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Treatment of Neonatal Calf Diarrhea with an Oral Electrolyte Solution Supplemented with Psyllium Mucilloid

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Dairy calves under 14 days of age with naturally occurring, uncomplicated diarrhea were treated for 3 days with a hypertonic oral electrolyte solution with (n = 15) or without (n = 12) psyllium. Clinical response and clinical pathology data were compared between the 2 groups. Glucose absorption was evaluated on days 1 and 3 by measurement of plasma glucose and lactate and serum insulin concentrations for 4 hours after formula administration. On day 1, glucose, lactate, and insulin concentrations were lower in psyllium-fed calves than in control calves, with significant differences noted in glucose and lactate concentrations at several time points ($P < 0.05$). Plasma lactate concentrations were higher at several times in both treatment groups on day 3 than on day 1 ($P < 0.05$). Fecal consistency was markedly different in psyllium-fed calves as compared with control calves within 24 hours of psyllium supplementation. Fecal percent dry matter content was lower in psyllium-fed calves than in control calves at least once a day during supplementation and on day 3 compared with day 0 in the psyllium-fed calves ($P < 0.05$). There were no significant differences in clinical performance scores, hydration status, arterial blood gas, serum anion gap, electrolyte, or total CO_2 concentrations. Addition of psyllium to an oral electrolyte solution resulted in immediate alterations in glucose absorption without impairing rehydration in diarrheic calves, but differences were transient and did not affect clinical outcome.

Key words: Enteritis; Glucose; Insulin; Lactate.

The optimal treatment of neonatal calf diarrhea has been the subject of clinical and scientific interest in recent years. Interest stems from the fact that enteritis is a leading infectious cause of morbidity and mortality in calves, resulting in economic losses for the cattle industry.[1,2] Treatment strategies are directed at correcting the severe electrolyte and acid–base imbalances and fluid and energy deficits that often accompany calf diarrhea. Traditionally, the mainstay of therapy has included administration of hypertonic oral or parenteral electrolyte solutions containing glucose and alkaline buffers.[3] However, these solutions are not adequate for meeting caloric requirements and sustaining body weight in healthy calves or those with diarrhea.[4] Therefore, efforts have been directed at identifying alternative energy substrates or other substances that enhance nutrient absorption and improve efficacy of oral replacement solutions for treatment of diarrheic calves.[5,6]

A novel approach to correcting the energy deficits that accompany calf diarrhea is to enhance nutrient absorption from the gastrointestinal tract by the use of dietary fiber. The addition of fiber to orally administered electrolyte solutions may improve glucose absorption by slowing gastric emptying.[7,8] Dietary fiber may have other beneficial effects in diarrheic animals, including improved nutrient assimilation, intestinal epithelial regeneration, restoration of the normal mucosal barrier to enteric bacterial translocation, and restoration of the normal large intestinal microbial flora.[7] Psyllium mucilloid, a nondigestible, soluble fiber component of *ispaghula* husks, is one such dietary fiber supplement. A preliminary study failed to demonstrate clinical efficacy of psyllium for treatment of diarrhea in calves,[8] but a short supplementation period or small calf numbers may have contributed to the lack of observable benefit.

The purposes of this study were to compare clinical response and clinical pathology data in calves with naturally occurring diarrhea that were given a commercial hypertonic, energy-dense oral electrolyte solution with or without psyllium and to compare glucose absorption in these 2 groups of calves.

Materials and Methods

Calves

Twenty-seven Holstein calves less than 14 days of age that were admitted to the Colorado State University Veterinary Teaching Hospital with diarrhea between October 1995 and April 1996 were included in this case control study. On admission, calves were given a complete physical examination, which included determination of body weight, rectal temperature, fecal consistency, heart and respiratory rates, and thoracic auscultation. Calves were excluded from the study if physical examination or laboratory findings suggested a focus of infection in addition to the gastrointestinal tract. Hydration status was estimated using clinical findings such as skin turgor, eye position, mucous membrane dryness, and mentation.[9] Clinical performance score was evaluated and categorized using the modified Karnofsky clinical performance scheme[10] (Table 1). The clinician (MLC) was not blinded to the calves in each treatment group and examined all calves. Calves were housed in individual stalls in a climate-controlled isolation facility for the duration of the study.

