J. Dairy Sci. 93:3635–3640
doi:10.3168/jds.2009-3044

Technical note: Evaluation of a scoring system for rumen fill in dairy cows

O. Burfeind,*† P. Sepúlveda,†‡ M. A. G. von Keyserlingk,† D. M. Weary,† D. M. Veira,§ and W. Heuwieser*†[1]
*Clinic for Animal Reproduction, Faculty of Veterinary Medicine, Freie Universität Berlin, Koenigsweg 65, 14163 Berlin, Germany
†Animal Welfare Program, Faculty of Land and Food Systems, The University of British Columbia, 2357 Main Mall, Vancouver, BC, V6T 1Z4, Canada
‡Doctorate Program, Faculty of Clinical Veterinary Sciences, Universidad Austral de Chile, PO Box 567, Valdivia, Chile
§Agriculture and Agri-Food Canada, Pacific Agriculture Research Station, Agassiz, BC, V0M 1A0 Canada

ABSTRACT

Changes in feed intake are useful in early detection of disease in dairy cows. Cost and complexity limit our ability to monitor dry matter intake (DMI) of individual cows kept in loose-housing systems. A 5-point subjective scoring system has been developed to visually describe rumen fill, but no work to date has evaluated these scores as an indicator of feed intake. The objective of this study was to evaluate the performance of within-cow changes in visual rumen fill scores as estimates of changes of DMI and feed intake in dairy cows. Our results illustrate that rumen fill scored on a scale from 1 to 5 has substantial intra- (Cohen's kappa coefficient = 0.69) and interobserver (Cohen's kappa coefficient = 0.68) repeatability. Within-cow changes in visual rumen fill score are correlated with changes in DMI (Spearman's rank correlation = 0.68). The depth of the paralumbar fossa (mean ± SD; 5.6 ± 0.9 cm) changes considerably (up to 4.8 cm) within 70 ± 5 min. This more objective measure was also correlated with visual rumen fill scores (Spearman's rank correlation = −0.62). Our results indicate that subjective rumen fill scores are statistically associated with both an objective measure of paralumbar fossa indentation and feed intake. However, much of the variation in visual rumen fill scores is not associated with either measure, suggesting that caution is required in clinical usage of these scores.
Key words: rumen fill, dry matter intake, dairy cow, validation

Changes in feed intake can be useful in early disease detection in dairy cows (Oetzel, 2004). Reduced DMI is associated with clinical manifestation of diseases (Zamet et al., 1979) such as mastitis (Bareille et al., 2003). More recent studies have shown that declining DMI prepartum is a risk factor for metritis (Huzzey et al., 2007) and subclinical ketosis (Goldhawk et al., 2009) postpartum. Clearly, monitoring individual cow DMI on commercial farms would be of value. Several systems for monitoring individual intake in group-housed cows are available (e.g., Growsafe, Growsafe Systems Ltd., Airdrie, Alberta, Canada; Insentec, Marknesse, Holland), but these are costly and likely impractical for use on most commercial dairy farms.

Visual examination is an important component in health evaluation of cows, particularly early in lactation (Guterbock, 2004; Smith and Risco, 2005). Recently, the systematic use of visually discernable signs ("cow signals") has been promoted as a tool for monitoring cow health (Aalseth, 2005; Hulsen, 2006). These signals include a 5-point visual scoring system for rumen fill (Zaaijer and Noordhuizen, 2003).

Rumen fill, defined as the total amount of liquid and DM (kg) in the rumen, is related to DMI (Hartnell and Satter, 1979), ration composition, digestibility, and the rate of passage of ingested feed (Aitchison et al., 1986; Llamas-Lamas and Combs, 1991). However, neither the repeatability of visually estimated rumen fill scores nor the relationship to DMI has been previously validated. The objectives of this study were 1) to determine repeatability (inter- and intraobserver) of visual rumen fill scoring, 2) to study variation of visual rumen fill scores throughout the day in ad libitum-fed cows, 3) to evaluate relationships between visual rumen fill scores and DMI and as-fed feed intake (**AFI**), and 4) to compare visually estimated rumen fill scores with directly measured depths of the paralumbar fossa.

