Comparison of rumination activity records of pressure sensors and acoustic sensors

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Abstract

Automatic health monitoring in dairy cows is gaining more and more importance. One indicator to detect imbalances is rumination activity. Several methods have been developed for recording, e. g. time and intensity of rumination. The objective of this work was to compare rumination records of two types of rumination sensors, namely a pressure sensor, ART-MSR, and an acoustic sensor, RuminAct, with each other. Records of rumination time per 2 hours were evaluated and compared intermittently to direct observation. Records of both sensor types were correlated significantly ($r = 0.58$, $p < 0.01$, $N = 527$). Correlation between direct observation and ART-MSR ($r = 0.99$, $p < 0.01$, $n = 18$) was higher than between direct observation and RuminAct ($r = 0.88$, $p < 0.01$, $n = 18$). Differences in rumination records of the two tested sensor types were influenced by time of the day and the individual cow.

Keywords: rumination, sound, jaw movement, health monitoring, dairy cows

1. Motivation

Rumination activity is of great importance for metabolic activity of dairy cows and might be a useful tool for monitoring of animal health. Rumination stimulates saliva production and therefore ensures optimal conditions for cellulolytic activity in the rumen (Beauchemin et al., 1989). In former times, visual observation was the most reliable technique for detecting rumination, but this method has proven being laborious and limited in the number of animals observed (Beauchemin et al., 1989). Progress in development of methods to detect rumination has led from rather unsuitable technologies to techniques detecting rumination activity automatically. Advantages of newer techniques developed in recent years are an unaffected animal behaviour, a sufficient storage capacity and an acceptable handling while older systems had several limitations (Schirmann et al., 2009). The aim of this study was to compare rumination records of two different methods, namely a pressure sensor and an acoustic sensor, and to compare both methods with records gathered by direct observation.

2. Material and Methods

Data were collected at the federal state research farm LVZ Futterkamp (chamber of agriculture Schleswig-Holstein). In total, 190 dairy cows, of which most are German Holstein, are kept at the farm, with an average milk yield of 10.700 kg/305 d (3.9 % milk fat and 3.2 % milk protein). Data collection took place in August and September 2011, including three days for adaptation and four to eight days per cow for recording (Table 1). Rumination activity of seven cows was recorded continuously by acoustic sensors (RuminAct, Milkline, Italy) and, at the same time, by pressure sensors (ART-MSR rumination sensor, ART, Switzerland). In addition rumination data of two cows were gathered intermittently by direct observation in order to validate the systems. Nine 2-h-blocks were recorded for each of the two cows (Table 1; observation block 1-9, in Figures 1-2). For direct observation, a defined rumination period started with the cow chewing rhythmically after having regurgitated the first bolus. As breaks between rumination boluses last 4.3-4.4 s (Jile, 2003) a rumination period was considered finished when more than 30 s had passed after the last bolus without swallowing a new one.

TABLE 1: Extent of data gathered by ART-MSR, RuminAct and direct observation

Cow	Compared methods	N[1]	Days
12	ART-MSR / RuminAct	71	7
54		85	8
110		77	7
111		79	7
910		61	6
991		85	8
994		69	6
54	ART-MSR / RuminAct / direct observation	9	4
110		9	4

[1]N: number of recorded 2-h-blocks

Cows were chosen by random from a group of 36 cows kept together in one compartment of the barn. Milking took place from 5 a.m. to 7 a.m. in the morning and from 3 p.m. to 5 p.m. in the afternoon. While cows were milked, total mixed ration (TMR) was supplied in feeding troughs at approximately 6 a.m. and 4 p.m. Main components of TMR fed were grass silage, corn silage and concentrate.

