J. Dairy Sci. 101:1–11
https://doi.org/10.3168/jds.2017-13247

Effects of feeding unlimited amounts of milk replacer for the first 5 weeks of age on rumen and small intestinal growth and development in dairy calves

C. T. Schäff,* J. Gruse,* J. Maciej,* R. Pfuhl,† R. Zitnan,‡ M. Rajsky,‡ and H. M. Hammon*[1]
*Institute of Nutritional Physiology "Oskar Kellner," and
†Institute of Muscle Biology and Growth, Leibniz Institute for Farm Animal Biology (FBN), 18196 Dummerstorf, Germany
‡Institute of Nutrition, Research Institute for Animal Production Nitra, National Agricultural and Food Centre, 95141 Luzianky, Slovakia

ABSTRACT

The development of the gastrointestinal tract in newborn calves is essential for sufficient nutrient uptake. An intensive milk feeding during the neonatal period may impair the rumen development in calves. The aim of this study was to investigate effects of milk replacer (MR) feeding in unlimited amounts for the first 5 wk of age on the gastrointestinal growth and development in preruminant calves at wk 9 of age. Twenty-eight newborn Holstein and Holstein × Charolais crossbred calves (19 male and 9 female) were fed MR ad libitum (ADLIB) or in restricted amounts (6 L per day; RES) until wk 5 of age. Thereafter, the MR intake of ADLIB was gradually reduced at wk 6 and 7, and all calves received 6 L of MR per day until wk 9 of age. In wk 9, calves were slaughtered and carcass and organ weight as well as rumen papilla size in the atrium, ventral sac, and ventral blind sac, and villus size of the mucosa in the small intestine (duodenum; proximal, mid, and distal jejunum; and ileum) were determined. The expression of mRNA associated with the local insulin-like growth factor (IGF) system was measured in the rumen epithelium. Ad libitum MR feeding increased MR intake and growth in ADLIB without influencing concentrate intake compared with RES. Carcass weight in wk 9 was greater in ADLIB than in RES. The density of the rumen papillae in the atrium and ventral blind sac was greater in RES than in ADLIB calves, but surface area of the epithelium was not different between groups in the investigated regions of the rumen. The mRNA abundance of *IGF1* in the atrium tended to be greater and the *IGFR1* mRNA abundance in the ventral sac tended to be lower in the ADLIB than in the RES feeding group. The rumen pH and volatile fatty acid concentrations were not affected by MR feeding intensity. In mid-jejunum, villus circumference was greater in ADLIB than in RES calves. In the distal jejunum, villus surface area and the villus height/crypt depth ratio were greater and the villus circumference and height tended to be greater, whereas crypt depth was smaller in ADLIB than in RES calves. The findings from this study indicate that ad libitum MR feeding for 5 wk of age followed by its gradual reduction promotes growth performance without any negative influence on gastrointestinal growth and development in dairy calves at 9 wk of age.

Key words: calf, milk feeding intensity, gastrointestinal development, insulin-like growth factor system

INTRODUCTION

Ad libitum milk or milk replacer (**MR**) feeding programs during the early preweaning period result in a greater nutrient intake and allow calves to achieve a higher ADG and BW than restricted milk feeding (Hammon et al., 2002; Jasper and Weary, 2002; Maccari et al., 2015). New automated feeding systems allow calves to drink large amounts of milk or MR per day by several small portions and facilitate the weaning process without detrimental effects on the digestive system (Hammon et al., 2002; Khan et al., 2011; de Passille and Rushen, 2016). The enhanced postnatal growth performance has long-lasting developmental effects and may promote health and individual milk production (Khan et al., 2011; Bach, 2012; Van Amburgh and Soberon, 2013). However, intensive milk feeding regimens are still under discussion due to the possible negative effect on solid feed intake and rumen development (Drackley, 2008; Gelsinger et al., 2016; Khan et al., 2016), but when calves receive up to 6 L of milk/d they do not reach their growth potential during the pre-weaning period (Hammon et al., 2002; Schäff et al., 2016; Frieten et al., 2017). When comparing growth performance in dairy calves with the more natural situations in beef calves, an elevated milk and solid feed intake at the same time should be feasible when milk and solid feed intake are distributed over the day by automated feed-

Received May 29, 2017.
Accepted August 29, 2017.
[1]Corresponding author: hammon@fbn-dummerstorf.de

ing systems (Egli and Blum, 1998; Maccari et al., 2015; de Passille and Rushen, 2016). An adequate nutrient supply from liquid and solid feeds is probably most important for optimal dairy performance in later life (Gelsinger et al., 2016) and sufficient concentrate intake in the pre-weaning period is necessary to maintain constant growth and weight gain after weaning (Drackley, 2008; Bach, 2012). Therefore, there is great interest in developing pre-weaning feeding protocols that enable an accelerated growth performance and adequate maturation of the rumen function at once.

