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Original Paper

Drinking regime evaluation with continuous ruminal monitoring boluses

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The aim of this study was to continuously monitored drinking regime of 7 dairy cows of Holstein breed using boluses during 24 weeks of lactation in relation to the outside temperature and observed daily drinking regime with the impact of drinking on rumen temperature at University Experimental Farm in Oponice. Animals were fed once daily and milked 3 times per day. The bolus pH and temperature values implemented via esophagus were measured every 15 minutes (96 data points per day) with accuracy ±0.1 ph and °C. Outside temperature by FREEMETEO meteorological server (48 times per day) was measured. Outside temperature can affect the drinking regime of dairy cows. During lactation weeks with higher outside temperature higher average number of drinking events (ANDE) was determined. The biggest difference between weeks in ANDE 18.33% ($p = 0.000$) was found. Daily ANDE 9.25±1.85 and average daily temperature (ADT) 19.03±5.19 °C were observed. The most of the drinking events (NDE) concentrated to 4 main peaks (25.17%) during working hours (74.98%) was found. After the feed intake and milking the highest frequencies of NDE were observed. The highest average ruminal temperature after drinking (ARTAD) during night before first feeding due to lower NDE in this time were found. Overall ARTAD 36.86 °C was observed. The most measured ruminal temperatures after drinking (RTAD) (51.53%) in the interval 35–37 °C were found. This research proved that continuous ruminal monitoring with boluses is an appropriate tool for drinking regime evaluation and heat stress determination in herd of dairy cows.

Keywords: bolus, rumen, temperature, water intake, outside temperature

1 Introduction

Water supplies for both humans and livestock are becoming a subject of increasing importance. Indeed, climate change and drinking water deficits in certain areas have meant that supplies of clean water for livestock are becoming problematic, at least during certain periods of the year. Water is considered the most important nutrient for health and performance in dairy herds. Loss of water from the body occurs through milk production, urine and fecal excretion, sweat and vapour loss from lungs (NRC, 2001). A adequate water intake is essential to avoid negative effects on animal health, performance and welfare (Murphy,1992; Meyer et al., 2004), and 25 and 50% restriction of drinking water relative to ad libitum intake decreased feed intake and milk yield in dairy cows (Steiger Burgos et al., 2001). Results of several experiments showed that an average of 83% of the water demand is met by drinking (NRC, 2001). Many studies found the association between water intake and outside temperature and between water intake and the number of drinking events (Matarazzo et al., 2003; Brown-Brandl et al., 2006; Arias et al., 2008). Drinking activity can be monitored continuously and simultaneously for randomly enrolled cows using a data acquisition system based on an individual radio frequency identification collar (Cardot et al., 2008) or with observers (Jago et al., 2005). Huzzey et al. (2005) monitored drinking activity of dairy cows using video cameras connected to a video multiplexer and a time-lapse videocassette recorder. Bewley et al. (2008) monitored ruminal temperature using boluses permanently residing in the cow's reticulum and indentified temperatures influenced by drinking events. The aim of this study was to monitored drinking regime of dairy cows using boluses during lactation in relation to the outside temperature, daily drinking regime and the impact of drinking on rumen temperature.

2 Material and methods

2.1 Animals and housing

Measured data from 7 dairy cows of Holstein breed (average age 3.57) in cooperation with the University Experimental Farm in Oponice during 24 lactation weeks were collected. Selected cows had average milk production 10 175 kg per lactation with 3.94% of fats, 3.10% of crude proteins and 4.70% of lactose. Experimental cows were housed in the groups with another dairy cows together.

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2.2 *Feeding and water availability*

Animals were fed once daily with Total Mix Ratio (Table 1) ad libitum between 4:00 and 5:00 and milked 3 times per day at 6:00, 12:00 and 18:00. Corn silage (pH 3.85) and alfalfa silage acidity (pH 4.85) with Sodium Bicarbonate (550 g $head^{-1}$) and Magnesium Oxide (51 g $head^{-1}$) were neutralised. In one section for 20 dairy cows two drinkers were available.

