Feed Intake of Goats During Volatile Fatty Acid Injections into Four Gastric Areas

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Abstract

Previous experiments indicate that changes in rumen fluid concentration of volatile fatty acids may be factors in the control of feed intake of ruminants. The present experiment was designed to test the sensitivity of different areas of the stomachs to volatile fatty acids. Water (control) or 1.0 mM fatty acid solutions (pH = 6.5) (2 days each) were injected into the dorsal rumen, ventral rumen, ventral reticulum, or abomasum of goats during spontaneous meals. Acetate (.75 and .65 moles per day) injected into the dorsal rumen or abomasum decreased feed intake 30 and 20% (P < .01). Propionate (approximately .80 mole per day) injected into each of the gastric areas decreased feed intake approximately 34% (P < .05). Similarly, a fatty acid mixture (55% acetate, 30% propionate, and 15% butyrate) injected into each gastric area decreased feed intake 23 to 49% (P < .02). We conclude that the dorsal rumen probably contains receptors for acetate and propionate, but the propionate response may be due, in addition, to receptors in the gastric veins. Injections into the abomasum, in contrast to those in the ruminoreticulum, probably result in unphysiological concentration changes although there is a similar decrease in feed intake.

Introduction

Sodium acetate and propionate or a mixture of volatile fatty acids (VFA) injected during spontaneous meals into the dorsal rumen of goats decrease feed intake (7,8). Because relatively small quantities of VFA are required, it is possible that these metabolites have a direct role in the complex hunger-satiety mechanism (3). Increasing the acetate concentration of rumen fluid more effectively reduced feed intake than simply increasing acetate content without an accompanying increase in concentration (9). The decrease in feed intake varies directly with the moles injected per meal if ingesta dilution is minimal (8). The feeding response to acetate or propionate is clearly due to more than compensation for added metabolizable energy (7, 8), an osmolarity increase, or acid moieties (8, 10). In other experiments the feed intakes of cattle and sheep decreased following intraruminal injections of volatile fatty acids; however, the injections, over various periods of time, were not given just during spontaneous meals (10, 11, 14, 20, 23, 25).

Since feed intake is decreased much more per mole by intraruminal than by intravenous injections, acetate receptors are hypothesized to be located on the lumen side in the gastric areas of goats (7). Receptors for propionate may be the same as or similar to those for acetate, but recent experiments show that they may also be located on the blood side of the ruminal area (4, 5).

The present experiment was designed to determine the sensitivity of different gastric areas of goats to volatile fatty acids as measured by their effect on feed intake.

Methods

Five goats weighing an average of 24.5 kg were surgically prepared with Silastic catheters (1.25 mm id, Pilling Co., N.Y.) in the ventral rumen, reticulum, and abomasum (Fig. 1). The end of each catheter had a 1-cm collar (5.0 mm od) implanted through the wall by the method of Witzel (18). Each was then brought subcutaneously near a ruminal fistula fitted with a cannula in the dorsal rumen. Catheters were clamped closed and were flushed with water every other day.

The goats were individually caged in a room at 24 ± 1°C and were fed ad libitum a concentrate grain ration (Omolene, Ralston Purina). Feed and water orts and treatment solutions injected were measured between 8 and 9 A.M. When eating, a goat broke a light beam impinging on a photocell which activated a peristaltic pump and a solenoid valve as described previously (7).

The solutions tested were 1.0 mM concentrations of the sodium salts of acetate (3 goats), pro-
Catheters were surgically implanted in the ventral rumen, reticulum, and abomasum, and a cannula fitted into a fistula in the dorsal rumen of each goat. The arrows denote the approximate entry point of each injection site.

Propionate (4 goats), and a mixture of 55% acetate, 30% propionate, and 15% butyrate (4 goats) (all pH 6.5). One treatment consisted of 2-day injections each in the following order: water, treatment solution, and water.

Paired t-tests tested for significance of pretreatments and treatment differences. A 3-way analysis of variance (treatments × goats × replicates) and a multiple range test (13) measured significance of the feed intakes of the different acetate treatments.

Results

In Figure 2 are the 2-day average feed and water intakes and mmoles injected of the sodium acetate experiment. Feed intake was depressed \( P < .01 \) during injection into the abomasum and dorsal rumen but not into the reticulum or ventral rumen. Feed intake during acetate injection into the dorsal rumen was less than that during reticular injections \( P < .05 \). Injections into the dorsal and ventral rumen and reticulum increased water intake \( P < .05 \), indicating that the sodium salt was absorbed.

The amount of solution injected is related
to the time an animal had its head in the feeder. Although the greatest amount of acetate was injected into the reticulum, there was no significant decrease in feed intake; on the other hand, the least amount injected into the abomasum caused a definite decrease in feed intake.

