

Time Budgets for Dairy Cows: How Does Cow Comfort Influence Health, Reproduction and Productivity?

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1. Introduction

As soon as we choose to house cattle rather than manage them at pasture, we are making a conscious decision to modify their behavior. Although the pastoral image of cows grazing lush green pastures promotes an ideal image for the dairy industry, oft used and misused by the industry to market its product, there are very good reasons for housing cattle. Heat stress from lack of shade, hunger due to lack of sufficient grazing, exposure to driving rain, snow and freezing cold weather and control of parasitism are all excellent reasons to develop a housing environment where we are better able to shelter the cow.

Dairy cow housing may take the form of a tiestall, freestall, or a bedded pack, but in this examination of the effect of cow comfort on health, reproduction and productivity I will focus on the freestall, which has emerged as the dominant housing system in many different climates around the world. Life in a freestall environment presents the cow with many challenges and I will examine the stresses on the dairy cow's time budget as a way of understanding the impact of poor cow comfort.

2. Time Budgets

The dairy cow is a workaholic. She spends much of her life operating at three times the energy cost of maintenance – something humans only approach while performing strenuous physical activities on a par with jogging six or more hours a day or competing in the Tour de France – and the dairy cow accomplishes this for a lifetime (Webster, 1993). So, if our cows make Lance Armstrong look like a 'couch potato', it seems reasonable to examine her daily requirement for food and rest, so that we can make sure we are providing for her needs to accomplish her goals.

From an analysis of 250 total 24-hour time budgets, we have collected from 208 cows housed in 17 freestall barns in Wisconsin, the average time spent performing each of five key behaviors is shown in Table 1.

Certain components of the cow's day are fixed and non-negotiable. The cow has to spend a large proportion of the day eating to fuel the large fermentation vat that she has to carry around with her. The TMR fed, freestall housed dairy cow eats for an average of 4.4 h/d (range 1.4-8.1). Note that this is about half the time that a grazing cow spends eating per day – pasture cows average around 8-9 h/d eating. She also needs to drink around 25 gallons of water per day (more in hot climates) and she will spend an average of 0.4 h/d at or around a waterer. Milking time is usually spent outside the resting area in all but tiestall herds, and in 17 Wisconsin herds milking 2-3 times a day, the average cow spent 2.6 h/d out of the pen milking, with a wide range from 0.9-5.7 h/d. With these fixed non-negotiable time slots, we have already taken $4.4 + 0.4 + 2.6 = 7.4$ hours out of the time budget, leaving under 17 hours remaining in the pen.

Table 1. The mean (range) 24-h time budgets for 208 cows filmed over 250 filming periods on 17 freestall barns in Wisconsin

Time left in the pen will be spent performing three activities – lying down, standing in an alley and standing in a stall. The average freestall cow spends 2.4 h/d standing in an alley socializing, moving between the feed bunk and stalls and returning from the parlor. Once in the stall, the average cow spends 2.9 h/d standing in the stall (range 0.3-13.0) and 11.3 h/d lying in the stall (range 2.8-17.6) on average – but note the wide ranges in these behaviors. We have determined that normal non-lame cows rarely spend longer than 2 h/d standing in a stall (Cook et al., 2004).

Lying behavior is typically divided into an average of 7.2 visits to a stall each day (called a lying session), and each session is categorized by periods standing and lying – called bouts. The average cow has 13.6 lying bouts

per day and the average duration of each bout is 1.2 h (range 0.3-2.9). Most cows will stand after a lying bout, defecate or urinate, and lie back down again on the contra-lateral side.

3. What constitutes a minimum rest period for a dairy cow each day?

From studies designed to make cattle work for access to a place to rest, it would appear that cows target around 12 h/d target lying time (Jensen et al., 2005; Munksgaard et al., 2005), and this is in agreement with the lying times found in well designed freestall facilities (Cook et al., 2004). It should be noted that this exceeds the reported lying times of cows at pasture of 9-11 h/d (Phillips and Rind, 2001; Tucker et al., 2007).