Table 1 Total Mix Ratio composition

DM (kg)	NEL (MJ kg^{-1})	CP (%)	NDF (%)	Starch (%)
25.45	153.86	15.74	24.35	25.39

abbreviations: DM – dry mater, NEL – netto energy of lactation, CP – crude protein, NDF – neutral detergent fiber

2.3 *Data measuring and data collecting*

Every dairy cow had implemented farm bolus for continual data measuring which was implemented through esophagus orally with the use of special balling gun. The bolus pH and temperature values were measured every 15 minutes (96 data points per day) with accuracy ±0.1. Outside temperature by FREEMETEO meteorological server (48 times per day) was measured. Used boluses (eCow Devon, Ltd., Great Britain) are characteristic with its small dimensions (135 × 27 mm) and weight 207 g. Data with the handset with antenna and dongle connected with USB dongle connector with the radio frequency 434 MHz in the milking parlour were downloaded. Collected data were summarized with HathorHBClient v. 1.8.1.

2.4 *Statistical evaluation*

Statistical evaluation with IBM SPSS v. 20.0 was realised. Descriptive statistics with One-way ANOVA were recalculated. Statistically differences between average daily outside temperatures (ADT), average ruminal temperatures after drinking (ARTAD) and average numbers of drinking events (ANDE) with post hoc Tukey Test were determined. Effect of outside temperature on number of drinking events with Pearson correlation coefficient (r) was realised. As drinking event a decrease in ruminal temperature less than -0.70% and ruminal pH less than 0.00% with previous data point using data filter was selected.

3 Results and discussion

Drinking regime of dairy cows during lactation with average temperatures during drinking events in the Figure 1 are shown. ANDE during monitored period 9.25±1.85 and ADT 19.03±5.19 were observed. Minimal reported ANDE found Jago et al. (2005) 5.2. Higher average ANDE for monitored period observed Huzzey et al. (2005) 9.5±0.4 and Perera et al. (1986) 9.4. Cardot et al. (2008) determined ANDE 7.3±2.8 during their experiment. The effect of ADT r = 0.132 on ANDE was determined (p = 0.001) but in 19 cases the same change – both increase or decrase in the comparison with previous week between ANDE and ADT was found. González Pereyra et al. (2010) found effect of outside temperature on ANDE r = 0.507 (p <0.05). Totally an average decrease in ANDE -4.87±5.38% and ADT -21.31±15.23% in comparison with

