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Effect of postpartum drenching on rumination time and reticuloruminal pH at a Hungarian dairy farm

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RESEARCH ARTICLE

ABSTRACT

The aim of this research was to investigate the effect of drenching with a feed additive on rumination time (RT) and reticuloruminal pH post-partum at a Hungarian large-scale dairy farm. One hundred and sixty-one cows were fitted with a Ruminact© HR-Tag and from these 20 also received SmaXtec© ruminal boli approximately 5 days before calving. Drenching and control groups were established based on calving dates. Animals in the drenching group were dosed three times (Day 0/day of calving/, Day 1, and Day 2 after calving) using a feed additive containing calcium propionate, magnesium sulphate, yeast, potassium chloride and sodium chloride mixed in approximately 25 L of lukewarm water. RT before calving and sensitivity to subacute ruminal acidosis (SARA) were considered in the final analysis. There was a significant decrease in RT in the drenched groups compared to the controls after drenching. Reticuloruminal pH was significantly higher and time below reticuloruminal pH 5.8 remained significantly lower in SARA-tolerant drenched animals on the days of the first and the second drenchings. Drenching temporarily decreased RT in both drenched groups compared to controls. The feed additive had a positive effect on reticuloruminal pH and time below reticuloruminal pH 5.8 in tolerant drenched animals.

KEYWORDS

dairy cow, calcium propionate, yeast, calving, SARA

INTRODUCTION

The transition period (from 3 weeks prepartum to 3 weeks postpartum) is considered the most important time for the dairy cow (Grummer, 1995; Drackley, 1999). Dairy cows face a sharp increase in energy demand after calving due to their rapidly increasing milk production, which coincides with a time of decreased dry matter intake (Esposito et al., 2014). This causes them to mobilize their body's energy reserves and enter a state of negative energy balance (NEB) (Grummer et al., 2004; Ingvartsen, 2006). This in turn makes the animals more susceptible to certain metabolic and microbial diseases (Drackley, 1999). In dairy cattle, one of the most important centres of metabolism is the rumen. Rumination time decreases physiologically in the week before calving (Pahl et al., 2014; Kovács et al., 2017). The disturbance of ruminal function contributes NEB, making the transition period a time, in which most infectious and metabolic diseases occur (Goff and Horst, 1997).

There are several methods, by which ruminal function can be influenced to optimize ruminal metabolism and to minimize the negative consequences of the transition period on the general health of cows. Drenching is one of the methods widely used to maintain health in

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the peripartal period. The definition of drenching is the process of administering a drug or drugs in liquid form to an animal. It can be performed using a drenching gun (small amount – up to 1 L), or a drenching set (oesophageal/reticuloruminal tube, drenching bucket and pump – up to 40 L).

Drenching solutions around calving may contain glycogenic precursors, macro- and microminerals, and yeast products among others. Glycogenic precursors (propylene glycol, glycerol, calcium propionate) are metabolized into propionate in either the rumen or the liver (Clapperton and Czerkawski, 1972; Hippen et al., 2008). Liu et al. (2010) has found that calcium propionate increased plasma glucose concentration and decreased plasma beta-hydroxybutyrate (BHB) and non-esterified fatty acid (NEFA) concentrations. Active dry yeast cultures may influence ruminal function positively by exerting effects on ruminal pH, the concentration of volatile fatty acids, the counts of certain bacteria and the level of fibre catabolism (Williams and Newbold, 1990). Studies have shown that yeast supplementation can increase or stabilize ruminal pH (Miller-Webster et al., 2002; Jouany, 2006), while other authors have reported a decrease in ruminal pH (Harrison et al., 1988).

Ruminal function can be monitored via the measurement of rumination time and reticuloruminal pH. We found no data on the influence of drenching on any of these parameters in dairy cows. Thus, the aim of our study was to investigate the effect of drenching with the feed additive on rumination time and reticuloruminal pH (mean daily pH and total time spent below a reticuloruminal pH of 5.8) in the days after calving.

