Is A Lifetime Rumen Monitoring Bolus Possible?

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Monitoring the rumen can permit better management of nutrition and detection of calving. Boluses to measure temperature, and pH in experiments have appeared in recent years. Recent developments show that the life of the bolus can be extended to manage the cow throughout its adult life.

Introduction

In 1968 Johnson & Sutton demonstrated a pH datalogging probe suspended into the rumen of fistulated animals and described the benefits and difficulties of rumen monitoring. Recent developments in wireless and microcomputing have enabled us to develop boluses that can be inserted by mouth and remain accurate for several weeks (Mottram et al., 2008). This paper describes recent developments to extend the life of wireless temperature and pH monitoring boluses and speculates about how their capabilities can be enhanced and extended to the working lifetime of the cow.

Bolus Design

The essential features of a pH bolus are a sensor, an A/D converter, a microprocessor, a wireless transceiver, antenna and either some weight to maintain the specific gravity between 2 & 3 or an expanding wing to prevent expulsion through one of the two orifices in the rumen. To be easy to insert by mouth the bolus should be less than 26 mm diameter and as short as possible.

Location

The rumen has multiple chambers with different functions and a differing profile of rumen pH, the ventral sac being the most active part where a mat of cellulose is constantly churned by peristaltic muscular action. Winged boluses are designed to reside here. Weighted boluses reside in the rumen reticulum along with the other indigestible material a cow can take in during her lifetime.

Sensor Issues

The principal cause of the short life of current boluses is drift of the pH sensors. The most extended life of current sensors was 42 days ±0.2 pH (Mottram et al,2008) but some sensors survive 100 days. The traditional pH sensor is a well developed technology that measures the potential between a reference electrode and a hydrogen ion selective electrode made of treated glass. The reference junction is made of porous teflon backed by reference gel and an impermeable membrane. These are typically used in lab environments where recalibration is possible. The advantage of this sensor is that it is well developed and triple junction versions showing long lives (over two years) in situ in places where access and recalibration is impossible. The disadvantage is that it is big. In 2003 we made shorter fatter sensors believing that the volume of electrogel was a factor reducing drift. That design proved difficult to make reliably and although the best boluses lasted many weeks, many failed as soon as inserted into the cow. Our current design corrects the fundamental oversight which is to operate a glass electrode upside down as this caused leakage of air from the Teflon and its replacement under gravity by rumen liquor. eCow now uses quality assured sensors passed through a metal end cap to orient the sensor tip downwards in buoyant conditions.

Ion Selective Field Effect Ttransucer (ISFET) based boluses have been used (Zosel et al, 2009, Gasteiner et al 2008) but rarely with any extended life. ISFET sensors can be made very small but this then brings the reference electrode close to the rumen liquor and the risk of contamination. All pH sensors need a membrane between the liquid under test and the sensing electrode, this membrane needs to be robust to prevent the erosion by the rumen environment.

Wireless Transceivers

The choice of radio frequency is limited by the available ISM bands 13.56 (used by RFID) 433 & 915 MHz. With careful antenna design, good signals can be obtained at these frequencies several metres outside the cow. The radio signal tends to be strongest close to the ground and behind the animal as if the rib cage was acting to inhibit transmission, thus a receiving antenna in the pit area of a milking parlour would be ideal.

Battery Life

Power is only required to operate microprocessor and wireless. The wireless transceiver both listening and transmitting consumes most power. By software control power consumption can be minimised. The early Silsoe bolus used 3 AAAA batteries giving 625 mAh at 4.5 V and had a theoretical life of 12 months. One lithium cell has enabled us to increase the power to 700 mAh at 3V. The ballast could be made up with more batteries as these have a specific gravity of 2.1.

Other Sensors

Monitoring pH has been a goal in research for many years as a means to manage diets. Our target should now be to reduce pollution. We need ionic indicators that can be correlated to methane and nitrogen pollution. We can then add these sensors to our bolus platform.

Conclusions

The bolus has developed to the point where is can be routinely be used in fistulated animals in research. There is no impossible technical obstruction to boluses to operate in the rumen for three or more years.

References

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