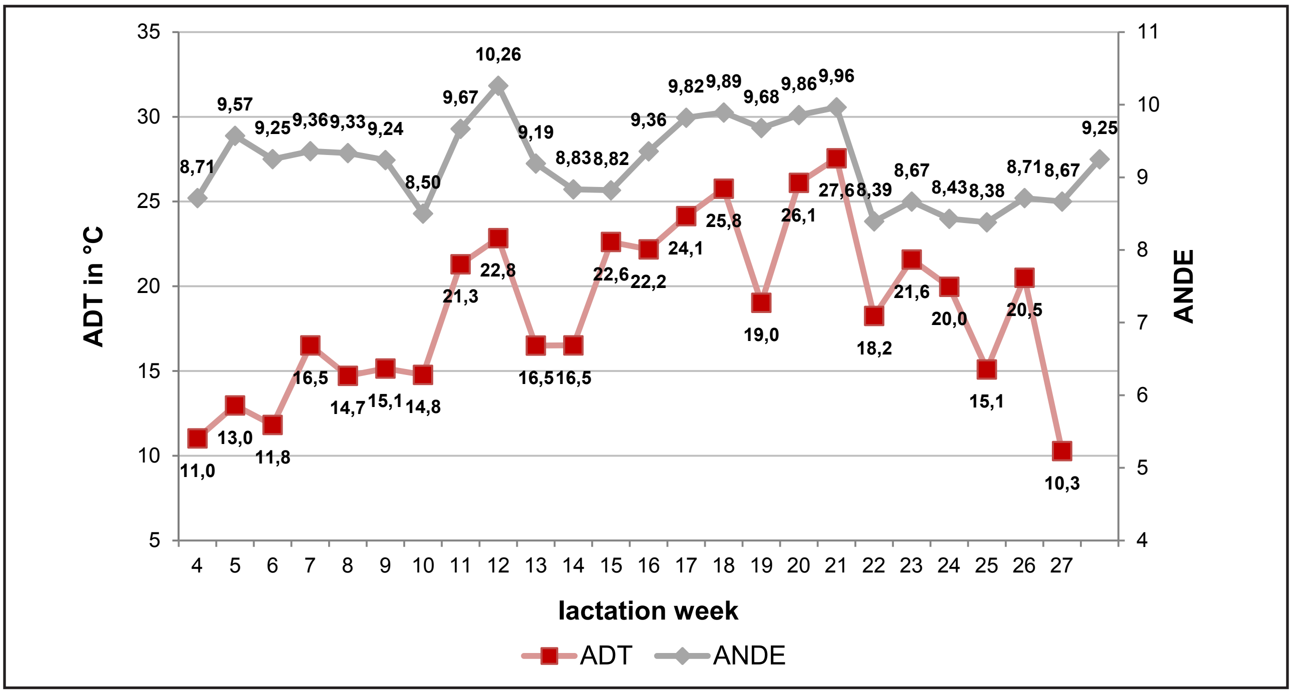

Figure 1 Drinking regime and average daily outside temperature during 24 weeks of lactation
abbreviations: ADT – average daily outside temperature; ANDE – average number of drinking events

previous week for 9 weeks was determined. The average increase in ANDE 4.68±4.24% and ADT +22.12±15.49% compared to previous week for 10 weeks was observed. Between lactation weeks statistically significant differences were determined ($p = 0.000$). Between 4th and 5th lactation a rise in ANDE +9.84% and ADT +17.64% were found. After that ADT fall by -8.91% and in ANDE -3.36% in the 6th lactation week was determined. In the 7th week of lactation a gain in ANDE +1.19% and ADT +39.76% ($p = 0.000$) and in the 8th lactation week a drop in ANDE -0.28% and ADT -10.87% was observed. In 9th lactation week a distinct development between ANDE (-1.02%) and ADT (+2.93%) was detected. Statistically significant difference between 10th and 12th lactation week in ANDE -17.17% was found. After that a fall in ANDE -10.44% and ADT -27.77% ($p = 0.000$) in 13th lactation week was determined. In 14th, 15th and 16th lactation week a different development between ANDE (-3.89%; -0.13%; +6.07%) and ADT (+0.09%; +37.19%; -1.94%) was observed again. Statistically significant difference between 14th and 15th week of lactation was found (37.19%; $p = 0.000$). During 19th lactation week a decrease in ANDE -2.17% and ADT -26.15% ($p = 0.000$) was found. After that in 20th and 21st lactation week an increase in ANDE and ADT was observed again. In ANDE it was +1.85% and 1.09%; in ADT +37.19% ($p = 0.000$) and +5.56%. Statistically significant difference between 12th and 22nd lactation week -18.21% in ANDE was determined. In 22nd lactation week decreased ANDE -15.77% and ADT -33.77% ($p = 0.000$). This decrease by another increase in ANDE +3.26% and ADT +18.26% in 23rd ($p = 0.000$) lactation week was fallowed. In 24th and 25th lactation week a statistically significant differences in ANDE in comparison with 12th lactation week -17.87% ($p = 0.028$) and -18.33% ($p = 0.020$) and a decrease in ANDE -2.75%; -0.56% and in ADT -7.46%; -24.43% ($p = 0.000$) were found. In 26th lactation week an another rise in ANDE +3.98% and ADT +35.87% ($p = 0.000$) was observed. This rise with another fall in ANDE -0.55% and ADT -49.92% ($p = 0.000$) was replaced.

Temperatures measured after drinking and number of drinking events in Figure 2 are shown. Only 0.85% of RTAD in the interval over 40 °C were found. The 2nd smallest group 5.34% of RTAD in the interval under 35 °C was determined. In the interval 39–40 °C were 6.99% of RTAD and in the interval 38–39 °C it was 14.93%. The most of RTAD in the temperature interval 37–38 °C and 35–37 °C were found. The interval 37–38 °C from 20.36% of RTAD and 35–37 °C from 51.53% of RTAD was consisted. After comparison of number of drinking events during day 4 peaks were determined. First peak in the time of 1st feeding at 5:00 was found (380). After 1st milking at 6:00 a sudden decrease -26.58% in NDE was found. Between 1st and 2nd milking NDE oscillated from 247 to 289 and represented 31.18% of NDE during the day. Next peak of NDE after 2nd milking at 13:00 was found (381). After that a sudden decrease -33.07% at 14:00 and -34.12% at 15:00 of NDE was found again. Then a linear rising trend of NDE before 3rd milking was determined. NDE increased by +23.81% at 16:00 and +39.81% at 17:00. After the 3rd milking at 18:00 another rise + 21.38% in NDE and 3rd at 19:00 and 4th peak at 21:00 of NDE was found. After the highest peak at 21:00 a rapid decrease -40.87% at 22:00