MATERIALS AND METHODS

The study was conducted in full compliance with the guidelines of the Animal Experimentation Committee (Budapest, Hungary).

Animals and management

Two hundred clinically healthy Holstein-Friesian dairy cows (mean parity ± SD 3.1 ± 1.1; range: 2–6) on the dairy farm of Dózsa Agricultural Ltd.-Tass, Hungary were enrolled in the study. Prepartum animals were kept in a free-stall barn in a large group (up to 80 animals). Prepartum animals were selected for calving based on their insemination date, and they were housed (from 3 to 5 days before their expected calving date) in one of five calving pens (approximately 5 × 7 m, each). The calving pens also served as fresh cow pens for the first five days after calving. Each calving pen contained up to 6 animals.

In the calving pens, the composition of each group was dynamic, with cows entering and leaving the group depending on their actual calving dates. Calving pens were bedded with deep straw. Before calving, cows were fed a prepartum total mixed ration (TMR) twice daily at approximately 06:00 a.m. and 05:00 p.m. ad libitum containing a dietary forage-to-concentrate ratio of 78:22 on a dry matter (DM) basis. After calving, cows were fed a fresh cow diet (forage-to-concentrate ratio 54:46 on a DM basis) at approximately 08:00 a.m. and 05:00 p.m. ad libitum. Water was available ad libitum.

Data collection

Cows that entered the calving pen in the study period were fitted with Ruminact® HR-Tags (SCR Engineering Ltd., Netanya, Israel) (n = 200) and with SmaXtec ruminal boli (SmaXtec Animal Care GmbH, Graz, Austria) (n = 20).

The HR-Tag device consisted of a neck collar with a counterweight and a data logger. Each logger had a built-in microphone that could record the sound of rumination. Rumination time (RT) was recorded using 2-min resolution and stored at 2-h intervals, as described and validated by Schirmann et al. (2009). For automatic data transfer, an antenna using wireless technology was placed on the wall of the middle calving pen. It captured the raw data that were then sent to a computer. All data were saved in Excel format after the collar was removed on Day 5 postpartum.

In one batch of cows, SmaXtec ruminal boli were placed in the rumen using a balling gun in accordance with the user's manual. Data were gained individually using a handheld receiver on around Day 30 after calving. Data were later transferred in Excel format to a computer for further analysis.

Drenching

Cows were randomly assigned into either the treatment (drenched) or the control group based on their calving dates. The treatment group was dosed three times [within 24 h after completion of calving and on two subsequent days (Day 1 and Day 2)], using a Sano Drenching Set (Sano Modern Animal Nutrition Ltd., Csém, Hungary). Animals in the control group were managed in the same way as the treatment group, but they were not drenched. The drenching solution contained 680 g calcium propionate, 230 g magnesium sulphate, 110 g potassium chloride, 50 g sodium chloride (Reanal Laboratory Chemicals Ltd, Budapest, Hungary), 230 g yeast (Europrotein Ltd., Verőce, Hungary) in approx. 25 L of lukewarm tap water. Each dose of the drenching mixture was measured and stored in individual bags at room temperature and used within a few days after preparation. The exact times of calving and drenching were recorded.

Statistical analysis

Data were analysed using the R3.5.2 statistical software (R Core Team, 2018). RT and reticuloruminal pH data were checked for normality using the Shapiro-Wilk test. The distribution of animals in the study groups was tested with two-sample proportion test.

The mean RT of the animals in the calving pen was calculated and the sum of the last four days before calving was used to create a herd 96-h average. Cows below this average were categorized as 'Low rumination' and those above as 'High rumination'. These categories were merged

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with the drench/control system to create the final groups. Animals that did not have 96 h of RT data before calving were excluded from the final analysis.