The RuminAct-sensor contains a microphone for recording rumination sounds and a microprocessor for data converting. The system calculates data within 2-h intervals and is able to store 22 h at maximum. Download of the data was realized by infrared readers above water troughs. The ART-MSR sensor includes a pressure sensor, which is able to recognize jaw movements through shifts in pressure, and a logger for data storing. R-based software attaches jaw movements to activities “rumination” and “eating” by using learned data (Nydegger et al.; 2011). In order to compare both systems, rumination time per 2 hours was calculated. Data were stored in Excel 2010 and evaluated by t-test in PASW Statistics 18 to perform comparisons of means.

3. Results & Discussion

3.1. Comparison of ART-MSR and RuminAct

Rumination activity per 2 hours averaged 42.5 +/-22.7 min and 34.2 +/-18.7 min if recorded by ART-MSR and RuminAct, respectively. The results for mean rumination of RuminAct-sensors agreed with those in Schirmann et al. (2009), who estimated mean and standard deviation (SD) of 35.1 +/-3.2 min per 2-h-block. The mean rumination activity per cow recorded by ART-MSR varied between 41.1 min and 43.7 min/2-h-block while those of RuminAct showed a wider range varying from 18.7 min to 43.7 min/2-h-block (Table 2). The mean difference between both systems (8.3 min/2-h-block) was statistically significant ($p < 0.01$). The mean differences per cow between both systems ranged from -1.9 min/2-h-block (cow 991) to 24.4 min/2-h-block (cow 111). Thereby, positive values represent higher values for ART-MSR. Standard deviation for the difference of systems was highest for cow 111 (24.2 min/2-h-block) and lowest for cow 994 (10.3 min/2-h-block). In general, ART-MSR values clearly exceeded those recorded by RuminAct, whereas means of rumination of cow 991 and cow 994 were slightly lower than when recorded by RuminAct (Table 2).

TABLE 2: Mean and standard deviation (SD) of rumination activity within 2-h-blocks detected by ART-MSR and RuminAct per cow

cow	N[1]	ART-MSR		RuminAct		Level of significance[2] for mean difference
		Mean	SD	Mean	SD	
12	71	42.7	23.1	37.7	17.3	0.013
54	85	43.7	20.5	30.4	14.6	0.000
110	77	41.1	20.5	33.2	19.5	0.000
111	79	43.1	27.6	18.7	12.5	0.000
910	61	43.5	22.8	34.2	15.4	0.001
991	85	41.8	24.7	43.7	19.4	n. s.
994	69	41.5	18.4	42.7	18.7	n. s.
All	527	42.5	22.7	34.2	18.7	0.000

[1]N: number of recorded 2-h-blocks
[2]: T-Test, $p < 0.05$

Values within 2-h-blocks recorded by ART-MSR and RuminAct were correlated significantly, but with moderate correlation coefficients ($r = 0.58$, $p < 0.01$, $N = 527$). Coefficients of correlation per individual cows varied from $r = 0.48$ to $r = 0.84$ (each $p < 0.01$, $N = 61 – 85$).

Table 3 shows the mean rumination activity of all seven cows during the course of the day. Both systems detected periods of high rumination during nighttime from 10 p.m. to 6 a.m. and during daytime from 10 a.m. to 4 a.m. In between these time blocks there was a decrease in rumination time. This decrease might be explained by milking and feeding times as during feed intake the available time for rumination will decrease. It should be noted that the difference in recorded rumination activity between both systems was not constant during the course of the day. Rumination activity recorded by ART-MSR was below the one of RuminAct in the 2-hour-block between 6 a.m. and 8 a.m. For all remaining 2-hour-blocks it was the opposite way round (Table 3). The maximum difference between RuminAct and ART-MSR data, namely 16.1 min/2-h-block, was found between 2 p.m. and 4 p.m. Likewise, in the 2-h-blocks between 8 p.m. and 4 a.m. the difference between both types of systems was comparatively large.

