RUMINAL CHANGES DURING THE ONSET AND RECOVERY OF INDUCED LACTIC ACIDOSIS IN SHEEP

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Summary

Four crossbred wethers equipped with rumen fistulas were used to study changes in rumen pH, motility and the synthesis of volatile fatty acids and lactic acid during the onset and recovery of induced lactic acidosis. Acidosis was induced by the addition of sucrose (15 g/kg BW) in 700 ml of water through the fistula. Mean maximum lactic acid concentration was near or in excess of 100 mM of rumen fluid during the first 48 hr postinducement. The minimum pH values observed for each sheep were 4.53, 4.13, 4.29 and 4.48. Propionic and butyric acids were absent from rumen samples by 14 hr postinducement. Acetic acid concentrations decreased to <5 mM during the first 24 hr following the addition of the sugar. Rumen motility decreased in frequency and amplitude during the first 4 hours. Normal rumen motility was observed in one sheep by 52 hr but not in another, until 84 hr postinducement. Two of the four sheep were “off feed” by 4 postinducement, while the remaining two did not become anorexic until 7 hours. Animals began to consume small amounts of alfalfa when rumen pH values increased to >5.0 but consumption similar to preinducement intake was not observed until the rumen pH was >6.0 and lactic acid could no longer be detected in the rumen fluid.

(Key Words: Acidosis, Lactic Acid, pH Motility, Anorexia, Volatile Fatty Acids.)

Introduction

Over a period of years numerous research reports have been published on lactic acidosis and the effects the disorder has on the reticulo-rumen (Hungate et al., 1952; Dunlop and Hammond, 1965; Allison et al., 1964; Huber, 1971; Ryan, 1964; Uhart and Carroll, 1967). Changes that occur in rumen pH, volatile fatty acids, formation of lactic acid and rumen motility as well as many others have been documented and reviewed (Elam, 1976; Huber, 1976; Slyter, 1976; Brent, 1976).

The purpose of the present research was to induce lactic acidosis in sheep equipped with rumen fistulas and monitor rumen changes such as motility, pH, volatile fatty acids and lactic acid, not only in the developmental stages of the disorder but also during the recovery period. Many of the studies involving the inducement of acidosis have resulted in death of the animals and, as a result, data on recovery periods are lacking. The objectives were to observe the conditions existing at the time the sheep went “off feed” as well as when they began to consume feed again in order to gain a better understanding of the conditions existing when rumen stasis occurs and when rumen motility resumes.

Materials and Methods

Animals. Four crossbred wethers (A, B, C, D) weighing 48 to 55 kg were prepared with rumen fistulas following procedures outlined by McCann et al. (1973). Animals were given a minimum of 60 days recovery time before rumen motility studies were conducted. The sheep were maintained on grass-alfalfa hay prior to the studies. Water and trace mineralized salt were available ad libitum at all times.

Inducement of Acidosis. The sheep were given sucrose at the level of 15 g/kg BW in a 700 ml solution of water warmed to 39 C. The sucrose solution was placed in the rumen through the fistula at 0800 immediately following rumen motility tracings and rumen pH determination.

Rumen Motility Recordings. The sheep were
placed in separate metabolism crates 3 days prior to any recordings. Rumen motility was recorded prior to the morning feedings and at 4, 8 and 12 hr postfeeding on 2 consecutive days before inducing acidosis. Diets consisted of chopped alfalfa offered once daily, and the animals were allowed to eat *ad libitum* for a 4-hr period. Rumen motility was recorded prior to the addition of sucrose and 2, 4, 7, 10, 14, 24, 28, 32, 36, 48, 52, 60, 72, 76, 84, 96 and 108 hr postinducement.

The recording apparatus consisted of a thick wall balloon (finger cot) mounted over a one hole No. 2 rubber stopper which was connected to a 61 cm section of semi-rigid .64 cm O.D. aluminum tubing. A small plastic catheter was run down through the tubing, flared and sealed with wax to prevent any air leakage from the balloon once it was inflated. The balloon was securely fastened to the stopper by wrapping with suture material and covering with waterproof tape. The catheter from the balloon was connected to a pressure transducer with the aid of Leur-lock fittings. A second catheter tube led from the dome of the pressure transducer to a 50-ml syringe with a Leur-Lock holder. The balloon was inflated with 30 ml of air. Back pressure on the syringe was eliminated with the aid of a three-way stopcock. A polygraph connected to the electrical transducer was used to record the movements of the reticulo-rumen.

In preparation for recording the balloon apparatus was inserted through the cannula and inflated with the aid of the syringe. A one-hole No. 5 rubber stopper that had been moved down over the aluminum tubing acted to hold the device in place by fitting tightly into the barrel of the rumen cannula (figure 1). Motility in different sections of the reticulo-rumen were recorded by bending the aluminum tubing towards the desired area. Further adjustment was possible by sliding the aluminum tubing in or out through the rubber stopper held in the barrel of the cannula.