In the final analysis, the changes in RT were examined. A generalized linear mixed model (GLMM) was created with the time intervals/days, drench number, and group as fixed effects and cow ID as random effect to determine the influence of each factor. One-way ANOVA and Tukey's post hoc tests were used to determine significant changes of RT within each group at each drenching. For more detailed analysis, Low rumination and High rumination groups were separated. To examine the effect of drenching in both, the data of the two groups were compared with independent-sample *t*-tests at each time interval/day. Only post-calving RT values were used to calculate pre-drenching averages before first drenching.

Pre-calving reticuloruminal pH was analysed individually for each cow. Time spent below reticuloruminal pH of 5.8 was summarized daily until the day of calving. Animals that spent over 330 min/day below a reticuloruminal pH of 5.8 on any pre-calving day were classified as subacute ruminal acidosis (SARA) sensitive, while the rest of the cows were classified as SARA tolerant (Zebeli et al., 2008). These categories were merged with the drench/control system to create the final groups. After calving, daily reticuloruminal pH averages were analysed, and for the time below reticuloruminal pH of 5.8, daily sums were used.

For the analysis of reticuloruminal pH and the time spent below a reticuloruminal pH of 5.8, Sensitive and Tolerant groups were separated. To examine the effect of drenching in both, the data of the two groups were compared with independent-sample *t*-tests at each day. One-way ANOVA and Tukey's post hoc tests were used to determine significant changes within each group in the first 7 days after calving.

A probability of $P < 0.05$ was considered as statistically significant.

RESULTS

Rumination time before calving

In total, 161 animals were included in the final analysis. Based on their calving dates, 89 animals were assigned to the drenching and 72 cows to the control group. In the last 96 h before calving the herd mean RT was 1,967 ± 298 min. In the Low rumination ($n = 71$) and High rumination ($n = 90$) groups, the mean RT was 1,699 ± 215 min/96 h and 2,176 ± 152 min/96 h, respectively. The final study groups of Low rumination control, Low rumination drenched, High rumination control and High rumination drenched consisted of 34, 37, 38 and 52 cows, respectively ($P > 0.05$), and their distribution was considered even.

Figure 1 shows the changes in RT in the experimental groups during the pre-calving period. RT was significantly lower in the interval −2 and calving compared to the previous intervals within both groups ($P < 0.05$). The significant difference in the RT between the Low and High rumination groups disappeared at interval −2 (7.3 ± 10.9 min/2 h and 11.2 ± 16.2 min/2 h, respectively).

Effect of drenching on rumination time

Table 1 represents the changes in the study groups around the time of the drenchings (the second and third drench showed no significant difference, so they are presented in the same column).

There was no significant difference in RT between the pre-drenching intervals and the interval of the first drench in Low rumination groups and in High rumination control.

