Comparison of Rumen Fluid pH by Continuous Telemetry System and Bench pH Meter in Sheep with Different Ranges of Ruminal pH

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Research Article

We aimed to compare the measurements of sheep ruminal pH using a continuous telemetry system or a bench pH meter using sheep with different degrees of ruminal pH. Ruminal lactic acidosis was induced in nine adult crossbred Santa Ines sheep by the administration of 15 g of sucrose per kg BW. Samples of rumen fluid were collected at the baseline, before the induction of acidosis (T0) and at six, 12, 18, 24, 48, and 72 hours after the induction for pH measurement using a bench pH meter. During this 72-hour period, all animals had electrodes for the continuous measurement of pH. The results were compared using the Bland-Altman analysis of agreement, Pearson coefficients of correlation and determination, and paired analysis of variance with Student’s t-test.

The measurement methods presented a strong correlation (r = 0.94, P < 0.05) but the rumen pH that was measured continuously using a telemetry system resulted in lower values than the bench pH meter (overall mean of 5.38 and 5.48, resp., P = 0.0001). The telemetry system was able to detect smaller changes in rumen fluid pH and was more accurate in diagnosing both subacute ruminal lactic acidosis and acute ruminal lactic acidosis in sheep.

1. Introduction

Rumen lactic acidosis is a nutritional metabolic disease that causes great economic losses in ruminants and can evolve into subacute, acute, or chronic forms. Subacute ruminal lactic acidosis (SARA) is caused by the sudden intake of a high-carbohydrate diet when the rumen has not yet adapted. The intake of this type of food stimulates the rumen microflora to ferment, producing short-chain fatty acids (SCFAs) and lactic acid, which are rapidly used by fermenting bacteria [1]. Acute rumen lactic acidosis (ARLA) is characterised by the excessive intake of soluble carbohydrates and elevated lactic acid concentrations, with a subsequent reduction in ruminal pH and marked clinical manifestations [2, 3].

The rumen is the main organ that is involved in ARLA and SARA, and therefore, this organ is the first to be evaluated in suspected cases of these diseases. The rumen has a heterogeneous environment in terms of the pH because its physiological value presents variation and is influenced by the type of food that is consumed, by water intake and by rumination [1]. The stability of the pH in the rumen is maintained by the relation between the bacterial population, growth substrates that are available in the organ, fermentation products, and the buffering effect of the saliva [3–5].
Among the collection methods of rumen contents for the measurement of ruminal pH, the most common are a ruminal probe, rumenocentesis, and ruminal fistula, which is typically measured using a bench pH meter. Recently, internal continuous sensors that are wired or that are wireless have been used. The continuous measurement system of ruminal pH through these internal sensors has been employed in cannulated cattle to study ruminal metabolism [6–9]. This approach offers a means to study the interaction between different ruminal variables, which enables the mobility of the animal. Moreover, the continuous measurement of ruminal pH can detect rapid fluctuations in variables that are often more difficult to acquire with punctual evaluation [10].

The aim of this study was to compare the measurement of ruminal fluid pH using a continuous telemetry system and a bench pH meter under ARLA, SARA, and normal conditions.

2. Materials and Methods

Nine crossbred Santa Ines sheep with an average weight of 45 ± 1.8 kg and age of 24 months were used. All sheep underwent surgery for the implantation of a silicone rumen cannula and were dewormed (Cydectin, Zoetis Animal Health, Campinas, Brazil). After the surgery, the animals passed through a period of 60 days for recovery and adaptation to the new conditions of management and diet.

During the adaptation period and throughout the course of the study, the animals were fed a basal diet that was calculated at 2.7% of body weight; with the dry matter composed of 75% hay coat cross and 25% commercial concentrate pellets (Fri-Sheep 22/70, Nutreco Animal Nutrition, Pitanguerias, Brazil), which was offered twice daily. Sheep had free access to water.

The animals were kept in individual metabolic cages at the Centre for Research in Ruminant Nutritional and Metabolic Diseases, Department of Veterinary Medicine, Faculty of Veterinary Medicine and Animal Science, University of S˜ao Paulo (USP). This study was approved by the local Animal Ethics Commission.

