Long-term measurement of reticuloruminal pH-value in dairy cows under practical conditions by an indwelling and wireless data transmitting unit

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Introduction and Objectives

Subacute rumen acidosis (SARA) is a widespread herd health problem in high yielding dairy cows (Duffield *et al*., 2004), characterized by a persistent abnormally low rumen pH. It has been shown that rations with high sugar and starch contents increase the occurrence of SARA. In dairy cows, the negative effects on health associated with SARA are reduced dry matter intake (DMI), decreased body condition, diarrhoea, rumenitis and inflammation, caudal vena cava syndrome, displacement/ulceration of the abomasum, laminitis and immunosuppressive disorders (Dirksen, 1990; Nordlund *et al.* 1995; Ossent *et al.*, 1997; Gantke *et al.*, 1998; Owens *et al.*, 1998; Cooper *et al.*, 1999; Enemark, 2008; Plaizier *et al.*, 2008; Sato *et al.*, 2012).

SARA is difficult to diagnose in the field (Duffield *et al*., 2004). The evaluation of fermentation conditions in rumen fluid would be the most meaningful criterion and the definitive test for SARA is the determination of the reticuloruminal pH-value (Nordlund, 2003; Krause and Oetzel, 2006; Alzahal *et al.*, 2007). pH-value can be measured in the rumen fluid which is either collected with a stomach tube (Garret *et al.*, 1999; Bramley *et al.*, 2008; Steingass and Zebeli, 2008) or by rumenocentesis (Kolver and DeVeth, 2002; Bramley *et al.*, 2008; O'Grady *et al.*, 2008). Yet, it has been shown that the technique used to collect ruminal fluid affects the measured pH values (Dirksen, 1990; Kolver and Garret, 1994; Seemann and Spohr, 2007). In particular, Seemann and Spohr (2007) have found that the stomach tube technique overestimated the pH value by about 0.5 pH-units when compared to rumenocentesis, as a result of saliva contamination. They also suggested that rumenocentesis might have negative effects on animal health.

Recent techniques use indwelling pH probes placed in the rumen (Duffield *et al.*, 2004; Strabel *et al.*, 2007) or in the reticulum (Enemark *et al.*, 2003; Gasteiner *et al.*, 2009, Mottam 2009, Sato 2012) for a continuous monitoring of reticuloruminal pH. This method is advantageous as it allows diurnal recording (Keunen *et al.*, 2002; Duffield *et al.*, 2004; Gasteiner *et al.*,2009), but data collection requires either the removal of the chip via a rumen cannula (Dado and Allen, 1993; Nocek *et al.*, 2002; Cottee *et al.*, 2004; Rustomo *et al.*, 2006; Penner *et al.*, 2007) or the data transmission by cable to an external unit, fixed onto the animal (Krause and Oetzel, 2006).

Gasteiner *et al.* (2009) have described and evaluated a wireless data transmitting unit allowing continuous measurement of reticuloruminal pH and thereby long term investigations are possible. Rumen cannulated cattle are not essential when using this technique as the probes are given orally, also shown in trials with grazing dairy cows (Gasteiner et al. 2012).

Objective of this study was the continuous and long term measurement of the ruminal pH in high yielding dairy cows under practical conditions. Focus was put on interpretation of both, individual pH-data and herd pH-data.

Material and Methods

An indwelling bolus-system for continuous monitoring of the reticuloruminal pH-value was given to 36 non rumen cannulated dairy cows out of 6 herds. Data were collected in an internal memory chip and sent via radio transmission to an external receiver. Ruminal pH was measured at intervals of 600 sec over a period of first 80 days of lactation, starting 7 d prior to calving date. Daily mean, minima, maxima and time ruminal pH (min/d) below 6.3; 6.0; 5.8 and 5.5 were calculated. Individual milk yield and milk composition, feeding conditions and ration composition in terms of roughage and concentrate sources were determined and nutrient components were analysed. Statistical analysis was conducted by GLM (Statgraphic Plus 5.1

Results

Individual examples for SARA, pH-short-term drops, daily pH-fluctuations and "off feed syndrome" could be detected and these were linked with their causation (figures 2-6).