It is commonly suggested that cow's make more milk when they are lying down as blood flow through the external pudic artery increases by around 24-28% when lying compared to standing up (Metcalfe et al., 1992; Rulquin and Caudal, 1992), and failure to achieve adequate rest has negative impacts on lameness (Cook and Nordlund, In press), ACTH concentrations (Munksgaard and Simonsen, 1996), cortisol response to ACTH challenge (Munksgaard et al., 1999) and growth hormone concentrations (Munksgaard and Løvendahl, 1993; Ingvarsen et al., 1999) – suggesting that there is a significant stress response.

Some workers have suggested that there is a linear relationship between time lying and milk production of the order of 2-3.5 lbs of milk increase for each additional hour of rest (Grant, 2004). While this may be true, we have not seen such a relationship and milk yield has not been significant in any of the lying time models in our time budget studies (Figure 1).

Figure 1. Association between last recorded DHIA milk yield (lbs) and daily lying time (h/d) for 250 time budgets from 208 cows in 17 herds.

It seems more likely that the requirement for rest is a threshold event and that all cows, regardless of yield, require a minimum period, which in a freestall environment, I suggest is around 12 h/d. Note that this is longer than the lying times observed in grazing cattle, when the majority of standing time is spent on dirt rather than concrete. Factors which challenge the cow's time budget will impact the time available for rest, and the common challenges that we present cows with on a daily basis include:

1. Prolonged time spent milking
2. Competition for stalls due to overstocking
3. Poor stall design
4. Inadequate heat abatement
5. Excessive time spent in lock-ups

Therefore, to understand the impact of poor cow comfort on dairy cow health and productivity, let us examine the potential impact of each of these challenges.

3.1. Prolonged time spent milking

If we use 12 h/d as the 'required time for lying' as our starting point, and re-examine the time budget by subtracting time feeding and drinking in addition to what we view as 'normal' times standing in the alley and time standing in the stall, we find that the time available for milking is $24 - (12 + 4.4 + 0.4 + 2.4 + 2) = 2.8$ h/d.

From a facility design perspective, this means that herds that wish to milk 3 times a day must limit time out of the pen to 56 minutes each milking. If cows walk at around 3 feet per second at best, factoring in other delays, total travel time to and from the milking center would be a minimum of 5 minutes or so, leaving around 50 minutes for milking.

The most efficient parlors currently achieve a rate of milking that approaches 4.5 turns per hour (one turn being the time taken to fill and empty a row of milking stalls), and obviously the longer the row of stalls, the greater the throughput in terms of cows milked per hour. Each turn takes 13.3 minutes to milk at 4.5 per hour, so the actual number of turns milked in 50 minutes (our maximum allowable milking duration for all of the cows in a pen) would be 3.8. The maximum group sizes therefore range from around 60 cows up to 228 cows across the range of parlor

sizes typically constructed in North America. Unfortunately, pens are sized based on turn time alone and they are often overstocked. It is therefore not uncommon to find time out of the pen exceeding 5 h/d in many dairy herds. In this scenario, the dairy cow simply has no other option but to reduce resting time. It is perhaps not surprising then that time out of the pen milking was a significant factor for increased lameness prevalence in a recent survey of free stall herds (Espejo and Endres, 2007), and we have found a relationship between time spent in the holding area and cow body temperature in the summer (Scheffers, 2008).

Table 2. Target group size based on minimizing time out of the pen milking to 2.8 h/d in 3X milking herds.

Time out of the pen milking is not only a function of parlor throughput, but also distance traveled from the pen to the parlor and back again. In our current estimate, we are allowing 5 minutes for transfer time to and from the parlor back to the pen. A 5,000 cow dairy, with a group size of 208 cows would have 24 milking pens. Typically, we build facilities with four pens per barn, one in each quadrant, with the pens emptying in the middle, so this facility would have 6 barns, each at least 100 feet wide, spaced with a gap between buildings of 1.5 building widths, or 150 feet. Now we have a situation where many cows must walk 800 feet per milking or 0.45 miles a day to and from the milking center. It is not surprising therefore to see the emergence of thin soles and associated lameness as a result of this increased requirement for traffic on hard wearing surfaces (Shearer et al., 2006). Lame cows do not travel as quickly as non-lame cows – so transit time increases, which leads to increased time out of the pen.

