Technical note: The use of a physical activity monitor to estimate the eating time of cows in pasture

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ABSTRACT

Accurate eating time can be used as an index of forage dry matter intake in grazing cows. To develop a method for easily estimating the eating time of dairy cows in a pasture, 8 lactating Holstein cows were fitted with collars equipped with commercial uniaxial accelerometers; namely, the Kenz Lifecorder EX (LCEX; Suzuken Co. Ltd., Nagoya, Japan), and were allowed to graze in a pasture for 4, 8, or 20 h daily for 7 d. The LCEX device recorded the intensity of the physical activity categorized into 1 of 11 activity levels ranging among 0 (no movement), 0.5 (subtle) and from 1 to 9 (1, light; 9, vigorous intensity) every 4 s during the experimental period. The activities of the animals were also video-recorded for 11 h and were manually classified into 7 categories (eating, searching, ruminating, standing resting, lying resting, drinking, and walking) at 4-s intervals. According to the count distribution of the activity levels for the categorized activities, 94.4% of the counts involving eating activity ranged from activity level 1 to 7. On the other hand, most of the counts were activity level 0 or 0.5 when ruminating and resting activities were observed. No records of activity level 8 or 9 were found in any activities. When activity level 1 was used as a threshold for discriminating eating from the other activities, the lowest misclassification rate of 5.5% was observed. With a threshold of activity level 1, the eating times in pasture for cows grazing for 4, 8, and 20 h/d were 142.8, 290.6, and 438.4 min/d, respectively, and the proportions of the time spent in pasture that were made up of eating time were 0.66, 0.67, and 0.38, respectively [the proportion during daytime (8 h of the 20-h grazing treatment) was 0.63 and that at nighttime (12 h of the 20-h grazing treatment) was 0.23]. The use of the LCEX device allows for easy measurement of eating time and facilitates the determination of the pattern of eating activity in pasture for grazing cows.

Key words: activity monitor, uniaxial accelerometer, eating time, grazing cow

Technical Note

Estimation of the DMI of grazing cows is more difficult and less accurate than determining the DMI of cows in confinement systems (Bargo et al., 2003), although it is important to know the DMI of lactating cows to manage their nutrition. From grazing behavior data, pasture DMI can be expressed as the product of daily eating time (min/d), biting rate (bite/min), and bite mass (g of DM/bite; Rook, 2000). In particular, total daily eating time is a key constraint on DMI and changes greatly to compensate for DMI according to forage availability (Iason et al., 1999); therefore, daily grazing time can be used as an index of foraging DMI. Grazing time can be measured visually or automatically (Forbes, 1988), but the former is labor intensive. In addition, although devices for measuring eating time have been developed since the 1950s (Balch, 1952), they have not been extensively used due to their being trial products or to expense or operational difficulties (Ungar and Rutter, 2006).

The Kenz Lifecorder EX (LCEX; Suzuken Co. Ltd., Nagoya, Japan), a new device for monitoring uniaxial acceleration, has recently been developed as a commercially available tool for the management of and research on human health at a comparatively low price (US\$245 per unit; Abel et al., 2008). The LCEX not only provides a step count per minute and estimates energy expenditure, but also records the intensity of physical activity at 4-s intervals. In the research performed to date in which this device was used to record the intensity of physical activity, the LCEX has been used to evaluate physical activity in children under free-living conditions (McClain and Tudor-Locke, 2009) and to monitor motor activity in patients with Parkinson disease (Saito et al., 2004). It allows continuous recording at 4-s intervals for 5 wk of activity at 11 scaled magnitudes, and the collected data can be downloaded to a computer using Kenz Physical Activity Analysis software (ver.

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1.00). The use of the device may make it possible to easily monitor animal behavior in detail. The objective of this study was to verify that the intensity of physical activity data recorded by the LCEX could be used to distinguish eating activity from the other activities of cows in pasture.

The management of cows and all procedures in the present study were performed in accordance with the Animal Experimental Guidelines of the National Agricultural Research Center for Hokkaido Region.