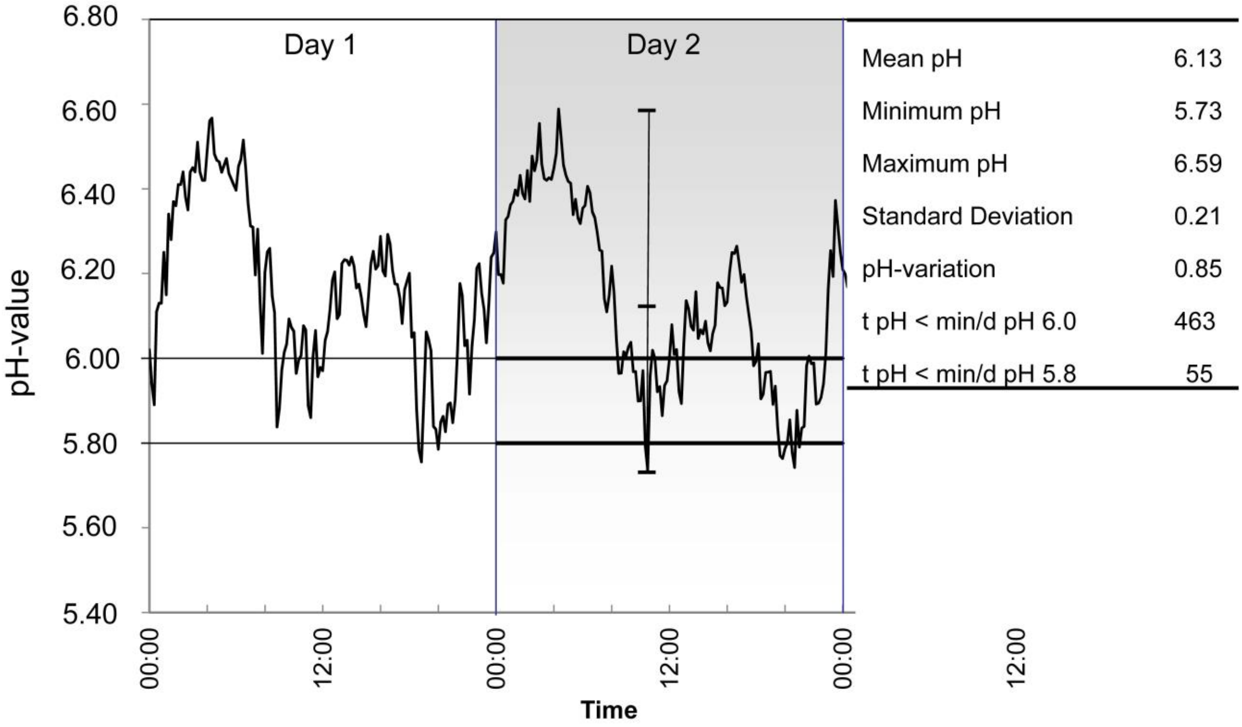

Figure 1: Example for the diurnal pattern of reticuloruminal pH of 1 representative cow over a period of 2 days. Interpretation of individual pH-data is based on mean pH, minimum and maximum pH and time pH was below specific pH-limits (6.0, 5.8). Each drop in the pH-value corresponds to the ingestion of feed and each increase is linked with rumination or break of feed intake. Thus the diurnal pH variations are the expression of the feeding management.