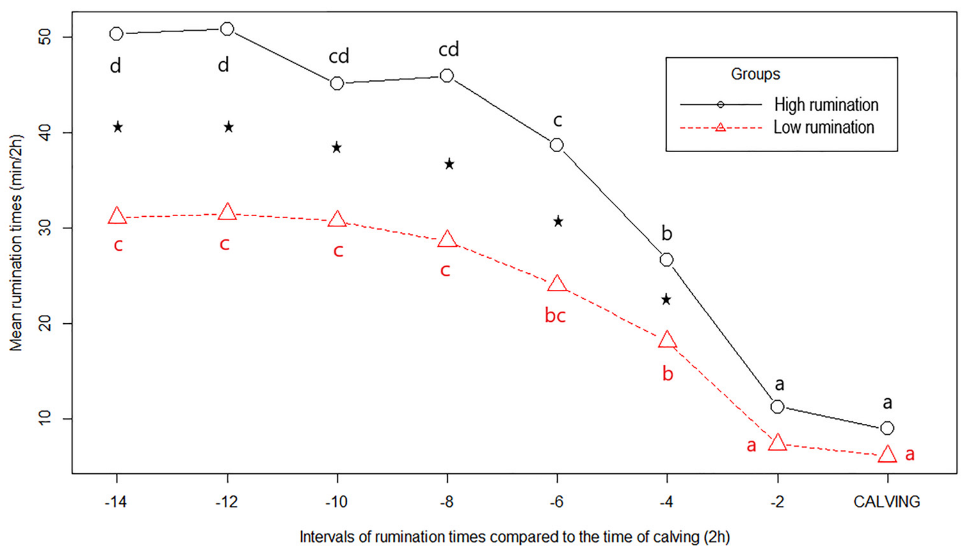

Fig. 1. Rumination time (min/2 h) in dairy cows with High rumination time and Low rumination time until the completion of calving. The stars indicate significant differences between groups ($P < 0.05$). The different letters (from "a" to "d") above/below the lines indicate significant differences found using one-way ANOVA, within each group ($P < 0.05$)

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Table 1. Rumination time (RT) (min/2h, mean ± SD) in the study groups before and after drenching. "DRENCH" indicates the 2-h interval in which the drenching was performed. Averages of the first drenching were listed separately from the second and third, and only post-calving RT values were used to calculate pre-drenching averages before the first drench. The stars indicate significant differences between each pair of groups, found using independent sample *t*-tests (rows between each pair of vertical lines) ($P < 0.05$). The different superscripts indicate significant differences found using one-way ANOVA, within each group (every column individually) ($P < 0.05$)