TABLE 3: Mean and standard deviation (SD) of rumination activity within 2-h-blocks detected by ART-MSR and RuminAct per seven cows

Time of day	N[1]	Mean ART-MSR	SD ART-MSR	Mean RuminAct	SD RuminAct	Level of significance[2] for mean difference
00-02	42	56.2	18.0	44.8	17.2	0.005
02-04	49	63.4	17.6	50.8	15.8	0.000
04-06	49	58.2	15.5	52.0	15.3	0.023
06-08	49	25.8	20.9	26.8	16.4	n. s.
08-10	49	30.2	20.1	23.7	14.5	0.003
10-12	49	41.7	20.7	33.6	16.5	0.003
12-14	49	39.5	19.2	34.8	18.2	n. s.
14-16	49	48.7	18.9	32.6	15.6	0.000
16-18	48	31.1	18.7	23.3	12.6	0.015
18-20	39	27.8	20.6	22.9	15.0	n. s.
20-22	29	36.2	19.8	25.5	14.8	0.000
22-24	27	50.5	18.2	35.8	16.6	0.001

[1]N: number of recorded 2-h-blocks
[2]: T-Test, $p < 0.05$

One explanation for deviating values of the two tested sensors might be disturbing noises from the surrounding. In this context noise sources like e. g. milking parlour or feeding troughs have to be mentioned. However, RuminAct-sensors installed in the milking parlour and troughs did not record any sounds comparable to rumination activity. Burfeind et al. (2011) reported that sounds of calves drinking milk from a nipple did not influence the RuminAct-system. Nevertheless, the above mentioned authors found a rather low accuracy of the system used in animals younger than nine months and they cannot completely exclude technical limitations.

3.2. Comparison of ART-MSR, RuminAct and direct observation

Direct observation was done in nine 2-h-long observation blocks per cow. In figures 1 and 2 the results of the direct observation are compared with concomitant records of the two rumination sensors ART-MSR and RuminAct.

In average, 36.2 min/2-h-block were recorded in direct observation of cow 54 (Figure 1), 32.2 min/2-h-block and 32.0 min/2-h-block were calculated based on records of ART-MSR and RuminAct, respectively. The data were lower than in visual observation when recorded with either ART-MSR (mean difference and SD: -4.0 +/-3.12 min/2-h-block; p = 0.005) or RuminAct (-4.2 +/-6.92 min/2-h-block; p = 0.105). Only in observation block 4 and 5 did values recorded by RuminAct exceed those of direct observation and ART-MSR, for all other observation blocks the highest values were estimated by direct observation. RuminAct recorded a rumination activity of 2 min in observation block 5 of cow 54, in which no rumination was detected by the other methods.

