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# Abrupt weaning reduces postweaning growth and is associated with alterations in gastrointestinal markers of development in dairy calves fed an elevated plane of nutrition during the preweaning period

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## ABSTRACT

The benefits of feeding elevated quantities of milk to dairy calves have been well established. However, there is a reluctance to adopt this method of feeding in commercial dairy production because of concerns around growth, health, and ruminal development during weaning. The objective of this study was to characterize the effect of an abrupt (0 d step-down) or gradual (12 d step-down) feeding scheme when calves are fed an elevated plane of nutrition (offered 1.35 kg of milk replacer/d). For this experiment, a total of 54 calves were randomly assigned to an abrupt or a gradual weaning protocol before weaning at 48 d of life. Calves were housed and sampled in individual pens for the duration of the experiment, and milk, starter, and straw intake were measured on a daily basis. Body weight was measured every 6 d, whereas blood, rumen fluid, and fecal samples were collected on d 36 (pre-step-down), 48 (preweaning), and 54 (postweaning) of the experiment. Although the growth rates of the step-down calves were lower from d 37 to weaning (0.62 ± 0.04 vs. 1.01 ± 0.04 kg/d), the postweaning average daily gain was greater compared with the group that was abruptly weaned (0.83 ± 0.06 vs. 0.22 ± 0.06 kg/d). Total ruminal volatile fatty acid was greater in the step-down group on the day of weaning (d 48; 59.80 ± 2.25 vs. 45.01 ± 2.25 mmol), whereas the fecal starch percentage was lower during postweaning compared with the abruptly weaned calves (d 54; 3.31 ± 0.76 vs. 6.34 ± 0.76%). Analysis of the digestive tract of bull calves on d 55 revealed minimal differences between gross anatomy measurements of gut compartments as well as no morphological differences in rumen papillae development, yet the total mass of rumen when full of contents was larger in the step-down calves (7.83 ± 0.78 vs. 6.02 ± 0.78 kg). Under the conditions of this study, the results showcase the benefits of a step-down feeding strategy from an overall energy balance standpoint, due to increased adaptation of the gastrointestinal tract preweaning.
**Key words:** calves, weaning, gastrointestinal development

## INTRODUCTION

In conventional production systems, dairy calves have traditionally been restricted to milk intake at levels less than half of their voluntary milk intake (~10% of birth weight). The rationale for this approach is to encourage solid feed intake, rumen development, and early weaning, which generally reduces the costs for raising calves. In contrast, research investigating elevated milk feeding schemes shows longer term benefits, which challenges the traditional approach of restricted milk feeding. For example, feeding calves elevated levels of milk (~20% of birth weight) has been shown to improve health, growth rates, feed efficiency, and lifetime production (Soberon et al., 2012). The implementation of elevated milk feeding schemes has increased over the past decade; however, the majority of producers are hesitant to adopt this strategy due to concerns that feeding elevated milk will decrease solid feed intake and rumen development, resulting in depressed growth and health of dairy calves during weaning (Khan et al., 2011, 2016).

To offset the challenges of weaning from elevated milk feeding, a strategy termed the "step-down" was developed, denoting a timed decrease in the amount of milk offered to create a gradual weaning process. To our knowledge, the first example of a step-down protocol was reported by Khan et al. (2007) in a study that showed increased solid feed intake and growth during weaning in step-down calves fed an elevated plane of nutrition compared with conventionally fed, abruptly weaned calves. In the dairy industry, the definition of step-down encompasses all levels of nutrition, differ-

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ent durations of the steps, and different methods of reducing the milk intake (Vasseur et al., 2010). Most studies investigating step-down protocols from elevated feeding schemes use automated calf feeding systems that feed calves at higher frequencies (>4 times/d) and can program equally distributed reductions through the duration of the step-down. For example, Sweeney et al. (2010) studied the duration of the step-down and noted that calves fed large amounts of milk via an automated feeder (>4 meals/d with a gradual step-down) displayed better pre- and postweaning intake and higher BW when the duration of the step-down was 10 d compared with 4 and 0 d. However, a limited number of studies have investigated weaning strategies from elevated planes of nutrition when calves are fed 2 times per day, which is the most common method of feeding in the dairy industry (Vasseur et al., 2010). In addition, there is a large knowledge gap regarding how weaning protocols affect gastrointestinal development. Most research related to characterizing the structural and functional adaptations of the gastrointestinal tract of calves during weaning has been conducted with calves fed a low plane of milk nutrition preweaning.

