Technical Note: Validation of a System for Monitoring Feeding Behavior of Dairy Cows

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ABSTRACT

An electronic system has been designed that allows for passive monitoring of feeding behavior of individual cows housed in a free-stall barn. The objective of this study was to validate the data generated by this GrowSafe feed alley monitoring system. Twelve lactating cows were each monitored for 24 h using both the GrowSafe system and time-lapse video. The GrowSafe estimation of number of meals consumed by each cow showed perfect agreement with meal frequency identified using the video recordings. The duration of these meals, as estimated by GrowSafe, was highly correlated with the meal duration derived from the video ($R^2 = 0.98$). Despite the excellent agreement for these meal-based measures, for each cow we found some instances in which the video showed that a cow was present at the feed alley but GrowSafe failed to detect cow presence (12.6% of observations) and a few instances in which the reverse was true (3.5% of observations). However, all the missed or extraneous data from the GrowSafe system were closely associated in time with known periods of feeding. These results indicate that this feed alley monitoring system can provide very good measures of meal frequency and meal duration and reasonable estimates of instantaneous feed alley attendance for loose-housed dairy cattle.

(Key words: feeding behavior, dairy cow, validation)

The time spent eating, and the pattern of meals, can obviously have important effects on total daily intake of dairy cattle (Grant and Albright, 2000). For that reason, a great deal of recent research in dairy nutrition and management has focused not only on changes in intake, but also on changes in feeding behavior. Over the past few decades, management of North American dairy farms has moved from tie stalls to loose housing

systems such as free stalls. This move to loose housing has made the collection of feeding behavior data more difficult. Traditionally, feeding behavior of loose-housed cows was monitored through direct human observation, but this method is labor intensive, making observations on multiple animals and days difficult. The use of time-lapse video recordings (Friend et al., 1977; Vasilatos and Wangsness, 1980) increases the ability to monitor many animals for multiple days; however, transcription of these videos is also labor intensive.

With the introduction of various individual intake monitoring systems, researchers (e.g., Tolkamp et al., 2000) have collected continuous feeding behavior data for loose-housed cows. However, cows using these systems are required to access feed via an electronic gate, potentially changing feeding behavior compared to that in commercial loose-housed systems. Access to feed via a specific feeding station may also reduce the number of competitive interactions that occur during feeding compared with feeding from an open feed alley like that used on commercial loose-housed farms.

Radio frequency has been employed for many years as a means of electronically identifying cows (Erasmus and Jansen, 1999). Recently, a radio frequency electronic monitoring system (GrowSafe Systems Ltd., Airdrie, AB, Canada) has been designed that allows for the passive monitoring of individual cow presence at the feed alley. The system was originally described by Sowell et al. (1998) and validated by Schwartzkopf-Genswein et al. (1999) for the monitoring of feeding behavior of feedlot cattle, but this technology has not been validated for measuring feeding behavior of loose-housed dairy cattle fed via a feed alley. The objective of this study was to validate the measures generated by the GrowSafe system, by comparing these estimates with measures from time-lapse video recordings.

Two groups of six lactating Holstein cows were monitored continuously for 24 h using the GrowSafe feed alley monitoring system and time-lapse video. The cows were housed in adjacent pens in a free-stall barn located at The University of British Columbia Dairy Education and Research Centre (Agassiz, BC, Canada) and were

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managed according to the guidelines set by the Canadian Council on Animal Care (1993). Each animal had access to a sand-bedded free stall. Cows were fed a TMR (30% corn silage, 8% grass silage, 4% alfalfa hay, 5% third-cut grass hay, 16% steam-rolled corn, and 37% concentrate mash on a DM basis) from a feed alley (0.6 m of space/cow) with access via a neck rail. Animals were fed daily at approximately 0600 and 1600 h and were milked at approximately 0600 and 1700 h daily.

The GrowSafe system was modified from that previously described (Schwartzkopf-Genswein et al., 1999), so that data transfer from the reader panel to the computer occurred via radio frequency. The antenna mats (each 7.2 m long and 0.75 m wide) used to detect transponders were laid on the floor of the feed alley adjacent to the tombstone with feed delivered on top of the mats. All animals were fitted with a passive transponder, which was encased in a plastic ear tag (All Flex, Inc., Dallas, TX) and attached to the bottom of the neck collar. The system was designed to detect the transponder when within 50 cm of the antenna mat, such as when a cow placed her head under the neck rail and over the feed. This system worked by scanning set locations along the mat each at 6-s intervals. Whenever a transponder was within range, the reader panel recorded presence (a 'hit') of the transponder including time and location on the mat. These data (transponder number and time stamp) were downloaded continuously via radio frequency to a computer housed approximately 100 m from the panel. The computer was equipped with GrowSafe feed alley monitoring software version 6.38.

