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Effects of partial replacement of corn grain with lactose in calf starters on ruminal fermentation and growth performance

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ABSTRACT

The objective of this study was to evaluate effects of partial replacement of dry ground corn with lactose in calf starters on dry matter intake, growth rate, ruminal pH, and volatile fatty acid profile. Sixty Holstein bull calves were raised on a high plane of nutrition program until 55 d of age. Calves were fed texturized calf starters containing 30.1% steam-flaked grains and lactose at 0 (control), 5, or 10% (n = 20 for each treatment) on a dry matter basis. All calves were fed treatment calf starters ad libitum from d 7 and kleingrass hay from d 35. Ruminal pH was measured continuously immediately after weaning (d 55–62) for 15 calves (n = 5 per treatment), and 3 wk after weaning (d 77 to 80) for the other 45 calves (n = 15 per treatment). Dry matter intake, growth performance, and ruminal pH variables were not affected by treatment. However, according to Spearman's correlation coefficient (r_s) analyses, lactose intake was positively correlated with dairy minimum ruminal pH ($r_s = 0.306$) for the data collected from d 77 to 80. Similarly, hay intake was not affected by treatment, but positively correlated with daily mean ($r_s = 0.338$) and maximum ruminal pH ($r_s = 0.408$) and negatively correlated with duration pH <5.8 ($r_s = -0.329$) and area pH <5.8 ($r_s = -0.325$), indicating that the variation in hay intake among animals might have masked treatment effects on ruminal pH. Ruminal molar ratio of acetate was higher (45.2 vs. 40.6%), and that of propionate was lower in 10% lactose than control (35.3 vs. 40.2%) for ruminal fluid collected on d 80; however, molar ratio of butyrate was not affected by treatment. These results indicate that lactose inclusion in calf starters up to 10% of dry matter might not affect dry matter intake and growth performance of calves, but that greater lactose and hay intake might be associated with higher ruminal pH.
Key words: calf, lactose, starter, volatile fatty acids, ruminal pH

INTRODUCTION

Consumption of easily fermentable carbohydrates in calf starters can stimulate rumen development and growth of epithelium of rumen (Baldwin et al., 2004; Drackley, 2008), microbial proliferation (Yáñez-Ruiz et al., 2015), and VFA production (Suárez et al., 2006a; Khan et al., 2016), as well as increased propionate and butyrate production in the rumen (Tamate et al., 1962; Khan et al., 2016). Dietary composition of calf starter can affect ruminal epithelial development by altering microbial fermentation end products (Nocek et al., 1984; Khan et al., 2008; Suárez et al., 2006b), and butyrate is considered to stimulate rumen epithelial growth to a greater extent than the other VFA (Tamate et al., 1962; Bergman, 1990).

However, high-starch diets often induce low ruminal pH in calves (Suárez et al. 2006a; Khan et al., 2016). During the weaning transition, calves often experienced ruminal pH below 5.8 (Anderson et al., 1987), which is attributed to large intake of rapidly fermentable carbohydrates (Khan et al., 2016). In addition, the low ruminal pH might be also attributed to underdeveloped ruminal epithelium of calves, where fermentation acid production exceeds the absorptive capacity of the ruminal wall (Williams et al., 1987). Subacute ruminal acidosis, defined as ruminal pH below 5.8 (Garret, 1996), is associated with depressed DMI, laminitis, and rumenitis in mature cows (Kleen et al., 2003), and decreased rumen motility and increased keratinization of the papillae in calves (Bull et al., 1965). In addition, SARA can cause liver abscesses, as low ruminal pH can damage rumen wall allowing pyogenic bacteria to reach the liver (Kay, 1960; Bull et al., 1965).

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Feeding lactose, the primary nutrient in whey, may mitigate SARA in calves. Chamberlain et al. (1993) reported that feeding lactose increased ruminal pH in sheep compared with other sugars and starch. Dietary inclusion of lactose (DeFrain et al., 2004; DeFrain et al., 2006) or a ruminal dose of lactose (Oba et al., 2015) increased ruminal butyrate concentration in mature cows. In addition, lactose feeding tended to increase DMI in mature cows (DeFrain et al., 2004); however, effects of feeding lactose on ruminal fermentation and animal performance have not been extensively studied for calves.

We hypothesized that lactose inclusion in calf starters would increase ruminal butyrate concentration, ruminal pH, starter intake, and growth performance of calves. The objective of our study was to evaluate effects of partial replacement of a starch source with lactose in calf starters on DMI and growth performance before and after weaning, as well as ruminal pH and VFA profiles after weaning.

