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Effects of solid feed level and roughage-to-concentrate ratio on ruminal drinking and passage kinetics of milk replacer, concentrates, and roughage in veal calves

H. Berends,*[1,2] J. J. G. C. van den Borne,* N. Stockhofe-Zurwieden,† M. S. Gilbert,* T. Zandstra,* W. F. Pellikaan,* C. G. van Reenen,‡ E. A. M. Bokkers,§ and W. J. J. Gerrits*
*Animal Nutrition Group, Wageningen University, PO Box 338, 6700 AH Wageningen, the Netherlands
†Central Veterinary Institute, Wageningen University and Research Centre, PO Box 65, 8200 AB Lelystad, the Netherlands
‡Livestock Research, Animal Sciences Group, Wageningen University and Research Centre, PO Box 65, 8200 AB Lelystad, the Netherlands
§Animal Production Systems Group, Wageningen University, PO Box 338, 6700 AH Wageningen, the Netherlands

ABSTRACT

Effects of solid feed (SF) level and roughage-to-concentrate (R:C) ratio on ruminal drinking and passage kinetics of milk replacer, concentrate, and roughage were studied in veal calves. In total, 80 male Holstein-Friesian calves (45 ± 0.2 kg of body weight) were divided over 16 pens (5 calves per pen). Pens were randomly assigned to either a low (LSF) or a high (HSF) SF level and to 1 of 2 R:C ratios: 20:80 or 50:50 on a dry matter (DM) basis. Roughage was composed of 50% corn silage and 50% chopped wheat straw on a DM basis. At 27 wk of age, measurements were conducted in 32 calves. During the measurement period, SF intake was 1.2 kg of DM/d for LSF and 3.0 kg of DM/d for HSF, and milk replacer intake averaged 2.3 kg of DM/d for LSF and 1.3 kg of DM/d for HSF. To estimate passage kinetics of milk replacer, concentrate, and straw, indigestible markers (CoEDTA, hexatriacontane C_{36}, Cr-neutral detergent fiber) were supplied with the feed as a single dose 4, 24, and 48 h before assessment of their quantitative recovery in the rumen, abomasum, small intestine, and large intestine. Rumen Co recovery averaged 20% of the last milk replacer meal. Recoveries of Co remained largely unaffected by SF level and R:C ratio. The R:C ratio did not affect rumen recovery of C_{36} or Cr. Rumen fractional passage rate of concentrate was estimated from recovery of C_{36} in the rumen and increased from 3.3%/h for LSF to 4.9%/h for HSF. Rumen fractional passage rate of straw was estimated from Cr recovery in the rumen and increased from 1.3%/h for LSF to 1.7%/h for HSF. An increase in SF level was accompanied by an increase in fresh and dry rumen contents. In HSF calves, pH decreased and VFA concentrations increased with increasing concentrate proportion, indicating increased fermentation. The ratio between Cr and C_{36} was similar in the small and large intestine, indicating that passage of concentrate and straw is mainly determined by rumen and abomasum emptying. In conclusion, increasing SF level introduces large variation in passage kinetics of dietary components, predominantly in the rumen compartment. The SF level, rather than the R:C ratio, influences rumen recovery of concentrate and roughage. Our data provide insight in passage kinetics of milk (Co representing the milk replacer) and SF (Cr and C_{36} representing roughage and concentrate, respectively) and may contribute to the development of feed evaluation models for calves fed milk and SF.

Key words: calves, passage rate, nutrient utilization, forage-to-concentrate ratio

INTRODUCTION

Provision of a minimum amount (50 to 250 g/d) of fibrous feed for veal calves is compulsory according to guidelines of the European Union (97/2/EC Directive by the EU Council). Solid feed (**SF**) provision reduces abnormal oral behaviors (Kooijman et al., 1991; Veissier et al., 1998; Webb et al., 2012), and therefore contributes to improved calf welfare. Furthermore, an economic incentive exists to replace MR by SF in veal calf diets due to increasing prices of milk replacer (**MR**) ingredients. With increasing amounts of SF provided, products from rumen fermentation contribute to maintenance requirements and growth at the expense of nutrients from MR. In a previous study, we showed that the contribution of SF and MR to BW gain of veal calves largely follows its contribution to digestible energy supply, but effects of age exist (Berends et al., 2012a, 2014). Underlying mechanisms are not

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[1]Corresponding author: Harma.Berends@nutreco.com.
[2]Current address: Trouw Nutrition R&D, Veerstraat 38, 5831 JN Boxmeer, the Netherlands.

