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Inclusion of psyllium in milk replacer for neonatal calves. 2. Effects on volatile fatty acid concentrations, microbial populations, and gastrointestinal tract size[1]

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ABSTRACT

Fermentable fibers such as psyllium increase volatile fatty acid (VFA) concentrations in the lower digestive tract and increase the gastrointestinal tract (GIT) mass of many mammals. We reasoned that psyllium inclusion in milk replacer might produce similar effects in neonatal dairy calves, which could lead to improved growth and health. Male Holstein calves were fed a milk replacer (22% crude protein, 20% fat) either without or with psyllium (1.1% of dry matter, DM) from 2 d through 28 d of age. Milk replacer was reconstituted to 12.5% DM and fed at 12% of calf body weight, adjusted weekly. Water was offered ad libitum but no starter was fed. Three calves per treatment were harvested weekly to sample digesta from the reticulo-rumen, abomasum, jejunum, proximal colon, and distal colon, and to determine length and mass of GIT components. Psyllium in milk replacer increased the proportion of butyrate in reticulo-rumen contents from 2.4 to 3.2% of total but did not affect total VFA concentrations. Total VFA concentrations were very low in the jejunum but psyllium tended to increase total VFA, acetate, and valerate concentrations; valerate accounted for 15.9 and 16.7% of total VFA (molar basis) for control and psyllium calves, respectively. Psyllium increased total VFA concentrations in the proximal and distal colon by 104.4 and 45.6%, respectively, but had little effect on the profile of VFA. Psyllium in milk replacer increased populations of bifidobacteria (from 9.7 to 10.3 $\log_{10}$ cfu/g of DM) and lactobacilli (from 8.2 to 9.4 $\log_{10}$ cfu/g of DM) in the reticulo-rumen, but did not affect populations in jejunum or colon. Calves fed psyllium had 12.0% greater total GIT mass and 9.4% greater GIT as a percentage of body weight. Psyllium tended to increase mass of the reticulo-rumen and significantly increased mass of duodenum (34.2%), jejunum (14.5%), and colon (14.6%). Density of intestinal tissues from calves fed psyllium-supplemented milk replacer was 25.9% greater in the jejunum and 25.3% greater in the ileum, and tended to be greater in duodenum and colon than tissue from control calves. Supplementation of psyllium to milk replacer increased fermentation in the colon, mass of the total GIT, and populations of bifidobacteria and lactobacilli in the reticulo-rumen.
Key words: psyllium, dairy calf, gastrointestinal mass, fermentation

INTRODUCTION

Neonatal dairy calves are subject to development of scours (diarrhea) and other gastrointestinal upsets, which contribute to high rates of morbidity and mortality (National Animal Health Monitoring System, 2007). Fermentable dietary fibers may help improve gut health via several physiological mechanisms (Mälkki, 2001). Inclusion of soluble fibers in the diet improved gut barrier function in rabbits (Gómez-Conde et al., 2007) and decreased severity of an experimental *Salmonella typhimurium* infection in piglets (Correa-Matos et al., 2003). Psyllium, a viscous, moderately fermentable, nonstarch polysaccharide, ameliorated the secretory diarrhea induced by enterotoxigenic *Escherichia coli* in piglets (Hayden et al., 1998).

Dietary psyllium has been studied in humans and other species for its potential effects on digestive function, rate of passage, nutrient absorption, intestinal morphology, and intermediary metabolism (Yu et al., 2009). Psyllium is fermented by fecal microbiota from humans (Campbell and Fahey, 1997), monkeys (Costa et al., 1989a), dogs (Swanson et al., 2001), and rats (Edwards et al., 1992). Increased fermentation of psyllium in the lower tract of rats results in greater concentrations of VFA, which in turn increase gastrointestinal tract (**GIT**) mass (Leng-Peschlow, 1991; Edwards et

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al., 1992; Schneeman and Richter, 1993). The VFA, particularly butyrate, act to increase mass and function of intestinal tissues by serving as metabolic substrates, by directly stimulating gene transcription for certain proteins such as nutrient transporters, and by stimulating release of the gut trophic hormone glucagon-like peptide-2 from enteroendocrine L cells (Tappenden et al., 2003).