*Rumen Samples.* A sample of rumen contents from the ventral sac was removed through the fistula with the aid of a vacuum pump prior to every recording. The pH of the sample was

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*Statham P 23 transducer, Statham Industries, Inc., Oxnard, CA 93030.*

*Gilson polygraph, model M5P, Gilson Medical Electronics, Inc., Middletown, WI.*
measured within 1 min of removal using a
digital pH meter.

Analysis. Lactic and volatile fatty acid
(VFA) analyses on rumen samples were done
by gas chromatography using a modified
procedure outlined by Carlsson (1973). Prepa-
ration of samples for gas chromatography
involved obtaining a 5-ml sample of rumen fluid
and placing it in a centrifuge tube containing 1
ml of 25% metaphosphoric acid. These tubes
were allowed to stand under refrigeration for a
minimum of 4 hr before being centrifuged at
12,500 rpm for 20 minutes. Supernatants were
removed and used for lactic and VFA analysis.
This procedure does not differentiate between
D and L forms of lactic acid.

Results

Acute acidosis developed in each of the four
sheep (table 1) with typical symptoms being
observed. All animals went off feed, became le-
thargic, had increased respiration rates and
developed moderate diarrhea. Rumen fluid
became very fluid in consistency when the pH
dropped below 5.0.

Animals A and B were anorexic by 4 hr
postinducement, while animals C and D did not
refuse feed until 7 hr after the addition of the
sucrose. Lactic acid was detected in the rumen
of each animal at the time the animals refused
feed, with concentrations ranging between 20.3
and 54.1 mM and corresponding pH values of
5.50 and 4.57, respectively. Maximum rumen
concentrations of lactic acid were near or in
excess of 100 mM in each of the four sheep,
but considerable variation was noted in the
time when the maximum concentration oc-
curred. Sheep B had its maximum concentra-
tion 10 hr postinducement, while sheep C did
not reach the maximum until 48 hr postin-
ducement. Sheep C appeared to be recovering
by 32 hr and began to eat alfalfa hay. The feed
consumed seemed to reinduce acidosis; the
animal became anorexic, lethargic and by 48 hr
had a rumen lactic acid concentration of nearly
twice that detected in the 32-hr sample. Of the
four animals, sheep C required the longest
period to recover and consume preinducement
quantities of feed. Complete anorexia contin-
ued in all animals until the rumen pH rose

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a Animal would no longer respond to feed.
b Animal began eating small amounts of feed.
c Animal consuming full feed.
above five. Lactic acid concentrations in rumen samples at the time first feed was consumed were between 55 and 70 mM. Intake at this point was minimal and animals would not stand and eat for more than 15 min at any one time. Feed intake did not approach preinducement levels until rumen pH values were >6 and lactic acid could no longer be detected in the rumen. For sheep D, these conditions were present by 48 hr, while for sheep C, normal feed intake did not occur until 96 hr postinducement.

Motility in the reticulo-rumen was greatly reduced 4 to 10 hr following the addition of sucrose to the rumen, indicating individual variation between sheep (figure 2 and 3). Considerable variation in motility was noted on the second and third days postinducement among the four sheep. Recordings indicated sheep D was the only animal exhibiting rumen contractions at 28 hr postinducement, although the contractions were below preinducement values in both frequency and amplitude. Rumen motility was evident in recordings from sheep C by 52 hr postinducement, but contractions were reduced in amplitude and frequency compared to preinducement recordings (figure 2a and 2b).

The relationship of individual volatile fatty acid (VFA) to the inducement of acidosis is shown in figure 4. Both C3 and C4 acids were reduced to concentrations of <2 mM by 10 hr following the addition of sucrose to the rumen. By 14 hr neither acid was detected in the rumen fluid of any of the four sheep. With the exception of sheep D, the C3 and C4 acids were not detected again until 48 hr or later postinducement. Sheep C, which was off feed the longest, did not have C3 acid present in the rumen for a period of nearly 48 hours. Butyric acid in sheep C was absent for a period of 58 hours. Sheep D, which was off feed the shortest period of time, did not have detectable levels of C3 and C4 acids for 12 and 20 hr postinducement, respectively. Acetic acid concentrations in the acidotic sheep followed similar patterns to other VFA. Concentrations fell to 10 mM or less by 14 hr postinducement. While C2 concentrations never reached zero, all four sheep did reach concentrations of <5 mM during the first 24 hr after inducement.

Sheep D, the first to recover, had C2 concentrations of >20 mM by 36 hr while sheep C did not reach this level until 84 hr postinducement. At the time each animal had returned to near preinducement feed in take levels, C2, C3, and C4 acid concentrations were >30, >11 and >5 mM/liter, respectively.

