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Effects of Alcohol Ethoxylate and Pluronic Detergents on the Development of Pasture Bloat in Cattle and Sheep[1]

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ABSTRACT

A series of studies was conducted to determine the efficacy and possible modes of action of a water-soluble mixture of alcohol ethoxylate and pluronic detergents (AEPD; Blocare 4511, ANCARE, Auckland, NZ) in preventing pasture bloat in ruminants grazing or fed freshly harvested alfalfa. Ten cannulated Suffolk wethers were offered freshly harvested alfalfa; five were given a daily intraruminal dose of 40 ml of 50% AEPD (vol/vol) 1 h before feeding, and five (controls) were dosed with water. Viscosity of ruminal fluid was reduced ($P < 0.001$) in AEPD-treated wethers, relative to the controls, for the first 2 h after feeding but not at 4 h after feeding and beyond. Treatment with AEPD did not affect dry matter (DM) intake, digestibility of DM, acid detergent fiber, or neutral detergent fiber, or N digestion and retention, implying that AEPD likely would not affect milk production. In a crossover grazing study, five of the wethers were given AEPD in drinking water (0.1%, vol/vol); treatment with AEPD was 100% effective for preventing bloat in sheep grazing early-bloom alfalfa for 4 h daily. Replicate grazing studies were conducted with cattle in Lethbridge, AB; Lacombe, AB; and Kamloops, BC. Treated animals received AEPD in the water (0.06%, vol/vol) and grazed vegetative alfalfa for 6 h daily. As it did with sheep, AEPD treatment effectively precluded the bloat observed in control animals. Consequently, AEPD may be a valuable tool for alfalfa pasture-based dairy production although further study is required to develop an integrated model for optimal administration under a variety of climatic conditions.
(**Key words:** bloat, alfalfa, grazing, pluronic detergent)

Abbreviation key: AEPD = a water-soluble mixture of alcohol ethoxylate and pluronic detergents.

INTRODUCTION

Pasture-based systems for milk production are currently being reexamined in North America (18, 32). Pasture-based systems have made New Zealand a world leader in low-cost dairy production (8), while total confinement of dairy cows is coming under increasing scrutiny from ethical and animal welfare perspectives (3). Unfortunately, milk production generally declines when cows are moved from confinement to a grazing system (10) as nutrient levels, even in intensively managed grass species will not sustain high producing animals over the complete grazing season (18). One alternative would be to graze alfalfa, as performance of cattle grazing alfalfa may equal that of animals given harvested feed in confinement (31). However, livestock producers are reluctant to graze alfalfa due to the threat of pasture bloat and possibly catastrophic levels of death loss (12, 22). As a result, the potential of alfalfa for dairy production is seldom realized in pasture-based production systems.

Pasture bloat results from the accumulation of gas in the rumen (7, 21) due to formation of a stable foam (6), to an animal's inability to eructate, or both (27). Numerous factors such as type of forage (14), forage maturity (22), rate of digestion (21), animal behavior (12), animal genetics (6, 13), ambient temperature (22), and precipitation or dew (21) may interact and produce pasture bloat in grazing cattle and sheep. The strate-

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gies developed to control pasture bloat are also numerous. These include breeding alfalfa to reduce its initial rate of digestion (9, 19), grazing grass-legume mixes (12), or including nonbloating legumes with alfalfa (15, 26), and a variety of bloat-control agents (13, 21, 22). Although much effort has been expended on developing strategies, none prevent bloat completely.

Bloat control agents can be divided into two categories: 1) antibiotics, which alter rumen fermentation (27), and 2) surfactants, which reduce the stability of foam in the rumen (21, 22). Antibiotics such as monensin are thought to reduce bloat either by shifting ruminal VFA production from acetic to propionic acid (33), thereby reducing methane and carbon dioxide production (20), or by inhibiting the growth of bacteria thought to be responsible for bloat (6).