The experiment was conducted for 21 d (from June 16 to July 6, 2007; the average temperature was 18.0°C, ± 2.8) using 8 Holstein cows [BW, 597 ± 55 kg; milk yield, 33.4 ± 4.4 kg/d; parity, 1.8 ± 0.7 ; DIM, 148 ± 29 d (mean $\pm$ SD)]. The cows were divided into 3 groups of 2, 3, and 3 cows, respectively, corresponding to 3 grazing periods: **G4h**: 4 h (approximately 0930 to 1330 h)/d; **G8h**: 8 h (approximately 0930 to 1730 h)/d; and **G20h**: 20 h (approximately 0930 to 1730 h and 1930 to 0730 h)/d for each 7-d trial. The cows were brought to the barn for milking twice daily at 0900 and 1900 h. They were fed concentrate and hay based on each cow's BW, milk yield, and parity in the barn before each milking.

The pasture (total area, 1.575 ha; 90 m $\times$ 175 m), which was a meadow fescue/white clover mixed stand, was divided into 14 equal-sized plots (1,125 m²; 45 m $\times$ 25 m). During the experimental period, the herbage mass (>4 cm) was >1,000 kg of DM/ha. All the cows were moved to a new plot of the pasture at approximately 0930 h after the morning milking. The times at which the cows entered and left a plot were recorded to determine the actual time spent in pasture.

The LCEX device (60 g; width, 72.5 mm; height, 41.5 mm; thickness, 27.5 mm) was used to measure the behavior of individual cows in the pasture. The ceramic piezoelectric sensor samples uniaxial (vertical) accelerations at a rate of 32 samples/s (range, 0.06–1.94 g; Kumahara et al., 2004). The signal is filtered by an analog bandpass filter and digitized (McClain et al., 2007). A maximum pulse over 4 s is recorded as the acceleration value and is subsequently categorized into 1 of 11 levels [activity levels: 0 (no movement), 0.5 (subtle), 1, 2, 3, 4, 5, 6, 7, 8, and 9, with 1 indicating light activity and 9 indicating vigorous intensity] every 4 s. The LCEX was enclosed in a waterproof pouch, which was tied to the side of a collar worn around the neck of each cow during the experimental trial. At the end of each trial, the data measured by the device were downloaded to a personal computer. Of the obtained data, count data were recorded every 4 s, which were categorized into 11 levels and used to analyze the animals' activities.

A total of 11 h (approximately 80 min per cow) of the daytime behavior of all of the animals was recorded on videocassette over 3 d during the experimental period. The clock of the video recorder was accurately synchronized with that of the LCEX. The recorded animal behaviors were observed and manually classified into 7 activity categories every 4 s as defined here: (1) eating: herbage prehension, mastication, and swallowing; (2) ruminating: ruminating while standing or lying down; (3) searching: moving slowly with the head down while searching for suitable grass to eat; (4) standing resting: standing, resting, with the head up; neither ruminating nor eating; (5) lying resting: lying down, not ruminating; (6) drinking: drinking water at a water supply; and (7) walking: walking purposefully, either between the barn and the pasture or between the water trough and the pasture plot.

