

# Towards routine monitoring of rumen pH, temperature and redox in ruminants

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## **Abstract**

Techniques to monitor rumen pH wirelessly has been proposed in research over a number of years. The ability monitor the dairy cow and manage feed is the next step which this paper addresses.

Reduction-oxidation potential changes dynamically within the rumen of dairy cattle and can be seen to hold interesting relationships with pH values and identifiable drops in temperature which have been accredited to drink events. Reduction-oxidation potential represents all the chemical reactions that cause a change in the oxidations state of atoms, where oxidation is the loss of electrons and reduction is the gain of electrons. Since the pH of a solution approximates the negative logarithm of the concentration of hydronium ions  $H_3O^+$ , a change in pH implies a change in the concentration of  $H_3O^+$  and so the effect would be to create an altered net positive charge and so impacting on the reduction-oxidation potential. The consumptions of any matter changing the pH, for example fluid during a drinking event or feed, hence causes a dynamic change in redox and we have data to evidence this.

## **Introduction**

Previous work has reported on research, what is now required is to show that a pH bolus can be used long term to monitor dairy cows. pH bolus long term graphs.

Temperature readings from healthy cows, taken from the reticulum, typically reside around a mean value with significant periodic drops which are identifiably outside of the normal stable behaviour. Their distribution suggests that they are the result of the cow drinking. Analysing readings of pH and Redox at the times around these drops provides some interesting insights into the dynamic behaviour associated to the act of drinking. It appears that the initial process of drinking causes some mixing of acidic fluids in the rumen and in the path of the fluid in the throat. This causes short term fluctuations in Redox and transient declines in pH before the environment settles down to more predictable behaviour.

## **Materials and methods**

The rumen bolus was constructed of a stainless steel end cap within which a sampling chamber was machined to provide a space around combined electrode pH probe and a redox sensor made of a 5 mm diameter gold disk. The pH and redox sensor shared the common triple junction reference AG/AgCl electrode embedded in the combined electrode, a technique protected by UK Patent application 2011 ). A thermistor was embedded in the steel end cap to measure temperature between 30C and 45 C. The signals from the sensors were measured by an ADC and stored and transmitted by a wireless integrated circuit on demand from a base station held by an operator standing next to the animal. The electronics were encapsulated in a resin matrix that was resistant to rumen liquor. The resulting bolus was 115 mm long by 26.5 mm diameter with

hemispherical ends. The stainless steel end cap ensured that the sensor tended to point down towards the base of the rumen. The non weighted end had a steel hoop embedded to enable the bolus to be tethered at different points within fistulated cows. The signal from each sensor was collected every 60 s and the results for each 15 minute period stored.

The bolus was inserted into the rumen via the fistula or in intact cows by mouth, from where it migrated to the reticulum under the peristaltic forces

Data was downloaded regularly and files concatenated to give long term profiles.

### **The data:**

This paper considers two data sets collected in two different locations. The first data set is a long term farm data set and the second was conducted in research animals with the intentions to analyse redox in the rumen.

The data analysed consists of 15 samples for 3 cows each over approximately 5 days with readings of pH, temperature and Redox taken continuously and averaged over 5 minute intervals to filter out some of the statistical noise.

### **Temperature:**

The temperature readings in each of the data sets mostly resides around the cows body temperature, however there are clear and frequent drops of around 2 to 3 C occurring approximately twice every hour and lasting for around ten minutes before returning to the mean. If a cow were to take a drink, the cool liquid would pass down the throat and in the digestive system where it would be warmed. The frequency and range of these changes in temperature appear to be characteristic of the expected behaviour of the act of drinking and so can be considered to correspond to it.