Clinical Trial

Dehydration and acidosis at the time of admission were corrected using a balanced polyionic solution with sodium bicarbonate added based on the following formula: 0.5 × body weight in (kg) × base deficit.[11] The solution was administered via a 14-gauge catheter (Abbocath-T, Abbott Hospitals Inc, Chicago, IL) placed in the jugular vein and connected to a gravity-flow infusion apparatus. At least half of the calculated fluid and base deficits were replaced within the first 6 hours of treatment, with complete correction within 24 hours. After hydration and mentation were restored, calves were randomly assigned

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Table 1. Modified Karnofsky clinical performance scale.[10]

Score	Description	Criteria
0	Normal	Fully active, able to perform at expected level
1	Restricted	Restricted activity level; lethargic, but able to eat, drink, and ambulate
2	Compromised	Severely restricted in activity level; ambulatory only to the point of drinking when offered bottle and defecating and urinating from a standing position
3	Disabled	Completely recumbent, must be force fed
4	Dead	Dead

to one of 2 treatment groups. Over the next 3 days, calves were fed either a standard glucose-containing electrolyte solution (control group) or the standard solution with psyllium mucilloid added (psyllium group). The hypertonic oral rehydration solution (Biolyte™, Upjohn Co, Kalamazoo, MI) was prepared by dissolving 90 g of powder per liter of warm tap water (35–40°C). For supplemented calves, psyllium mucilloid was added by suspending 20 g of psyllium (Psyllium mucilloid, Equi Aid Products, Inc, Phoenix, AZ) per liter of warm solution. Solutions were fed within 5 minutes of preparation. Each calf was fed 60 mL/kg of body weight per feeding 3 times a day. Calves that refused to drink the entire quantity were fed the remainder through an orogastric tube. Free choice water was offered by bottle or pail, and amount consumed was measured. Calves were weighed on each day of the study period. Before each feeding, calves were given a physical examination and clinical score. Fecal consistency was qualitatively assessed (scale of 0–3; 0 = solid and 3 = watery).

Sample Collection

Jugular venous blood was collected aseptically for hematologic and biochemical evaluation on admission and after IV fluid administration. At the same times, arterial blood samples were collected anaerobically from the brachial artery for blood gas analyses. On each of the 3 days of oral fluid supplementation and just before the first feeding of the day, jugular venous blood was collected aseptically through the catheter and divided among microhematocrit, polypropylene without additive, and lithium heparinized microfuge tubes. Packed cell volume (PCV) and total plasma protein (TPP) were determined from the microhematocrit tubes. Serum and plasma were harvested from the other tubes. Serum electrolyte (sodium, potassium, chloride), anion gap, and total CO_2 concentrations were determined. The rest of the serum and all of the plasma was stored at 0°C for subsequent analysis of serum insulin and plasma lactate and glucose. On days 1 and 3 of oral fluid replacement, 3 mL of venous blood was obtained through the jugular catheter immediately before the first oral supplementation of the day and at 30, 45, 60, 90, 120, 150, 180, 210, and 240 minutes postprandial for measurement of serum insulin and plasma glucose and lactate concentrations.

After gentle stimulation of the perineum with a gloved hand, fecal samples were collected on admission and 3 times per day for the 3 days of the study. Samples were collected in air-tight plastic containers and refrigerated until determination of fecal dry matter content.

Analytic Methods

Serum electrolytes, total CO_2, and biochemical analytes were measured by an autoanalyzer (Hitachi 911, Boehringer Mannheim Corp, Indianapolis, IN). Blood gas analyses was performed using an automated pH/blood gas analyzer (StatPal II pH and Blood Gas Analysis System, Unifet Inc, La Jolla, CA, or Radiometer 330 automated blood gas analyzer, Copenhagen). Plasma glucose and lactate concentrations were measured by a semiautomated analyzer (YSI Model 2700 Select, Yellow Springs Instrument Co, Yellow Springs, OH). Serum insulin concentration was determined using a validated bovine radioimmunoassay.[12] Fecal samples were dried to a constant weight (approximately 4 days) in an oven kept at 70°C. Fecal dry matter content was calculated as (dry weight at 70°C/wet weight) × 100%.