Interval (hours relative to drenching)	1st drench				2nd and 3rd drench			
	Low rumination control (n = 34)	Low rumination drench (n = 37)	High rumination control (n = 38)	High rumination drench (n = 52)	Low rumination control (n = 34)	Low rumination drench (n = 37)	High rumination control (n = 38)	High rumination drench (n = 52)
−12	^{ad}27.47 ± 22.63	^{ab}23.83 ± 20.55	^{ac}30.09 ± 22.88	^{df}31.82 ± 19.76	^{bcd}38.98 ± 22.12	^{cde}29.17 ± 22.78	^{bd}44.18 ± 20.83	^{ef}38.77 ± 20.75
−10	^{ad}21.13 ± 18.01	^{ab}14.42 ± 17.92	^{ac}28.97 ± 22.84	^{cde}25.67 ± 20.52	^{b}43.39 ± 23.83*	^{abd}22.67 ± 18.06*	^{bd}43.22 ± 19.66	^{eg}42.09 ± 24.55
−8	^{ab}15.56 ± 17.55	^{ab}17.57 ± 14.47	^{a}20.89 ± 17.32	^{ad}19.14 ± 15.46	^{bcd}38.87 ± 21.54	^{be}28.22 ± 17.58	^{bc}41.13 ± 20.23	^{de}35.19 ± 21.17
−6	^{abc}17.95 ± 17.40	^{a}7.71 ± 12.35	^{a}20.02 ± 18.07	^{ad}20.50 ± 17.38	^{ac}28.28 ± 20.74*	^{ab}14.89 ± 13.48*	^{a}30.75 ± 21.91	^{cd}27.98 ± 17.25
−4	^{ab}15.27 ± 16.08	^{ab}15.44 ± 19.43	^{a}20.54 ± 15.88	^{bd}21.68 ± 18.90	^{ab}24.78 ± 19.16	^{abc}20.58 ± 15.83	^{a}28.68 ± 19.60	^{cd}28.58 ± 18.90
−2	^{a}12.36 ± 14.42	^{a}5.33 ± 10.68	^{a}18.05 ± 17.21*	^{ab}11.31 ± 14.78*	^{a}23.59 ± 17.61*	^{a}9.53 ± 10.40*	^{a}31.71 ± 18.40*	^{ab}17.88 ± 17.22*
DRENCH	^{abc}18.19 ± 17.25*	^{a}3.33 ± 4.93*	^{a}19.17 ± 15.11*	^{a}7.16 ± 12.35*	^{ad}31.15 ± 19.44*	^{a}10.44 ± 15.88*	^{ab}35.91 ± 18.69*	^{a}12.54 ± 15.99*
2	^{abc}19.42 ± 15.05*	^{a}5.33 ± 6.65*	^{ab}25.27 ± 17.30*	^{ab}11.44 ± 16.23*	^{ad}31.15 ± 16.45*	^{a}10.83 ± 13.09*	^{a}31.56 ± 19.20*	^{ab}14.65 ± 13.42*
4	^{abc}20.35 ± 18.30*	^{a}9.11 ± 15.15*	^{ab}25.36 ± 21.72*	^{abc}16.02 ± 15.59*	^{a}22.50 ± 18.43*	^{a}11.71 ± 13.85*	^{a}28.32 ± 18.79*	^{bc}22.35 ± 18.46*
6	^{ad}26.96 ± 22.73*	^{ab}11.72 ± 14.41*	^{ac}27.88 ± 20.68	^{bd}21.36 ± 16.16	^{ab}26.09 ± 21.14*	^{ab}14.91 ± 16.3*	^{a}32.04 ± 19.44	^{cd}29.30 ± 21.55
8	^{ad}30.88 ± 23.12	^{ab}18.50 ± 24.45	^{bc}36.27 ± 20.73	^{ef}33.72 ± 19.60	^{ad}35.36 ± 22.06*	^{be}25.71 ± 19.13*	^{bc}42.50 ± 21.71	^{eg}40.68 ± 21.41
10	^{bd}33.58 ± 22.31	^{ab}22.00 ± 20.01	^{c}38.20 ± 18.51	^{ef}37.67 ± 18.91	^{ad}36.71 ± 21.10	^{e}36.77 ± 21.45	^{cd}48.14 ± 19.85	^{fg}45.04 ± 21.08
12	^{cd}36.19 ± 21.86*	^{ab}17.89 ± 16.60*	^{bc}35.98 ± 20.33	^{f}41.52 ± 22.60	^{cd}41.07 ± 23.14*	^{be}28.26 ± 20.24*	^{cd}49.07 ± 20.87	^{g}47.74 ± 19.65
14	^{d}40.62 ± 22.35	^{b}28.50 ± 22.22	^{bc}35.02 ± 20.14	^{f}40.21 ± 23.04	^{cd}41.27 ± 25.20	^{de}34.89 ± 20.13	^{d}52.50 ± 22.35	^{fg}45.84 ± 22.91