MATERIALS AND METHODS

Animals and Housing

Sixty Holstein male calves (4–6 d of age, BW = 47.3 ± 0.7 kg; mean ± SD) were collected from commercial dairies in Fukushima and Ibaraki prefectures (Japan) and transported to the Dairy Technology Research Institute (Yabuki, Fukushima, Japan). Calves were born on March 20 to April 13, 2015 (group 1), and May 7 to June 2, 2015 (Group 2). Calves were further blocked by birthdate, BW, and farm origin, and randomly assigned to 1 of 3 calf starter treatments (n = 20 for each treatment). Calves were raised in individual hatches (made by fiber-reinforced plastics with wood grating floor) without bedding materials. When calves were arrived in the research farm, they received 5 mL of Terramycin (Zoetis Japan, Tokyo, Japan) and 0.1 mL of Duphafral Forte (Zoetis Japan) via subcutaneous injection and received 5 mL of Ivermec PO (Fujita Pharm, Tokyo, Japan) via percutaneous absorption. In addition, all calves received 5 mL of Ektecin Liquid (Meiji Seika Pharma, Tokyo, Japan) and 20 mL of Baycox Bovis (Bayer Yakuhin, Osaka, Japan) via oral administration on d 3 and 21 after arrival, respectively.

Feeding

All calves were fed a milk replacer (28% CP and 15% fat; 166.7 g/L) using a bucket with a soft rubber nipple twice daily at 0615 and 1615 h. Milk replacer was offered at 600 g/d until d 13, 800 g/d from d 14 to 20, and 1,200 g/d from d 21 to 41, 800 g/d from d 42 to 48, and 600 g/d from d 49 to 55; calves were then weaned on d 56. All calves had free access to fresh water supplied by a bucket with a soft rubber nipple. Calves were fed texturized calf starters containing 30.1% steam-flaked grains and lactose at 0 (control), 5.0 (**LAC5**), or 10.0% (**LAC10**) on a DM basis. All calf starters were formulated for 23.1% CP (Table 1). Treatment calf starters were offered ad libitum using an 8-L bucket from d 7. Feeding time of calf starters was 1000 h initially, but when calves consumed more than 900 g/d (as fed) of starter, calves were fed twice daily (1000 and 1500 h; equal volume of starter). Kleingrass hay was offered at 50 g/d (as fed) from d 42 to 48, 100 g/d (as fed) from d 49 to 55, and 150 g/d (as fed) after d 56. Refused calf starters and hay were cleaned daily at 1000 h and their intakes were recorded.

Data and Sample Collection

Body weight, withers height, hip height, horizontal body length, hip width, and heart girth were measured

Table 1. Dry matter ratio of ingredients on calf starter formulations

Composition	Treatment[1]		
	Control	LAC5	LAC10
Ingredient, % of DM			
Steam-flaked corn grain	9.9	9.9	9.9
Steam-flaked barley grain	20.2	20.2	20.2
Alfalfa dehydrated pellet	3.7	3.7	3.7
Molasses cane	0.4	0.4	0.4
Pellet	65.8	65.8	65.8
Pellet, % of DM			
Dry ground corn	14.9	8.2	1.6
Wheat feed flour	1.6	1.6	1.6
Soybean flour	2.2	3.4	4.4
Wheat bran	9.0	9.0	9.0
Soybean meal	17.3	16.8	14.6
Rapeseed meal	1.3	1.3	1.3
Heated soybean[2]	7.1	7.1	7.1
Corn gluten meal	2.3	2.6	4.1
Ground beet pulp	4.1	4.1	4.1
Dehydrated alfalfa	0.0	0.6	1.9
Cane molasses	3.7	3.7	3.7
Calcium carbonate	1.2	1.2	1.2
Salt	0.7	0.7	0.7
Calcium phosphate	0.6	0.6	0.6
GC mix 21[3]	0.5	0.5	0.5
Lactose[4]	0.0	5.0	10.0

[1]Treatment: Control = calf starter containing no lactose; LAC5 = calf starter containing 5% of lactose on a DM basis; LAC10 = calf starter containing 10% of lactose on a DM basis.

[2]Heated soybean (SoyPlus, West Central Cooperative, Ralston, IA).

[3]GC mix 21 (trace mineral and vitamin premix, Zenrakuren, Tokyo, Japan), containing vitamin mix 16.0%, trace mineral mix 6.3%, and rice bran 77.7%.

[4]Lactose (Hilmar 5030 Extra Fine Grind Lactose, Hilmar Ingredients, Hilmar, CA).