Animal Feed Science and Technology 172 (2012) 66–79

Contents lists available at SciVerse ScienceDirect

Animal Feed Science and Technology

journal homepage: www.elsevier.com/locate/anifeedsci

Ruminal acidosis in feedlot cattle: Interplay between feed ingredients, rumen function and feeding behavior (a review)☆

L.A. González[a,*], X. Manteca[b], S. Calsamiglia[b], K.S. Schwartzkopf-Genswein[c], A. Ferret[b]

[a] Department of Animal Science, University of Manitoba, Winnipeg, Manitoba, R3T 2N2, Canada
[b] Animal Nutrition, Management, and Welfare Research Group, Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, 08193-Bellaterra, Spain
[c] Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, Alberta T1J 4B1, Canada

ARTICLE INFO

Keywords:
Feedlot cattle
Ruminal acidosis
Feeding behavior

ABSTRACT

Ruminal acidosis in feedlot cattle is a common metabolic disorder of digestive origin with significant economic and welfare implications. The main risk factors are high grain, low roughage diets because of their high rate and extent of degradation by rumen microbes. Diet formulation should therefore consider the proportion, method of processing and type of grain; the proportion, fiber concentration and particle size of forages; and the use of feed additives. Grain and forage characteristics, and feed additives, may determine the rate and amount of organic acids produced in the rumen. In addition, diet formulation may also affect feeding behavior, *i.e.* feed intake and chewing behaviors, which has a great influence on ruminal fluid acid–base balance. Feeding characteristics associated with low ruminal fluid pH are: high dry matter intake and ingestion of large meals because of the greater amount of acid production per period of time, high eating rate because of lower feed ensalivation, short time spent chewing while eating and ruminating because of lower daily saliva production, and large variations in feeding behavior patterns throughout the day such as less frequent meals and rumination. The ruminal acid–base balance requires synchronization in time between acid production and neutralization through saliva, as well as elimination through absorption, wash-out from the rumen, and metabolization. Greater proportions of roughage in the diet and greater particle size leads to slower eating rate and longer chewing time which favors saliva production, and smaller meals which reduce the amount of acid production. Adaptation of feeding behavior to diets with greater proportion of concentrates also plays an important role, as smaller meals and more even distribution of intake throughout the day lead to a better synchronization in time between acid production and elimination or neutralization. Monensin increases the frequency of meals and reduces meal size which is beneficial for ruminal fluid pH, whereas sodium bicarbonate at high concentrations produces the opposite effects and reduces rumination. In addition to diet formulation, feeding management and the social environment may also affect feeding behavior and consequently, ruminal fluid pH. Delivering the feed twice daily results in better synchronization in time between feed intake (acid production), rumination (saliva production), and elimination of fermentation products from the rumen. In contrast, feeding

Abbreviations: DM, dry matter; DMI, dry matter intake; Msize, meal size; NDF, neutral detergent fiber; SB, sodium bicarbonate; TCT, total chewing time; VFA, volatile fatty acid.

☆ This paper is part of the special issue entitled: Rumen Health: A 360° Analysis, Guest Edited by A. Van Vuuren, S. Calsamiglia and Editor for Animal Feed Science and Technology, P. Udén.

* Corresponding author. Present address: CSIRO Livestock Industries, PMB P.O., Townsville QLD 4810, Australia. Tel.: +61 7 4753 8559; fax: +61 7 4753 8600.
E-mail address: LucianoAdrian.Gonzalez@gmail.com (L.A. González).

0377-8401/$ – see front matter
doi:10.1016/j.anifeedsci.2011.12.009

programs that restrict feed amount and time available allow animals to become hungry, whereas restricted feeding space increases competition among group mates. Both situations lead to fewer and larger meals eaten at a faster rate, and consequently, greater risk of ruminal acidosis.

1. Introduction

Ruminal acidosis is a nutritional disorder of cattle which receives a lot of attention by the feedlot industry even though it occurs with relatively low frequency. Monitoring services of animal health in North American feedlots report that only 1.9% of animals housed in the feedlots develop digestive diseases (USDA, 2000) and the average cost of each treatment is $6.20 US (USDA, 2001). Monthly mortality rates in North American feedlots range between 0.17% and 0.42% of the animals and digestive disorders are responsible for 30–42% of these deaths (Smith, 1998; Galyean and Rivera, 2003). In addition, ruminal acidosis and feeding of acidogenic diets have been associated with a reduction in feed intake (Britton and Stock, 1989; Stock et al., 1995), damage of the digestive tract tissue (Aslan et al., 1995; Nocek, 1997), liver abscesses (Nagaraja and Chengappa, 1998; Nagaraja and Titgemeyer, 2007), laminitis (Nocek, 1997), and inflammatory responses (Plaizier et al., 2009). All these effects may not only reduce animal production and profitability but also welfare.