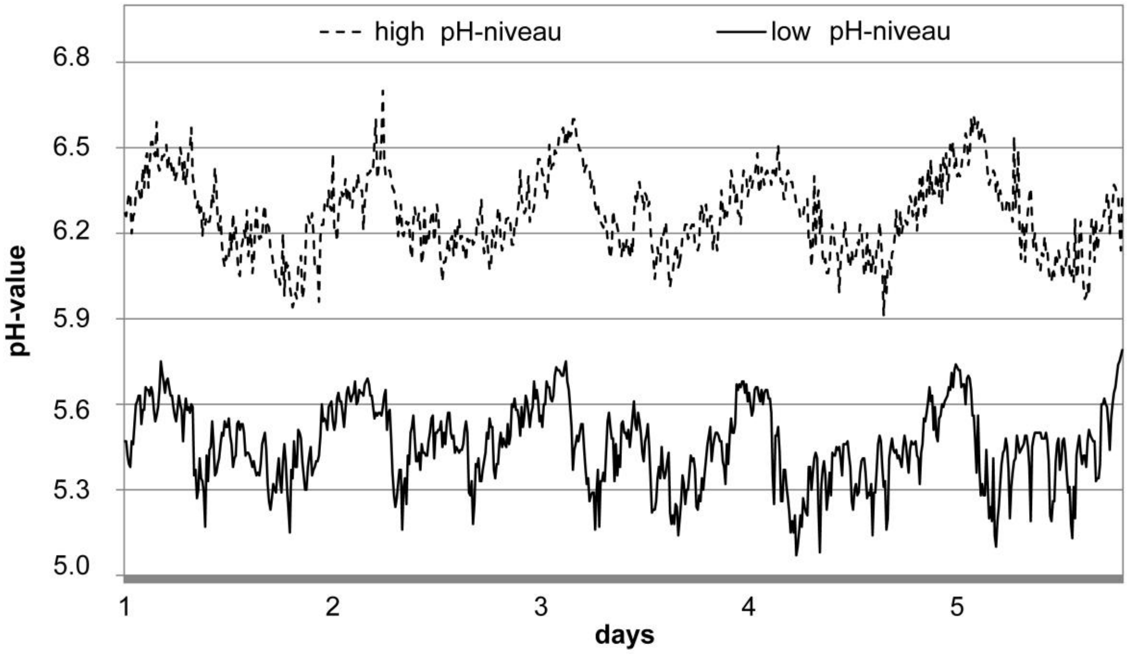

Figure 2: Interpretation of individual pH-data showing the effect of amount of fed concentrate: Feeding 6 kg/day concentrate, a higher pH-niveau (mean pH 6.27) was found when compared to concentrate feeding of 12 kg/d ("low pH-niveau"), which was leading to a mean pH 5.46 and provoking clinical signs of rumen acidosis in this cow.