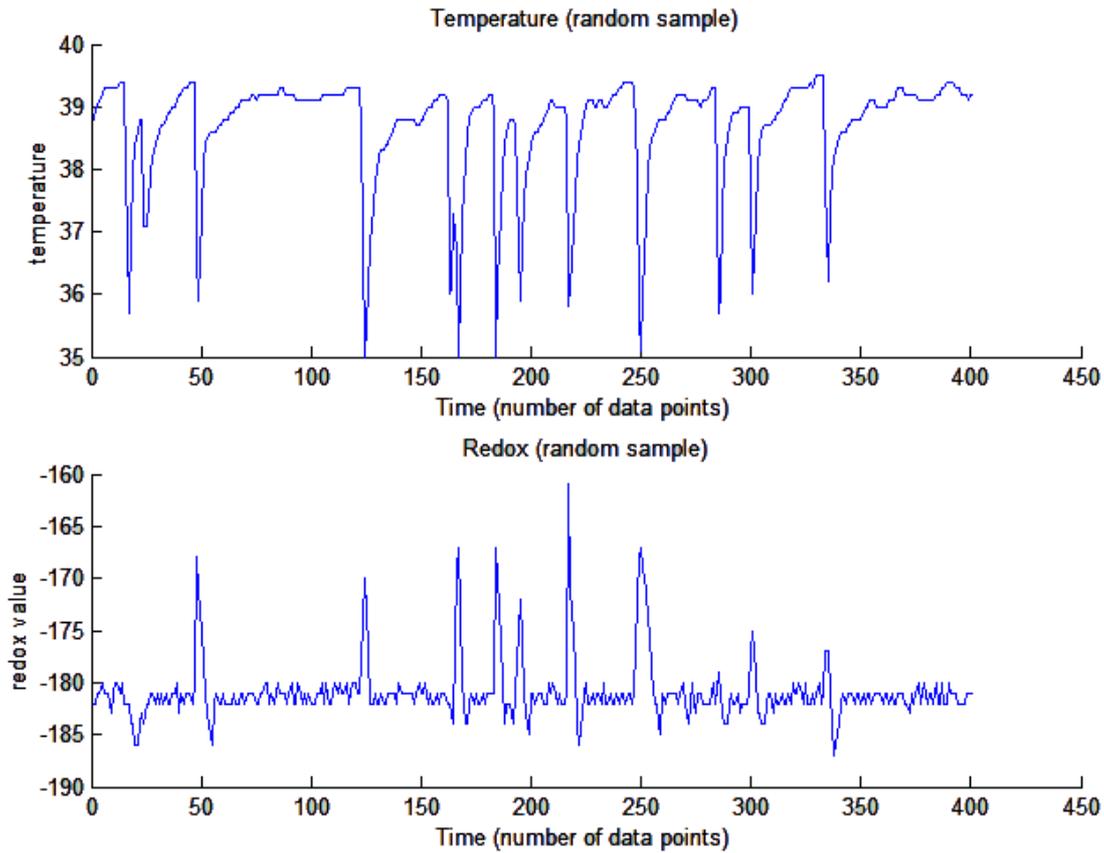
The drops in temperature each conform to similar topology with a sharp decline followed by a distinct trough and then a sharp climb back to the mean. Through calculating derivatives and specifying thresholds it is possible to identify the times at which the cow initially takes a drink, the times at which the temperature is reduced the most and when the temperature returns back to the mean. These times are useful to compare to changes in Redox and pH readings at the same times to see what the effect intakes of liquid has on these measures.

### **Redox and pH:**

Redox, or reduction-oxidation, reactions are all the chemical reactions that cause a change in the oxidations state of atoms, where oxidations is the loss of electrons and reduction is the gain of electrons. The pH of a solution approximates the negative logarithm of the concentration of hydronium ions  $H_3O^+$ . For a change in pH and so a change in the concentration of  $H_3O^+$  there would be an expected change in the net positive charge of the solution and so a change in Redox reading. The solution in the rumen and reticulum is generally acidic and so for drops in temperature corresponding to times when the cow has taken a drink, for a pH neutral fluid such as water, this should cause pH values to rise and so cause the Redox values to decline. If the reticulum pH is initially above pH 7 then the opposite effect would occur so that the pH would drop and Redox rise.