A video camera (Panasonic WV-BP330; Osaka, Japan) was positioned approximately 6 m above the feed alley of each experimental pen. Output from the cameras was recorded with a time-lapse video recorder (Panasonic AG-6540) in 48-h mode and a digital video multiplexer (Panasonic WJ-FS216). The clocks on the video recorder and the computer collecting the GrowSafe data were synchronized at the outset of the experiment. Red lights (100 W) were hung 6 m above the feed alley to facilitate video recording at night. Cows were individually identified with symbols on both sides of their body using hair dye. Cows were scored as present at the feed alley when the neck collar passed over the tombstone and above the feeding surface.

Raw data were summarized for each cow and for each minute of the day ($n = 1440$), recording cow presence (1) or absence (0) at the feed alley as determined by both the GrowSafe system and video.

Meal-based estimates of feeding behavior rely on the use of a meal criterion, which is the minimum time interval between visits to consider the next feed alley visit as being part of a new meal. A meal criterion of 27.74 min was used following DeVries et al. (accepted).

This criterion was used to calculate meal frequency (meals d^{-1}) by counting the number of intervals between visits to the feed alley that exceeded the criterion and adding one. Meal duration (min meal $^{-1}$) was calculated as the time from the first visit until, but not including, an interval between visits that exceeded the criterion.

We regressed (SAS, 1985) measures of behavior generated by GrowSafe (dependent variables) onto those from video (independent variables), testing for slope and intercept effects. Comparisons between the video and GrowSafe animal presence data within cows were performed by chi-square 2×2 contingency tables (presence and absence at each minute, as determined by GrowSafe and video). These data were also used to calculate predictability (likelihood that a cow detected by GrowSafe is actually present at the feed alley), sensitivity (likelihood that a cow present at the feed alley is detected present by GrowSafe), and specificity (likelihood that a cow that is absent from the feed alley is detected as absent by GrowSafe) estimates according to Martin et al. (1987).

The GrowSafe monitoring system provided estimates of feeding behavior that were very similar to that observed from video. Meal durations ranged from 31.72 to 57.49 min meal $^{-1}$ for the GrowSafe data and 33.42 to 58.37 min meal $^{-1}$ for the video data. Meal frequency ranged from 5 to 10 meals d^{-1} for both the GrowSafe and video data. The line equations and coefficients of determination were calculated for meal duration ($y = 0.96x + 0.63$, $r^2 = 0.98$) and for meal frequency ($y = x$, $r^2 = 1$). In both cases the coefficients were significant ($P < 0.001$), but the intercept did not differ from zero and the slope did not differ from one ($P > 0.3$).

In the previous validation work with this system using beef feedlot cattle, researchers found that the GrowSafe data for meal frequency and meal duration were overestimated compared with that found from video analysis (Schwartzkopf-Genswein et al., 1999). However, these researchers used a short meal criterion (85 s) that had not been established objectively. The use of an objectively calculated meal criterion (Tolkamp et al., 2000; DeVries et al., 2003) likely results in a more biologically relevant estimate of meal measures. In the current study we used an objectively defined meal criterion and found a very good agreement between the GrowSafe meal measures and those from video.

The monitoring system records presence of individual cows at the feed alley. Recent work with the GrowSafe system in a free-stall dairy barn has shown that the most repeatable measures across time were based on the number of hits (measure of presence) at the feed alley: a measure that does not rely on a meal criterion (DeVries et al., 2003). However, prior to the current study, there has been no published work to validate the

Figure 1. Feed alley presence data for 24 h, for two cows, collected using time-lapse video surveillance and the GrowSafe system. The two cows illustrate the best (cow 7) and worst (cow 9) correlations for the comparison between the two collection methods.

GrowSafe system's ability to monitor animal presence at the feed alley. Figure 1 illustrates the agreement of estimates of animal presence as collected by both GrowSafe and video. For all 12 cows there was a high correlation (Table 1) between the two methods in detecting presence at the feed alley. High values for pre-

dictability (96.5%), sensitivity (87.4%), and specificity (99.2%) all indicate that the GrowSafe system is a reasonable method for detecting cow presence.

For 12.6% of the observations that animals were confirmed present at the feed alley using video, the GrowSafe system failed to record animal presence. These observations were likely due to several sources of error. External sources of radio frequency can cause lost signals from the system (Schwartzkopf-Genswein et al., 1999), and a local police station (0.5 km from the farm) was a likely source of such interference. There may also have been instances where the cow lifted her head out of the 50-cm read range but still remained over the tombstone. Reductions in the read range could have occurred due to changes in the orientation of the neck collar that place the transponder further from the mat. Indeed, such shifts would also change the orientation of the transponder to the mat, further reducing the read range (Schwartzkopf-Genswein et al., 1999).