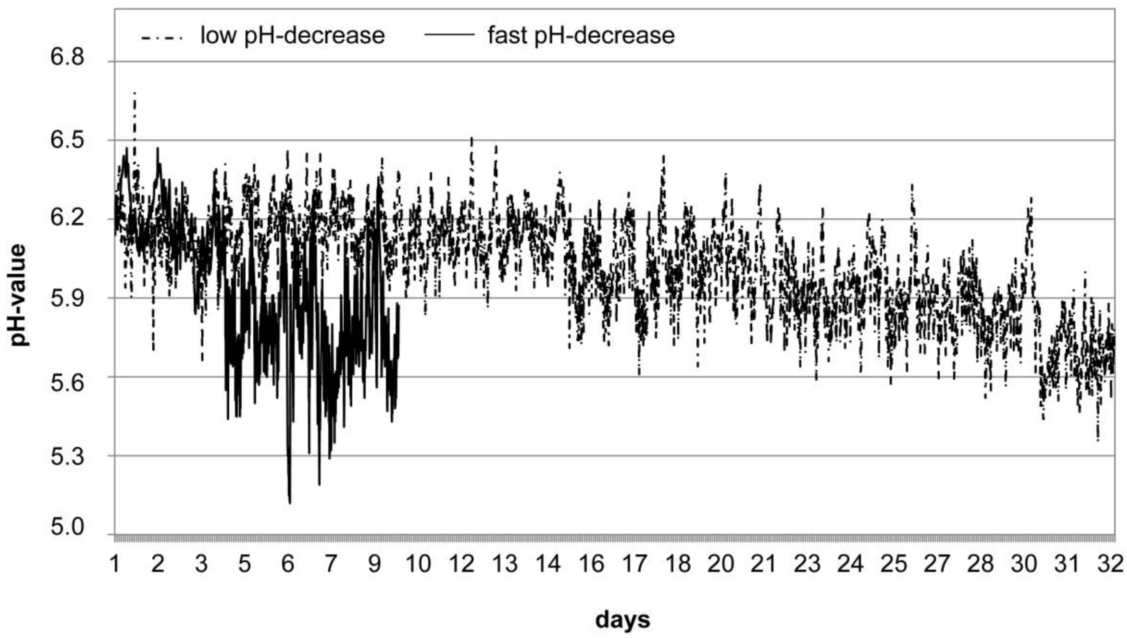

Figure 3: Interpretation of individual pH-data showing the effect of adaptation period to increasing amounts of concentrate feeding: ("days" meaning "days in milk DIM"): starting

with 1 kg concentrate/day on day 1 after parturition, when increasing the supplementation of concentrate by 250 g/day (“low pH-decrease”), pH steadily decreased, no clinical signs of rumen acidosis were seen in this cow and daily milk yield was > 40 kg. An increasing supplementation of 1 kg concentrate per day (“fast pH-decrease”) led to a rapid decrease of pH with big pH-fluctuations. Due to severe clinical signs of rumen acidosis, the experiment in this cow was stopped.

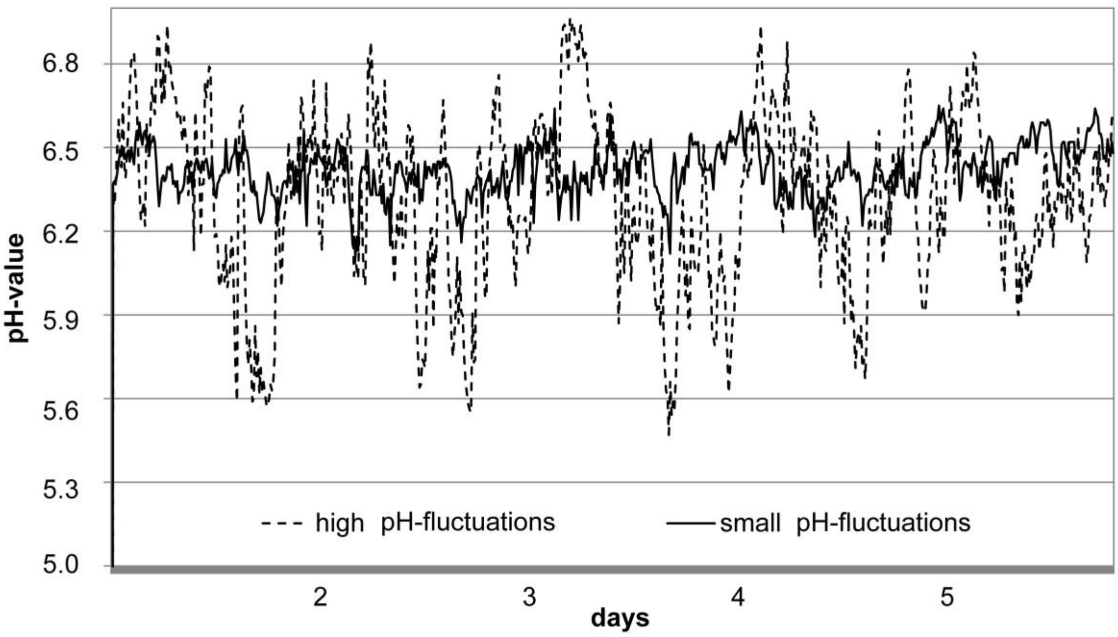

Figure 4: Interpretation of individual pH-data showing the effect of feeding management: separate feeding of offered feedstuff (hay, concentrate, grass silage, corn silage and concentrate again) is provoking very high pH-fluctuation whilst the same diet fed as Total mixed ration (TMR) shows small pH-fluctuations.