Four experiments were conducted at the University of British Columbia Dairy Education and Research Centre (Agassiz, British Columbia, Canada) and were managed according to the guidelines set by the Canadian Council on Animal Care (1993). A total of 220 Holstein-Friesian dairy cows were used. All cows were housed in a freestall barn. Combinations of early-lactation, mid-lactation, and dry cows were used in experiments 1, 2, and 3 of this study and were housed by stage of lactation in groups of 12. The pens were equipped with 12 freestalls fitted with mattresses (Pas-

Received December 31, 2009.
Accepted April 30, 2010.
[1]Corresponding author: wolfgang.heuwieser@ubc.ca

ture Mat, Promat Inc., Woodstock, Ontario, Canada) covered with approximately 5 cm of sand. Each pen was equipped with 6 feed bins and 1 water bin (Insentec, Marknesse, Holland) that were validated for monitoring feed and water intake of loose-housed cows (Chapinal et al., 2007). Late-lactation cows and a second group of mid-lactation cows were used in experiment 4 of this study and housed in a group of 36 cows in pens with 36 deep-bedded sand freestalls. The cows had free access to feed and water. Feed was delivered at the feed alley with access via a pendulous neck-rail. Early-lactation and mid-lactation cows were fed twice daily at 0600 and 1600 h a TMR consisting of 50.6% concentrate and mineral mix, 29.3% corn silage, 11% grass silage, 5.4% alfalfa hay, and 3.7% grass hay on a DM basis (DM: 51%; CP: 18.1% of DM; NDF: 33.4% of DM). Dry cows and late-lactation cows were fed once daily at 0800 h. The TMR for the dry cows consisted of 44.3% alfalfa hay, 32.4% corn silage, and 23.3% concentrate and mineral mix on a DM basis (DM: 44%; CP: 15.4% of DM; NDF: 44.1% of DM), whereas the TMR for the late-lactation cows consisted of 67.7% weigh backs of the early- and mid-lactation cows, 15.6% concentrate and mineral mix, 7.5% grass silage, 4.6% grass hay, and 4.6% alfalfa hay on a DM basis (DM: 59%). All lactating cows were milked twice daily (approximately 0700 and 1700 h).

Rumen fill was estimated by visual evaluation of the paralumbar fossa on a scale from 1 to 5 (Table 1) according to the system of Zaaijer and Noordhuizen (2003). Using this description, 3 observers practiced scoring rumen fill as a group using 35 ± 5 cows for 5 d before the initiation of the experiments. Data generated during this training phase were not used for the analysis. During the course of all experiments visual rumen fill was scored when the cows were standing with all 4 legs on the same level and no rumen contractions were occurring.

Experiment 1 was conducted to determine interobserver repeatability of visual rumen fill scoring and to study variation of visual rumen fill scores throughout the day in ad libitum-fed cows. Rumen fill of 42 multiparous cows was scored independently by 3 investigators 3 times daily (0800, 1400, and 1900 h) over a period of 5 d. Additionally, cumulative DMI was measured for these cows. To provide a wide variation, cows from different stages of lactation were used: 10 from early lactation [parity (mean ± SD): 3 ± 1.3; DIM: 20 ± 12], 10 from mid lactation (parity: 3.4 ± 2.1; DIM: 97 ± 11), 10 from late lactation (parity: 3 ± 1.9; DIM: 264 ± 43), and 12 dry (parity: 2.6 ± 1.9).

Experiment 2 consisted of 3 replicates with 67 (parity: 2.6 ± 1.9; DIM: 101 ± 51), 70 (parity: 2.4 ± 1.9; DIM: 97 ± 53), and 71 (parity: 2.6 ± 1.8; DIM: 95

Table 1. Rumen fill score and appearance of paralumbar fossa[1]

Rumen fill score	Appearance of paralumbar fossa		
	Relationship to the transverse processes	Relationship to the last rib	Shape
1	Cavitates a hand's width inside under the transverse processes	Cavitates a hand's width behind it	Empty rectangle
2	Cavitates less than a hand's width inside under the transverse processes	Cavitates a hand's width behind it	Triangle
3	Falls about a hand's width vertically down and then bulges out	Cavitates less then a hand's width behind it	
4	Arches out immediately below it	Skin is covering the area behind it	Bulges out directly
5	Transverse processes not visible	Last rib not visible	Rumen almost obliterates it

[1]Summarized from Zaaijer and Noordhuizen (2003).