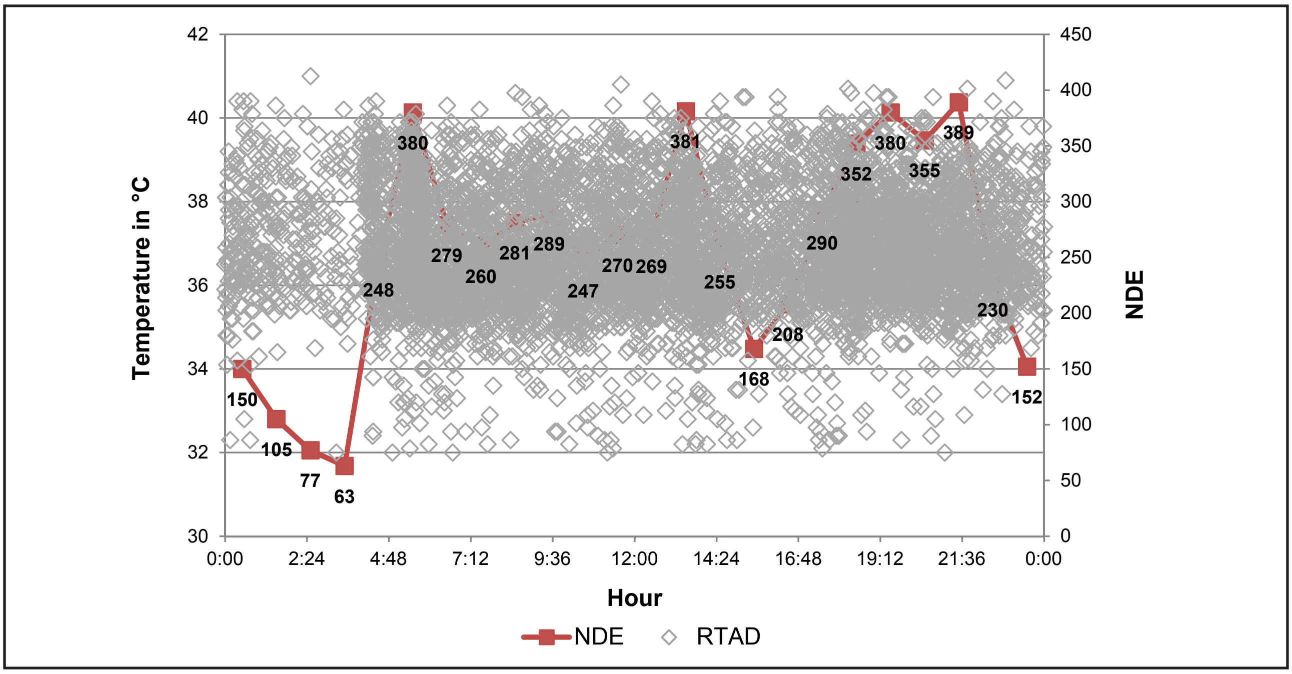

Figure 2 Ruminal temperatures measured after drinking and number of drinking events during day
abbreviations: RTAD – ruminal temperature after drinking; NDE – number of drinking events

Table 2 Average ruminal temperature after drinking event

Hour	Mean	S.D.	Cv	Min.	Max.
0	37.00^{abce}	1.58	4.26	32.3	40.4
1	37.39^{bc}	1.31	3.50	34.4	40.3
2	37.17^{abce}	1.27	3.41	34.5	41.0
3	37.26^{abce}	1.69	4.52	32.0	40.2
4	37.25^{c}	1.54	4.13	32.0	40.4
5	36.95^{abce}	1.45	3.92	32.1	40.1
6	36.45^{d}	1.37	3.76	32.0	40.3
7	36.71^{ad}	1.31	3.57	32.2	40.2
8	36.68^{ad}	1.32	3.61	32.3	40.6
9	36.84^{abd}	1.38	3.74	32.5	40.3
10	36.61^{de}	1.45	3.97	32.2	39.8
11	36.85^{abce}	1.46	3.95	32.0	40.8
12	36.84^{abd}	1.32	3.58	32.9	40.4
13	36.83^{abe}	1.40	3.80	32.2	40.0
14	36.70^{ad}	1.45	3.96	32.2	40.4
15	36.83^{abcd}	1.35	3.66	32.3	40.5
16	36.88^{abcd}	1.48	4.01	32.9	40.5
17	36.80^{ad}	1.46	3.96	32.1	40.1
18	37.02^{abc}	1.32	3.58	32.5	40.7
19	36.98^{abce}	1.21	3.27	32.3	40.6
20	36.84^{abe}	1.22	3.31	32.4	40.5
21	36.83^{abe}	1.23	3.34	32.0	40.7
22	36.99^{abce}	1.27	3.43	33.4	40.9
23	36.92^{abcd}	1.23	3.33	34.5	40.2
Total	36.86	1.38	3.75	32.0	41.0