The videotaped activity data collected in every 4-s interval were matched to the LCEX activity levels (**AL**) recorded every 4 s for each cow according to the time on both clocks. All data from 8 cows (total of 10.97 h) were combined, and the relationship between the observed activities and the AL of the LCEX was analyzed. Table 1 shows the frequency distribution of the observed activities with the simultaneous AL. The most common observed activity was eating (4.45 h), followed by ruminating (2.86 h), standing resting (1.96 h), and lying resting (0.85 h). All of the activities fell into the categories from AL₀ to AL₇, with no activities in AL₈ or AL₉. In the observed eating activity, the activity level with the highest number of counts was AL₂, with a total of 2,008 (50.1%) time intervals, followed by AL₃ (589 intervals, 14.7%) and AL₁ (479 intervals, 12.0%). On the other hand, in the ruminating, standing resting, and lying resting activities, the AL with the highest number of counts was AL₀ (1,442, 1,011, and 608 intervals, respectively). The percentages of the total numbers of intervals spent in these 3 activities that were categorized as either AL₀ or AL_{0.5} were 98.9, 96.8, and 99.2%, respectively. In the searching, drinking, and walking activities, the activity level with the highest count was AL_{0.5}. Discriminant analysis (Schleisner et al., 1999) was used to distinguish eating from the other activities using the AL as explanatory variables. When AL₁ was used as a threshold for discriminating eating from the other activities (eating $\geq$ AL₁), the lowest misclassification rate of 5.5% was observed (Figure 1). Eating activity includes various dynamic movements: biting, chewing, and neck (head) shaking. Due to these dynamic movements, high activity levels ($\geq$ AL₁) were recorded at the neck. Biting (pulling grasses) is considered the most frequent movement in eating activity, and it resulted in

Figure 1. The rates of misclassification observed in determining the threshold level for eating activity. The calculation of the total rate of misclassification when the threshold level for eating activity is *m* was as follows: [(total number of eating categorized < *m*) + (total number of the other activities categorized ≥ *m*)] × 100/9,869 (total number). At the optimal threshold activity level = 1, there were 320 false-positive observations (3.24% of 9,869) of behaviors other than eating that received activity scores of 1 to 7 and 223 false-negative observations (2.26% of 9,869) of eating behavior scored at activity levels 0 or 0.5; combined, there were 543 total misclassifications or only 5.5% of 9,869.

a high level of neck movement due to the resistance of living plants.

Using AL₁ as the threshold, the daily mean eating times (the number of counts categorized into AL₁ to AL₇ multiplied by 4 s) of the cows were calculated (Table 2). The daily values were 142.8 ± 23.1, 290.6 ± 25.7, and 438.4 ± 39.1 min/d for the G4h, G8h, and G20h groups, respectively. Based on the actual time spent in pasture [212.7 for G4h, 429.7 for G8h, and 1,142.4 for G20h; 429.7 (daytime) and 712.7 (nighttime) min], the proportions of the time spent in pasture that comprised eating time were 0.66 (G4h), 0.67 (G8h), and 0.38 (G20h). The proportion of the daytime spent in pasture that was composed of eating time for the G20h group was 0.63, which was significantly higher (*P* < 0.01) than the corresponding proportion of the nighttime (0.23). In the study by Perez-Ramirez et al. (2008), when the time spent in pasture was reduced from 8 to 4 h, eating time decreased from 301 to 199 min, and the proportion of the total time spent on eating increased from 0.63 to 0.83. The reason that eating time and the proportion of the total time composed of eating time in the G4h group were lower in our study than in that of Perez-Ramirez et al. (2008) was probably that the supplementary feed was not restricted in our study. Our finding, that a greater proportion of total time was spent as eating time during the daytime than the nighttime, was consistent with the finding of

Table 1. Frequency of the activities observed by video recording with the simultaneous activity levels (AL) measured every 4 s by the LCEX device (Kenz Lifecorder EX, Suzuken Co. Ltd., Nagoya, Japan) in 8 dairy cows

Activity	Time spent (h)	Activity level ¹										Total	
		0	0.5	1	2	3	4	5	6	7	8		9
Eating	4.45	6	217	479	2,008	589	370	52	191	92	0	0	4,004
Eating (% of time spent)		0.1	5.4	12.0	50.1	14.7	9.2	1.3	4.8	2.3	0	0	
Ruminating	2.86	1,442	1,102	17	10	0	1	0	0	0	0	0	2,572
Standing resting	1.96	1,011	693	28	21	7	0	0	0	0	0	0	1,760
Lying resting	0.85	608	148	4	2	0	0	0	0	0	0	0	762
Searching	0.38	70	158	34	31	20	8	13	4	1	0	0	339
Drinking	0.16	38	100	3	2	0	0	0	0	0	0	0	143
Walking	0.32	20	155	38	58	12	5	0	1	0	0	0	289
Activities other than eating	6.52	3,189	2,356	124	124	39	14	13	5	1	0	0	5,865
Total	10.97	3,195	2,573	603	2,132	628	384	65	196	93	0	0	9,869

¹Activity levels: 0 (no movement), 0.5 (subtle), and from 1 to 9 (1, light; 9, vigorous intensity).