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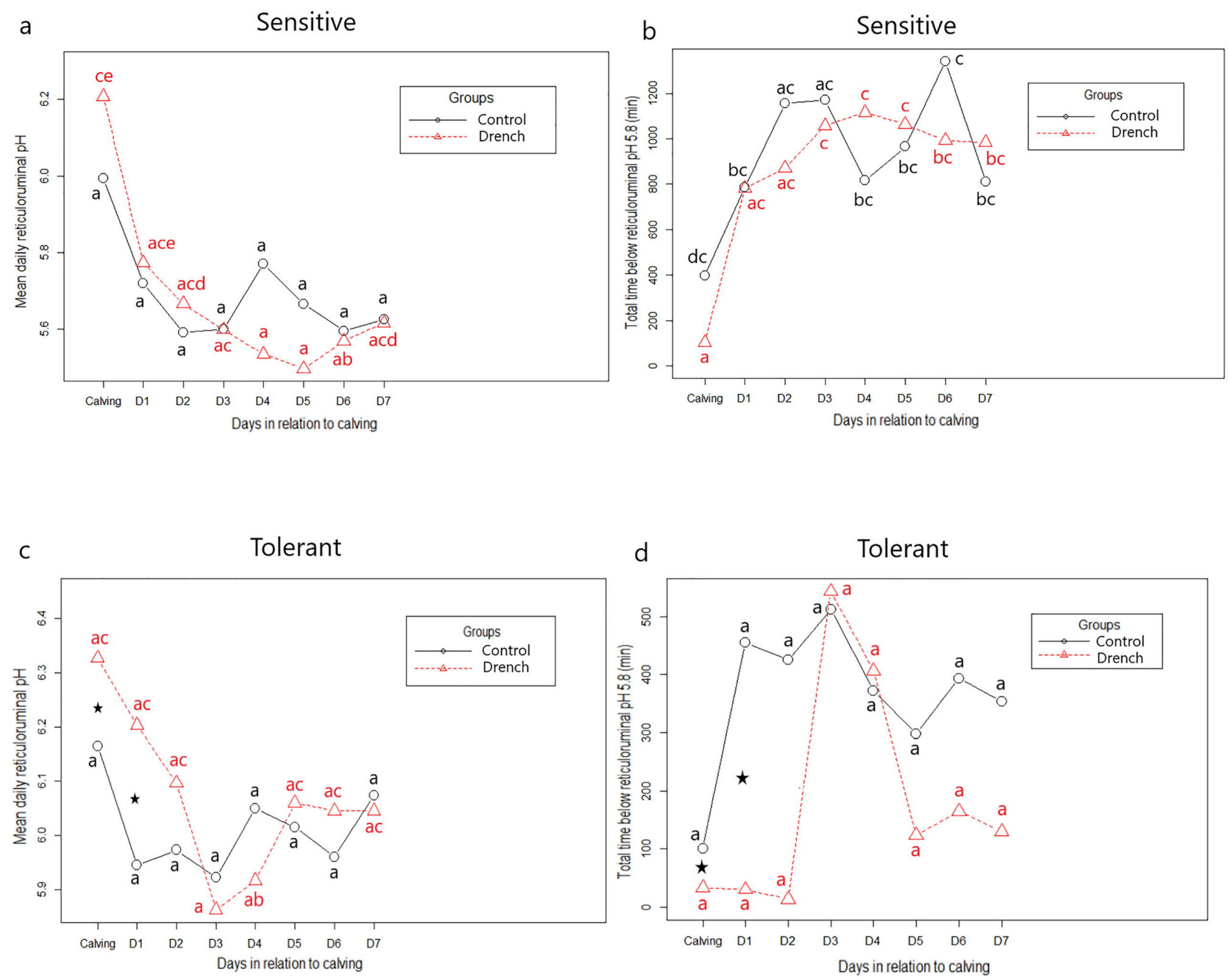

Fig. 2. a and b represent the changes of mean daily reticuloruminal pH and total time below reticuloruminal pH 5.8, respectively, in SARA (subacute ruminal acidosis) sensitive animals (control, drench). 2c and 2d represent the changes of mean daily reticuloruminal pH and total time below reticuloruminal pH 5.8, respectively, in SARA tolerant animals (control, drench). Animals in drench groups were drenched on the day of calving and the two subsequent days. The stars indicate significant differences between groups ($P < 0.05$). The different letters (from "a" to "e") above/below the lines indicate significant differences found using one-way ANOVA, within each group ($P < 0.05$)

In High rumination drench, there was a significant decrease in the RT at drenching compared to several previous intervals, and after drenching RT increased to pre-drenching levels by interval 6 ($P < 0.05$). The significant difference between High rumination control and High rumination drench, and between Low rumination control and Low rumination drench disappeared at intervals 4 and 6, respectively.

At the second and third drenching, RT at the time of drenching did not differ significantly from pre-drenching RT in any of the control groups. There was a significant decrease in RT at the time of the drenching in Low rumination drench compared to intervals −12 and −8, and in High rumination drench compared to intervals −12 to −4 ($P < 0.05$). Post-drenching RT increased to the level of the pre-drenching intervals in Low rumination drench and High rumination drench by intervals 8 and 4, respectively. RT was significantly lower in Low rumination drench compared to Low rumination control in most intervals, and in High rumination drench compared to High rumination control in intervals −2 to 4 ($P < 0.05$).