± 51) cows, again employing 3 independent observers. Cows in each replicate were scored twice by the same observer to determine intraobserver repeatability. Cows were scored in groups of 20 ± 5 animals to limit the time between scores to 15 ± 5 min. A second person recorded the cows' identification number and the visual rumen fill score.

Experiment 3 was conducted to evaluate relationships between within-cow changes in visual rumen fill score and changes in DMI and AFI in multiparous cows. Early-lactation cows (n = 28; parity: 3.1 ± 1.3; DIM: 12 ± 12) and mid-lactation cows (n = 10; parity: 3.4 ± 2.1; DIM: 97 ± 11) were scored at 1900 h ± 15 min by a single trained observer for 16 d and 5 d, respectively. Within-cow changes in visual rumen fill scores were compared with changes in DMI and AFI calculated for a 24-h interval. Data collected during experiment 1 were used to assess the relationship between within-cow changes in visual rumen fill score and changes in DMI and AFI, comparing differences between the daylight hours (0800 to 1900 h) and the night hours (1900 to 0800 h).

In experiment 4, variation in the depth of the left paralumbar fossa within cow (intracow variation) was measured directly and the relationship between the depth of the left paralumbar fossa and visual rumen fill score was determined. This was done because the visual assessment of the depth of the paralumbar fossa is an integral component when visually scoring rumen fill (Zaaijer and Noordhuizen, 2003; Table 1). First, the depth of the left paralumbar fossa was measured in 24 multiparous early-lactation cows (parity: 3.2 ± 1.3; DIM: 17 ± 11) 10 times every 7 ± 1 min to determine intracow variation. Depth was measured using an instrument consisting of 2 flat irons (45 cm × 2.5 cm × 0.4 cm; 28 cm × 2.5 cm × 0.4 cm) welded together at an angle of 50° with the angle point located 7 cm from the end of the long side (Figure 1). The long side was positioned on the transverse processes such that the end touched the cranial part of the left hip bone. The short side was pointed in a cranioventral direction and its end was placed on the last rib. A bushing positioned 10 cm from the end of the angle point ensured a constant position and angle of a measuring probe relative to the cows' left paralumbar fossa. The probe was pointed onto the skin of the paralumbar fossa and fixed by a screw. The depth of the paralumbar fossa was expressed as the length from the tip of the probe to the inner rim of the bushing. The variation in depth within the 5 classes of visual rumen fill scores (intrascore variation) was also determined. The depth of the paralumbar fossa was measured in 131 cows (parity: 2.8 ± 1.7; DIM: 143 ± 102) by a single experienced independent investigator, and 2 trained independent observers assigned a visual rumen fill score. The 3 observations were performed within 2 ± 1 min/cow. All data were documented in Excel (version 2003, Microsoft Corp., Redmond, WA) and statistical analyses were conducted with MedCalc (version 10.1.3.0, MedCalc Software, Mariakerke, Belgium).

Figure 1. Device used to measure the depth of the paralumbar fossa.

Reliability of agreement between different observers (interobserver) and repeated observations (intraobserver) was analyzed with Cohen's kappa coefficient (κ_w; Hoehler, 2000). Cohen's kappa coefficients were weighted quadratically to penalize disagreements in terms of their seriousness (Sim and Wright, 2005). Cohen's kappa coefficient can result in values between 0 and 1. A value of 1 illustrates perfect agreement, whereas values close to 0 demonstrate poor agreement. Additionally, Spearman's rank correlation (r_S) was calculated to describe relationships between and within investigators (Brown and Hayden, 1985) and between within-cow changes in visual rumen fill scores and changes in DMI and AFI. The relationship between the depth of the left paralumbar fossa and visual rumen fill score was also assessed by Spearman's rank correlation. Spearman's rank correlation can result in values from −1 to 1. A value of 1 illustrates a perfect positive relationship between 2 variables, 0 demonstrates no relationship, and −1 describes a perfect negative relationship. Differences between within-cow changes in visual rumen fill scores and DMI and AFI were analyzed by ANOVA. To evaluate the variation of the rumen fill score throughout the day in ad libitum-fed cows, the mean and SD were calculated for 3 independent observers at 0800, 1400, and 1900 h. Descriptive statistics were used to quantify variation of the depth of the paralumbar fossa within the different classes of rumen fill (intrascore variation) and within cows (intracow variation).