Pluronic detergents are water-soluble surfactants that have widespread application as industrial defoaming agents and are used in a variety of laundry detergents and cosmetics (35). Pluronic detergents and the related chemicals, alcohol ethoxylates, have been used in Australia and New Zealand to control pasture bloat in dairy cattle for over 20 yr and are recognized to be nontoxic to ruminants when administered at recommended concentrations (21). Water-soluble bloat treatments can be used as a drench to treat acute bloat or can be given at lower concentrations to prevent bloat, either in the water supply or by spraying onto pastures when administration through drinking water is not feasible (27). Blocare 4511 (ANCARE, Auckland, New Zealand) is a combination of alcohol ethoxylate and pluronic detergents (**AEPD**) and was developed as a preventative and treatment for pasture bloat targeted to dairy cattle grazing alfalfa or red clover (21). Although AEPD is not yet registered for use in North America, preliminary data demonstrate that this mixture is 100% effective for controlling bloat in ruminants fed freshly harvested alfalfa (21).

If ruminal fermentation and nutrient digestibility are not adversely affected by AEPD, this agent could enable safe grazing of alfalfa for pasture-based production of milk and meat without compromising productivity. The present studies were conducted to: 1) establish possible mode(s) of action of AEPD in controlling pasture bloat, 2) determine the effects of AEPD on ruminal fermentation and apparent digestion of nutrients, and 3) establish the efficacy of AEPD under a variety of climatic conditions in western Canada.

MATERIALS AND METHODS

All animals used in these studies were cared for according to standards of the Canadian Council on Animal Care (5). The bloat preventative used was soluble in water and contained a mixture of alcohol ethoxylate and the pluronic detergents L62 and L64 (43). Recommended dosing levels under severe bloat challenge, used in 1997 studies, were for once daily administration of 20 ml AEPD, or up to 0.1% (vol/vol) AEPD in drinking water. Recommended dosing levels under moderate bloat challenge, 0.06% (vol/vol) AEPD, were used in 1998 studies.

Digestibity Study—Sheep in Confinement

This study commenced June 2, 1997, and involved 10 ruminally cannulated yearling Suffolk wethers (average weight 82 ± 5 kg). The wethers were penned individually, had free access to fresh water throughout the study, and were fed at 0900 h daily. They were given fresh, prebloom alfalfa (13.5 kg/d, as fed) gathered with a flail-type harvester 2 h before feeding. The wethers were randomly assigned to receive daily intraruminal doses (40 ml) of water (controls) or 50% (vol/vol) aqueous AEPD (n = 5). Ruminal dosing was conducted 1 h prior to feeding, commencing on d 3. Feed refusals were collected and weighed on a daily basis. Samples (200 g) of the forage offered and of the feed refusals were collected daily, frozen, and stored at –30°C until analyzed. On d 11 (after 8 d of AEPD treatment), 100-ml samples of rumen contents were collected 1, 2, 4, 6, and 8 h after feeding. Foam height was measured on ruminal fluid immediately after straining the rumen contents through cheesecloth into 100-ml graduated cylinders. Total collections of feces and urine were conducted from d 13 to 19. Each morning, 45 ml of 8N H_2SO_4 was added to the urine collection jugs to prevent volatilization of ammonia from the urine. Feces and urine were subsampled daily (10%) and stored at –30°C until analyzed. On d 18, 5 g of Co-EDTA (in 50 ml of H_2O) and 25 g of Cr-mordanted alfalfa fiber were placed in the rumen through the cannula at 0930 h, and ruminal contents were sampled at 0900 (predosing), 1000, and 1100 h, then every 2 h until 2300 h, and continuing at 2-h intervals on d 19 from 1000 to 2400 h.

Grazing Study—Sheep

The 10 wethers from the digestibility study were randomly assigned to two treatment groups for a crossover grazing study in which they were turned into pasture daily for a 4-h grazing session (0900 to 1300 h). The study was conducted on a 1.6-ha pasture of alfalfa (var. Beaver) near Lethbridge, AB, and comprised two 14-d periods. The entire pasture was clipped 4 wk before grazing commenced, and half of it was clipped again 2 wk later. This ensured availability of similarly mature early and midbloom alfalfa (17) for grazing in both periods. Separate grazing paddocks (18.2 m^2) for each treatment group were delineated with fencing panels, and were moved each day.

Treatments consisted of no AEPD (control) or 0.1% (vol/vol) AEPD in the drinking water. Inclusion of AEPD in the treated water was started 2 d before the first grazing session. When not grazing, the wethers were penned by treatment groups, and water (± AEPD) was available on a 24-h basis. After 2 wk, the wethers were crossed over between treatments (i.e., AEPD was added to or eliminated from the water supply). Alfalfa hay was fed for 2 d, then the daily 4-h grazing sessions were resumed on the previously ungrazed half of the alfalfa pasture.