The experimental induction of rumen lactic acidosis was performed in all animals through the administration of 15 g of sucrose per kg/BW directly into the rumen according to the protocol described by Kezar and Church [11] and Afonso et al. [12].

In all animals, a continuous telemetry measurement system, which measures the rumen fluid pH every 5 minutes and has a sensitivity of 0.01 pH units, was installed. The system was composed of a submersible electrode (PHE-6510, weighing 120 grams) (Omega Engineering Inc., Connecticut, USA), that was coupled to a data logger (OM-CP-PHI10) (Omega Engineering Inc., Connecticut, USA), a transfer cable (OM-CP-IFCI10) (Omega Engineering Inc., Connecticut, USA), and a specific software (Omega 2.04.6) (Omega Engineering Inc., Connecticut, USA). The electrode was implanted in the ventral sac of the rumen as described previously by AlZahal et al. [6].

The electrodes and data logger were calibrated using the aforementioned software and standard solutions (Merck, São Paulo, Brazil) with pH values of 4.0 and 7.0, with the calibration procedure performed using the software as indicated by the manufacturer. The system for the continuous measurement electrode was placed in each animal from the baseline and remained in place for 72 hours.

To compare the results that were obtained by the telemetry system, punctual samples of ruminal contents were collected from the ventral sac of the rumen, at the same location of the continuous electrode, at the following times: $T_0$ (baseline), $T_{6h}$ (six hours), $T_{12h}$ (twelve hours), $T_{18h}$ (eighteen hours), $T_{24h}$ (twenty-four hours), $T_{36h}$ (thirty-six hours), $T_{48h}$ (forty-eight hours), and $T_{72h}$ (seventy-two hours) after the sucrose administration. The samples, which contained approximately 100 mL of rumen contents, were collected using a plastic probe that was attached to a vacuum pump and were promptly analysed using a bench pH meter (Model PG 1800, Genhaka, São Paulo, Brazil) with a sensitivity of pH 0.01.

To study the relation between two measurements systems, a Bland-Altman analysis of agreement between methods was performed and the Pearson coefficients of correlation ($r$) and determination ($r^2$) were calculated. We also run a paired analysis of variance (ANOVA) with means compared using Student’s $t$-test. This ANOVA was performed first globally and then considering only normal (pH ≥ 5.6), SARA (5.6 < pH ≤ 5.0), or ARLA (pH < 5.0) pH ranges. The significance level adopted was 5%. Considering the telemetry system as the gold standard, the sensitivity, and specificity of the conventional method were evaluated separately in SARA and ARLA pH ranges.

3. Results and Discussion

The mean pH values of the rumen fluid were 5.48 and 5.38 for the conventional system and telemetry system, respectively, with significant differences ($P = 0.0001$) between the two methods. Bland-Altman analysis shows a positive bias for the ruminal fluid pH measured thought bench pH meter, but with a strong correlation ($r = 0.94$, $P < 0.05$) between the two methods of measurement, as shown in Figure 1.

Table 1 presents the comparison between the results of the rumen pH between the two measurement methods that
Table 1: Means, standard deviations (SD), and linear correlations of rumen pH as measured by a bench pH meter and by a continuous telemetry system at different pH ranges.

| Method       | Average pH measured | Normal pH range (>5.6) | SARA pH range (5.6 < pH ≤ 5.0) | ARLA pH range (≤5.0) |
|--------------|---------------------|------------------------|--------------------------------|---------------------|
|              | Mean                | SD                     | Mean                           | SD                  | Mean                | SD                  |
| pH bench     | 5.48<sup>A</sup>    | 0.99                   | 6.64<sup>A</sup>               | 0.40                | 5.40<sup>A</sup>    | 0.14                | 4.54<sup>A</sup>    | 0.27                |
| Telemetry system | 5.38<sup>B</sup>   | 1.01                   | 6.42<sup>B</sup>               | 0.37                | 4.80<sup>B</sup>    | 0.44                | 4.33<sup>B</sup>    | 0.30                |

Superscripts indicate difference ("<sup>P < 0.05</sup>" as determined by Student's t-test; "<sup>r</sup><sup>2</sup>" determination coefficient; "<sup>r</sup>" correlation coefficient.

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