Figure 2. Typical patterns of eating behavior of grazing cows over 24 h. The vertical axis represents the number of 4-s periods, and the maximum level is 5 min ($4 \text{ s} \times 75$). The time spent eating was the sum of 4-s periods of eating activity estimated on the basis of the relationship between actual eating times and activity levels (AL) of 1 to 7 [of 11 activity levels: 0 (no movement), 0.5 (subtle), and from 1 to 9 (1, light; 9, vigorous intensity)] in a subsample of behavioral observations that were video recorded. The eating activity data in this figure were only applied when the cows were in pasture.

Arnold and Dudzinski (1978), who found that grazing cattle were more active in daylight than in darkness.

A typical pattern of eating activity of a dairy cow over 24 h for the G4h, G8h, and G20h groups was developed (Figure 2) in which an activity level of 1 to

7 for one time interval was regarded as 4 s of eating activity. The graphs clearly showed that eating activity started immediately after cows entered the pasture in both the morning and evening. Two peaks were found in daytime grazing: a peak after entering the pasture

Table 2. Daily mean eating times and the proportion of the actual time spent in pasture made up of eating time in dairy cows

Item	Treatment ¹					
	G4h		G8h		G20h	
	Mean	SD	Mean	SD	Mean	SD
Actual time spent in pasture ² (min/d)						
Daytime	217.7		29.7		429.7	
Nighttime	—		—		712.7	
Total	217.7		429.7		1,142.0	
Eating time by LCEX ³ (min/d)						
Daytime	142.8	23.1	290.6	25.7	272.0	39.1
Nighttime	—		—		166.4	56.5
Total	142.8		290.6		438.4	
Eating time/time spent in pasture						
Daytime	0.66	0.10	0.68	0.06	0.63	0.07
Nighttime	—		—		0.23	0.08
Total	0.66		0.68		0.38	

¹Grazing periods were designated G4h = 4 h (approximately 0930 to 1330 h)/d; G8h = 8 h (approximately 0930 to 1730 h)/d; and G20h = 20 h (approximately 0930 to 1730 h and 1930 to 0730 h)/d.

²Actual time spent in pasture between entering and exiting the plot.

³Time spent eating in each situation was estimated based on the relationship of actual eating times to activity levels of 1 to 7 in a subsample of behavioral observations that were also video recorded. LCEX = Kenz Lifecorder EX (Suzuken Co. Ltd., Nagoya, Japan).

(from 1000 to 1200 h) and a peak before sunset (1530 to 1730 h). On the other hand, nighttime grazing had 3 peaks: a peak after entering the pasture (1930 to 2030 h), a peak at midnight (0030 to 0130 h), and a peak near sunrise (0400 to 0630 h). Arnold and Dudzinski (1978) also found that a major eating period of grazing cattle begins around sunrise and another before sunset. On the other hand, it was difficult to determine the eating time that occurred while the cows were in the barn, because the activity level was much lower as the cows ate concentrate and hay at the feed bunk than when they pulled grasses in the pasture.