Body and organ growth is regulated by the systemic and local expression of the somatotropic axis (Breier et al., 2000; Le Roith et al., 2001; Hammon et al., 2012). Enhanced MR feeding stimulates the systemic somatotropic axis in the preruminant calf (Bartlett et al., 2006; Maccari et al., 2015; Schäff et al., 2016). On the other hand, the local IGF and insulin system affects gastrointestinal growth and development in the preruminant calf (Blum, 2006; Penner et al., 2011; Hammon et al., 2012) and the local IGF and insulin receptor gene expression in ruminal epithelial cells is under nutritional control in ruminants (Shen et al., 2004; Naeem et al., 2012; Connor et al., 2014). However, it is not known whether an ad libitum MR feeding program influences the local gene expression of the IGF and insulin system in the ruminal epithelium of the preruminant calf. We recently published our data on the IGF-I and IGF binding proteins (**IGFBP**) as well as insulin plasma concentrations in calves, resulting in elevated IGF-I and insulin plasma concentrations during and after the intensive MR feeding period (Schäff et al., 2016). In the present study we hypothesized that the intensive MR feeding for 5 wk of age followed by gradual reduction of its intake has no detrimental effects on the gastrointestinal growth and development, especially in the rumen, and that the intensive MR feeding stimulates the local IGF system in the ruminal epithelium of the preruminant calf. Therefore, we investigated feed intake, gastrointestinal growth and epithelial size, ruminal VFA concentrations, and the mRNA abundance of IGF-I, IGFBP, and the receptors for IGF-I and insulin in the ruminal epithelium at wk 9 of age before weaning to characterize differences of the gastrointestinal growth and development with respect to intensive MR feeding in the first 5 wk of age.

MATERIALS AND METHODS

Animals, Feeding, and Diets

The experimental procedures were carried out according to the German Animal Welfare law and the animal care guidelines of the State Government in Mecklenburg-Western Pommerania, Germany (LALLF M-V/TSD/7221.3–2.1–011/12).

The experimental setup was recently described in a companion paper (Schäff et al., 2016). Briefly, 28 German Holstein (n = 5) or German Holstein × Charolais crossbred calves (n = 23) were fed either ad libitum (**ADLIB**; 3 Holstein and 11 Holstein × Charolais; 8 male and 6 female) or restricted (**RES**; 2 Holstein and 12 Holstein × Charolais; 11 male and 3 female) amounts of milk reconstituted from MR (SalvaLac MiraPro 45, Salvana Tiernahrung, Klein-Offenseth Sparrieshoop, Germany; 125 g of powder/L; Supplemental Table S1; https://doi.org/10.3168/jds.2017-13247) for the first 5 wk of life by an automated feeder (Förster Technik GmbH, Engen, Germany). In wk 6 and 7 the available amount of MR for ADLIB calves was reduced step by step to 6 L per day and kept constant afterward. The RES group received up to 6 L per day for the whole experimental time by automated feeder (Förster Technik GmbH). Calves were housed on straw bedding in one pen with 2 compartments and 2 feeding stations for young calves (up to 3 wk of age) and older calves (from wk 4 of age on), respectively. Calves of both groups were mixed in the same compartments and used the same feeding stations for young and older calves, respectively. All calves had free access to water and concentrate (Kälber Start 18/3, Vollkraft Mischfutterwerke, Karstädt, Germany; Supplemental Table S1; https://doi.org/10.3168/jds.2017-13247). Concentrate was provided by automated feeders (Förster Technik GmbH).

Measurement of daily feed intake and weekly weight gain as well as prophylactic treatments were described recently (Schäff et al., 2016). The nutrient compositions of the MR and concentrate were analyzed according to the Weender standard procedure (Naumann and Bassler, 2004). Total intake of ME was calculated according to Drackley (2008).

Tissue Sampling and Analyses

Calves were slaughtered before weaning on d 60 of age [exact age was (LSM ± SE) 59.8 ± 0.6 d for ADLIB and 60.1 ± 0.7 d for RES calves]. Empty rumen, omasum, and abomasum weight as well as weight and length of the small intestine were determined. Samples of the rumen [atrium ruminis (atrium), saccus ventralis (ventral rumen sac), and saccus cecus caudoventralis (ventral blind sac)] and small intestine (duodenum; proximal, mid, and distal jejunum; and ileum) were collected and cut in 1-cm^2 pieces and fixed in 4% formaldehyde solution for morphometrical measurements. Additional samples from the 3 rumen areas were stored at −80°C for gene expression measurements.