Statistical Methods

Data were analyzed by the Kolmogorov-Smirnov test for normality of distribution.[13] Normally distributed data were analyzed by repeated measures analysis of variance for time (day or period), treatment (psyllium or control), and subject (animal) effects and interactions (time × treatment, time × subject, treatment × subject).[14] Individual means then were compared by Fisher's least significant difference post hoc test.[13] Clinical performance scores and dehydration indices were ana-

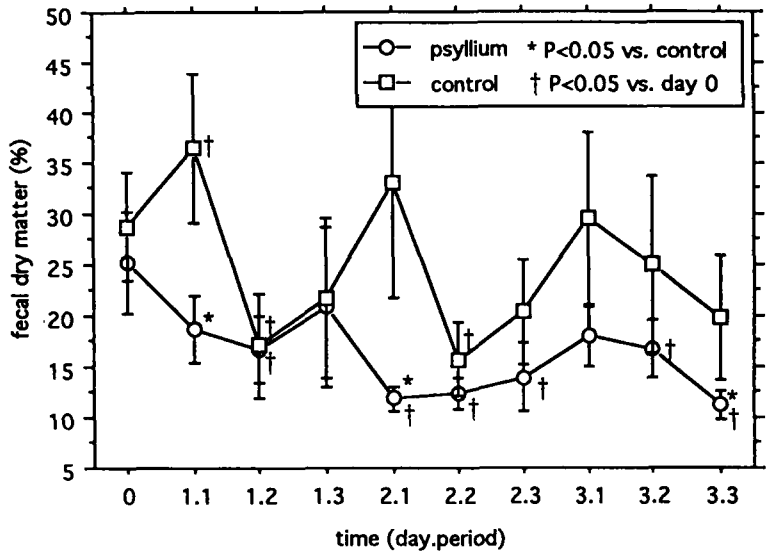

Fig 1. Fecal dry matter content (%) for calves fed a psyllium-supplemented oral electrolyte solution (psyllium) (n = 15) and calves fed a standard oral electrolyte solution (control) (n = 12).