A lot of research has been conducted to study the effects of diet, management, cattle genetics, and the environment on rumen function and metabolic processes. Previous reviews on ruminal acidosis have focused on rumen microbiology (Nagaraja and Titgemeyer, 2007), nutrition and diet formulation (Krause and Oetzel, 2006; Plaizier et al., 2009), bunk management (Schwartzkopf-Genswein et al., 2003), and metabolic and histological changes (Penner et al., 2011). However, the effects of feeding and social behaviors on gastrointestinal function in cattle are less understood and research in this area is scarce (Galyean and Rivera, 2003). Daily feed intake determines acid production whereas chewing determines saliva (and thus buffer) production (Beauchemin et al., 1994). Therefore, these two components of feeding behavior (*i.e.* intake and chewing) throughout the day are closely related to the course of ruminal fluid pH or acid–base balances. The present review focuses on the influence of feeding behavior on ruminal fluid acid–base balance and expands on recent findings on the relationships between feeding behavior and ruminal acidosis. Short-term feed intake behavior can be summarized by meal size and frequency, eating rate and distribution of intake throughout the day (Nielsen, 1999; Tolkamp et al., 2000). It is important to note, that the method used to calculate these short-term feeding behavior measurements (*e.g.* definition of a meal) may have a great influence in the outcomes (Tolkamp et al., 2000). Therefore, caution should be taken when comparing results among studies as discrepancies maybe due to this issue. Short-term chewing behavior can also be assessed through the frequency and distribution of chewing bouts throughout the day. The interrelationships between feed intake behavior, chewing behavior and rumen function can be studied over long (*i.e.* from day to day) or short (within a day) time spans. In addition, such interrelationships also depend on diet characteristics and management.

The objective of this review is to expose the current knowledge about the interplay between rumen function, short-term feeding and chewing behaviors, feed ingredients, and management.

2. Ruminal acidosis and the relationship with feed intake

Acidosis is often categorized in several forms, including acute and sub-acute types often called clinical and sub-clinical, respectively. Animals exhibit acute acidosis as an overt illness following consumption of readily fermentable carbohydrates in sufficient amounts to threaten life (Nagaraja and Titgemeyer, 2007). With sub-acute acidosis, feed intake and performance might be reduced but animals do not appear sick (Owens et al., 1998). However, the economic impact caused by the effects of sub-clinical acidosis on animal performance could be greater than those of acute acidosis (Britton and Stock, 1989). Ruminal fluid pH of 5.6 or lower is considered the benchmark for sub-acute ruminal acidosis whereas a pH below 5.0 is considered the benchmark for acute acidosis (Owens et al., 1998; Krause and Oetzel, 2006; Nagaraja and Titgemeyer, 2007). In acute acidosis, ruminal fluid pH reaches such low levels because of the accumulation of lactic acid as a result of increased production while its utilization by ruminal microbes is reduced because lactic acid is not fermented any more (Nagaraja and Titgemeyer, 2007). Subsequent absorption of organic acids into the bloodstream might overwhelm the bicarbonate buffering system, the excretion rate of acids, and the capacity of tissues and organs to metabolize acids resulting in systemic acidosis (Brown et al., 2000). In sub-clinical acidosis, the reason for pH dropping below 5.6 is the accumulation of volatile fatty acids. Although lactic acid is produced during sub-clinical acidosis, it does not accumulate because lactate-fermenting bacteria remain active (Goad et al., 1998) and rapidly metabolize it to volatile fatty acids. Ruminal fluid pH does not always explain the typical signs and symptoms of ruminal acidosis although it is the most commonly used indicator (Huber, 1976). Both a reduction in feed intake and variation in feed intake among days have been used as indexes of subclinical acidosis based on the concept that an increased variability from day to day is associated with feeding acidogenic diets (Britton and Stock, 1989; Stock et al., 1995; Bevans et al., 2005). However, the reduction in feed intake in acidotic cattle is inconsistent and may depend on the extent and convergence of multiple factors associated with low ruminal pH and the control mechanisms of feed intake. Many theories for the reduction of dry matter intake during sub-clinical acidosis have been hypothesized: low ruminal fluid pH, high concentration of fermentation products (volatile fatty acid, VFA), high osmolality, inflammatory