Table 2. Within-cow changes in DMI (kg) and in as-fed feed intake (kg) in relation to within-cow changes in visual rumen fill scores (RFS; experiments 1 and 3)

			Change in cumulative feed intake (kg)			
			DM		As fed	
Time of RFS	Change in RFS	n[1]	Mean ± SD	95% CI	Mean ± SD	95% CI
Evening[2]	−2	2	−2.3 ± 0.2	−4.5 to −0.2	−4.6 ± 0.5	−8.7 to −0.4
	−1	43	−0.9 ± 2.9	−1.8 to −0.1	−2.1 ± 6.1	−4.0 to −0.2
	0	196	0.0 ± 3.7	−0.5 to 0.5	0.1 ± 7.4	−1.0 to 1.1
	+1	47	0.4 ± 3.5	−0.7 to 1.4	0.9 ± 7.5	−1.3 to 3.1
	+2	—	—	—	—	—
Morning and evening[3]	−2	7	−11.5 ± 2.2[a]	−13.6 to −9.5	−22.6 ± 4.4[a]	−26.7 to −18.6
	−1	62	−6.5 ± 5.8[a]	−8.0 to −5.1	−13.1 ± 11.4[a]	−16.0 to −10.2
	0	125	−0.3 ± 6.0[b]	−1.4 to 0.7	−0.7 ± 12.7[b]	−2.9 to 1.7
	+1	58	7.1 ± 5.3[c]	5.7 to 8.5	14.5 ± 10.4[c]	11.8 to 17.3
	+2	5	11.6 ± 4.8[c]	5.7 to 17.5	23.0 ± 8.9[c]	12.0 to 34.0

[a–c]Means within a column with different superscripts differ ($P < 0.01$).

[1]Number of paired observations.

[2]Rumen fill scores were taken daily at 1900 h describing changes between a 24-h period.

[3]Rumen fill scores were taken daily at 0800 and 1900 h describing changes between day and night.

The intraobserver reliability for the 2 rumen fill scoring sessions showed agreement ($\kappa_w = 0.69$; $r_S = 0.66$; $P < 0.001$; experiment 2). Similarly, the interobserver agreement for 2 independent observers showed agreement in rumen fill scores ($\kappa_w = 0.68$; $r_S = 0.71$; $P < 0.001$; experiment 1).

Spearman's rank correlation between changes in visual rumen fill score and changes in DMI and AFI within cow evaluated using 257 paired observations was 0.68 and 0.67 ($P < 0.\ 01$), comparing differences between day and night in experiment 1. Spearman's rank correlation was 0.1 (n = 288) between within-cow changes in visual rumen fill score and DMI ($P = 0.09$) and AFI ($P = 0.08$), comparing differences from day to day (24 h). Cows in experiment 1 had higher DMI during the day (0800 to 1900 h; 13.3 ± 4.4 kg) than during the night (1900 to 0800 h; 7.1 ± 3.2 kg). This finding corresponds with reports of highest feeding activity during the daytime and early evening (0600 to 1800 h; DeVries et al., 2003) in dairy cows. The relationship between changes in visual rumen fill scores and changes in DMI and AFI within cows as well as high DMI during the day likely explains the higher visual rumen fill scores recorded at 1900 h compared with 0800 and 1400 h in experiment 1 (observer A: 0800 h: 3.1 ± 0.7, 1400 h: 3.4 ± 0.7, 1900 h: 3.6 ± 0.7; observer B: 0800 h: 3.2 ± 0.8, 1400 h: 3.5 ± 0.8, 1900 h: 3.7 ± 0.7; observer C: 0800 h: 2.8 ± 0.7, 1400 h: 3.1 ± 0.8, 1900 h: 3.2 ± 0.7; n = 210).

