Stocking Density and Time Budgets

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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 can 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) for cows in a free-stall environment.

Table 1. Typical 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

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 production cows. It is interesting that these elite cows, as well as Beecher Arlinda Ellen (the first cow to produce >50,000 lb 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 all 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.

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).

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 absolute time budget need, it is easy to see how our management practices can very easily perturb the cow's normal time budget. In fact, if cows are kept outside of the pen and denied access to resources such as stalls, feed, and water for greater than approximately 3.5 h/d, then they will be forced to give up some other activity since there are only 24 hours in a day. Often, resting time or feeding time will be reduced with negative consequences for productivity and health. 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. Excessive time spent in headlocks (>1 hour/day), especially in the fresh pen, is another common way to interfere with the cow's time budget.

Natural Behavioral Needs of Dairy Cattle

Cows have a strong behavioral need to rest

Recently, Jensen et al. (2004) demonstrated that cows have a very strong motivation to rest, and that this motivation to rest increases as the length of rest deprivation becomes greater. In fact, lying behavior has a high priority for cattle after relatively short periods of lying deprivation. Cows have a definite requirement for resting (lying down) that they attempt to achieve, even if it means giving up some feeding time. A key concept is that feeding and resting behavior are linked in dairy cattle. Numerous studies show that management factors that interfere with resting inevitably reduce feeding behavior as well. A classic paper published by Metz (1985) evaluated what cows would do when access to either rest (stalls) or feed (manger) was prohibited. 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%. We have observed similar responses in dairy cows in a recent study here at Miner Institute at 130% and 145% stocking density (Hill et al., 2006).

Resting and feeding behavior are even linked during the transition period. First-calf heifers and mature cows that had greater lying and ruminating activity on days -2 and -6 prepartum also had greater feed intake and milk yield during days 1 to 14 postpartum (Daniels et al., 2003). This relationship raises an important question: how do we motivate cows to rest and ruminate during the close-up period?

Cows require 12 to 14 hours/day of rest (lying down). Benefits of resting include: potentially greater milk synthesis due to greater blood flow through the udder, greater blood flow to the gravid uterus during late lactation, increased rumination effectiveness, less stress on the hoof and less lameness, less fatigue stress, and greater feed intake. Grant (2004) has proposed that each additional one hour of resting time translates into 2 to 3.5 more pounds of milk per cow daily. Figure 1 summarizes data from experiments conducted at Miner Institute between 1998 and 2004 and illustrates the relationship between resting time and milk yield.

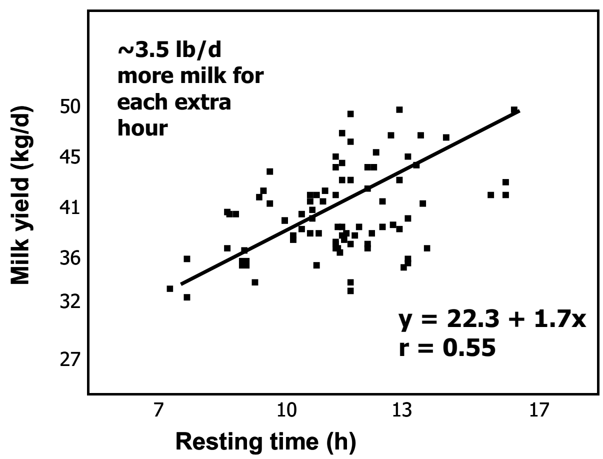

Figure 1. Relationship between resting time and milk yield in dairy cows (from Grant, 2004).

The bottom line is that lying has a higher priority than eating and social interactions for both early and late lactation dairy cows, and that cows compensate for reduced access to resting by spending less time eating to free up time for making up lost resting activity (Munksgaard et al., 2005). Interestingly, although little time is allocated to social contact with other cows, under conditions of limited access to feed and stalls, cows still defend their ability to have some social interactions – showing that they are social creatures.

Cows have a naturally aggressive feeding drive

The naturally aggressive feeding drive of lactating dairy cows was best described by Dado and Allen (1994) when they concluded that higher producing (and typically older cows) eat more feed, eat larger meals more quickly, ruminate more efficiently, and drink more water more quickly than lower producing (and typically younger cows). Some competition for feed is inevitable with dairy cows. Even with unlimited access to feed, cows interact in ways that give some cows an advantage over others (Oloffson, 1999).

