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# *Invited review:* Practical feeding management recommendations to mitigate the risk of subacute ruminal acidosis in dairy cattle

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## ABSTRACT

Rumen health is of vital importance in ensuring healthy and efficient dairy cattle production. Current feeding programs for cattle recommend concentrate-rich diets to meet the high nutritional needs of cows during lactation and enhance cost-efficiency. These diets, however, can impair rumen health. The term "subacute ruminal acidosis" (SARA) is often used as a synonym for poor rumen health. In this review, we first describe the physiological demands of cattle for dietary physically effective fiber. We also provide background information on the importance of enhancing salivary secretions and short-chain fatty acid absorption across the stratified squamous epithelium of the rumen; thus, preventing the disruption of the ruminal acid–base balance, a process that paves the way for acidification of the rumen. On-farm evaluation of dietary fiber adequacy is challenging for both nutritionists and veterinarians; therefore, this review provides practical recommendations on how to evaluate the physical effectiveness of the diet based on differences in particle size distribution, fiber content, and the type of concentrate fed, both when the latter is part of total mixed ration and when it is supplemented in partial mixed rations. Besides considering the absolute amount of physically effective fiber and starch types in the diet, we highlight the role of several feeding management factors that affect rumen health and should be considered to control and mitigate SARA. Most importantly, transitional feeding to ensure gradual adaptation of the ruminal epithelium and microbiota; monitoring and careful management of particle size distribution; controlling feed sorting, meal size, and meal frequency; and paying special attention to primiparous cows are some of the feeding management tools that can help in sustaining rumen health in high-producing dairy herds. Supplementation of feed additives including yeast products, phytogenic compounds, and buffers may help attenuate SARA, especially during stress periods when the risk of a deficiency of physically effective fiber in the diet is high, such as during early lactation. However, the usage of feed additives cannot fully compensate for suboptimal feeding management.
**Key words:** dairy cow, ruminal pH, subacute rumen acidosis, physically effective fiber

## INTRODUCTION

Dairy cows have high nutritional demands during lactation. A common practice to meet these high requirements for energy and MP is to feed large quantities of concentrates, especially during early and mid lactation. Typically, grain-based high-starch concentrates are fed at the expense of high-fiber forages, thereby enhancing the energy density of the diet but also compromising physically effective fiber (**peNDF**) content of lactation diets. Physically effective fiber is needed in cattle diets to stimulate chewing activity and salivary buffer supply, rumen motility and mixing, and to maintain appropriate functioning of the rumen ecosystem (Allen, 1997; Zebeli et al., 2012). On the other hand, grain-rich concentrates are palatable and easily fermentable in the rumen. The rapid fermentation stimulates microbial growth but also generates large amounts of short-chain fatty acids (**SCFA**), especially glucogenic precursors, which are used by the host as metabolic fuels and precursors for synthesis of several metabolic compounds (Aschenbach et al., 2010).

Rapid production of SCFA relative to the buffer supply disrupts intraruminal acid–base regulation

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(Steele et al., 2011). Intermittent drops of ruminal pH (Dirksen, 1985) gradually affect rumen function and, if severe, long, and frequent enough, are designated as SARA. Due to mainly nonpathognomonic signs of SARA, controversy exists about its definition. The current guideline is that the risk of SARA increases when ruminal pH drops below 5.6 for more than 3 h/d (Plaizier et al., 2008) or below 5.8 for more than 5 to 6 h/d (Zebeli et al., 2008). Research in the last 10 yr has established that dairy cattle suffering from SARA have greater risks of developing costly metabolic disorders such as displaced abomasum, fatty liver, laminitis, liver abscesses, and downer cow syndrome (Plaizier et al., 2008, 2012; Zebeli and Metzler-Zebeli, 2012). Collectively, it can be anticipated that the secondary disturbances have far-reaching consequences for cattle health and productivity (Plaizier et al., 2008, 2012; Zebeli and Metzler-Zebeli, 2012).