Discussion

The affect of added sucrose on the changes occurring in the reticulo-rumen of the experimental sheep was as expected. Previous experiments with graded levels of sucrose led us to the 15 g/kg BW level used. We wished to obtain pH values between 4 and 4.5 and lactic acid concentrations near 100 mM in the rumen fluid. Other work at our station as well as that of other researchers made us well aware of the high risk of death in the animal if the rumen pH fell below 4.0.

Our lactic acid concentrations and pH values (mean values, hours 1 to 4) during the first 4-hr postinducement (20.26, 5.50; 21.17, 5.17; 46.26, 5.14 and 32.16, 5.28) disagree with
Figure 3a. Caudal ventral blind sac motility in Sheep B prior to and following the inducement of acidosis. 3b. Reticulum motility recordings in Sheep B prior to and following the inducement of acidosis.

those of Briggs et al. (1957) who reported that lactic acid levels of >20 mM were always associated with a rumen pH below 5.0. We believe that the method of analysis used in this study is possibly more sensitive, resulting in earlier detection of high levels of lactic acid earlier following inducement of acidosis.

The effect of lactic acid concentrations on the animal going off feed is unclear based upon the results of this study. Sheep A, C and D were eating when rumen lactic acid concentrations were 11.49, 48.3 and 32.2 mM, respectively. All three animals were anorexic 3 hr later although the lactic acid concentrations were <5 mM greater for two of the animals than when they were eating 3 hr earlier. Length of time following the appearance of lactic acid may be a factor but samples were not taken frequently enough during the first 8 hr to test this. Bueno (1975) infused DL-lactic acid into the duodenum of sheep and reduce dry matter intake by 50%. This would imply that rumen lactic acid concentration may not be the only factor affecting feed intake.

The role of lactic acid on rumen motility remains unanswered. Juhász and Szegedi (1968) lowered the pH of the rumen below 5.0 with lactic acid but noted stasis of the rumen did not occur for 2 to 4 hours. Our work showed there was a decrease in the frequency and amplitude of contractions at 2 hr postinducement, prior to the formation of detectable levels of lactic acid in the rumen fluid (figure 2). Although sheep C had a concentration of rumen lactic acid >100 mM (52 hr), contractions were very evident (figure 2). These strong contractions, despite the high concentrations of lactic acid, cause one to further question the role of lactic acid as the major factor in inhibiting rumen motility. Dougherty et al. (1975) showed strong rumen contractions in two of four sheep with pH values of 4.4 and 4.5, 72 hr after inducing acidosis in sheep using corn and oats. Corresponding lactic acid concentrations were not given for the study.

The near total absence of volatile fatty acids in the rumen fluid following the inducement of acidosis agrees with the work of Ryan (1965) for similar pH values and lactic acid concentrations. The amounts and percentages of VFA’s present when preinducement feed intake levels were reached are in agreement with values reported by Uhart and Carroll (1967) for VFA’s present at the time steers resumed eating after being off feed when suddenly switched to a high grain diet.

Initial loss of rumen motility and anorexia seem to be closely related, at least with respect to time. Similar results were reported by Lane (1968). The sheep in the present experiment developed motility with reduced frequency and amplitude while the animals were anorexic, but preinducement feed intake levels and preinducement motility tended to occur at about the same time for individual animals. It remains to be answered whether the strong contractions of the reticulo-rumen induced normal appetite, or if increased feed intake induced contractions similar to those occurring before acidosis.

One should consider other factors which occurred at the time normal levels of feed were being consumed following acidosis. Lactic acid in the rumen had declined to undetectable levels. The volatile fatty acid concentrations
had risen to >50 mM and the rumen pH was >6. All of these factors appear to be interrelated in the recovery process that occurs in animals which have developed acidosis. Additional factors such as histamine (Dougherty, 1942), endotoxins from bacteria (Mullinax et al., 1966) and secretin (Bruce and Huber, 1973) may very well be involved but were not studied in these experiments.

The procedures for obtaining rumen motility data used in this study could lend themselves for use with any rumen fistulated animals with minor modifications. The use of a balloon apparatus for measuring rumen motility does not give rise to as continuous or as high quality recording as those using radiotelemetric methods. It does have the advantage of requiring much less time and expense in preparation. The most difficult problem in the procedure was the placement of the balloon into the rumen for each reading since exact positioning in the same location required some adjustments for proper recording. This became easier as the operator became more familiar with the animals and apparatus. Differences in activities (eating, resting or ruminating) can account for some of the differences observed in recordings in the same location at different times (Church, 1975). While we assembled more than one balloon apparatus, we noted some variation between recordings when different units were used. We were fortunate in that the device proved to be very durable, allowing the same apparatus to collect recordings on all four sheep.

**Figure 4.** Volatile fatty acid concentrations in the rumen fluid of sheep prior to and following the induction of acidosis.

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**Literature Cited**


Huber, T. L. 1976. Physiological effects of acidosis on