Reticuloruminal pH before calving

One cow was excluded from the reticuloruminal pH analysis because it was sent to slaughter before the data could have been transferred. The remaining nineteen animals were assigned to Sensitive control ($n = 4$), Sensitive drenched ($n = 6$), Tolerant control ($n = 5$), and Tolerant drenched ($n = 4$) based on their calving date and prepartum reticuloruminal pH. Calving neither influenced reticuloruminal pH significantly in the SARA-sensitive nor in the SARA-tolerant groups.

Effect of drenching on reticuloruminal pH

Drenching had no major effect on reticuloruminal pH and time below reticuloruminal pH 5.8 in either group on the

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2-h scale, so only the daily scale was used for further analysis. The number of the drench administered did not affect mean reticuloruminal pH significantly, thus all three drenches are visualized on the same figure (Fig. 2a–d).

There was a decrease in mean reticuloruminal pH in both Sensitive groups on the days after calving. In Sensitive control, this decrease was not significant. In Sensitive drenched, a significant difference was found on Days 4, 5 and 6 compared to the day of calving ($P < 0.05$). There was no significant difference in the mean reticuloruminal pH between the sensitive groups (Fig. 2a). Total time below reticuloruminal pH 5.8 increased in both Sensitive groups after calving. In Sensitive control, the increase was not significant. In Sensitive drenched, the elevation became significant on Day 3 compared to calving. There was no significant difference between the two groups (Fig. 2b).

There was no significant difference within either Tolerant group in terms of mean reticuloruminal pH and total time below reticuloruminal pH 5.8 on the days after calving. A significant difference was found between Tolerant control and Tolerant drenched on the day of calving and on Day 1 in both mean reticuloruminal pH and total time below reticuloruminal pH 5.8 ($P < 0.05$) (Fig. 2c and 2d).

DISCUSSION

The present study investigated the effect of drenching with the feed additive on rumination time and reticuloruminal pH on the days after calving. Monitoring the health of the rumen in the transition period has recently become easier. Rumination time as well as reticuloruminal pH and temperature can be continuously measured and analysed individually or on herd level, using either transponders or indwelling sensors.

This study further confirmed previous results regarding physiological changes in RT before calving. On the day of calving a pronounced decrease of RT was observed by several research groups (Soriani et al., 2012; Schirmann et al., 2013; Büchel and Sundrum, 2014), and it was detected in both the Low and High rumination groups of the current study, even though a significant difference was found between the Low and High rumination group before calving that disappeared by interval −2. Some researchers detected a complete stop of rumination around the time when calving was completed (Pahl et al., 2014). Interval −2 and the interval of calving presented the lowest RT in both groups, but the averages remained above zero. The cessation of rumination can be explained by the events around parturition (Jensen, 2012). Rumination restarts at around 4–6 h (Büchel and Sundrum, 2014), or on average 355 min (Pahl et al., 2014) after calving. In this study this aspect of RT was not explored.

Drenching is one of the routinely applied prophylactic treatments after calving. It can be done using a drenching gun (≤1 L) or a stomach pump (up to 40 L), or simply by giving the drenching solution in a bucket (drinkable drench), depending on the compound/recipe used. No previous study had been found by the authors detailing the direct effect of drenching on ruminal function, but metabolic diseases and higher BHB levels had been associated with lower RT (Soriani et al., 2012; Stangaferro et al., 2016), thus the effect of drenching on energy balance could be explored as an influencing factor of RT.