Mean DMI in experiment 3 was 21.1 ± 4.8 kg/d. This amount of DMI is comparable with that of healthy early-lactation cows (14.8–18 kg of DM/d) reported earlier for the same housing system (Huzzey et al., 2007; Goldhawk et al., 2009). Within-cow changes in visual rumen fill scores provide an estimate of changes in DMI and AFI, comparing 2 periods with differing intake (day and night; Table 2). Overall, these results demonstrate that within-cow changes in visual rumen fill scores may be a reasonable estimate of changes in DMI and AFI.

The average intracow variation in the depth of the paralumbar fossa was 5.6 ± 0.9 cm (CV = 16%; experiment 4). When 10 scores were taken over a 70 ± 5-min period on the same cow, the range varied in depth from 1.2 to 4.8 cm. Variation in depth within each of the different visual rumen fill scores (intrascore variation) was also high for both observers (Table 3; experiment 4). The number of observations differs between the 2 observers because the depth was analyzed for the given scores of each observer independently. However, agreement between the 2 observers was comparable with experiment 1 ($\kappa_w = 0.67$). Spearman's rank correlation between the depth of the paralumbar fossa and the rumen fill score was −0.64 and −0.60 for observer A and B, respectively ($P < 0.001$; experiment 4).

These results illustrate that visual rumen fill scores show intra- ($\kappa_w = 0.69$; $r_S = 0.66$; $P < 0.001$; experiment 2) and interobserver ($\kappa_w = 0.68$; $r_S = 0.71$; $P < 0.001$; experiment 1) repeatability. Moreover, these scores are correlated with an objective measure of the depth of the left paralumbar fossa, a measure that changes considerably over a 70-min period. This variability likely confounded the accuracy of visual rumen fill scoring between and within investigators because the visual assessment of the depth of the paralumbar fossa is an integral component when visually scoring rumen fill (Zaaijer and Noordhuizen, 2003; Table 1).

Table 3. Mean depth (cm) and range (cm) of the left paralumbar fossa and rumen fill scores (experiment 4)[1]

	Rumen fill score[2]					
	2		3		4	
Parameter	Obs A	Obs B	Obs A	Obs B	Obs A	Obs B
No. of observations	14	28	63	61	50	35
Mean depth ± SD (cm)	5.7 ± 1.2	4.8 ± 1.2	4.5 ± 1.2	4.3 ± 1.2	3.2 ± 1.0	2.9 ± 1.0
Range[3] (cm)	4.3	4.5	6.8	6.7	5.8	3.9

[1]Obs = rumen fill score observer.

[2]In this experiment, no observations were made in rumen fill scores 1 and 5.

[3]Range = maximal depth − minimum depth.

We did observe a relationship between changes in visual rumen fill scores and DMI and AFI within cow on a 24-h basis (DMI: $r_S = 0.1$, $P = 0.09$; AFI: $r_S = 0.1$, $P = 0.09$; n = 288; experiment 3), comparing differences between day and night (DMI: $r_S = 0.68$, $P < 0.01$; AFI: $r_S = 0.67$, $P < 0.01$; n = 257; experiment 1). We speculate that the different relationships when comparing the 24-h basis with the 11- to 13-h intervals exist because we used only healthy cows with no significant changes in DMI or AFI over 24 h (Table 2). However, when analyzing the differences between day and night we are comparing 2 periods with significant differences in DMI (Table 2), as has been shown previously. Regarding these results, we hypothesize that a change of visual rumen fill score within cow from day to day might be indicative of a decrease in DMI and AFI, which has to be tested in further studies. Because a decrease in DMI is indicative of developing disorders, we suggest that this measure should be used on farms on a daily basis at the same time of day to determine changes of DMI within cow in early lactation. Furthermore, attention should be paid that cows are standing with all 4 legs on the same level and that no rumen contractions are occurring while visually scoring rumen fill because this might bias the results. Further research is needed to identify more accurate cowside estimates of DMI and to determine whether changes in visual rumen fill scores can be used to identify cows at risk for disease.