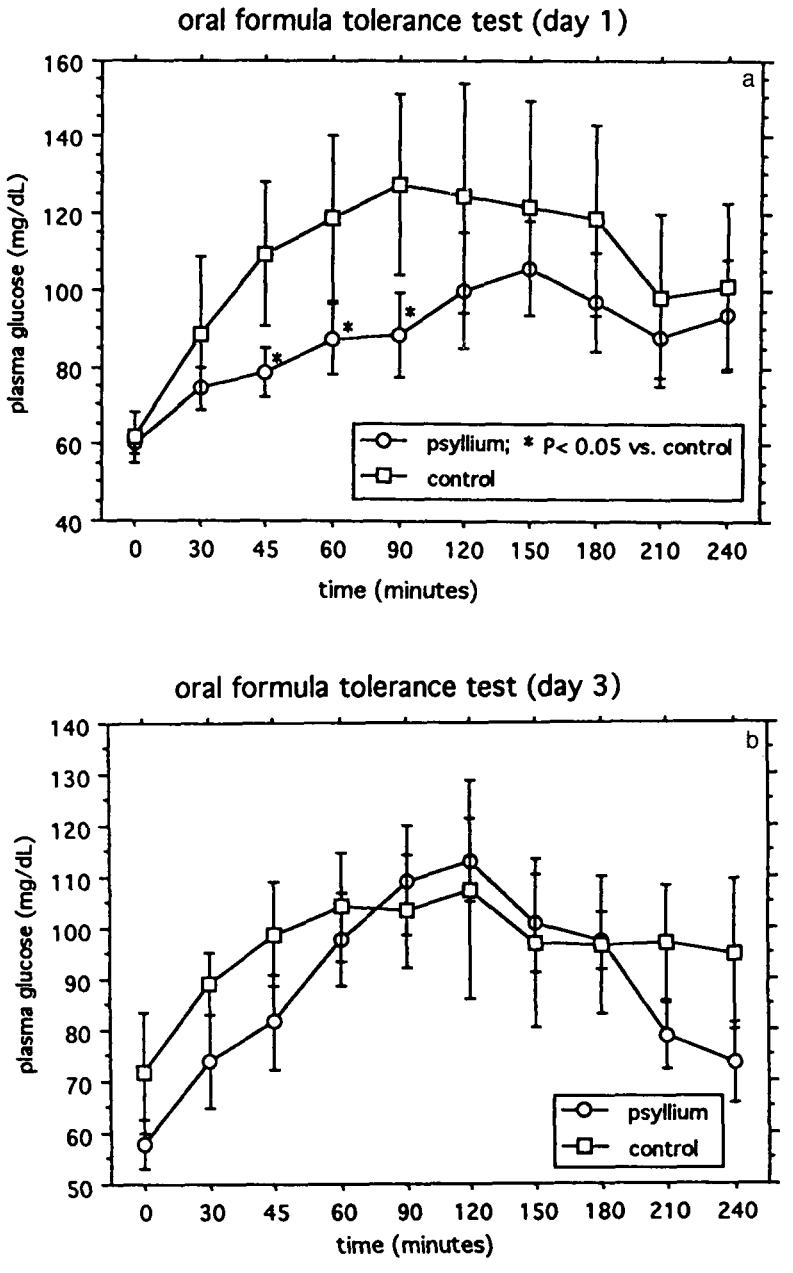

Fig 2. Change in plasma glucose concentration over time on day 1 **(a)** and day 3 **(b)** after oral administration of a psyllium-containing electrolyte solution (psyllium) (n = 15) and a standard electrolyte solution (control) (n = 12).

lyzed by the Mann-Whitney *U*-test.[14] Data were expressed as mean ±1 standard deviation (SD), and statistical significance was determined when $P < 0.05$.

Results

There were no significant differences in age, body weight, degree of dehydration, or clinical performance score between groups of calves on admission or at the beginning or throughout the trial. All calves were dehydrated and had metabolic acidosis on admission, but these abnormalities were corrected during the period of IV fluid administration. All measured blood gas data, PCV, TPP, and serum electrolyte concentrations were within reference ranges at the beginning of the feeding trial and remained so throughout the trial. There were no differences between groups for these analytes.

The psyllium-containing electrolyte solution was as palatable to the calves as was the electrolyte solution alone. Feces became gelatinous, viscous, and voluminous in the psyllium group within 12 hours of starting psyllium supplementation, and fecal consistency was markedly different in the psyllium-fed calves as compared with the controls at 24 hours after psyllium supplementation. Fecal dry matter content in the psyllium group was significantly lower than that on day 0 for much of the trial (Fig 1). On each of the 3 days of the study, the fecal dry matter content of the psyllium-fed calves also was lower than that of the controls for at least one time point.