Additionally, for 3.5% of observations when the GrowSafe systems indicated that a cow was present at the feed alley, the video showed that the cow was not present. These extraneous observations were likely due to interference caused by the physical structures of the facility. For example, there were several physical structures (e.g., gates, fencing, lying stall partitions, and components of the feed alley neck rail) that may have acted as unintended antennae for signals (Schwartzkopf-Genswein et al., 1999). As illustrated in Figure 1, even for the cow with the worst correlation

Table 1. Records of cow presence (1) and absence (0) at the feed alley for every minute of the day ($n = 1440$) for 12 cows as recorded by the GrowSafe system and by video recordings, and the phi correlation coefficients for chi-square test of association of the two methods. All phi coefficients are significant at $P < 0.001$.

Cow	1, 1 ¹	1, 0 ²	0, 1 ³	0, 0 ⁴	Phi
1	320	6	29	1085	0.93
2	261	10	22	1147	0.93
3	235	17	39	1149	0.87
4	289	7	34	1110	0.92
5	253	9	38	1140	0.90
6	261	13	28	1138	0.91
7	287	3	17	1133	0.96
8	134	2	29	1275	0.89
9	247	18	74	1101	0.81
10	304	12	63	1061	0.86
11	248	5	53	1143	0.88
12	264	10	20	1164	0.93
Mean	258.6	9.3	37.2	1137.2	—

¹Number of minutes whereby both GrowSafe and video detected animal presence.

²Number of minutes whereby only GrowSafe detected animal presence.

³Number of minutes whereby only video detected animal presence.

⁴Number of minutes whereby neither GrowSafe nor video detected animal presence.

(cow 9) between the two data collection methods, all feeding observations by GrowSafe occurred during feeding bouts confirmed by video. This result suggests that it was likely the metal near the feed alley (i.e., neck rail) that acted as a false antenna when cows were in close proximity to the feed alley.

Although we have validated the GrowSafe records against the time-lapse video observations, some errors may also occur with video observations. For example, when using time-lapse video, errors may occur in recording the exact times when a cow's neck collar came within the read range of the mat. Additionally, due to the 6 s scanning method of the GrowSafe system, some animals may not be detected immediately when they start to feed, resulting in a different entry time compared with the video data.

In conclusion, the GrowSafe system can be used to monitor the feeding behavior of loose-housed dairy cattle. The GrowSafe system, used with an appropriate meal criterion, provides an accurate estimation of meal-based measures of feeding behavior. Furthermore, this system provides a reasonable estimate of when animals are present at the feed alley. Recording errors can be reduced by carefully monitoring factors such as transponder position and the number of metallic objects within close proximity of the feeding area.

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REFERENCES

- Canadian Council on Animal Care. 1993. Guide to the Care and Use of Experimental Animals. Vol. 1. E. D. Olfert, B. M. Cross, and A. A. McWilliam, ed. CCAC, Ottawa, ON, Canada.
- DeVries, T. J., M. A. G. von Keyserlingk, D. M. Weary, and K. A. Beauchemin. 2003. Measuring the feeding behavior of lactating dairy cows in early to peak lactation. *J. Dairy Sci.* 86:3354–3361.
- Eradus, W. J., and M. B. Jansen. 1999. Animal identification and monitoring. *Computers Electronics Agric.* 24:91–98.
- Friend, T. H., C. E. Polan, and M. L. McGilliard. 1977. Free stall and feed bunk requirements relative to behavior, production and individual feed intake in dairy cows. *J. Dairy Sci.* 60:108–116.
- Grant, R. J., and J. L. Albright. 2000. Feeding Behaviour. Pages 365–382 in *Farm Animal Metabolism and Nutrition*. J. P. F. D'Mello, ed. CABI Publishing, Wallingford, Oxon, UK.
- Martin, S. W., A. H. Meek, and P. Willeberg. 1987. *Veterinary Epidemiology—Principles and Methods*. Iowa State University Press, Ames.
- SAS User's Guide: Statistics, Version 5 Edition. 1985. SAS Inst., Inc., Cary, NC.
- Schwartzkopf-Genswein, K. S., C. Huisma, and T. A. McAllister. 1999. Validation of a radio frequency identification system for monitoring the feeding patterns of feedlot cattle. *Livest. Prod. Sci.* 60:27–31.
- Sowell, B. F., J. P. G. Bowman, M. E. Branine, and M. E. Hubbert. 1998. Radio frequency technology to measure feeding behavior and health of feedlot steers. *Appl. Anim. Behav.* 59:277–284.
- Tolkamp, B. J., D. P. N. Schweitzer, and I. Kyriazakis. 2000. The biologically relevant unit for the analysis of short-term feeding behavior of dairy cows. *J. Dairy Sci.* 83:2057–2068.
- Vasilatos, R., and P. J. Wangsness. 1980. Feeding behavior of lactating dairy cows as measured by time-lapse photography. *J. Dairy Sci.* 63:412–416.