A study conducted in 1998 provides the best illustration of the dairy cow's naturally aggressive feeding drive. In this study (Hansen and Pallesen, 1998) researchers measured the force applied to the feed barrier during eating. They observed that cows willingly exert greater than 500 pounds of force against the feed barrier in an attempt to reach as much feed in the bunk as possible. Pressure in excess of 225 pounds is sufficient to cause acute tissue damage – so cows will exert enough pressure to cause injury when trying to reach feed. This is perhaps the best illustration of the dairy cow's naturally aggressive feeding drive. We need to manage the feeding area and feed delivery system so that the cow does not need to exert these levels of force against the feed barrier while reaching for feed.

Grouping Strategies and Natural 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.

Achievement of social stability in a group of cattle is 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 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. An especially good example of this continuously changing group situation is the fresh pen. A reasonable analogy would be steady state conditions in the rumen – they are never truly achieved, just assumed.

Early decision-support 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 Cow Behavioral Responses

Stocking density will affect the time budget of dairy cattle. To-date, relatively few experiments have evaluated stocking density, and most 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 3 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 may 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.

Table 3. 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

Grouping of Cows and Heifers

Most of us are aware of the recommendation to group first-lactation heifers separately from mature cows. Various studies have shown that heifers housed separately have greater DMI and higher productivity than those housed in mixed groups, but why is this? Research from the 1970s showed a 10 to 15% improvement in eating and milk yield when first-calf heifers were grouped separately from older cows. There was a nearly 20% increase in resting activity when heifers were housed separately.

The common thinking is that, since heifers are smaller, they have more difficulty competing for feed. While this is often true, recent research has shown that there are actually many more differences between heifers and mature cows than we may have suspected.

For example, heifers take smaller bites and spend more time feeding than mature cows. Since mature cows are usually more dominant and can push heifers away from feeding spaces, grouping them separately may ensure that heifers have enough time to feed throughout the day. Recent Spanish work found that heifers grouped separately ruminate more and drink more. A companion study to this work published in the January issue of the *Journal of Dairy Science* (Bach et al., 2006) indicated that housing heifers separately may also provide the added benefits of increased efficiency of fat-corrected milk production and less body weight loss in the first month of lactation. The improvement in milk fat production might be associated with both the increase in rumination and greater number of meals per day observed in heifer-only groups.

Resting behavior can also be affected in mixed groups. Cows do not perceive all stalls equally. Research has shown that dominant, mature cows will lie in stalls nearest the feed manger, while heifers tend to lie in stalls along the back wall. The heifers that do lie in the stalls nearest the feed bunk ruminate less than those lying along the outside wall, perhaps indicating that they are stressed by the thought that an older cow might kick them out at any time. British researchers have also observed signs of stress exhibited by heifers in mixed groups such as more time spent fighting and grooming than heifers grouped separately.

Grouping heifers separately is particularly important in overcrowded situations. Subordinate animals are the first to be affected as stocking rates increase beyond 100%. Although we need to study it further, here at Miner Institute we recently found that increased stocking rates reduced time spent lying by heifers more than cows. It also appears that heifers decrease rumination more than cows as stocking rate increases, which complements the research mentioned earlier. If our results prove true, reduced rumination and a possible increase in feeding rate may result in acidosis. Combined with increased time spent standing, this could create a perfect storm and increase lameness in heifers just as we want them to start paying off all of the costs we just put into raising them.

We also observed a potential decrease of up to 18 pounds of milk per day for the heifers compared with the cows as the stocking rate increased to 131 and 142%. It will take a long time for a heifer to pay for herself with that extent of reduction in milk yield.

Stocking Density, Cow Behavior, and Performance during Transition Period

Research published during the past years illustrates the importance of creating the right environment for the transition cows in order to motivate them to be productive and healthy herd members. Major factors to consider are the natural behavioral patterns of transition cows, stocking rate, and grouping strategy of the close-up and fresh cow pens. Feeding, resting, and ruminating activity all decrease, and standing time increases, right at parturition. Also, we need to focus on the time spent managing transition cows. That time typically increases from virtually none to as much as several hours after calving. We need to keep in mind that cows cannot be out of their pens and away from their resources for more than 3.5 h/d or else they will be forced to take time out of required activities such as resting or eating.