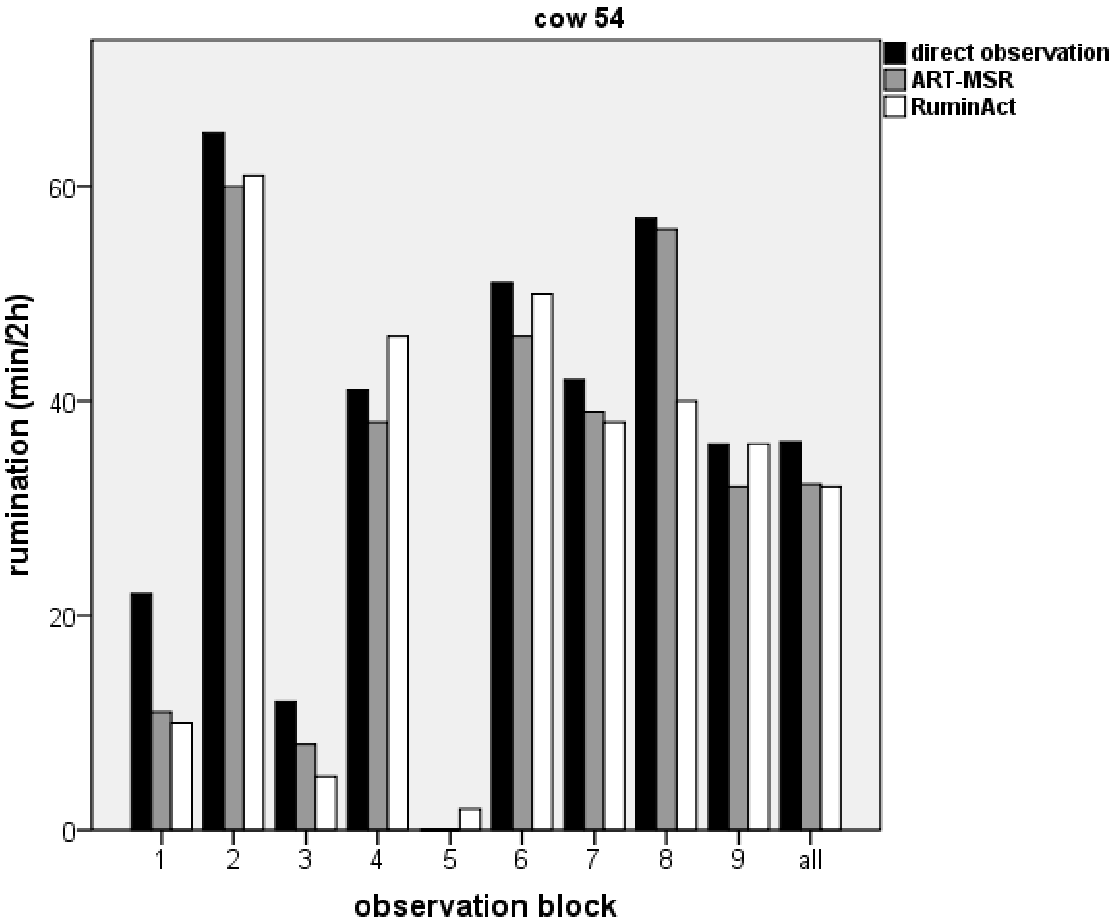

FIGURE 1: Rumination activity per 2-h-block detected by ART-MSR- and RuminAct-sensors and by direct observation (cow 54)

Rumination activity of cow 110 averaged 31.4 min/2-h-block during direct observation. Both sensors calculated lower rumination activity, namely 28.7 min by ART-MSR and 21.3 min by RuminAct (Figure 2). The differences between direct observation and ART-MSR (mean difference and SD: -2.7 +/-3.07 min/2-h-block; p = 0.021) and direct observation and RuminAct (-10.1 +/-3.54 min/2-h-block; p = 0.027) were both significant. Again, there was one single observation block, in which the RuminAct-sensor detected rumination activity of 8 min while the two other methods recorded zero rumination. Underestimation of visually estimated rumination activity by ART-MSR can in parts be explained by data classification in this system. Pauses between single rumination boluses were not classified as rumination by the ART-MSR-system but were counted as rumination by visual observation.

Burfeind et al. (2011) compared rumination activity estimated by direct observation and RuminAct-sensors for six groups of different aged calves and heifers. For four of these groups rumination detected by RuminAct was 4 to 12 min/2-h-block lower than when recorded by direct observation. In one group, values for RuminAct were 2 min/2-h-block higher than in observation and for the sixth group no difference was found. Results for subtraction of values from direct observation from those of RuminAct-sensors varied from approximately -35 min/2-h-block up to 20 min/2-h-block (Burfeind et al., 2011). Underestimation of rumination activity by RuminAct in comparison to direct observation was detected similarly in Burfeind et al. (2011) as in the results in this study. In both studies, overestimation was found to a smaller extend. The main difference between both studies was the age of animals as lactating dairy cows were used in the current study.