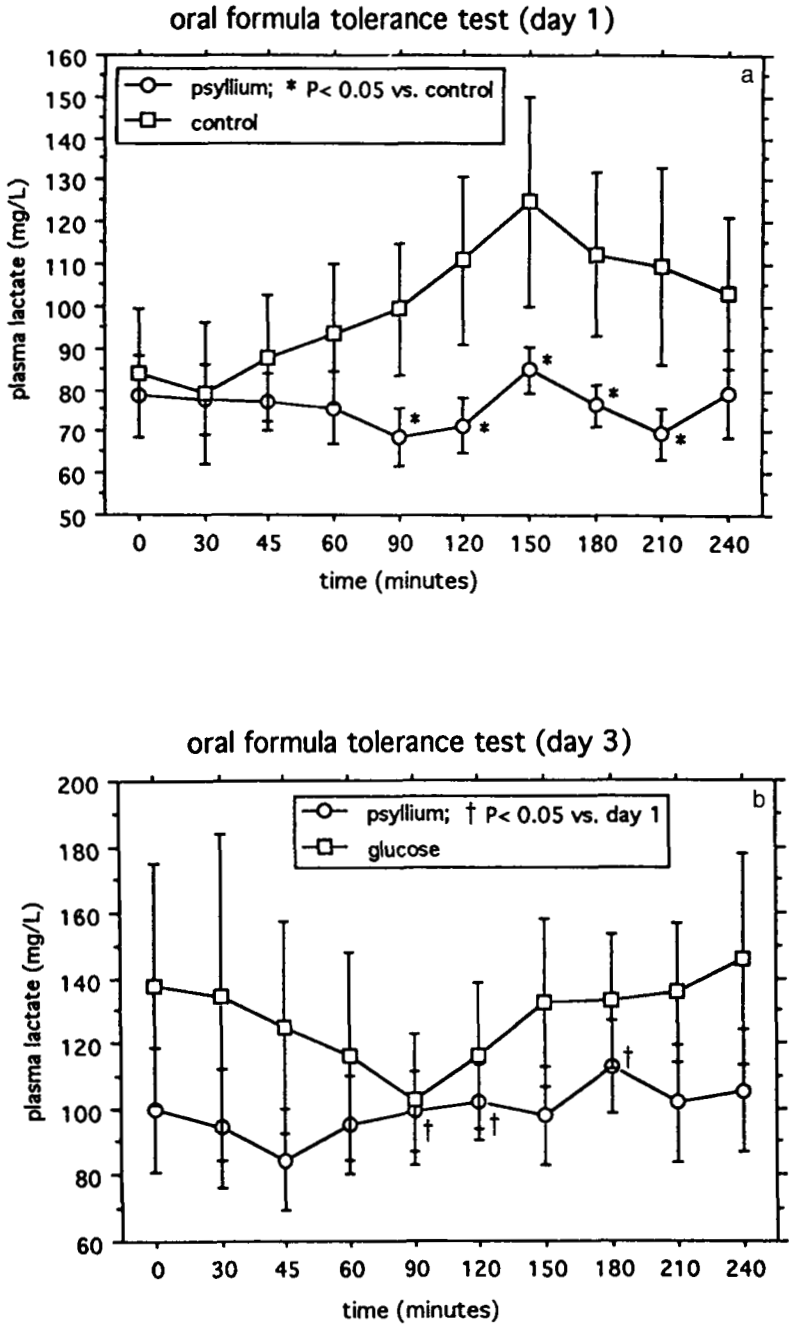

Fig 3. Change in plasma lactate concentration on day 1 **(a)** and day 3 **(b)** after oral administration of a psyllium-containing electrolyte solution (psyllium) (n = 15) and a standard electrolyte solution (control) (n = 12).

Preprandial glucose concentrations were not significantly different between groups at the start of the glucose absorption tests on days 1 and 3 (Fig 2a,b). Mean (±SD) plasma glucose concentration on day 1 at the start of the glucose absorption test was 60.54 (±10.70) mg/dL for the psyllium group and 61.89 (±17.70) mg/dL for the control group. Preprandial mean (±SD) plasma glucose concentration on day 3 was 57.97 (±16.08) mg/dL for the psyllium group and 71.70 (±30.68) mg/dL for the control group. On day 1, plasma glucose concentrations were lower in psyllium-fed calves than in control calves from 45 to 90 minutes after feeding, and peak concentrations were achieved later in the psyllium-fed calves (150 versus 90 minutes). There were no significant differences in time of peak or peak concentration between treatment groups on day 3.

Similar differences were seen in plasma lactate concentrations. Preprandial lactate concentrations were not significantly different between treatment groups at the start of the glucose absorption tests on days 1 and 3 (Fig 3a,b). Mean (±SD) preprandial lactate concentrations on day 1 were 78.62 (±32.85) mg/L for the psyllium group and 84.00 (±40.42) mg/L for the control group. On day 3, plas-