The causal relationships between current feeding strategies and incidence of SARA, as well as their consequences for rumen and host health, have been investigated intensively and the findings have been summarized in several comprehensive reviews (Plaizier et al., 2008, 2012; Steele et al., 2016). The results of this research have established the role of peNDF in the prevention of SARA in dairy cattle (Zebeli et al., 2012; GfE, 2014). The peNDF concept amalgamates the chemical (fiber) and physical (particle size) properties of the feed, providing a feasible tool for predicting physical effectiveness of a diet (i.e., when provided as TMR) under practical farm conditions. Besides the peNDF content in the diet, SARA incidence and severity depend on diet-related factors such as the amount and fermentability of starch fed and the feed intake level (Silveira et al., 2007; Zebeli et al., 2012). Feeding management factors are also crucially important in reducing the incidence of SARA. For example, the concept of TMR feeding ideally presumes simultaneous intake of forages and concentrates, thereby smoothing the daily fermentation pattern and avoiding periods of excessive fermentation activity. However, cattle commonly sort out the concentrates of their feed, resulting in an irregular and potentially inadequate peNDF intake, both when considering the intake profile of a given cow over the day and when considering feed sharing among cows of differing sorting efficiencies in a feeding cohort. This behavior is so common that the sorting and eating behaviors of cows have recently been emphasized by several researchers as strong causal factors of SARA (DeVries et al., 2008; Gao and Oba, 2014; Nasrollahi et al., 2017). As the extent of sorting depends on several management factors, large differences in the effects of sorting behavior may be expected among dairy farms with regards to SARA. Feeding management using TMR is commonly used on large dairy farms, and partial mixed ration (**PMR**) feeding is typically used on small and medium-sized farms, the latter with separate concentrate feeding in transponder feeding stations. Furthermore, the duration of adaptation to a new high-starch diet and the parity of the cows seem to play a role in the requirements for peNDF of cows to maintain ruminal pH within physiological ranges, thereby preventing SARA (Humer et al., 2015a; Pourazad et al., 2016). The main objective of this review is therefore to provide an overview of the practical methods available for assessing the adequacy of dietary fiber in dairy cow diets, as well as recommend practical feeding management guidelines to mitigate SARA in dairy herds.

## CHALLENGES TO REGULATE RUMINAL ACID–BASE BALANCE IN HIGH-PRODUCING DAIRY COWS

Nutrition for high-producing cattle aims to maximize the conversion of high levels of dietary ingredients into metabolic fuels and substrates to meet the high nutritional demands of the cow. The carbohydrate fraction of ruminally fermentable organic matter (**RFOM**) in a typical dairy cow TMR containing grain-based concentrates is composed of approximately one-half fiber and one-half nonstructural carbohydrate, with most of the latter being in the form of starch. Ruminally fermentable OM supply is a key determinant of microbial protein yield (Lanzas et al., 2007), which is the predominant source of amino acids for the cow. Furthermore, the majority of fermentation and the most efficient fiber degradation in the ruminant occurs in the rumen, so if the cow is to derive sufficient energy from the $\geq$30% of the diet that is NDF, it needs to be fermented to SCFA in the rumen by microbes. However, the production rate of SCFA (primarily acetate, propionate, and butyrate) must not be allowed to exceed the ruminal capacity for uptake and buffering over a whole day, requiring a balancing act of feeding microbes without disrupting ruminal pH (Steele et al., 2011).

In many TMR, starch is a substantial contributor to RFOM supply. The site of starch digestion differs dramatically between types of grains (Patton et al., 2012) and processing methods (Owens, 2005; Humer and Zebeli, 2017). Dairy cow diets based on grains such as wheat or barley (and even rye), corn, and sorghum have mean ruminal starch degradation of 76, 55, and 54%, respectively, based on a meta-analysis (Patton et al., 2012). These differences are decreased after postruminal digestion, with means of 95, 92, and 80%, respectively, for total-tract digestibility, indicating a compensation of digestion postruminally. Wheat, rye, and corn have the highest total starch contents (Offner et al., 2003;

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