Therefore, the objective of this study was to examine the effects of gradual (step-down) compared with abrupt weaning on energy intake, growth, and gastrointestinal development during pre- and postweaning when calves are fed an elevated plane of nutrition in 2 meals per day. We hypothesized that calves fed elevated planes of nutrition and weaned gradually consume more energy in solid feed intake and have less weight loss during postweaning through a more rapid development of the ruminant gastrointestinal tract.

## MATERIALS AND METHODS

The study was conducted at the Trouw Nutrition Agresearch Dairy facility (Burford, Ontario, Canada). All animal procedures were approved by the Trouw Nutrition Agresearch Animal Care Committee in accordance with the Canadian Council on Animal Care (2009) guidelines and the experiment was performed over 6 mo (April–September). The dairy calf facility consisted of one room with natural and positive pressure ventilation. Each calf was housed in an individual pen (245 cm × 121 cm) and bedded daily with wood shavings at 1000 h.

### *Experimental Treatments, Feeding, and Growth Measurements*

A total of 54 calves (20 female and 34 male calves) were housed in individual pens from birth to the end of the study (d 54). Calves were blocked by sex and randomly assigned to an abrupt (0 d step-down) or gradual weaning strategy (12 d step-down initiated at d 36 with a 50% reduction of milk until d 48) before complete milk replacer withdrawal at 48 d of life. All calves received at least 3 L of their dam's colostrum through a nipple bottle (Super Calf Nipple, Merrick's, Middleton, WI) within 2 h of calving and transition milk thereafter for the next 2 d of life. On d 3 and 4, all calves were transitioned to milk replacer (ShurGain Optivia Advantage, 26% CP, 16% crude fat, and 45% lactose, Nutreco Canada Inc., Guelph, ON, Canada) offered at 4.5 L of milk replacer per feeding (150 g/L resulting in 1.35 kg/d) and fed at 0600 and 1700 h using nipple pails from d 4 to the initiation of weaning (d 36). The milk replacer raw material consisted of skim milk powder, sweet whey powder, vegetable oils, delactosed whey powder, and premix. All calves had ad libitum access to calf starter (Optivia Advantage Calf Starter, 22% CP, 28% starch; 4% crude fat, 5% crude fiber containing a 3-mm base pellet, steam-flaked corn, oats, molasses, and soy oil, Nutreco Canada Inc.), chopped straw (8% CP, 3-cm chop length), and water from d 7 to 54, and daily orts were recorded for each feedstuff for the duration of the experiment. Body weights were recorded at 1000 h for both sexes every sixth day until d 54. Because bull calves were killed on d 55 (described below), additional feed intake measurements for female calves were taken until d 60 and BW on d 60 and 90 of life.

### *Ruminal pH and VFA, Blood BHB, and Fecal Starch*

Ruminal fluid, blood, and fecal samples were collected from each calf on d 36, 48 and 54 of the experiment. To assess ruminal fermentation, ruminal fluid was analyzed for pH and VFA concentration. Ruminal pH was collected using a Geishauser probe (Geishauser, 1993; Duffield et al., 2004) 3 to 4 h after the morning feeding (1000 h), as described by Benschop and Cant (2009). Ruminal fluid was immediately acidified in 0.6 *M* HCl, placed in liquid nitrogen and stored at −80°C until analysis. Volatile fatty acid concentrations were measured by GC (GC3400, Varian Canada, Mississauga, ON, Canada) with 2-ethylbutyric acid as an internal standard (Green et al., 1999). After the rumen fluid samples were frozen in liquid nitrogen, and the pH of the original sample was measured as an indicator of ruminal fermentation in less than 1 min after sampling using a pH meter calibrated before each reading (310 Oakton Instruments, Vernon Hills, IL).

Blood was collected via jugular venipuncture into a 6-mL sodium heparin vacutainer (Becton Dickinson, Franklin Lakes, NJ). After collection, blood was immediately stored on ice and centrifuged for 20 min at