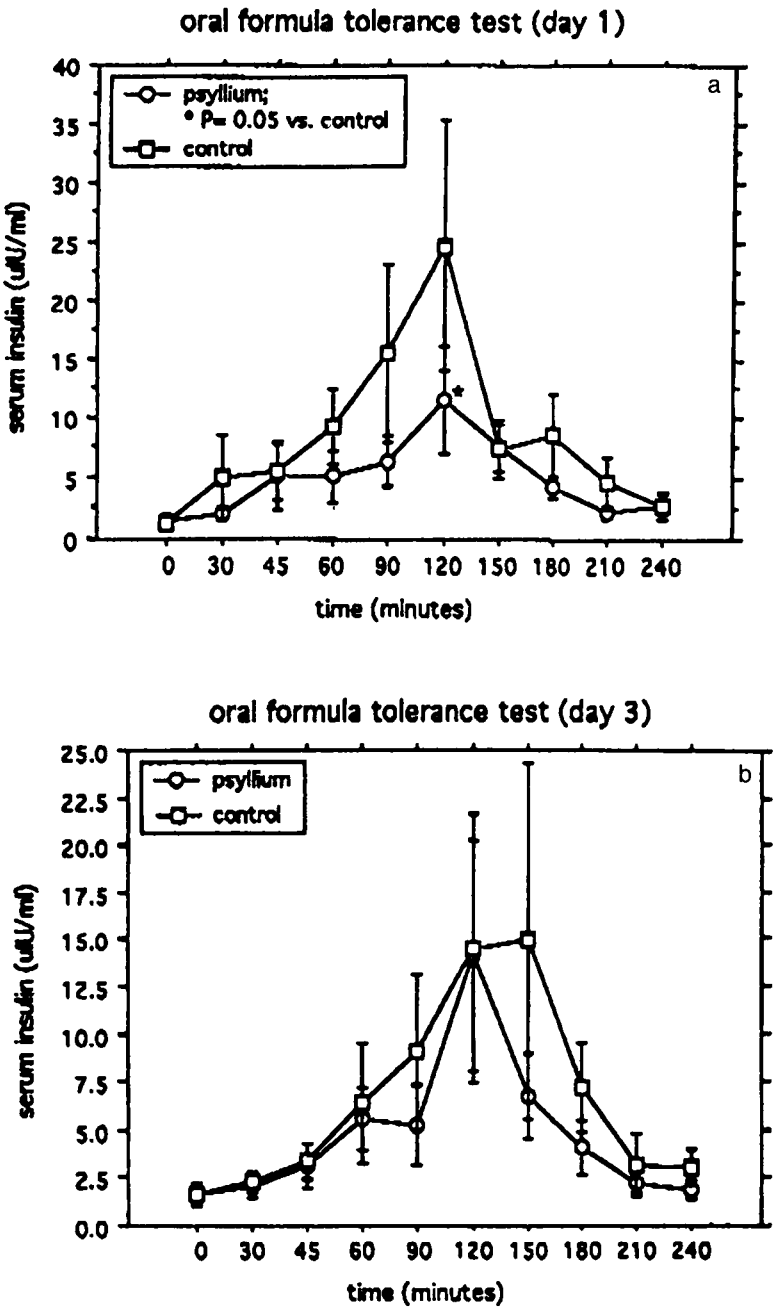

Fig 4. Change in serum insulin concentration on day 1 **(a)** and day 3 **(b)** after oral administration of a psyllium-containing electrolyte solution (psyllium) (n = 15) and a standard electrolyte solution (control) (n = 12).

ma lactate concentrations were higher in both treatment groups than they were on day 1. Plasma lactate concentrations were significantly lower in the psyllium-fed calves than in control calves from 90 to 210 minutes after feeding on day 1. In general, lactate concentrations did not increase significantly during the glucose absorption test on day 3. Mean (±SD) preprandial plasma lactate concentrations on day 3 were 99.81 (±62.93) mg/L for the psyllium group and 138.11 (±97.00) mg/L for the control group.

Serum insulin concentrations were significantly different between groups on day 1 at 120 minutes after feeding (Fig 4a). Mean (±SD) preprandial serum insulin concentrations on day 1 were 1.40 (±0.96) μLU/mL for the psyllium group and 1.34 (±1.02) μLU/mL for the control group. Mean (±SD) preprandial serum insulin concentrations on day 3 were 1.61 (±1.62) μLU/mL for the psyllium group and 1.58 (±1.42) μlU/ml for the control group (Fig 4b).

