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Relative transit time of chyme between duodenal and jejunal segments of the small intestine of cattle

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Abstract: Two steers (228 ± 4.5 kg) equipped with "T" type cannulas in the proximal duodenum, duodenal-jejunal juncture, and distal ileum were used to measure transit time of chyme within the duodenum and jejunum. Steers were fed (as fed basis) with 5.75 kg of chopped alfalfa hay per day. The transit time was measured during 3 consecutive days using aniline dye, which was pulse-dosed via the duodenal and jejunal cannulas. The site of each cannula placement was confirmed and the small intestine was dissected and measured. Time required between the infusion of aniline dye into the proximal duodenal cannula and its appearance at the duodenal–jejunal and distal ileal cannulas was 2:56 ± 0.06 and 176:00 ± 4.21 min:s, respectively. The lengths of the duodenal, jejunal, and ileal segments of the small intestine were 135 ± 4, 2730 ± 127, and 110 ± 1 cm, respectively. The relative transit time of chyme within the duodenum and jejunum averaged 46 and 14 cm/min, respectively.

Key words: Small intestine, steers, transit time

Many elements are involved in the absorption of nutrients and immunity factors in the small intestine. Factors such as pH, the optimal amount of enzyme, the physicochemical properties of nutrients, nutrient interactions, and intestinal transit time are some of the most important (1). Although many studies have been conducted to understand transit times in the reticulo-rumen and the large intestine (2–5), small intestinal transit time has received very little attention in ruminants, and no reports on relative transit times between the small intestinal segments in cattle are available. The aim of this trial was to evaluate the transit time of chyme between the duodenal and jejunal segments of the small intestine in cattle.

Two steers (Jersey × Holstein, 228 ± 4.5 kg) were equipped with "T" type cannulas (2.5 cm internal diameter) in the small intestine to measure the transit time of chyme within the duodenum and jejunum. Sites for cannula placement were 1) the proximal duodenum (6 cm from the pyloric sphincter); 2) the duodenum–jejunum junction (10 cm from the duodenocolic fold); and 3) the distal ileum (22 cm from the ileocecal valve). Two weeks prior to the surgery, steers were housed indoors in individual pens (3 × 4 m) with a neoprene floor under continuous lighting. The pens had individual feeders and automatic waterers. During this time, and throughout the experiment, steers were fed daily with 5.75 kg (as fed basis) of alfalfa hay, which was ground using a hammer mill (Bear Cat #1A-S, Westerns Land and Roller Co., Hastings, NE, USA) with a 7.6-cm screen before it was offered to the steers. The alfalfa hay contained (DM basis) 92.3% dry matter, 92.2% organic matter, 16.7% crude protein, 41.4% neutral detergent fiber, and 3.2% ether extract [determined according to AOAC (6) procedures] and was fed in equal proportions at 0800 and 2000 hours daily. The steers were fasted for 16 h before surgery. They were given an i.m. injection of 0.7 mg/kg of xylazine (Rompun, Bayer Corp., Shawnee Mission, KS, USA). When a sufficient depth of sedation was achieved, the steers were placed in the left lateral recumbency position and the surgical site was shaved. Surgical sites were anesthetized by tissue filtration (2% xylocaine, AstraZeneca Pharmaceuticals LP, Wilmington, DE, USA). Using sterile techniques, a paracostal laparotomy (13 cm) was performed 6 cm perpendicular to the flexure of the 13th rib in order to gain entrance into the peritoneal cavity. The procedures for cannulation of the duodenum and ileum were performed as outlined by Zinn and Plascencia (7) and Harrison (8), respectively. For jejeunal cannulation, the method involved the following steps:

i) Through the original incision, the duodenal caudal flexure was exteriorized and a 1-mm incision was made.

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ii) A semirigid endotracheal tube was introduced that reached the duodenal–jejunal flexure.

iii) The omentums (major and internal) were penetrated by blunt dissection.

iv) The tip of the tube was localized using palpation, and the duodenal–jejunal flexure was exteriorized.

v) The cannula was installed in the same manner as the duodenal and ileal cannulas.

vi) The cannula was exteriorized through a stab incision into the intercostal space of the 12th rib, approximately 9 cm perpendicular to the original incision and 15 cm below the transverse process of the lumbar vertebrae.

At 14 days postsurgery, the transit time was measured 3 times (before the morning meal, and 4 and 8 h postprandrium) for 3 consecutive days using aniline dye (Chefmaster, Santa Ana, CA, USA), which was pulse-dosed via the duodenal and jejunal cannulas. The aniline dye was infused by syringe (one-shot) at volumes of 15 mL and 60 mL for the duodenal and jejunal cannulas, respectively. Subsequently, the steers were euthanized by intravenous injection of sodium pentabarbitone (GFS Chemicals, Powell OH, USA). The sites of cannula placement were confirmed using anatomical references and the small intestines were then dissected and measured. The possible effects of the infusion time (0, 4, and 8 h postprandrium) on the transit time of chyme were tested using ANOVA. All animal care, handling, and surgical techniques followed protocols that have been approved by the University of California, Davis, Animal Use and Care Committee.