While it is possible to reduce wear rates with the use of rubber walking surfaces, which may help alleviate some of the lameness problems (Vokey et al., 2001), others have reported that excessive walking is a stress in itself, affecting production and udder health (Coulon et al., 1998). VanBaale et al. (2005) failed to identify an expected increase in milk production in a frequently milked fresh cow group in a large commercial dairy in Arizona, citing transfer time and distance from the parlor (285 feet) as a potential reason for the failure.

3.2. Competition for stalls due to overstocking

Studies monitoring overstocking in small groups of cows under tightly controlled situations suggest that overstocking does decrease lying time (Friend et al., 1977; Fregonesi et al., 2007). However, for lying times to drop below the target of 12 h/d, most of these studies find that stocking rates in excess of around 1.2 cows per stall are required, and much greater overstocking is required to see impact on milk yield and health indicators such as lameness (Leonard et al., 1996).

This observation makes sense because each cow is trying to find 12 hours of stall occupancy per day during a pen stay duration that is usually around 21 h/d – so this allows for a degree of time and space sharing. Of course, these studies fail to recreate the challenges faced by dairy cows on commercial herds each and every day – pen moves, social changes, time spent in lock up, delays in feed delivery etc., all of which influence the time budget for each cow and I would argue that for transition cows we need to supply one usable stall per cow. However, I will concede that cows with fewer daily stresses, such as pregnant or late lactation cows, may tolerate overstocking up to around 1.2 cows per stall.

Recently, we have started to identify the effects of breeding pen stocking density on breeding efficiency. Caraviello et al. (2006) identified bunk space in the breeding pen as the root node in a decision tree analysis of pregnancy status by 150 DIM, with a significant negative impact below 14 inches per cow. More recently, we have identified stocking density of breeding or high group pens as a significant negative influence on overall herd average conception rate and in a comparison of spring and summer performance in a risk factor analysis of 108 Alta Advantage herds (Scheffers, 2008).

There is also the issue of what constitutes a ‘usable stall’. Just because we build and provide a stall for a cow, it does not mean that all stalls are treated equally and used identical to one another. The ‘effective stall stocking density’ may be quite different in a situation with large mature Holstein cows occupying small 45” wide stalls in contrast to a situation with larger more appropriately sized stalls. For that reason, stalls should be sized appropriately to the size of the cows occupying them.

3.3. Poor stall design

Stalls must be designed to meet the requirement of each cow to obtain at least 12 h/d of rest, but designs which fail to provide for the movements of lying and rising, adequate resting space, or a cushioned surface will tend to reduce lying behavior to less than 10 h/d. In one study, free stalls with a concrete surface and a restrictive divider design resulted in reduced lying time, increased periods spent perching (standing half in and half out of the stall) and an increased rate of clinical lameness in heifers two months after calving compared with heifers kept in a stall with greater surface cushion and a less restrictive divider design (Leonard et al., 1994).

We have found that the main factor determining whether a cow spends time standing or lying down in the stall is lameness, and surface cushion and traction is the key determinant of the success of a stall surface. When cows with sore feet have to rise or lie down on a firm unyielding surface, such as a mat or a poorly cushioned mattress, the pain associated with the process leads to increased time spent standing in the stall between lying bouts, fewer lying sessions per day and a decrease in lying time (Cook et al., 2004; Cook et al., In Press). Thus, poor stall designs lead to lower lying times and increased risk for lameness, and cows once they become lame behave different to non-lame cows in the same stall design, leading to even lower resting times! Sand, because of its ability to supply traction and support to the weight bearing limb during rising and lying movements is an optimal surface for both non-lame and lame cows alike and results in short stall standing times, typically less than 2 h/d. It remains to be seen whether other deep loose bedding materials such as chopped straw, sawdust or composted manure solids behave in the same way, but it seems logical to expect that these materials would be more similar to deep sand than to a firm mat or mattress. However, until proof is obtained, sand remains the gold standard for stall base, with less risk for udder health issues than the other materials.

In numerous barn remodels, converting mattress barns into sand bedded barns, we have typically seen increases in milk production of the order of 1,000 to 4,000 lbs of milk per cow per lactation, with an average of around 2,000 lbs after about 1-2 years. We believe that this increase comes from a reduction in herd turnover rate due to improved lameness control, and the retention of older healthier cows in the herd. This leads to a re-stratification of the herd by age group and an increase in milk shipped per cow per day.