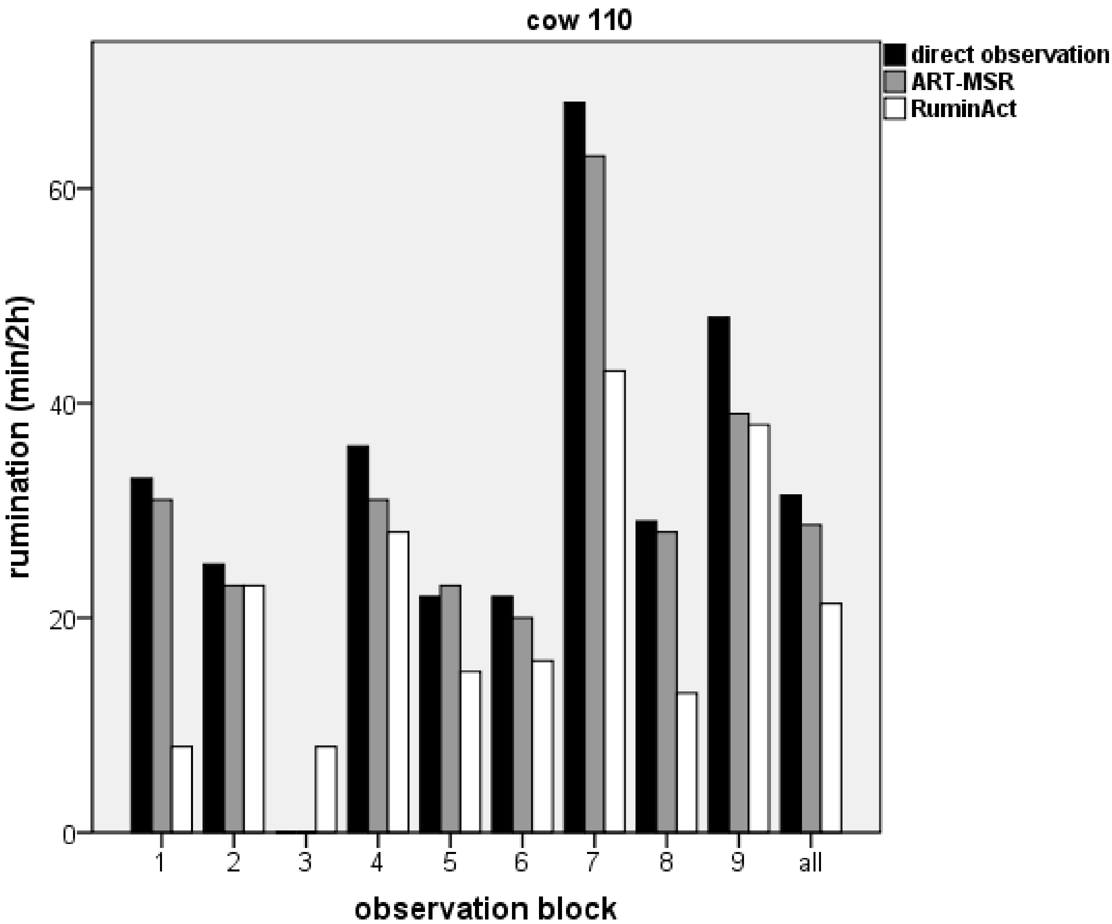

FIGURE 2: Rumination activity per 2-h-block detected by ART-MSR- and RuminAct-sensors and by direct observation (cow 110)

Durations of rumination activity recorded by ART-MSR and RuminAct were highly correlated ($r = 0.88$, $p < 0.01$, $n = 18$) for the two cows and the 2-h-blocks with direct observation. Data records of both sensors were in addition significantly correlated with data records from direct observation. The highest correlation was found between the ART-MSR-sensors and direct observation with $r = 0.99$ ($p < 0.01$, $n = 18$).The RuminAct-sensors and direct observation were correlated with $r = 0.88$ ($p < 0.01$, $n = 18$).

4. Conclusions

Results indicated that rumination activity was slightly underestimated if recorded by sensors compared to direct observation. Rumination activity per 2-hour-block recorded by ART-MSR was in average significantly higher than that recorded by RuminAct. Time of the day and individual cow had an influence on the absolute difference in rumination records of the two tested sensor types. The former might be influenced by e. g. milking or feeding times, the latter by quality of rumination sound (cow effect) or recording quality in the sensor (sensor effect).

5. Acknowledgments

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