ACKNOWLEDGMENTS

We thank the staff of The University of British Columbia Dairy Education and Research Centre and the University's Animal Welfare Program. Onno Burfeind was funded by a scholarship from Tiergyn Berlin e.V. (Berlin, Germany). This project was funded by the Natural Sciences and Engineering Research Council of Canada (Ottawa, Ontario, Canada), Freie Universität Berlin (Berlin, Germany), and Dairy Farmers of Canada (Ottawa, Ontario, Canada) and many other donors listed on the Animal Welfare Web site at http://www.landfood.ubc.ca/animalwelfare.

REFERENCES

Aalseth, E. 2005. Fresh cow management. What is important, what does it cost, and what does it return? Pages 1–12 in Proc. 7th West. Dairy Management, Reno, NV. Kansas State University, Manhattan.

Aitchison, E. M., M. Gill, M. S. Dhanoa, and D. F. Osbourn. 1986. The effect of digestibility and forage species on the removal of digesta from the rumen and the voluntary intake of hay by sheep. Br. J. Nutr. 56:463–476.

Bareille, N., F. Beaudeau, S. Billon, A. Robert, and P. Faverdin. 2003. Effects of health disorders on feed intake and milk production in dairy cows. Livest. Prod. Sci. 83:53–62.

Brown, G. W., and G. F. Hayden. 1985. Nonparametric methods: Clinical applications. Clin. Pediatr. (Phila.) 24:490–498.

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, Ontario, Canada.

Chapinal, N., D. M. Veira, D. M. Weary, and M. A. G. von Keyserlingk. 2007. Technical note: Validation of a system for monitoring individual feeding and drinking behavior and intake in group-housed cattle. J. Dairy Sci. 90:5732–5736.

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

Goldhawk, C., N. Chapinal, D. M. Veira, D. M. Weary, and M. A. G. von Keyserlingk. 2009. Prepartum feeding behavior is an early indicator of subclinical ketosis. J. Dairy Sci. 92:4971–4977.

Guterbock, W. M. 2004. Diagnosis and treatment programs for fresh cows. Vet. Clin. North Am. Food Anim. Pract. 20:605–626.

Hartnell, G. F., and L. D. Satter. 1979. Determination of rumen fill, retention time and ruminal turnover rates of ingesta at different stages of lactation in dairy cows. J. Anim. Sci. 48:381–392.

Hoehler, F. K. 2000. Bias and prevalence effects on kappa viewed in terms of sensitivity and specificity. J. Clin. Epidemiol. 53:499–503.

Hulsen, J. 2006. Cow Signals: A Practical Guide to Dairy Farm Management. Roodbond Publishers, Zutphen, the Netherlands.

Huzzey, J. M., D. M. Veira, D. M. Weary, and M. A. G. von Keyserlingk. 2007. Prepartum behavior and dry matter intake identify dairy cows at risk for metritis. J. Dairy Sci. 90:3220–3233.

Llamas-Lamas, G., and D. K. Combs. 1991. Effect of forage to concentrate ratio and intake level on utilization of early vegetative alfalfa silage by dairy cows. J. Dairy Sci. 74:526–536.

Oetzel, G. R. 2004. Monitoring and testing dairy herds for metabolic diseases. Vet. Clin. North Am. Food Anim. Pract. 20:651–674.

Sim, J., and C. C. Wright. 2005. The kappa statistic in reliability studies: Use, interpretation, and sample size sequirements. Phys. Ther. 85:257–268.

Smith, B. I., and C. A. Risco. 2005. Management of periparturient disorders in dairy cattle. Vet. Clin. North Am. Food Anim. Pract. 21:503–521.

Zaaijer, D., and J. P. Noordhuizen. 2003. A novel scoring system for monitoring the relationship between nutritional efficiency and fertility in dairy cows. Ir. Vet. J. 56:145–151.

Zamet, C. N., V. F. Colenbrander, C. J. Callahan, B. P. Chew, R. E. Erb, and N. J. Moeller. 1979. Variables associated with peripartum traits in dairy cows. I. Effect of dietary forages and disorders on voluntary intake of feed, body weight and milk yield. Theriogenology 11:229–244.