Researchers at the University of Wisconsin Veterinary School evaluated the effect of overcrowding on the prefresh, close-up pen. In their study, the pens contained both first-calf heifers and older cows. When stocking density was greater than 80% of stalls in the prefresh group of mixed cows and heifers, milk yield was reduced for the heifers during the first 83 days in milk following calving. In fact, for each 10% increase in prefresh stocking density above 80%, there was a 1.6-pound per day reduction in milk yield for the first-calf heifers. These data need to be compared with older research that evaluated the impact of headlock stocking density on feed intake during the close-up period. In this study, feed intake was markedly reduced at any manger stocking density greater than 90%.

Also, on-farm observations from Idaho showed a strong negative relationship between headlock stocking density in the close-up pen and incidence of abomasal displacements after calving (Kluth, 2005, personal communication). Whenever headlock stocking density was greater than 90%, then the incidence of DA’s went up sharply. Clearly, the take-home message of this research is that stocking density greater than 80 to 90% in the prefresh or close-up pen will result in lost milk production and greater fresh-cow health problems.

In the fresh-cow pen, there is less research, but still an indication that stocking densities less than 100% for both stalls and manger space will result in better feed intake, milk yield, and fewer health problems. Also, keeping first-calf heifers grouped separately from older cows in both the prefresh and postfresh pens will help to ensure better health and productivity of the first-lactation animals.

For cows beyond the fresh group, there is not as much information, but the data definitely show that beyond 120% overstocking of stalls that resting behavior usually drops off substantially. No doubt, there is considerable variability among farms, but if we are stocking are pens beyond 120%, then red flags need to be raised that a problem is much more likely.

For the transition period, monitoring milk yield can be a useful indicator of the overall effectiveness of the management system. Useful targets for both first-calf and mature cows for milk yield are:

- First lactation animals: target would be to observe an 8% increase in milk per day for the first 18 days of lactation. A problem exists if there is no increase in milk or milk yield is less than 65 pounds per day at 30 days in milk.
- For second and greater lactation animals, there should be a 10% increase in milk yield per day during the first 14 days of lactation. A problem exists if there is no increase in milk yield or if milk production is less than 85 pounds per day at 30 days in milk.

The bottom line is that stocking density of the transition pens is a key part of the management strategy. We have suspected this for a long while and now we have good evidence that we lose milk and suffer more health problems when we overstock the close-up and fresh cow pens. In fact, even 100% stocking rate is too high!

Recent Research on Stocking Density at Miner Institute

Recently, we summarized all of the research that related stocking density with resting activity (Grant, 2004). As you can see, there is considerable variation in cow response to stocking rate, but it appears that things become interesting above 120% stocking rate. These studies show that eating time is not influenced by stocking rate (although eating rate surely can be affected) and rumination decreased by 25% at 130% stocking rate versus 100%. It is important to remember that our goal is not to achieve zero competition. In fact, some competition is inevitable. Even with unlimited access to feed, for instance, cows will interact in ways that give some an advantage over others (Oloffson, 1999).

We have just finished a study at Miner Institute that evaluated the effect of 100, 115, 130, or 145% stocking density of stalls and manger space on production and behavior. The various stocking densities were obtained by chaining off stalls or closing headlocks. So, alley space remained constant which may have softened the effect of overstocking that we observed.

Overall, we observed that lying time was reduced by 1.1 hours/day when stocking density increased from 100 to 145%. At the same time, milk yield dropped numerically from 94.6 to 91.3 pounds/day. Interestingly, this 3.3 lb/day difference in milk yield agreed well with a large data set that we had pulled together last year from behavior research here at Miner where found that each one-hour change in resting time was associated with a 3.5 pound/day change in milk yield. Of course, it could all be coincidence, but I really believe that the relationship between resting and milk yield is real.

As stocking rate increased, standing time in the alleys increased and time spent ruminating while lying decreased. Interestingly, total feeding time was unaffected and averaged about 5 hours/day. What we couldn't measure in our study was rate of eating, and I suspect that this increased as stocking rate increased.

Things became even more interesting when we looked at the differential response of first-lactation versus older cows and lame versus sound cows. As stocking density increased, the difference in milk yield between younger and older cows grew from 6 pounds/day at 100% stocking rate up to nearly 15 pounds/day at higher stocking rates.