Different letters in the columns indicate significant differences. The mean difference is significant at the 0.05 level (Tukey Test); abbreviations: S.D. – standard deviation, Cv – Coefficient of variation, Min. – minimal value, Max. – maximal value

and -33.91% at 23:00 in NDE was observed. This decrease continued to 3:00 when NDE fall down by -1.32% (0:00), -30.00% (1:00), -26.67% (2:00) and -18.18% (3:00). The biggest difference in NDE 83.80% between 3:00 and 21:00 was determined. It can be state that dairy cows during night drink less. Only 12.78% of NDE between 22:00 and 3:00 was realised. On the other side during 4 peaks (5:00, 13:00, 19:00 and 21:00) 25.17% of NDE was found. This fact means that dairy cows drink water mainly after feeding and milking and during night is water intake low. During experiment 74.98% of NDE during working hours and 25.02% out of working hours were determined. Cardot et al. (2008) found 2 main and 3 smaller consumption peaks and 72.70% of NDE per day during working hours and 27.00% during night on the farm was achieved. Osborne et al. (2002) claims that 25.00 of NDE during night was realised. NDE occurred during the whole day but NDE peaks were in relationship with feeding and milking (Nocek and Braun, 1985; Osborne, 2002).

ARTAD are shown in the Table 2. Weak correlation -0.178 (p = 0.000) between ARTAD and NDE was found. Gasteiner et al. (2009) found in their experiment average ruminal temperatures from 38.12±0.80 °C to 38.55±0.83 °C. Bodas (2014) found ruminal temperatures from 34.57 °C to 39.78 °C with average 38.77 °C. Bewley et al. (2008) found dramatic decrease 9.2±0.2 °C of ruminal temperature after intake of cold water. ARTAD during day 36.86 °C was found. Higher ARTAD between 0:00 and 4:00 were found. This is the result of low water intake during hours before first feeding (only 12.78% of NDE was between 22:00 and 3:00). After feeding at 5:00 and 1st milking at 6:00 a slight decrease in ARTAD -0.81% and -1.35% was observed. This decrease can be attributed to higher NDE +293.65% at 4:00 and +53.25% at 5:00. After that change from -0.62% to 0.70% in ARTAD between 1st and 2nd milking was found. After 2nd milking a slight fall by -0.03% at 13:00 and -0.35% at 14:00 was determined. This small decrease is result of higher NDE (+41.64%) after

2[nd] milking. Lower NDE by -34.12% in comparison with NDE at 14:00 caused at 15:00 and 16:00 higher ARTAD by +0.37% and +0.13%. Before 3[rd] milking change -0.21% at 17:00 was found. Return from the milking parlour caused higher NDE. After 3[rd] milking a small decrease in ARTAD -0.10% at 19:00, -0.39% at 20:00 and -0.01% at 21:00 in comparison with previous hours was found. Last hours of a day changes between previous hours in ARTAD fluctuated from +0.43% to -0.20% at 22:00 and 23:00. The maximal difference 2.53% in ARTAD between 1:00 and 6:00 was observed.

4 Conclusions

Outside temperature can affect the drinking regime of dairy cows. The weak linear relationship between ADT and NDE r = 0.132 was determined (p = 0.001) but in 19 cases the same change – both increase or decrease in the comparison with previous week between NDE and ADT was found. During lactation weeks with higher outside temperature higher NDE was determined. The biggest difference between weeks in NDE 18.33% (p = 0.000) was found. Daily NDE 9.25±1.85 and ADT 19.03±5.19 °C were observed. The most of the NDE concentrated to 4 main peaks (25.17%) during working hours (74.98%) was found. After the feed intake and milking the highest frequencies of NDE were observed. The highest ARTAD during night before first feeding due to lower NDE in this time were found. Overall ARTAD 36.86 °C was found. The most measured RTAD (51.53%) in the interval 35–37 °C were found. This research proved that continuous ruminal monitoring with boluses is an appropriate tool for drinking regime evaluation and heat stress determination in herd of dairy cows.

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