3.4. Inadequate Heat Abatement

Thermal comfort and good air quality are very important for the health and well-being of the dairy cow. In general, the dairy cow is far more tolerant of cold than she is of heat stress. Once core body temperature reaches approximately 102 °F, mature Holstein cattle seek shade and stand rather than lie down (Lee and Hillman, 2007). Between four daily milking sessions that had a mean daily average temperature humidity index (THI) of between 56 and 74 in a mattress free stall barn fitted with feed bunk soakers and fans, we observed a 3 h/d increase in standing time between the coolest session and the hottest session (Cook et al., 2007). This increase was almost entirely due to an increase in time standing in the alley under fans and soakers. These data, together with an increased susceptibility to sub acute ruminal acidosis could explain the increase in claw horn lesion development observed in the period from September to November in many North American dairy herds.

In a recent survey of 29 freestall barns in the Upper Mid-West and California (Scheffers, 2008), we found that the most important factors for cooling the cow, lowering humidity in the barn and improving conception rates in the summer were:

- Orienting naturally ventilated barns from East to West rather than North to South
- Lowering stocking density in the breeding pen
- Providing sufficient fan capacity in the holding area (~1000 CFM per cow)
- Reducing time spent in the holding area and the parlor
- Providing fans over the resting area
- Utilizing soakers in the holding area

These six points provide our critical control points for heat abatement and good results can be achieved in naturally ventilated barns, located so as to capture prevailing winds in the summer. Barns may also be ventilated mechanically with either tunnel or cross ventilation and these provide an option for housing where natural ventilation is not viable.

3.5. Excessive Time Spent In Lock-Up

Excessive time spent locked up at the feed bunk may have a detrimental effect on daily time budgets. While cows are quite capable of compensating for a 1-2 hour change in routine, if lock up is prolonged and in association with other stressors – such as overstocking, then the ability of the cow to compensate and ‘catch-up’ on lying time may be exceeded. It is perhaps unfortunate that the cows we most commonly lock up for long periods are the fresh cows, immediately post-partum, at a time when they are most susceptible to changes in total daily standing time.

In large dairy herds, in order to monitor sick cows, we typically group the high risk animals in a single fresh cow group for a period of 14-21 days after calving, so that they can be monitored closely. So, how long is it acceptable to have cows locked up for while this check takes place?

Let us return to the time budget and now start with milking time at 2.8 h/d. Time left in the pen after resting for 12 h/d and standing in the stall for 2 h/d is 7.2 h/d. Time spent in lock up must compete with time standing in the alley, time feeding and time drinking. Cows may also eat while they are locked up at the feed bunk, but peak feeding activity after delivery of fresh TMR typically lasts no longer than 45 to 90 minutes before cows lie down and rest (Mentink and Cook, 2006). Locking cows up for 2 h/d would mean that time available in the alley would be reduced, and it is feasible that cows would make this choice. However, it is likely that lock up time exceeding 2 h/d cannot be compensated for as it is unlikely that a cow will willfully spend zero hours standing in the alley. Indeed, although the lock up time employed by Cooper et al., (2007) did not coincide with at least some feeding time, they did show that when cows were deprived of lying for 2-4 h/d, they only managed to recover approximately 40% of the lost lying time by 40 hours after the deprivation. These findings point to a maximum allowable lock up time of around 2 h/d, assuming that at least 1 hour of this coincides with fresh feed delivery, if we are not to erode the time available to the cow for rest.

4. Conclusions

There is reasonable evidence to suggest that cows housed in freestall facilities on concrete floors require a minimum of 12 h/d of rest in a comfortable stall. When their time budget is challenged through increased time out of the pen milking, overstocking, poor stall design, heat stress and prolonged time spent in lock-ups, the primary outcome is increased lameness. Using the example of improving the comfort of facilities through the use of sand bedding for example, the main benefits are accrued through a reduction in lame cows, improvements in herd turnover rate and retention of older, fitter mature cows in the herd. These benefits typically result in 2,000 lbs of milk per cow over 1-2 years.

While the impact of cow comfort on reproductive performance has not been fully quantified, the reduction in lameness is one potential mechanism. Recent multi-risk factor analyses have also highlighted the negative association between breeding pen stocking density and breeding efficiency, highlighting the importance of cow comfort which up until recently has not been given the attention it deserves.