In Figure 3 are shown the average feed and water intakes and amount injected during the sodium propionate experiment. There was a significant decrease in feed intake from injection into each of the gastric areas. In all areas, similar amounts of sodium propionate caused a similar depression in feed intake.

There was a significant depression of feed intake when the VFA mixture was injected into each of the stomachs (Fig. 4). Water intakes were increased during the injection into all gastric areas (P < .05). Similar amounts were injected into each of the stomachs except in the abomasum, into which about 100 mmoles less was injected.

**Discussion**

These data show that acetate injected into the dorsal rumen is more effective in depressing feed intake of goats than acetate injected into the ventral rumen or reticulum. Since goats eat approximately 10 meals per day (5, 8, 9), an average of about 75 mmoles was injected per meal. This would cause a concentration change of 15 to 20 mEq by the end of the meal if there was complete mixing. The local dilution of injections in the dorsal and ventral rumen were probably comparable, in that the 5 ml or less injected per minute during a meal, with the normal activity of feeding and ruminal motility, were diluted in a similar manner as they were "dripped" into the rumen. The largest change in concentration in the rumen still should have been in that area of the rumen near the injection site because of the rather slow mixing action of the rumen. That ventral reticular injections were quite ineffective in depressing feed intake is interpreted as evidence that receptors for acetate do not exist in the reticulum or even the omasum. Changes in concentration would probably be much greater in the reticulum than in the rumen during injections, since the volume

![Graph](image)

**Fig. 3.** Effects on feed and oral water intakes of propionate injected into goats during spontaneous meals are shown. Means (± SEM) are given with level of significance of differences between means of the pretreatment and treatment periods.
of the reticulum is less. Also, the turnover time of the reticulum fluid is probably shorter. Although some acetate probably entered the abomasum during the ruminoreticular injections, a large proportion of it would be expected to be absorbed prior to reaching the abomasum (12, 17). Clearly, the action of acetate in the abomasum cannot explain the response to acetate injection in the rumen.

The abomasal injections of acetate caused quite a large increase in the acetate concentration. The average injection per meal is estimated to be about 65 mmoles for this treatment; since goats normally eat for 15 minutes per meal (5, 8, 9), the approximate rate of injection was 4 mmoles per minute. The volume of the abomasum is approximately 500 ml (2, 24) and the digestive flow rate in sheep has been measured at about 13 ml/min after eating (16), so that the increase in concentration during a meal was approximately 100 mmolar. This concentration may be nearly 10 times normal while the increases in the ruminoreticulum are physiological (19). Acetate injections into the abomasum can cause greater amplitude and frequency of reticular contractions (1) which could disturb the animal and possibly slow the rate of eating. The amount injected per meal in our study was about one-half that injected by Ash (1). That acetate may be actively absorbed from the small intestine (21) soon after it is injected into the abomasum probably does not help explain the feed intake depression, since high concentrations of acetate in the blood were not effective in decreasing feed intake in goats (7). The action of acetate in the abomasum is probably due to a local effect which would seldom be of any physiological significance.

Propionate injections into each of the gastric areas are equally effective in decreasing feed intake. We would speculate that the same type of receptors may not be involved in each area. It is quite likely that the ruminoreticular injections decrease feed intake, because receptors

![Figure 4](image-url)

Fig. 4. Effects on feed and oral water intakes of a mixture of the sodium salts of volatile fatty acids (55% acetate, 30% propionate, and 15% butyrate) injected into goats during spontaneous meals are shown. Means (± SEM) are given with level of significance of differences between means of the pretreatment and treatment periods.
are activated on the ruminal wall (9) and probably also in the ruminal veins (4, 5). The abomasal injections may involve a different system. Propionate, like acetate, may be actively absorbed from the small intestine and, thus, enter the mesenteric blood soon after injection. Injections of propionate (75 mmoles per meal) into the mesenteric vein of sheep during spontaneous meals did not decrease feed intake (5). Therefore, it is questionable that the effect of abomasal injections was the result of propionate absorption into the blood stream; it seems more likely that the decrease in feed intake is from a local abomasal effect. Further evidence is that 22 g of propionate injected into the duodenum during 8 hr of feeding did not affect feed intake of sheep (15). Propionate, like acetate, in the abomasum produced unphysiological increases in concentration while those particularly into the rumen resulted in increases within the physiological range.

The injection of a mixture of volatile fatty acids into the stomachs caused responses comparable to those of acetate and propionate injected separately. Presumably, the propionate of the mixture was sufficient to cause a significant decrease in feed intake at all sites of injection.

It is likely that the propionate injected especially in the abomasum caused increased blood insulin. Approximately 4 mmoles/minute of propionate or butyrate injected into the ruminal vein resulted in sufficient metabolite passing through the liver to increase insulin levels in goats (22). It is unlikely, though, that this response had any part in the decrease of feed intake, since insulin injections failed to affect feed intake of goats (6).

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