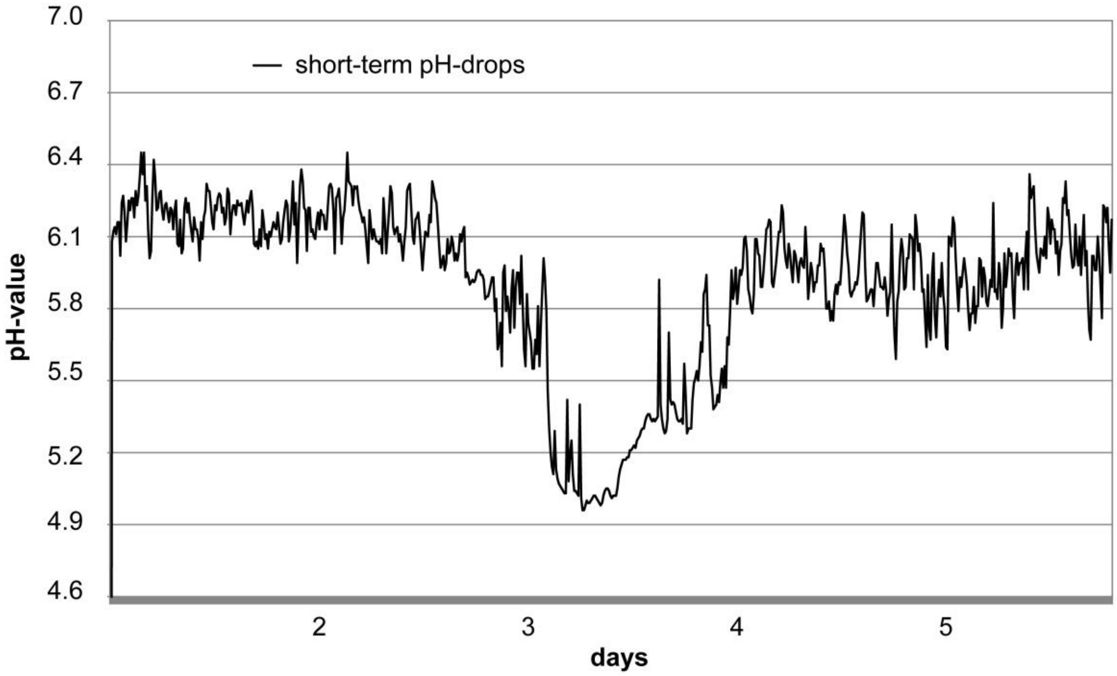

Figure 5: Interpretation of individual pH-data showing the effect of rapidly intake of high amounts of grain based concentrate, provoking a fast short term drop of pH-value.