clear, but it is likely that variation in rumen passage kinetics of SF components and ruminal drinking largely contributes to variation in digestible energy supply. No information exists on passage kinetics of dietary components throughout the gastrointestinal tract in veal calves fed a combination of MR and SF. In dairy calves, it was shown that reducing MR intake (up to 60% compared with a control) had only minor effects on rumen passage kinetics of SF (Broesder et al., 1990). In addition, roughage-to-concentrate (**R:C**) ratio (Colucci et al., 1982; Poore et al., 1990; Rotger et al., 2005), as well as SF level (Colucci et al., 1990), may affect passage kinetics, as observed in ruminants fed only SF. In calves, MR is generally assumed to bypass the reticulorumen by means of the esophageal groove reflex. However, MR may leak into the rumen due to a failure of the esophageal groove reflex or backflow of MR from the abomasum, referred to as ruminal drinking, which can be substantial in dairy calves (0–25%; Guilhermet et al., 1975; Abe et al., 1979) and veal calves (14 to 35%; Suárez et al., 2007; Berends et al., 2012b). The objective of the current study was to assess the effects of SF level and R:C ratio on ruminal drinking and passage kinetics of dietary components in veal calves fed MR, roughage, and concentrate.

MATERIALS AND METHODS

This study was conducted at the research facilities of VanDrie group (Scherpenzeel, the Netherlands). Procedures complied with the Dutch Law on Experimental Animals and the ETS123 (Council of Europe 1985 and the 86/609/EEC Directive) and were approved by the Animal Care and Use Committee of Wageningen University.

Animals, Experimental Design, and Housing

Eighty male Holstein-Friesian calves (2 wk of age; 45 ± 0.2 kg of BW) were purchased from commercial dairy farms and selected based on uniformity and clinical health. Calves were allocated to pens (5 calves per pen; 16 pens) based on BW. Pens were randomly assigned to 1 of 2 SF levels—a low SF level (**LSF**) or a high SF level (**HSF**)—and to an R:C ratio of either 20:80 or 50:50 (Table 1). Upon arrival, calves were adapted to the designated SF levels at a fixed R:C of 50:50 until wk 10. During the experimental period (wk 11 to 27 after arrival), calves were exposed to their assigned SF level and R:C ratio. During the last 2 d of the experimental period, passage kinetics were measured in 32 calves originating from 16 pens.

During the experimental period, calves were housed in groups of 5 calves in pens (3 × 3 m) equipped with wooden-slatted floors and fences and without bedding material. During the last 2 d of the experimental period, 2 calves per pen were randomly selected and housed in individual pens placed inside the group pen to facilitate individual feeding and monitoring. Individual pens measured 0.9 × 2.0 m and allowed audio-visual contact with group mates. Throughout the experiment, calves were exposed to daylight and artificial light from 0500 to 2300 h and to darkness during the remainder of the day. Animal health was checked daily by visual appraisal. Hemoglobin concentration in blood was measured across the trial at wk 11, 15, 19, and 23 and corrected by iron injection to comply with the minimum European Union level of 4.5 mmol/L at the end of the fattening period.

Diets and Feeding

The calves in the current study were selected from another experiment, which has been described by Berends et al. (2014). In short, roughage was composed of 50% corn silage (Table 2) and 50% chopped (3 ± 2 cm) wheat straw (Table 2) on a DM basis. Provision of SF increased biweekly and linearly during the experimental period (wk 11–27), and averaged 780 g of DM/d for LSF and 2,000 g of DM/d for HSF.

Daily DMI from MR during the measurement period is shown in Table 1. The concentration of MR (Table 3) was 188 g/L throughout the experimental period. The MR was supplied in buckets at 40 to 41°C, provided twice daily in equally sized meals at 0600 and 1600 h, respectively. Calves were allowed 15 min to consume the milk; refusals were collected.

The SF was prepared in a mixing wagon (Easymix 2, Vliebo, Veenendaal, the Netherlands), and provided as a mixture in a long feed trough in front of the pen directly after MR provision and collection of MR refusals. Solid feed refusals were removed and weighed once daily before the MR meal in the morning. During the experimental period, calves had free access to water provided via drinking nipples. During the 2-d measure-

Table 1. Daily DM provision of solid feed (SF) and milk replacer (g of DM/calf per day) in calves (n = 8 per treatment combination) fed at 1 of 2 levels of SF intake, at 1 of 2 roughage-to-concentrate ratios (R:C)[1] at 27 wk of age

	Low SF		High SF	
Type of feed	20:80	50:50	20:80	50:50
Solid feed	1,170		3,000	
Milk replacer	2,224	2,370	1,058	1,458

[1]Roughage consisted of 50% corn silage and 50% chopped wheat straw on a DM basis.