J. Dairy Sci. 97:985–1004
http://dx.doi.org/10.3168/jds.2013-7166

Effects of feed additives on rumen and blood profiles during a starch and fructose challenge

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ABSTRACT

We evaluated the effect of feed additives on the risk of ruminal acidosis in Holstein heifers (n = 40) fed starch and fructose in a challenge study. Heifers were randomly allocated to feed additive groups (n = 8 heifers/group): (1) control (no additives); (2) virginiamycin (VM); (3) monensin + tylosin (MT); (4) monensin + live yeast (MLY); and (5) sodium bicarbonate + magnesium oxide (BUF). Heifers were fed 2.5% of body weight (BW) dry matter intake (DMI) per day of a total mixed ration (62:38 forage:concentrate) and feed additives for a 20-d adaptation period. Fructose (0.1% of BW/d) was included for the last 10 d of the adaptation period. On d 21, heifers were fed to target a DMI of 1.0% of BW of wheat, fructose at 0.2% of BW, and their feed additives. Rumen fluid samples obtained by stomach tube and blood samples were collected weekly as well as during a 3.6-h period on challenge day (d 21). Virginiamycin and BUF groups maintained a consistently high DMI across the 20-d adaptation period. The MLY heifers had low DMI of the challenge ration. Average daily gain and feed conversion ratio were not affected by feed additives. All rumen and plasma measures changed weekly over adaptation and over the challenge sampling period with the exception of rumen total lactate and histamine concentrations, plasma oxidative stress index, and ceruloplasmin. Substantial within- and between-group variation was observed in rumen and plasma profiles at challenge sampling. No significant group changes were observed in rumen total volatile fatty acids, propionate, acetate-to-propionate ratio, isobutyrate, caproate, isovalerate, total lactate, D- and L-lactate, and pH measures on challenge day. Acetate concentration was increased in the BUF and control groups on challenge day. Butyrate concentration was lower in the MLY and MT groups compared with other groups at challenge. Valerate concentrations were lowest in the control, VM, and BUF groups and lactate concentrations were numerically lower in the MLY, VM, and BUF groups. Total lactate concentrations were >10 m*M* for each group throughout the challenge. Ammonia concentrations were lower in the MLY and MT groups. Histamine concentrations were decreased in MLY and increased in the VM and BUF groups. Plasma oxidative stress measures were not influenced by feed additives weekly or on challenge day, except for an increase in biological antioxidant potential in the control, VM, and MT groups on challenge day. Despite the large within-animal variation, all feed additives modified rumen function and may influence the risk of acidosis by different mechanisms; however, none stabilized the rumen in all heifers.

Key words: acidosis, feed additive, fructose, lactic acid

INTRODUCTION

Ruminal acidosis is a complex nutritional disorder. It is caused by the accumulation of organic acids initiated by the combination of consumption of large amounts of readily fermentable carbohydrates and insufficient intake of physically effective fiber (Nagaraja and Titgemeyer, 2007; Bramley et al., 2008). Periods of high risk for acidosis occur when dairy cattle are fed substantially more concentrate close to calving or when beef cattle enter the feedlot. The complex can occur from a relatively mild form where symptoms are subclinical to the peracute, resulting in death. Clinical signs include losses in production performance, diarrhea, dehydration, lameness, and decreased appetite (RAGFAR, 2007; Plaizier et al., 2008). Clinical definitions of acidosis, largely based on rumen pH, are inconsistent and can create confusion, leading to inaccurate diagnosis of acidosis (Kleen et al., 2003; Nagaraja and Titgemeyer, 2007; Plaizier et al., 2008). We largely concur with the view of Britton et al. (1989) that "acidosis is not one disease, but rather a continuum of degrees of ruminal acidity." Perhaps this description could be reworded to "degrees of safe sequestration of hydrogen."

Received June 21, 2013.
Accepted September 11, 2013.
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Inclusion of feed additives is one practice of several used to reduce acidosis risk in the dairy and beef industries. A substantial body of evidence exists that supports the use of feed additives in cattle. However, relatively few papers exist that examine the effects of combinations of these on rumen profiles in vivo in dairy cattle (Clayton et al., 1999; Lean et al., 2000). Scientific evaluation of the effects of feed additives will allow producers, nutritionists, and veterinarians to make informed management decisions when considering their use and assist in the development of the most prudent use strategies for antimicrobial and other agents that modify rumen function.