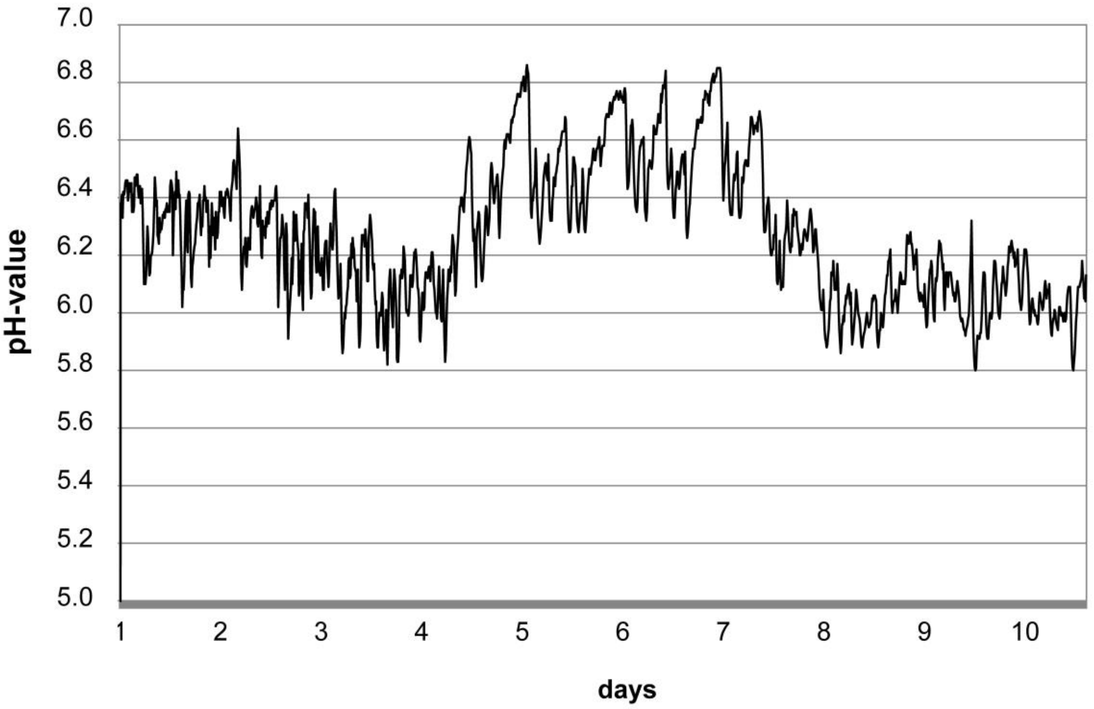

Figure 6: Interpretation of individual pH-data showing the effect of less feed intake provoking a heightened pH-level for a longer period of days (“off feed syndrome”).

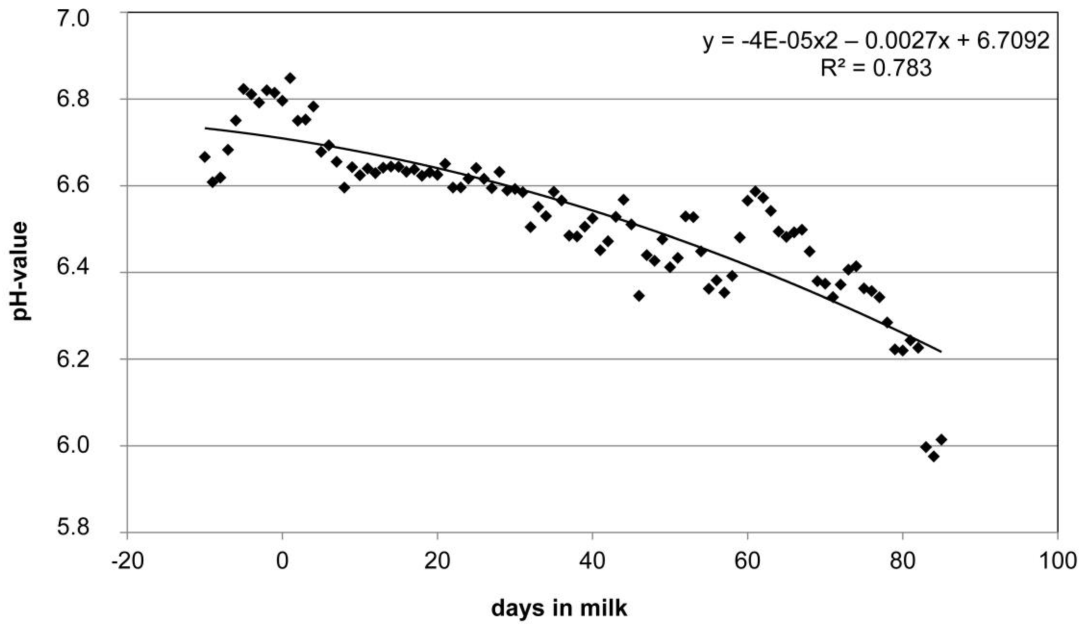

Figure 7: Interpretation of herd based pH-data. Each point reflects the man pH of 16 cows of 4 high yielding dairy herds, parturition on day 0. Mean pH around calving increased and decreased after calving. Mean pH was stable around pH 6.6 until 30th day in milk, then pH decreased steadily.

Mean pH-value for all cows was 6.5, ranging from pH 6.7 during dry period to pH 6.1 on day 80 of lactation. After an increase of pH-value within 3 days prior parturition, a significant decline of pH-value was seen immediately during the days after parturition, explainable by an increasing dry matter intake around calving, and a second decline occurred 25 to 30 days postpartum due to the increasing amount of fed concentrates (figure 7).

