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The continuous recording of the pH in the bovine rumen

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1. Details are given of modifications to standard pH measuring equipment enabling it to be used to record continuously the pH in the bovine rumen for up to 4 weeks. The operation of the apparatus and examples of its use are presented.

Many investigations of metabolism within the reticulo-rumen require frequent determinations of the pH of the digesta. This paper describes a means of determining and recording continuously the pH within the rumen of cattle without disturbing the rumen contents. Recordings lasting up to 4 weeks have been made successfully from cows offered diets ranging from straw alone to rolled barley or flaked maize alone.

METHODS

Description of apparatus. The apparatus for the continuous measuring of pH in the bovine rumen is shown in Pl. 1*a*. Pl. 1*b* and *c* illustrate the component parts and provide a guide to assembly. The apparatus consists of a Pye Ingold combined glass and reference electrode (Pye Catalogue No. 450 E_O2) protected by a stainless steel housing and polyvinyl chloride tubing.

The housing is in three sections. The middle section holds the electrode. The internal diameter at the top of this section is designed to hold the top of the electrode firmly in position. The electrode is secured at the bottom of the middle section by a suitably bored rubber bung. This bung also serves as a seal to prevent water entering the middle section. The bottom section of the housing protects the exposed bulb of the electrode from damage; it is perforated with holes of about 5 mm diameter to permit the passage of rumen contents past the bulb. The electrode bulb is further protected by a silk bag, sown with silk thread, which is attached round the bottom section by a jubilee clip. The silk bag prevents the accumulation of particulate matter around the bulb yet allows fluid to pass through. The top section completes the housing; an O-ring forms a leak-proof seal between the top and middle sections.

The lead on the electrode is shortened to about 12 cm and the wander plug discarded. It is linked to the pH meter by a co-axial cable of suitable length. The cable is protected within the rumen and for about 50 cm outside by polyvinyl chloride tubing (15 mm internal diameter) which is attached to the top section of the housing by a jubilee clip. A split, bored rubber bung provides a seal at the other end of the polyvinyl chloride tube. The cable and electrode must be kept dry between the two rubber bungs, the split one at the far end of the polyvinyl chloride tubing and the other securing the electrode in the middle section of the housing. To reduce dangers of water vapour causing shorting, the co-axial cable entries are sealed with weather-proof plastic compound (British Insulated Callenders Cables Ltd, London).

Weights totalling 2·0 kg are attached to the bottom section of the housing by a jubilee clip. These anchor the electrode on the bottom of the rumen and prevent it being moved about with the ingesta. A sleeved rubber bung holds the whole assembly in the rumen cannula (Balch & Cowie, 1962).

The pH meter used is a Pye Universal (W. G. Pye and Co. Ltd, Cambridge). Instability of readings due to earthing problems proved serious initially. It was overcome by earthing the electrode housing and the metal stanchions restraining the cow through the pH meter and by inserting a capacitor in the meter between the terminals marked mV− and REF+ (current models of the meter include this modification as a standard feature). The pH is recorded continuously on a recording milliammeter (Record Electrical Co., Altrincham, Cheshire) with a chart speed of 1 in./h.

Assembly and operation. Before use, the electrode is tested against standard buffers, pH 4·0 and 7·0. For 24 h before insertion into the rumen, the electrode is immersed in standard buffer, pH 7·0, and the reading recorded; this permits any variations in reading to be investigated and the causes eliminated. When a stable reading has been obtained, the apparatus can be assembled. The plastic guard protecting the wick and bulb of the electrode is removed with great care. The electrode is then firmly secured in the middle section of the housing. Plastic sealing compound is packed round the electrode in the upper part of the middle section before the top section of the housing is screwed on. The polyvinyl chloride tubing is then secured. At this stage the reading should again be checked before the bottom section, the silk bag and weights are attached. The electrode unit can now be inserted carefully into the rumen. It is usually positioned so that the weights just reach the floor of the ventral sac of the rumen below the fistula. Sufficient slack is left in the co-axial cable to allow the animal to lie down without straining the cable. The split rubber bung grips the cable firmly so that any strain on the cable is taken at that point and not at the connexion near the electrode; the cable within the polyvinyl chloride tubing is left very slack. The cable is tied along a supporting line above the animal; no pulleys are used. Recording is begun as soon as the electrode is in position, but at least 30 min is usually required for the reading to reach a steady value.