Our primary aim was to evaluate the efficacy of the following feed additives to reduce acidosis risk during a non-life-threatening, but substantial, starch and fructose challenge: virginiamycin, combinations of monensin and tylosin, monensin and yeast, and sodium bicarbonate and magnesium oxide. We hypothesized that feed additives would reduce acidosis risk in cattle compared with unsupplemented control cattle, as indicated by production, rumen, inflammation, and oxidative stress measures. We also intended to further examine the pathophysiology and clarify definitions of ruminal acidosis.

MATERIALS AND METHODS

Animals and Housing

The study was conducted on 36 pregnant and 4 nonpregnant Holstein heifers from a commercial dairy herd (n = 40). All heifers were between 15 to 21 mo of age and had a mean BW of 383 ± 49 kg on arrival at the study site located at Cobbitty [New South Wales (**NSW**), Australia]. For the duration of the study, all heifers, when not being fed or sampled, were kept as 1 herd in a paddock with little or no available feed DM and with ad libitum water access. All experimental procedures were approved by the SBS*cibus* Animal Ethics Committee (SBS*cibus* 0512-0513).

Experimental Design

Each heifer was enrolled in the study for a period of 29 d, consisting of 5 experimental periods: (1) preadaptation (d −2 to 0), (2) adaptation I (d 1 to 10), (3) adaptation II (d 11 to 20), (4) challenge (d 21), and (5) postchallenge (d 22 to 26; Figure 1). Heifers were randomly assigned by identification number to 1 of 5 feed additive groups (n = 8 heifers/group) and 1 of 4 blocks (A to D; n = 10 heifers/block), with 2 heifers/group assigned to each block using a random numbers table generated from Stata v.11 (StataCorp LP, College Station, TX). Enrolment into the study was staggered, with heifers assigned to each block entering the study 1 d after the previous block to allow sampling of 10 heifers/d only, over 4 consecutive days. Sample sizes were based on previous studies in which significant differences in fermentation characteristics were observed (Golder et al., 2012; Lean et al., 2013). To ensure that feeds were allocated correctly, farm workers were not blinded to feed-additive groups.

Feed-Additive Groups

The feed-additive groups were as follows: (1) control (no additives); (2) virginiamycin (**VM**); (3) monensin + tylosin (**MT**); (4) monensin + live yeast (**MLY**); and (5) sodium bicarbonate + magnesium oxide (**BUF**). The feed additives (Table 1) were incorporated into wheat pellets mixed on top of each heifer's TMR, with the exception of the yeast, sodium bicarbonate, and magnesium oxide, which were weighed out separately in individual feeding portions and mixed on top of the TMR. All heifers received the same amount of wheat pellets (Figure 1); however, those received by the control and BUF heifers contained no feed additives.

Diet

The rations offered in each of the experimental periods are detailed in Figure 1. The predicted chemical composition of the rations offered during the adapta-

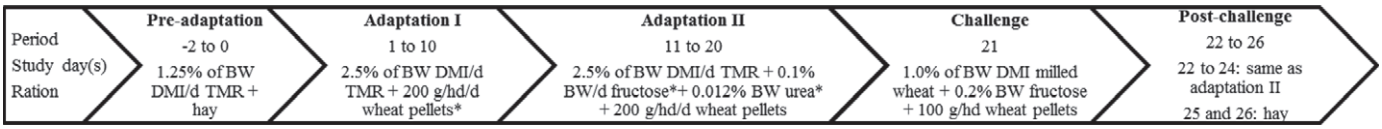

Figure 1. Experimental periods and their corresponding study days and rations offered during the study. The rations were offered in equal proportions twice daily, with the exception of the challenge period. Rumen and blood samples were collected on d 0, 7, 14, and 21 during their respective experimental periods. Wheat pellets contained respective feed additives for their groups as indicated in Table 1. Heifers in the monensin + live yeast (MLY) group received yeast and those in the sodium bicarbonate + magnesium oxide (BUF) group received sodium bicarbonate and magnesium oxide in addition to wheat pellets. *Introductory doses were offered for the initial days before the full rate was offered. TMR = 62:38 forage:concentrate, consisting of 31.5% wheaten hay, 30.5% alfalfa hay, and 38% milled wheat; hd = head.