**Results:**

For each data set the Redox values remained mostly consistent with a few short term significant fluctuations outside of the small standard deviation. This suggests that the readings are not particularly dynamic and mostly remain stable over long periods of time. However each of the significant fluctuations, lasting between 10 and 15 minutes, occur, with a strong certainty, at times when there has been significant drops in temperature. This relationship can be seen in the following figure with spikes in Redox occurring at times of a drop in temperature for a random sample of the data.



The following table captures the certainty of this relationship for all of the data analysed.

Cow	# Drinking events	# Redox fluctuations	# Redox fluctuations around times of drinking events	# Drinking events with no change in redox	mean redox	maximum redox	minimum redox
1	466	371	365	101	-178	-152	-188
2	272	126	122	150	-180	-159	-187
3	56	56	56	0	-193	-169	-208

The fluctuations in redox are typically characterised by a large initial peak followed by smaller trough, both outside of the standard deviation, before returning to the mean. However this is counter intuitive since if the fluctuations occur at times when the cow has taken a drink then the expected behaviour would be for the Redox reading to solely experience a decline since the pH

value should have moved towards 7 from below, supposedly causing a smaller net positive electrical charge. Moreover there would be a further expectation for there to be a one to one relationship with drops in temperature and fluctuations in Redox, so that there is a fluctuation in Redox for each drop in temperature, but this is not the case. This implies a more complicated scenario than first perceived. Looking to the pH values at the times when there has been significant drops in temperature extends this picture.

The drops in temperature are characterised by an initial turning point where the first order derivative of the temperature with respect to time becomes negative, the time at which the drop in temperature reaches a local maximum and when it recovers. Considering the times of these events, when there has been a change in redox, for the pH values, the expectation is that the gradient between those consecutive pH values would be positive since the intake of the water should cause a change in pH to move closer towards pH 7. However calculating these values reveals that between the time of the cow first taking the drink and the point at which the temperature reaches a local minimum the pH is in decline and so the pH in the reticulum becomes more acidic.

However it appears that this unexpected behaviour is transient. Considering the pH at times when the temperature is at a local minimum and the time at which the temperature has fully recovered the gradient between the pH values is positive. This indicates that there is an average decline in acidity over the time period between intakes of fluid after the transient rise at the time of the cow drinking, which more neatly conforms to the predicted behaviour. The average behaviour of the pH around drinking events for each cow is captured in the following table.

	Just before a fluctuation in redox	During a fluctuation in redox	Just after a fluctuation in redox
Cow	Mean pH	Mean pH	Mean pH
1	6.27	6.25	6.29
2	6.17	6.16	6.73
3	6.34	6.27	6.31

## ***Discussion***

The periodic drops in temperature appear to be characteristic of the act of the cow taking a drink both in the frequency and the effect on the temperature. The act of drinking a pH neutral fluid would cause the pH of the rumen to become rise since it is an acidic environment and this in turn should have caused Redox readings to become smaller.

However it appears that the initial act of drinking causes unexpected short term behaviour in the pH in that it experiences an initial decline, before climbing as expected. More over, although each of the fluctuations in the Redox occur at times when there has been a significant drop in temperature, it is not a one to one relationship and generally the values are much more stable than first perceived and so less effected by small changes in pH and in fact it only appears to significantly change for 10 to 15 ten minutes before settling back down to its mean.

The act of drinking would cause contents in the rumen and in the path of the fluid to become mixed

in and stirred up. This would cause acidic solutions in the throat and the rumen to be washed over the bolus as the fluid mixes until settling down. However this effect would be transient and so the dynamics within the rumen would become calmer and settle down to more predictable behaviour a short time after the cow has taken a drink. This is evident in dynamics of the pH conforming with expected behaviour after the temperature drop but not during and the Redox remaining stable outside of the initial periods of the cow drinking.

These results need to be tested on more data and also on behaviour of redox and temperature in the ventral sac of the rumen.

**References:**

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