The readings obtained by means of the electrode are checked periodically. Zero drift can be checked as frequently as the stability of the pH meter requires; we have rarely found it to be a problem. The readings obtained while the electrode is in the rumen can be checked by taking rumen samples by aspiration through a tube fitted with a filter which is kept in the rumen near the pH electrode. Differences of pH between the continuous recording and the aspirated sample of up to 0·2 unit are accepted. The electrode is removed from the rumen at least every 24 h to permit the silk bag to be replaced. At these times the electrode, and particularly the bulb and wick, are washed, using a wash bottle, and the readings are checked against standard buffers.

RESULTS

Recordings for periods lasting up to 4 weeks have been obtained in cows given diets consisting of straw, hay, flaked maize or rolled barley alone and in various combina-

tions. Agreement between the pH determined by the continuous recording and the pH of aspirated samples is usually within 0·2 unit. This is shown in Fig. 1 which also illustrates changes in pH associated with feeding in a cow established on a diet of 8·4 kg rolled barley daily given in two equal feeds. The speed of response of the electrode to changes in rumen pH is dependent primarily on the rate of passage of rumen contents through the silk bag. When starchy diets are given the consistency of the rumen contents often becomes unusually thick and, during rapid changes of pH such as follow the sudden substitution of flaked maize for hay in the diet, the pH recorded by the electrode may lag temporarily behind the pH in the rumen contents by up

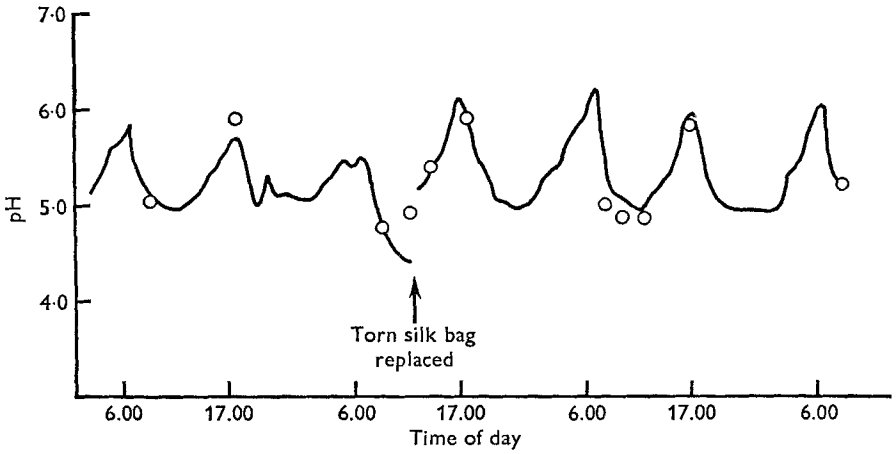

Fig. 1. Variation in rumen pH in a cow established on a diet of 8·4 kg rolled barley daily, offered in two equal feeds at 06.00 h and 17.00 h. The pH of samples taken by aspiration from a point near the electrode is shown, ○. The interruption in the recording after the second morning feed illustrates the effect on the reading of a tear in the silk bag protecting the electrode (see p. 306).