The findings of this study did not reveal any positive effect of drenching with the current additive on RT. Drenched groups had significantly lower RT than controls in the intervals after treatments. This can be explained by the properties of calcium propionate, which is reported to be able to stall abomasal movements for a short period of time (Breukink, 1991), which might influence ruminal motility. Calcium propionate also produced ambiguous results in studies investigating its effect on energy balance. Researchers found no or little positive effect after mixing it into the TMR or using it as a drench in 1–20 L of water (Stokes and Goff, 2001; Enemark et al., 2009), with only some detecting a decreased plasma BHB and/or NEFA concentration (Liu et al., 2010). Propylene glycol could be a better solution either delivered by drenching gun or mixed into 10 L of water to improve energy balance and prevent the negative effect on abomasal motility (Pickett et al., 2003; McArt et al., 2011), although symptoms of toxicity can manifest above a dose of 500 g/day (Trabue et al., 2007).

After all drenching events, the significant difference between the treatment and control groups disappeared sooner in High than in Low rumination, which might be explained by the better initial ruminal motility, and consequently better compensation of the effects of drenching in the High rumination group. It was established that healthy animals have higher RT postpartum (Stevenson et al., 2020), and this could have played a role in their adaptation.

There was a significant difference between Low rumination control and drench at intervals −10 and −6 before the second and third drenching, for which no explanation was found. Interval −2 was always the time for the morning milking and veterinary examinations, which could be associated with lower RT in most groups. Another major limitation of the study is the lack of means to differentiate between the effect of the additive and the effect of the drenching event. Drenching itself might be a cause of stress for the animals (Grandin and Shivley, 2015), but it is the only viable way for the feed additive to be delivered, so the two factors were analysed as one.

Fresh cows undergo a lot of metabolic changes including an increased risk of SARA. Zebeli et al. (2008) defined SARA-sensitive cows as those that have either a daily reticuloruminal pH lower than 6.16 or spend more than 5.24 h a day below a reticuloruminal pH of 5.8. The prevalence of SARA in a herd is estimated to be 19% in early lactation (Garrett et al., 1997). SARA has a number of negative consequences on the health of cows, including reduced feed intake and fibre digestion, increased bacterial endotoxin production resulting in laminitis and lameness, and inflammation (Plaizier et al., 2008).

Supplementing animals with yeast can be achieved most easily by mixing it into the TMR. Yeast is reported to have a

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positive effect on milk yield in early-lactation cows (Harris and Lobo, 1988), and some researchers reported its beneficial effects on the reticuloruminal pH (Miller-Webster et al., 2002; Jouany, 2006), but these findings are contradicted by others (Harrison et al., 1988). Data on the effect of yeast administered in a drench are scarce.

The present study shows a decrease in reticuloruminal pH in the days after calving, which is consistent with previous data (Garrett et al., 1997; Kovács et al., 2017). Drenching events had no significant effect on either reticuloruminal pH or the time below reticuloruminal pH 5.8 in any of the sensitive groups. In contrast, in Tolerant drenched reticuloruminal pH was significantly higher and time below reticuloruminal pH 5.8 remained significantly lower than in Tolerant control on the days of the first and the second drenching events. The difference in the reticuloruminal pH of Tolerant drenched compared to Tolerant control can be explained by the yeast content of the drench recipe used. Yeast has been reported to increase and stabilize reticuloruminal pH (Miller-Webster et al., 2002; Jouany, 2006) by influencing the numbers of certain bacteria in the rumen, and this effect was prominent in Tolerant drenched cows. In Sensitive drenched, however, the same effect could not be observed. This might have been due to the recipe not containing enough yeast to balance the already decreasing ruminal pH. It is also possible that in the case of SARA-sensitive animals, yeast supplementation should be started earlier, in the days before calving, to achieve the same effect.

It can be concluded that drenching temporarily decreased RT in both drenched groups compared to controls. The drenching recipe had a positive effect on reticuloruminal pH and time below reticuloruminal pH 5.8 in Tolerant drenched animals. Even though drenching is widespread in dairy farms to improve animal health, the findings obtained so far only partially support this concept.

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