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Table 1. The mean (range) 24-h time budgets for 208 cows filmed over 250 filming periods on 17 freestall barns in Wisconsin

N=250	Mean	Range
Parity	2.7	1-10
Milk Yield (lbs)	91	24-160
Days in milk	158	7-541
Locomotion Score (1-4)	1.7	1-3
Time lying down in the stall	11.3	2.8-17.6
Time standing in the stall	2.9	0.3-13.0
Time standing in the alley	2.4	0.2-9.4
Time drinking	0.4	0-2.0
Time feeding	4.4	1.4-8.1
Time milking	2.6	0.9-5.7

Figure 1. Association between last recorded DHIA milk yield (lbs) and daily lying time (h/d) for 250 time budgets from 208 cows in 17 herds.

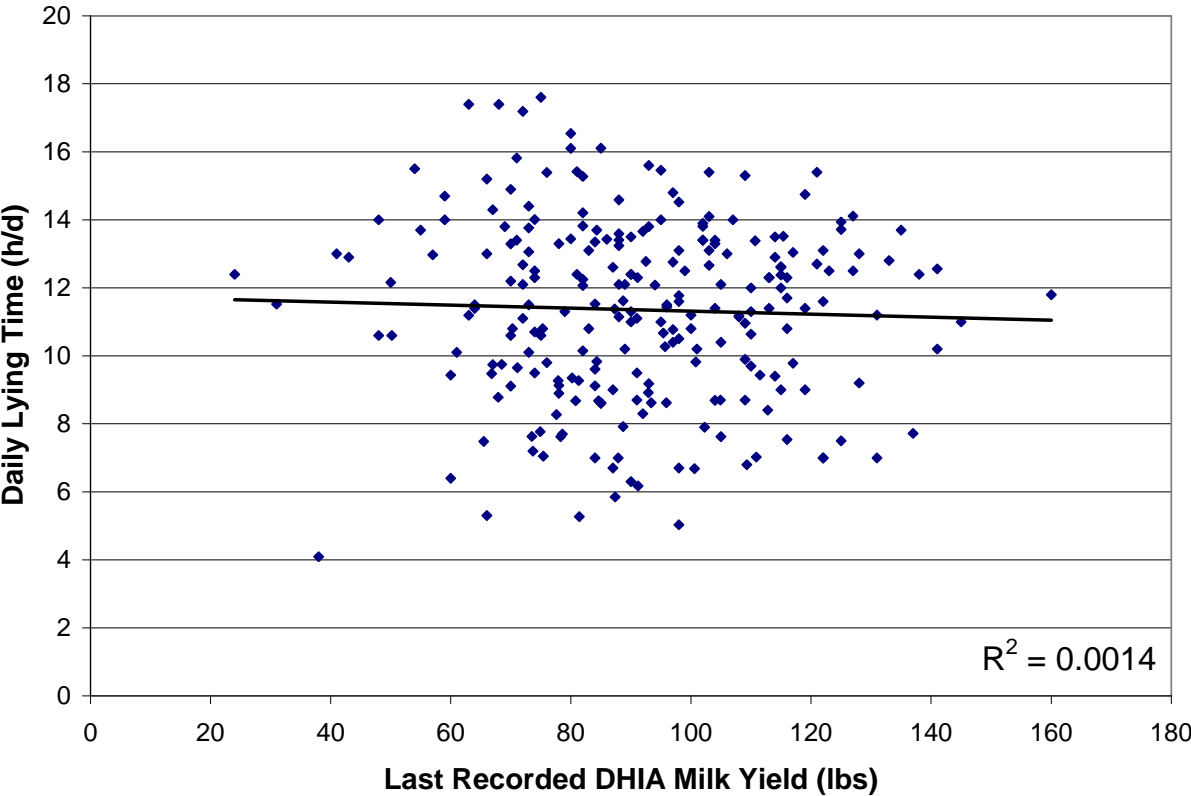


Table 2. Target group size based on minimizing time out of the pen milking to 2.8 h/d in 3X milking herds.

Parlor Size	Double 8	Double 12	Double 16	Double 20	Double 30
Maximum group size = Cows milked in 3.8 turns	61	91	122	152	228