Discussion

The objectives of this experiment were to test the pH-measurement system under practical conditions in high yielding dairy cows. The cows used for the trial were selected randomly and assumed to be healthy before the beginning of the measurements.

Repeated measurement of reticuloruminal pH values remains the only way to quantify the balance between acid production, acid removal and buffering capacity in the reticulorumen (Westwood *et al.*, 2003). In the our study pH-value was measured at the bottom of the reticulum continuously, as the probes, orally given, will end up there due to their weight at

least 24 hours after having been given. It was also proven that the measurement of the reticular pH value in cattle is representative for the ruminal pH value (Gasteiner *et al.*, 2009, sato et al. 2012), for this very reason the term “reticuloruminal pH value” is used in our work.
Continuous measurement of the reticuloruminal pH value is advantageous in comparison with a single measurement because rumenocentesis or oral stomach tubing must not be performed very frequently. The data obtained from continuous pH measurement (in presented study 144 pH measurements/cow/day) provide a good insight into pH variability in the reticuloruminal system. Reticloruminal pH-value was recorded continuously in 36 non rumen cannulated dairy cows out of 6 herds until their 80th day p.p. The pattern of the pH in the reticlorumen showed a significant correlation with the day of lactation. During the week before calving an increase of the pH was seen, showing pH 6.6 up to a higher level (pH 6.8), remaining for 7 days around the calving day. After that, a decrease onto a level of pH 6.6 followed. This level remained unchanged until the day 20-25; but then pH decreased to a level of 6.2 or 6.0, respectively, around the 80th day in milk. Furthermore, there was a very close relation of the average pH in the reticlorumen to the daily milk yield (kg FCM). Whereas the pH-value was above 6.8 up to a milk yield of 25 kg, it was clearly beneath pH 6.6 at milk yields being higher than 40 kg.
The pattern of the pH value enables us to make conclusions regarding the composition of the diet and on feeding management (Gasteiner *et al.* 2012). The statistical analysis of such a large volume of data makes the outcome more precise and reliable in comparison to single measurements derived from oral stomach tubing or rumenocentesis. The diurnal pH variations are the expression of the feed intake as also described by Sato et al. (2012) and diurnal temperature variations can be seen as a consequence of water intakes of the animals. Each drop in the pH corresponds to the ingestion of feed and each drop in the temperature to the ingestion of water (Gasteiner et al. 2009).
Previous studies using continuous pH measurement included segments over the time/value relationship of the measured pH values and calculated the time above or below a certain defined pH threshold. Nocek *et al*. (2002) showed the effect of increasing the percentage of grain in the diet on mean ruminal pH value within specific ranges (<5; >5, <5.5; >5.5, <6). Plaizier *et al.* (2008) showed the duration of pH values below 5.6 in min/day. Segmentation over time/value eases interpretation, as shown in figure 1. Ghozo *et al.* (2005) also addressed the issue of the duration of SARA. They defined SARA as a rumen pH threshold of between 5.2 and 5.6 for > 176 min/day. Data from AlZahal *et al.* (2007) suggest that a period of

ruminal pH lasting longer than 473 and 283 min/day below pH 5.8 and 5.6, respectively, should be avoided to minimise health disturbances due to SARA. Basic principle for such reporting is the possibility to do continuous pH measurement in the reticulorumen, radio transmission of data is the base for gaining the data.

The results of the present trials were achieved by means of technical innovations, which open up new possibilities for a better understanding of physiology and pathology of the reticulorumen, not only in scientific areas. The use of pH-sensors under is possible on dairy farms under practical conditions as well. The results serve for the monitoring of animal health and for the check-up and controlling of the ration composition and feeding management. It was also shown that feeding failures are linked with pH-level, pH-deviations as well as with pH-increases or decreases. Therefore, the sensor system can be used for scientific purposes but also as a management tool at distinct "indicator animals", focussing on high yielding dairy farms.

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