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Subacute ruminal acidosis in dairy cows: The physiological causes, incidence and consequences

J.C. Plaizier [a,*], D.O. Krause [a], G.N. Gozho [b], B.W. McBride [c]

[a] Department of Animal Science, University of Manitoba, Winnipeg, MB, Canada R3T 2N2
[b] Department of Animal and Poultry Science, University of Saskatchewan, Saskatoon, SK, Canada S7N 5A8
[c] Department of Animal and Poultry Science, University of Guelph, Guelph, Canada N1G 2W1

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Abstract

During subacute ruminal acidosis (SARA) rumen pH is depressed for several hours per day due to accumulation of volatile fatty acids and insufficient rumen buffering. Surveys suggested an incidence of SARA of between 19% and 26% in early and mid-lactation dairy cows. Causes of SARA include feeding excessive amounts of non-structural carbohydrates and highly fermentable forages, and insufficient dietary coarse fiber. Consequences of SARA include feed intake depression, reduced fiber digestion, milk fat depression, diarrhea, laminitis, liver abscesses, increased production of bacterial endotoxin and inflammation characterized by increases in acute phase proteins. The increase in endotoxin is similar among methods for SARA induction, but depends on the diet fed before induction. Increases in acute phase proteins vary among methods of SARA induction, even when the methods result in similar rumen pH depressions. This suggests that the inflammatory response might not be solely due to bacterial endotoxin in the rumen.

Keywords: Subacute ruminal acidosis; Dairy cows; Dairy herd health; Milk production

Introduction

Milk yields of dairy cows in North America and Western Europe have increased substantially during recent years (Agriculture and Agri-Food Canada, 2005). As a result, the nutrient density of the diets fed to these cows has had to be increased. This increase has been primarily achieved by feeding more concentrates and less forages.

Feeding nutrient dense diets can result in a build up of organic acids in the rumen and reduced rumen buffering (Kleen et al., 2003; Stone, 2004; Rustomo et al., 2006a,b,c). The combination of these changes can lead to a depression of the rumen pH. When rumen pH is depressed for prolonged periods each day, e.g. <5.6 for >3 h/day, subacute ruminal acidosis (SARA) occurs (Kleen et al., 2003; Stone, 2004; Gozho et al., 2005). This disease affects feed intake, milk production, rumen microflora, rumen digestion, and can cause diarrhea, rumen mucosal damage, laminitis, inflammation, and liver abscesses in dairy cows (Nocek, 1997; Kleen et al., 2003; Stone, 2004; Alzahal et al., 2007). Several excellent reviews on SARA have been written in recent years (Kleen et al., 2003; Oetzel, 2003; Stone, 2004). This review will describe common causes and the incidence of SARA. Emphasis will be given on the effects of SARA on rumen microorganisms, bacterial immunogens and inflammation.

Definition of SARA

Current definitions of SARA are based on the pH of rumen fluid (Kleen et al., 2003; Oetzel, 2003; Stone, 2004; Duffield et al., 2004). This pH can be measured after the collection of rumen fluid, either with a stomach tube or by rumenocentesis, or by placing in-dwelling pH probes in the rumen of rumen-fistulated cows (Duffield et al.,

* Corresponding author. Tel.: +1 204 474 9500; fax: +1 204 474 7628.
E-mail address: plaizier@ms.umanitoba.ca (J.C. Plaizier).

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2004). Continuous monitoring of rumen pH is advantageous due to its high diurnal variation (Keunen et al., 2002; Duffield et al., 2004). The technique used to measure rumen pH affects the pH values.

There is disagreement as to a precise definition of SARA and there is also no agreement on which rumen pH depressions are detrimental to the health and production of dairy cows. Duffield et al. (2004) observed that the pH of rumen fluid samples using a stomach tube (oro-ruminal probe) and collected from the ventral sac of the rumen through a cannula were on average 0.35 and 0.33 pH units higher than the pH of rumen fluid samples collected by rumenocentesis. Those authors therefore, proposed that thresholds for abnormal pH indicating SARA should be 5.5, 5.8 and 5.9 when rumen fluid samples are collected by rumenocentesis, through a rumen cannula from the ventral sac, and using an oral probe, respectively. Garrett et al. (1999) used a threshold pH of 5.5 when rumen fluid samples were collected by rumenocentesis. Plaizier (2004) used a SARA threshold pH of 6.0 when rumen fluid samples were collected with a stomach tube at approximately 4 h after feeding, as a rumen pH below 6.0 reduced the growth of fibrolytic bacteria (Shi and Weimer, 2002). As rumen pH varies considerably throughout the day (Keunen et al., 2002), the timing of rumen fluid sampling also affects its pH. Hence, diagnosis of SARA requires standardization of the timing of rumen fluid collection and the threshold for SARA needs to reflect the sampling time.