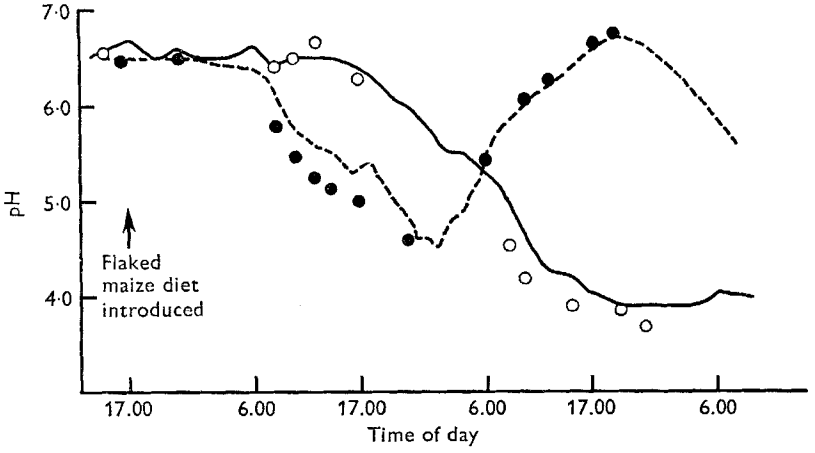

Fig. 2. Change in rumen pH in two cows, S 111 (——) and Brilliant (– – –), when the diet was changed abruptly from 8·4 kg hay daily to 8·4 kg flaked maize daily. Each ration was offered in two equal feeds daily at 06.00 h and 17.00 h. The pH of samples taken by aspiration from a point near the electrode is shown for S 111 (○), and Brilliant (●).

to 0·5 units (Fig. 2). This problem can probably be reduced if the silk bag is changed more frequently.

DISCUSSION

Though very satisfactory results have been obtained with the apparatus, considerable attention is required if readings are to be reliable.

Several workers have reported considerable differences in pH in different parts of the rumen contents (Bryant, 1964; Lampila & Poutiainen, 1966). For results to be meaningful it is therefore essential that the electrode remains in one part of the rumen as otherwise changes in pH recorded may merely reflect movement of the electrode through different sections of the contents. The bottom of the ventral sac was chosen as the electrode can be anchored there quite simply by weights and as the contents are usually most fluid at that point in the cow.

It was found necessary to protect the electrode by the stainless steel housing. Unless the housing is further covered by the silk bag, particles of feed rapidly accumulate round the electrode bulb; the result is usually a steady fall in pH reading due apparently to the accumulated feed particles preventing removal of fermentation products. The resulting low pH is a frequent indication that the silk bag has been torn and needs replacement (Fig. 1).

It is essential to prevent water or water vapour reaching connexions in the electrode system or the meter. This is especially a problem with milking cows which must be washed frequently. The precautions outlined earlier have succeeded in eliminating this problem. The cows are routinely kept on rubber mats but it is not known if this reduces earthing.

When an electrode has been in the rumen continuously for about 5 days, readings often become inaccurate. This appears to be due to a film of rumen contents which coats the bulb of the electrode. Recordings are now made by means of two electrodes which are exchanged every 24 h; the electrode which has been removed from the rumen is cleaned in 0·1 N-HCl in the succeeding 24 h.

We acknowledge the assistance of Professor J. A. F. Rook, now of the Department of Agriculture, University of Leeds, in early development of this apparatus. The co-operation of the Engineering Department of this Institute and of W. G. Pye and Co. Ltd, Cambridge, is also appreciated.

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EXPLANATION OF PLATE

a. The complete electrode assembly for measuring pH in the bovine rumen.
b. Electrode in housing; silk bag; weights.
c. Exploded view of electrode and housing.

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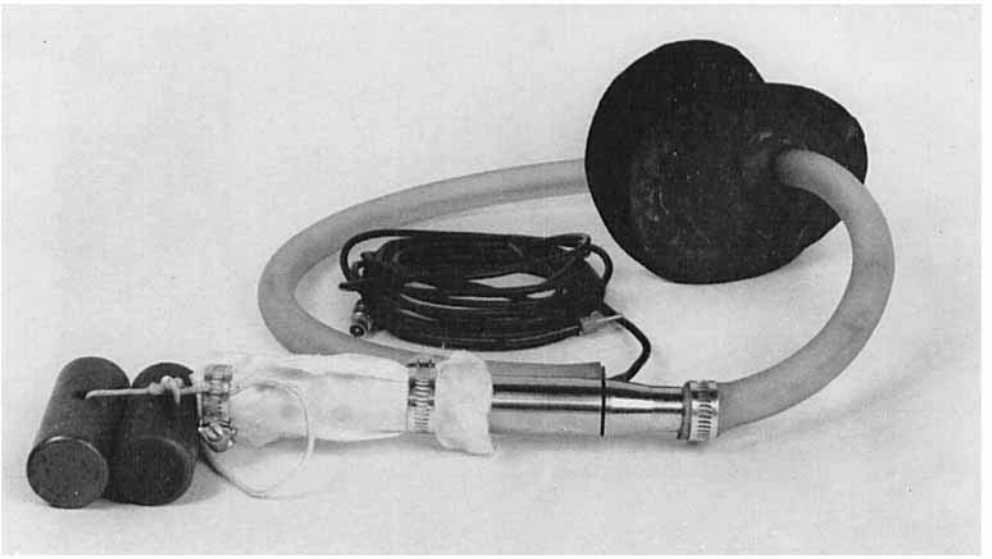

