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Rumen Bolus Extraction Method Using Absorbent Polymer for Timed Density Control

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Summary:
The rumen of cattle can be monitored using an electronic rumen bolus, which is designed to remain permanently in the rumen. However, rumen boluses with pH sensing capabilities often only function for approximately 3 to 6 months. After this period, the rumen boluses are generally retrieved through surgery or autopsy. We propose an alternative method of retrieval by manipulating the devices density to allow for time-gated natural excretion of a rumen bolus. The excreted device can then be recycled or recharged and used again to reduce waste and improve uptime of p monitoring in the rumen of cattle.

Keywords: rumen bolus, density control, absorbent polymer.

Introduction

Significant improvements in agricultural livestock techniques and technologies have been developed to reduce greenhouse gas emissions, improve productivity, and improve the overall quality of life for cattle. The enhancement of data quality and collection methods is crucial for advancing research in areas such as drug delivery, feed composition, and environmental changes [1]. Devices often referred to as electric rumen boluses provide a direct and autonomous method, as opposed to intermittent and invasive testing. An electric rumen bolus is a swallowable device designed to remain indefinitely in the rumen and perform measurements over 1-5 years or 3-6 months for pH-capable devices. These limitations typically stem from battery life and sensor drift. For pH sensing, this is due to the sensor surface becoming dirty and a lack of maintenance or recalibration [2]. Rumen boluses can remain within the rumen long term by adhering to specific density parameters. Densities of 1.3-1.6 g/cm^3 result in delayed expulsion, densities greater than 1.6 g/cm^3 prevent rumination, and densities greater than 3.0 g/cm^3 are considered permanent [3]. Therefore, it is possible to artificially control the time before an object can be naturally defecated by manipulating its density. We propose a variable density module capable of utilizing the surrounding rumen fluid to inflate over time, thus varying the density enough to pass through the digestive system naturally after a desired duration. Herein, we implement and verify that our variable density module can function normally in a cow's digestive system.

Design and Fabrication

The proposed design comprises a polymer casing that contains an absorbent polymer and a stretchable membrane. Rumen liquid enters through the liquid inlets and is absorbed by the absorbent polymer, causing it to expand and alter the overall density of the device. The analysis of the mechanism and module functionality is reported in our previous work [4]. However, considering the safety and psychological burden on the fistula cows used in the experiment, we redesigned our original device and pre-inflated it for ejection in approximately 36 hours (Fig. 1).

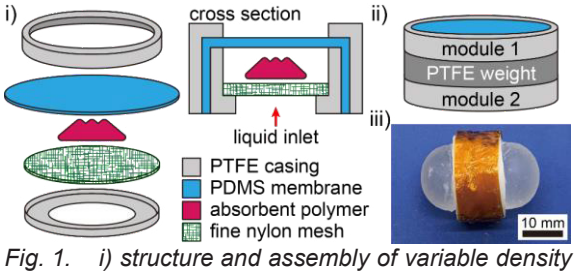

Fig. 1. i) structure and assembly of variable density module. ii) assembled device with PTFE weight. iii) fabricated device after inflation with Kapton tape layer.

The outer frame of the density variable module was made of Teflon (PTFE) using a bench-top CNC milling machine (KitMill CL100, ORIGINALMIND). The device is assembled by sandwiching a 1.00 mm thick PDMS membrane, 0.3 g of water-absorbent polymer, and nylon mesh

(PA-263μ, Azwan) together with cyanoacrylate (04612, Konishi) and silicone (HJ-148, Cemedine) as adhesives. A variable density module was adhered to each side of a solid 3.5 x 20 mm PTFE disc to form a single device. A diameter of 20 mm is appropriate to prevent duodenal obstruction. The overall weight of the assembled device was 1.4 g with a density of 1.7 g/cm^3. The estimated excretion time was reduced to 36 hours by pre-inflating the device in distilled water to an appropriate density of 1.3 g/cm^3 [5]. The outer frame of the modules and the sides of the weight were wrapped with Kapton tape and coated with a silicone adhesive for intestinal protection and improved visibility in feces.

Method

One fistula cow is herded into a paddock in the early morning without food, and two variable density devices are inserted through the fistula. Device 1 (D1) in the rumen and device 2 (D2) in the reticulum (Fig. 2i). The diet of the fistula cow was not restricted. However, the cow was kept in the paddock to aid in the monitoring of the manure and habitat for discharged devices during a one-week observation period.

Results and Discussion

D1 was confirmed to be discharged between 30 and 40 hours after being inserted into the rumen. The discharged device was found at some distance from the feces, with the weight and variable density modules separated. One of D1's PDMS membranes ruptured, with water-absorbent polymer found near the damaged device. The location of each part of D1 indicates the device remained in one piece until it was stepped on by the cow. This is further supported by the visibility and location of scattered polymer (Fig. 2ii-iii).

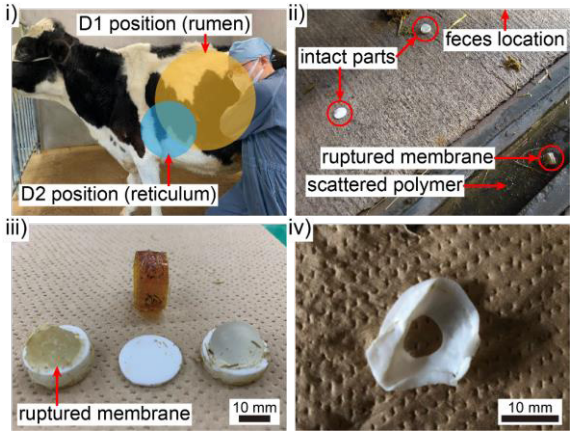

Fig. 2. i) placement of devices D1 and D2 in fistula cow. ii) site where D1 discharge was confirmed at 40 hours. iii) discharged components of D1. iv) warped component of D2 confirmed at 140 hours.

The ejection time of D1 was around 36 hours. However, parts of D2 were discharged between 130 and 140 hours. The parts were significantly deformed by intestinal pressure (Fig. 2iv). If the device broke in the rumen or reticulum, it would remain there, as the density of PTFE is 2.2 g/cm^3. Therefore, the device and weights are considered to have failed after migrating past the reticulum. Ongoing monitoring of the cow's health and wellbeing has shown no negative short-term or long-term effects. Our density-controlled device has demonstrated the capability to be excreted naturally with feces, but the strength of the device and the adhesive method need further improvement.

Conclusion

Our proposed variable density module was integrated with PTFE weights and implemented directly into the rumen and reticulum. The device placed in the rumen was successfully passed through the digestive system and defecated within 40 hours. The device placed in the reticulum was damaged and partially passed within 140 hours. This experiment has demonstrated our device's potential for controlled natural passage through the digestive system of cattle. Further investigations and improvements are planned.

Acknowledgment

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