Gozho et al. (2005) used a threshold of a rumen pH depression between pH 5.2 and 5.6 for at least 3 h/day, and feed intake was only reduced and inflammation only occurred at equal or greater rumen pH depressions. Cooper et al. (1999) also used a threshold of rumen pH between pH 5.2 and 5.6, but did not suggest a specific duration of this pH depression. Beauchemin et al. (2003) used rumen pH depression <5.8 as a threshold for SARA. The various definitions used for SARA combined with variability in diagnostic techniques used for the diagnosis of this disease, have contributed to different interpretations of this disease.

Causes of rumen pH depression

Rumen pH will fall when organic acids, such as volatile fatty acids (VFA) and lactic acid, accumulate in the rumen, and if rumen buffering cannot keep pace with the accumulation of these acids. Feeding more grains and less forages will increase the production of VFA in the rumen, as grains are generally more rumen digestible than forages (National Research Council, 2001). A recent survey in Ireland (O'Grady et al., 2006) suggested that SARA can also occur in pasture fed dairy cows and might be caused by the high rumen digestibility of these pastures. Feeding more grains and less fiber, as well as reducing forage particle size, also reduces the amount of time spent chewing (Mertens, 1997; Yang et al., 2001; Maekawa et al., 2002; Fairfield et al., 2007; Beauchemin et al., 2003; Yang and Beauchemin, 2006). It has been assumed that the increased time spent chewing, i.e. eating and ruminating, enhances saliva production (Church, 1988). Saliva contains inorganic buffers, such as sodium bicarbonate, that contribute to the neutralization of the organic acids produced during fermentation in the rumen (Church, 1988).

There are differences between sources of fiber including differences between sources of forage fiber in their capacity to stimulate chewing, and this capacity is affected by various physical and chemical characteristics of the feed (Mertens, 1997). To overcome this problem, the concept of physically effective fiber (peNDF) has been developed. This measure reflects the ability of a feed to stimulate chewing and saliva buffering in the rumen (Mertens, 1997). Many studies have been conducted on the effect of forage particle size and dietary peNDF on rumen pH. Various measures of peNDF content of feeds and diets have been used. Yang

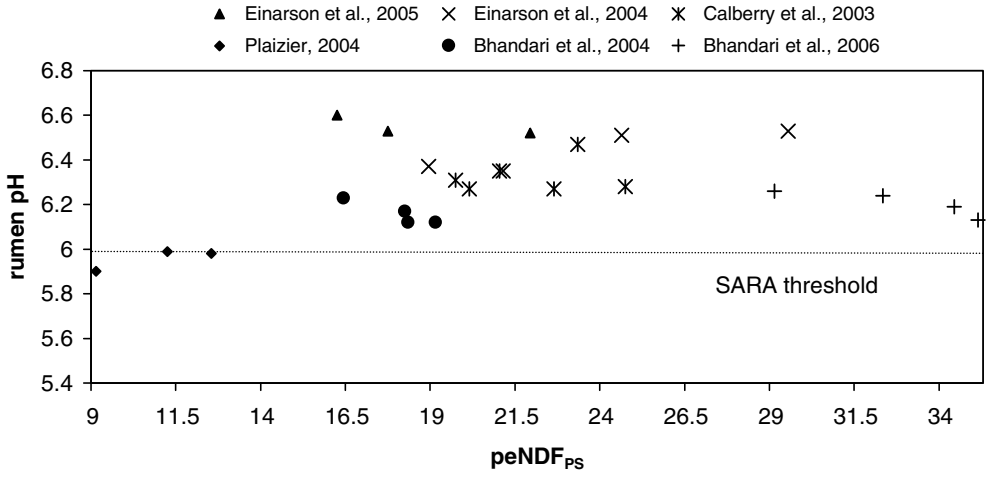

Fig. 1. Results of several studies on the effects of physical effective fiber as determined by the dietary NDF content multiplied by the proportion of the diet retained by 8 and 19 mm screens ($peNDF_{PS}$) and the pH of rumen fluid collected by stomach tube at 4 h after feeding.