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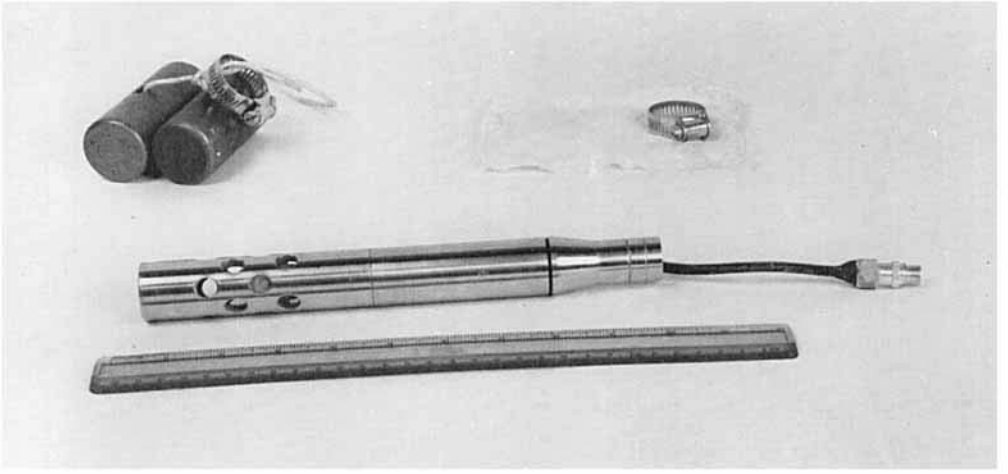

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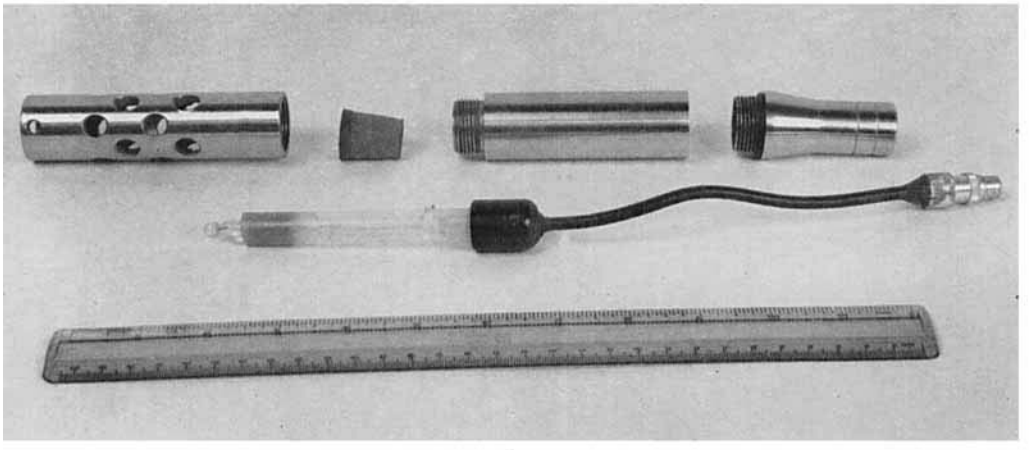

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