The use of activity level data allows the LCEX to distinguish the eating activity of cows in a pasture; neither significant improvements to the device nor special data analysis techniques are required. Specifically, the discrimination of eating activity from ruminating activity was clear. On the other hand, during searching activity, 32.7% of the counts were misclassified when a threshold of AL₁ was used, although the total time spent searching was much lower than the total time spent engaged in eating activities. Thus, improvements could be made in the use of the activity levels of the LCEX and in the data analysis to better discriminate between eating and searching activities. Regarding estrus activities, no mounting activity was recorded during the present observation period. Although the frequency and duration of mounting activity are much lower than those of eating activity, it is necessary to take into consideration that mounting activity involves head motion. Thus, eating time may be overestimated when numerous cows are in estrus at the same time. It

can be inferred that the influence of whisking away flies with the head on the misclassification of eating activity was not large, because the value of the activity level according to the LCEX depended on the intensity of the activity on which the cow spent the longest time in each 4-s period.

The measurement of eating time using an LCEX device as described in this report would ensure that estimation of DMI is optimized. This method of measurement would be a valuable tool in research on the nutritional management of grazing cows.

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REFERENCES

- Abel, M. G., J. C. Hannon, K. Sell, T. Lillie, G. Conlin, and D. Anderson. 2008. Validation of the Kenz Lifecorder EX and ActiGraph GT1M accelerometers for walking and running in adults. *Appl. Physiol. Nutr. Metab.* 33:1155–1164.
- Arnold, G. W., and M. L. Dudzinski. 1978. *The Ethology of Free-Ranging Domestic Animals*. Elsevier, Amsterdam, the Netherlands.

- Balch, C. C. 1952. Factors affecting the utilization of food by dairy cows. 6. The rate of contraction of the reticulum. *Br. J. Nutr.* 6:366–375.
- Bargo, F., L. D. Muller, E. S. Kolver, and J. E. Delahoy. 2003. Production and digestion of supplemented dairy cows on pasture. *J. Dairy Sci.* 86:1–42.
- Forbes, T. D. A. 1988. Researching the plant-animal interface: The investigation of ingestive behavior in grazing animals. *J. Anim. Sci.* 66:2369–2379.
- Iason, G. R., A. R. Mantecon, D. A. Sim, J. Gonzalez, E. Foreman, F. F. Bermudez, and D. A. Elston. 1999. Can grazing sheep compensate for a daily foraging time constraint? *J. Anim. Ecol.* 68:87–93.
- Kumahara, H., Y. Schuts, M. Ayabe, M. Yoshida, Y. Yoshitake, M. Shindo, K. Ishii, and H. Tanaka. 2004. The use of uniaxial accelerometry for the assessment of physical-activity-related energy expenditure: A validation study against whole-body indirect calorimetry. *Br. J. Nutr.* 91:235–243.
- McClain, J. J., C. L. Craig, S. B. Sisson, and C. Tudor-Locke. 2007. Comparison of Lifecorder EX and ActiGraph accelerometers under free-living conditions. *Appl. Physiol. Nutr. Metab.* 32:753–761.
- McClain, J. J., and C. Tudor-Locke. 2009. Objective monitoring of physical activity in children: considerations for instrument selection. *J. Sci. Med. Sport* 12:526–533.
- Perez-Ramirez, E., R. Delagrade, and L. Delaby. 2008. Herbage intake and behavioural adaptation of grazing dairy cows by restricting time at pasture under two feeding regimes. *Animal* 2:1384–1392.
- Rook, A. J. 2000. Principles of Foraging and Grazing Behaviour. Pages 229–236 in *Grass: Its Production and Utilization*. A. Hopkins, ed. Blackwell Science, Boston, MA.
- Saito, N., T. Yamamoto, Y. Sugiura, S. Shimizu, and M. Shimizu. 2004. Lifecorder: A new device for the long-term monitoring of motor activities for Parkinson's disease. *Intern. Med.* 43:685–692.
- Schleisner, C., P. Norgaard, and H. H. Hansen. 1999. Discriminant analysis of patterns of jaw movement during rumination and eating in a cow. *Acta Agric. Scand. A Anim. Sci.* 49:251–259.
- Ungar, E. D., and S. M. Rutter. 2006. Classifying cattle jaw movements: Comparing IGER behavior recorder and acoustic techniques. *Appl. Anim. Behav. Sci.* 98:11–27.