As stocking rate increased, the milk yield of lame cows was markedly reduced compared with sound cows. From 100% up to 130% stocking rate, the difference between sound and lame cows in milk yield increased by 26 pounds/day. At 145% stocking rate, the difference between sound and lame cows narrowed because the milk yield of sound cows suffered at this higher degree of stocking. As stocking rate increased to 145%, lying time of lame cows was reduced by one hour and ruminating time was reduced by nearly one hour as well.

With some assumptions and measures from our Institute herd, I made a rough calculation of margin per cow based on the results observed in this study. Even though they are tentative, the calculations point out an interesting trend which I believe would track well with the real-world situation. The margin per cow was similar between 100 and 115% stocking rate (actually it was very slightly greater at 115%), it dropped off substantially at 130%, and really nosedived at 145%. Obviously, this response will differ by farm and the management practices employed. But, these data do agree extremely well with the handful of reported studies that indicate that things become interesting somewhere around 120% stocking rate.

Time Budget Evaluator

We have developed a "Time Budget Evaluator" at 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 3. 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 2 lb/cow/d more milk. 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 several years, 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. At the bottom of the spreadsheet, there are calculations of potential losses in milk yield for first-calf heifers and lame cows in mixed groups based on the results of our overcrowding study discussed earlier.

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

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.

Selected References

Albright, J. L. 1993. Feeding behavior in dairy cattle. J. Dairy Sci. 76:485.

Bach, A., C. Iglesias, and I. Busto. 2006. A computerized system for monitoring feeding behavior and individual feed intake of dairy cattle in loose-housed conditions. J. Dairy Sci. 87:358(Abstr.)

Batchelder, T. L. 2000. The impact of head gates and overcrowding on production and behavior patterns of lactating dairy cows. In Dairy Housing and Equipment Systems. Managing and Planning or Profitability. Natural Resource, Agriculture, and Engineering Service Publ. 129. Camp Hill, PA.

Boe, K. E., and G Faerevik. 2003. Grouping and social preferences in calves, heifers, and cows. Appl. Anim. Behav. Sci. 80:175-190.

Dado, R. G., and M. S. Allen. 1994. Variation in and relationships among feeding, chewing, and drinking variables for lactating dairy cows. J. Dairy Sci. 77:132-144.

DeVries, T. J., M.A.G. von Keyserlingk, and D. M. Weary. 2004. Effect of feeding space on the inter-cow distance, aggression, and feeding behavior of free-stall housed dairy cows. J. Dairy Sci.

87:1432-1438.

DeVries, T. J., M.A.G. von Keyserlingk, and K. A. Beauchemin. 2003. Diurnal feeding pattern of lactating dairy cows. J. Dairy Sci. 86:4079-4082.

Grant, R. J. 1999. Management eye on the cow: Taking advantage of cow behavior. Page 39 in Proc. Tri-State Dairy Management Conference. November 10-11, Fort Wayne, IN.

Grant, R. J. 2003. Taking advantage of dairy cow behavior: cost of ignoring time budgets. In Proc. 2003 Cornell Nutr. Conf. For Feed Manufac. October 21-23. Cornell University. Wyndham Syracuse Hotel. Syracuse, NY.

Grant, R. J., and J. L. Albright. 2000. Feeding behaviour. In Farm Animal Metabolism and Nutrition. J.P.F. D'Mello, ed. CABI Publishing. New York, NY.

Grant, R. J., and J. L. Albright. 2001. Effect of animal grouping on feeding behavior and intake of dairy cattle. J. Dairy Sci. 84:E156-E163.

Kondo, S., and J. F. Hurnik. 1990. Stabilization of social hierarchy in dairy cows. Appl. Anim. Behav. Sci. 27:287-297.

Kondo, S., J. Sekine, M. Okubo, and Y. Asahida. 1989. The effect of group size and space allowance on the agonistic and spacing behavior of cattle. Appl. Anim. Behav. Sci. 24:127-135.

Matzke, W. C. 2003. Behavior of large groups of lactating dairy cattle housed in a free stall barn. M.S. Thesis. Univ. of Nebraska, Lincoln.

Matzke, W. C., and R. J. Grant. 2002. Behavior of primi- and multiparous lactating dairy cattle in commingled groups. J. Dairy Sci. 85:372(Abstr.)

Metz, J.H.M. 1985. The reaction of cows to short-term deprivation of lying. Appl. Anim. Behav. Sci. 13:310.

Olofsson, J. 1999. Competition for total mixed diets fed for ad libitum intake using one or four cows per feeding station. J. Dairy Sci. 82:69-79.