited in Grant and Albright (2001).

Table 5. Stocking density (relative to stalls) and relative behavioral responses with responses to 100% stocking density set to 1.00.

Citation	SD (%)	Resting	Eating	Ruminating	Standing
Batchelder (2000)	100		1.00	1.00	
	130		0.95	0.75	
Winkler et al. (2003)	66	1.02			0.95
	100	1.00			1.00
	150	0.88			1.22
Fregonesi et al. (2004)	100	1.00			1.00
	110	0.92			1.12
	120	0.88			1.15
	135	0.84			1.19
	150	0.80			1.25
Wierenga and Hopster (1990)	100	1.00	1.00		1.00
	125	1.00	1.04		1.25
	133	0.98	0.95		1.52
	155	0.93	1.01		1.46
Matzke and Grant (2002)	85	0.95	1.02		0.95
	100	1.00	1.00		1.00
	120	0.73	1.02		1.20

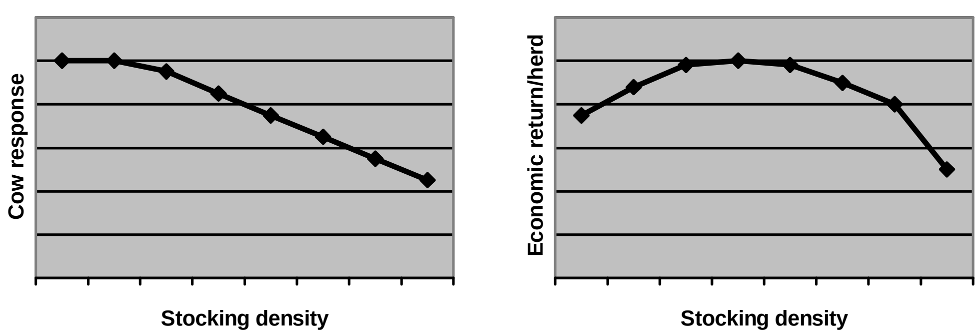

Figure 1. Stylized response to stocking density changing from under- to overstocked on an individual cow basis (a) and considering the economic impact on the herd (b).

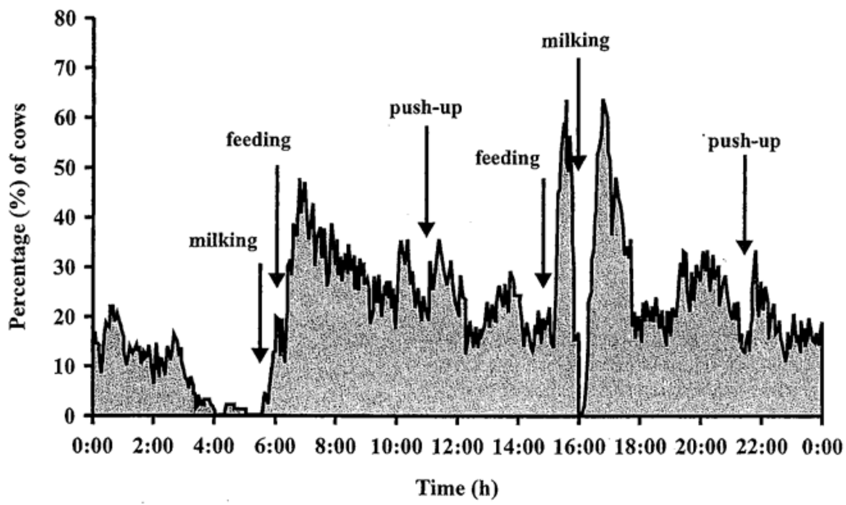

Figure 2. Dairy cow feeding activity during 24 h in a competitive environment (adapted from DeVries et al., 2003).

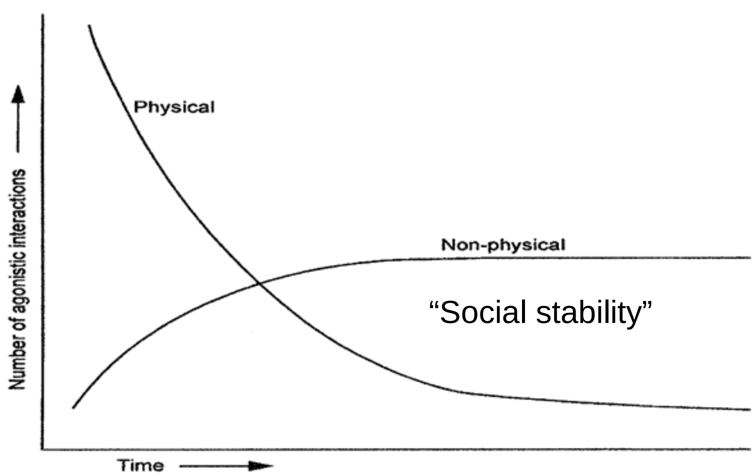

Figure 3. Agonistic interactions following regrouping in dairy cattle (adapted from Kondo and Hurnik, 1990).

TIME BUDGET EVALUATOR					
Farm Name:	A1 Dairy				
Date:	19-Feb-04				
Group of cows:	High cows				
			Time		
	Activity	Time (h)	Remaining (h)		
1. Time Away From Pen			24-h day		
	Milking[A]	3.0	21		
	Treatment[B]	0.0	21.0		
2. Behaviors in the Pen[C]				"Standard " Time for Activities (h)	
	Eating	5.5	15.5	5.5	
	Drinking	0.5	15.0	0.5	
	Standing & Other[D]	3.0	12.0	3.0	
3. Adjustment to Standing for Stocking Rate					
Enter cows in pen:	75				
Enter number of *useable* stalls:	75				
Stocking rate (%):	100%				
Adjusted standing time (h):	3		12.0	Standing time increases above 120% stock rate	
4. Resting (Lying) Time Available			12.0		
5. Adjustment to Resting (h) for Stocking Rate			12.0	Lying time reduced above 120% stocking rate	
			Average Cow	Elite Cow	
6. Resting Requirement (h/day)			12.0	14.0	"Elite" cows are top-10% by milk yield.
7. Resting Required - Resting Time Provided (h)			0.0	2.0	

Impact of Resting Activity:

	Average cow	Elite Cow	
Milk	0.0	-4.0	pounds milk/cow/day
Energy	0.00	-1.32	Mcal NEL/cow/day
Body Weight	0.00	-0.59	pounds/cow/day
Body Condition	0.00	-0.49	Score change in 100 days

[A]Enter time spent in transit to parlor, holding area, in parlor being milked, and time to travel back to pen.

[B]Time spent at management rail or elsewhere outside of pen.

[C]Enter times measured for your herd for eating and drinking, or use "standard" measures in column at right.

[D]Includes standing in alleys/stalls, grooming, fighting, estrous activity, idling, etc.

Figure 4. Excel spreadsheet “Time Budget Evaluator version 2.0” to calculate time available for resting and potential milk production loss when inadequate resting time is available or overcrowding occurs.