The GIT microflora of milk-fed calves is dominated by bifidobacteria and lactobacilli, similar to that of the GIT of milk-fed infants (Vlková et al., 2006). These genera can ferment many nonstarch polysaccharides and inhibit gut colonization by pathogenic bacteria (Servin, 2004). A larger GIT with a more stable population of desirable bacterial species and improved barrier function might improve growth and health in young dairy calves. Although psyllium has been investigated as an adjunct therapy for diarrhea (Naylor and Liebel, 1995; Cebra et al., 1998), little is known about the effects of continuous supplementation of psyllium to the diet of young calves.

Previously we reported that addition of psyllium to milk replacer increased viscosity of digesta in the abomasum and colon, decreased DM content of colonic digesta and feces, and decreased the passage rate of digesta in the total digestive tract of healthy neonatal calves (Cannon et al., 2010). As part of that study, the objective of the research reported here was to determine the effects of inclusion of psyllium in milk replacer on VFA concentrations and microbial populations throughout the GIT, as well as on weight, length, and density of GIT tissues in neonatal dairy calves. Our hypothesis was that psyllium would be fermented in the lower small intestine and colon with a resultant increase in concentrations of VFA in the lower digestive tract. Furthermore, we predicted that the increased VFA would stimulate greater mass and density of the GIT tissues.

MATERIALS AND METHODS

Animals and Feeding

All procedures were approved by the University of Illinois Institutional Animal Care and Use Committee (protocol number 04083). Details of selection of calves, general husbandry, and dietary management were presented previously (Cannon et al., 2010). Briefly, the study was conducted with 2 blocks of 12 and 22 male calves purchased from a local commercial dairy at less than 36 h of age. Healthy calves were transported to the University of Illinois Dairy Nutrition Field Laboratory (Urbana) and housed in individual hutches (Calf-Tel, Hampel Corp., Germantown, WI) on crushed limestone. No bedding was used, to minimize ingestion of organic bedding material that might confound treatment inferences.

Calves were blocked by pairs based upon birth date, BW, and total protein concentration in plasma and then randomly assigned within pair to each of the dietary treatments. These pairs of calves were then randomly assigned to harvest week. Treatments were milk replacers (Land O'Lakes Animal Milk Products Co., Arden Hills, MN) without (control; **CON**) or with a 1.1% inclusion of psyllium (**PSY**). Psyllium was obtained from Kadam Exports Pvt. (Mehsana, India). The level of psyllium supplementation was selected based on previous unpublished experiments as the lowest amount that significantly improved growth, fecal scores, and starter intake (B. L. Miller, Land O'Lakes Animal Milk Products, Arden Hills, MN; unpublished data). Milk replacers were formulated to contain 22% CP and 20% fat. Milk replacers contained only milk proteins and were not medicated. Although the diet formulation is proprietary, psyllium was added into the control formulation and so diluted all ingredients slightly. Calves were fed at 0600 and 1800 h. Milk replacers were reconstituted to 12.5% DM and fed at a rate of 12% of BW daily, adjusted weekly as calves grew. Water was available to calves for ad libitum consumption, with fresh warm water provided twice daily after each milk replacer feeding. No other feeds were offered.

Collection of Samples

Pairs of calves were harvested weekly for analysis as described by Cannon et al. (2010). Calves were not given their morning milk replacer before being euthanized. Calves were sedated by administration of Xylazine HCl intramuscularly (50 mg/mL; Fort Dodge Animal Health, Fort Dodge, IA) and then killed with an intravenous overdose of sodium pentobarbital (Fatal Plus, Veterinary Laboratories Inc., Lenexa, KS) followed by exsanguination.

When the calf was declared dead, the veterinarian opened the body cavity. The GIT was ligated at the caudal esophagus and rectum and removed as rapidly as possible without damaging the tract. To prevent movement of digesta between compartments, the different segments of the GIT were identified and ligated. The GIT was then divided into 3 portions: the stomach portion consisting of rumen, reticulum, omasum, and abomasum; the small intestine, consisting of duodenum, jejunum, and ileum; and the colon. Each portion was processed by a respective team of personnel for tissue and digesta collection.