Discussion

Psyllium supplementation altered carbohydrate absorption in these diarrheic calves compared with calves fed standard hypertonic oral electrolyte solutions without supplementation. Calves fed psyllium had lower peak glucose

concentrations and lower postprandial increases in insulin concentrations than did control calves. A similar response to psyllium supplementation has been seen in humans[15] and calves in another study.[8] Lower insulin concentrations may have been the result of enhanced insulin sensitivity in psyllium-fed calves[16] or reduced insulin release secondary to the lower peak glucose concentration.[15] The lower glucose peak may have been the result of fiber-induced delays in gastric emptying, which in turn slowed delivery of glucose to the small intestines,[7] or to fiber-induced increases in gastrointestinal hormones, which altered glucose absorption, insulin release, or insulin responsiveness.[17] Psyllium also may have inhibited small intestinal glucose absorption and increased microbial fermentation of glucose in the lower gut.[7] Although there is evidence that psyllium lowers overall glucose absorption, other investigators[8] failed to demonstrate a significant reduction in blood glucose concentration in psyllium-fed calves. Regardless of the mechanism, the result in this study was a reduction in the rate of glucose absorption into a range more compatible with efficient disposal. It is unclear why the effects of psyllium on glucose absorption and insulin release did not persist or become more pronounced over the 3 days of the study. These calves may have experienced physiologic adaptation similar to what occurs in healthy people after long-term psyllium administration.[18] In general, adaptation is thought to require a longer supplementation period than that used in this study,[18] but gastrointestinal transit time,[19] emptying kinetics,[19] glucose absorption, and insulin kinetics[20] can change almost immediately after diet changes.

Plasma lactate concentrations in both groups of calves resembled the pattern observed for glucose concentrations. Feeding commercial, energy-dense oral rehydration solutions to healthy calves results in high plasma lactate concentrations.[4] Lactate production is thought to increase under these conditions as hepatic glucose metabolism is overwhelmed and extrahepatic glycolysis occurs.[21] Glucose metabolism is less efficient when glycolysis exceeds the rate of complete oxidation because the lactate produced and released by peripheral tissues must be extracted by the liver, where gluconeogenesis from lactate requires a large amount of energy.[21] The difference in plasma lactate concentrations between control calves and psyllium-fed calves suggested that glucose was absorbed more rapidly from the gastrointestinal tract in control calves and escaped hepatic metabolism to be oxidized by peripheral tissues to lactate. By delaying glucose delivery to the intestine, psyllium may have reduced inefficient cycling.

The physiologic importance of the differences in fecal consistency and fecal water content observed in the psyllium-fed calves is unknown. Based on this and previous studies,[8] fecal changes appear to develop between 7 and 24 hours after beginning psyllium supplementation. Healthy people consuming a diet that includes psyllium have a lower percentage dry matter of feces, presumably because of the hygroscopic nature of undigested fiber.[18] The water-holding properties of fiber may have reduced the free fecal water in the psyllium-fed calves and allowed ease of collection. In contrast, the high free fecal water in the control calves may have made collection of all fractions of feces difficult. The higher fecal water content in psyllium-supplemented calves did not lead to differences in hydration or clinical score. The beneficial effects of psyllium on gastric emptying and intestinal absorption may have compensated for the osmotic effects. Control calves had cyclic increases in fecal water content each night that were not seen in the psyllium-supplemented calves. Psyllium may have protected calves against such increases and concurrent dehydration. Total water lost in feces was not determined, and the importance of these apparent differences in fecal consistency and percent dry matter is unknown.

Calf diarrhea often is an acute, self-limiting disease, and therapeutic agents with immediate short-term potential benefits may be desirable. Psyllium slowed glucose absorption in the short term, and may be beneficial in reducing the severe weight loss and catabolism that occur with diarrhea in calves.[22] The effects on glucose absorption did not persist for the 3 days of the study, however, and it cannot be determined whether the psyllium treatment decreased overall glucose absorption. These findings may not be applicable to alternative fiber sources or to all standard electrolyte solutions. More work must be done to establish beneficial effects of psyllium on glucose absorption and utilization. In light of the short-term effects on glucose absorption and lack of improvement in clinical score or metabolic parameters noted in this study, we cannot recommend the addition of fiber supplements to standard electrolyte solutions for the treatment of neonatal calf diarrhea.

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