No postsurgery problems were present in any animal. The characteristics of the aniline dye used as a marker in this trial was as follows: color = black (color #3185), pH = 4.01, and density = 1.02 g/mL. There were no differences in transit time due to the time of infusion (0, 4, and 8 h postprandrium morning meal). Likewise, Christie et al. (9) did not observe any differences in the diurnal duodenal flow rate in calves that were sampled before and after their morning meal. Characteristics of transit time and the length of intestinal segments are shown in the Table. Transit times, which are the time required between the infusion of aniline dye into the proximal duodenal cannula and its appearance at the duodenal–jejunal and distal ileal cannulas, were 2.56 ± 0.06 and 176 ± 4.21 min, respectively. No information on the transit time in a segment of the duodenum and jejunum is available. Although Wylie et al. (10) reported a time delay of 0.5 h for markers appearing from the abomasum (cannula placed in the greater curvature of abomasum) up to the duodenal cannula (positioned in the ascending duodenum), they explained that a value of 0.5 h was only possible because 0,

Table. Characteristics of body and intestinal length and relative intestinal transit time in steers (228 ± 4.5 kg BW) fed grounded alfalfa hay at level of 2.52% of BW (5.75 kg/day, as fed basis).

	Measure			
Item	Time delay, min:s	Length, cm	transit time, cm/min	ratio intestinal length: body length
Segment				
Duodenum [a]	2:56 ± 0:06	135 ± 4	46	
Jejunum–distal ileum [b]	176:00 ± 4:21	2840 ± 127	16	
Total [c]	178:56	2953	16.54	
Segment				
Duodenum [d]		135 ± 4		0.91
Jejunum [e]		2730 ± 127		18.32
Ileum [f]		110 ± 1		0.74
Total [g]		2975 ± 129		19.96
Body [h]		149 ± 7		

[a] Time required between infusion of aniline dye into the proximal duodenal cannula and its appearance at the duodenal–jejunal cannula (9 observations).

[b] Time required between infusion of aniline dye into the duodenal–jejunal cannula and its appearance at ileal cannula (9 observations).

[c] Total time = sum of times between infusion of aniline dye into the proximal duodenal cannula and its appearance at ileal cannula.

[d] From pyloric sphincter up to duodenal–jejunal flexure.

[e] From duodenal–jejunal flexure up to ileocecal fold origin.

[f] From ileocecal fold origin up to ileocecal valve.

[g] From pyloric sphincter up to ileocecal valve.

[h] From nuchal line (occipital bone) up to root of tail (sacrocaudal dorsal medium muscle).

0.5, and 1.0 h values were available for these parameters in their experiment. Gregory and Miller (11) found a transit time from the duodenum to the terminal ileum of 148 min in sheep (42.5 kg BW) fed with 1500 g/day of pelleted hay using phenol red as a marker. The lengths of the duodenal, jejunal, and ileal segments of the small intestine were 135 ± 4, 2730 ± 127, and 110 ± 1 cm, respectively. The ratio of body length (1.49 m) to intestinal length (total length of 29.8 m) resulted in a ratio of 1:20. The 1:20 proportion agreed closely with those reported by others (12–14). Considering the observed lengths of each segment, the whole small intestine and the time delay of the marker appearing in the duodenal and ileal cannulae, the relative transit time of chyme within the duodenum and jejunum averaged 46 and 14 cm/min, respectively**.** The faster passage observed in the proximal duodenum is mainly due to the effect of abomasal outflow, which is "diluted" as the chyme advances into the ileocecal valve (15). The time required for the aniline dye to infuse from the duodenal cannula into the ileal cannula averaged 2:59 h:min, with a relative transit time of 16.54 cm/min. A small intestinal (proximal duodenum to ileocecal valve) transit time of 2.1 h was determined in steers (142 kg BW) fed chopped (3.8-cm screen) alfalfa hay at a level of 2.0% of BW (16). The lower value observed by Goestsh and Owens (16) may have been due to the low level of intake (2.0 vs. 2.52% BW) in their experiment, with the latter being the result of the rate of intestinal flow, which has been negatively correlated with the level of food intake. On the other hand, a small intestinal transit time of 3.1 h (relative transit time of 19.7 cm/min) was determined for markers in sheep (17–19).

Considering that the duodenum represents less than 5% of the total length of the small intestine, that duodenal transit time is 3-fold faster than that of the rest of the small intestine. As pancreatic and bile secretions into the duodenum occur midway along its length, it can be concluded that the duodenum plays a minor role in net nutrient absorption from the small intestine.

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