Each grazing day, two 0.1-m^2 quadrats were placed randomly in each paddock and clipped to 3 cm immediately before the wethers were released into the paddocks for grazing. Immediately after grazing, the quadrats were randomly placed and clipped again. Each forage sample was sorted into alfalfa and weed components and frozen at −30°C for later analysis. In addition, forage samples were clipped during the grazing session to simulate forage selection by the wethers, and were frozen for analysis (Table 1).

While grazing, and for 2 h afterward, the wethers were observed at approximately 30-min intervals for development of bloat. Those exhibiting symptoms were removed from the paddock, relieved of intraruminal pressure by opening the cannula, and returned to the paddock although only the initial bloat was recorded for animals with multiple bloats in 1 d. Each day at 1400 (i.e., 1 h after grazing), ruminal contents (100 ml) and fecal grab samples (50 g) were collected from each wether. Ruminal contents were processed immediately, whereas fecal samples were frozen for subsequent analysis. The lignin ratio method of Harris (11) was used to estimate apparent digestion of DM, ADF, NDF, and N. During the ruminal collection, each wether was also scored for severity of bloat according to a 5-point scale assessing ruminal content frothiness and abdominal distension (22).

Table 1. Stage of maturity and proximate analyses of alfalfa fed to or grazed by sheep in 1997.

	Digestibility study[1]	Grazing study[2]
Stage of maturity	early/late bud	early/mid bloom
Analysis		
DM, %	14.91 ± 1.5	20.77 ± 1.2
	% (DM basis)	
CP	21.29 ± 0.97	27.07 ± 1.13
NDF	43.47 ± 1.89	24.05 ± 1.01
ADF	30.86 ± 2.10	17.13 ± 1.54
Lignin	6.17 ± 0.09	3.19 ± 0.12

[1]Alfalfa harvested daily using a flail-type harvester that clipped within 3 cm of ground level.

[2]Samples collected from leaf material in top 10 cm of growth to approximate forage selection by animals during grazing.

Grazing Studies—Cattle

In the fall of 1998, grazing studies were conducted in Lethbridge, AB (Aug. 20 to 27), Lacombe, AB (Aug. 28 to Sept. 14) and Kamloops, BC (Sept. 24 to 30). Study duration was determined by the number of days required to record at least 26 incidents of bloat (22). The studies involved ruminally cannulated control cattle (n = 10, 8 and 10 in Lethbridge, Lacombe and Kamloops, respectively) and 29, 20, and 29 intact yearling cattle (mixed breeds 275 to 325 kg) in the treated groups. In Lethbridge, control/cannulated animals were five mature Jersey steers (550 kg liveweight) and five yearling Jersey steers (320 kg liveweight). Lacombe cannulated animals were beef-cross steers (420 kg liveweight), while Kamloops controls were mature Jersey steers (550 kg liveweight). In each study, cattle were allowed to graze for 6 h daily (0800 to 1400 h) on pure stands of early- to late-bud alfalfa (17), and were given no supplemental feed. Treatments consisted of no AEPD (control) or 0.06% (vol/vol) AEPD in the drinking water. The pasture at Kamloops was divided and equipped with two waterers, so water (± AEPD) was available for 24 h, but the cattle in Lethbridge and Lacombe had access to water only during the 18 nongrazing hours. Inclusion of AEPD in the treated water was begun 2 d before grazing started. Cattle exhibiting bloat during the grazing period were removed from the paddock, relieved of intraruminal pressure by opening the cannula, and returned to the paddock. The presence of bloat was recorded on a 5-point scale (22) based on observations of ruminal distension, and foaming and (or) release of ruminal contents.

A fourth trial was conducted, in Kamloops, using the 10 mature Jersey steers from the previous study. It was designed as a crossover study and commenced October 1, 1998. The steers were permitted to graze alfalfa for 6 h daily and the incidence of bloat was monitored. Five steers were given AEPD (0.06% wt/vol) in their drinking water during 9 d of grazing while the other five were given untreated water. Animals were crossed over to the other treatment for d 10 through 16.

Chemical Analyses

Forage and feces. Dry matter of harvested forage was determined from triplicate 500-g samples collected daily and oven-dried (24 h at 105°C; Table 1). Forage samples and fecal samples for N determination were freeze-dried in a Virtis 25 XL Sentry (Virtis Co., Gardiner, NY) for analysis. Additional fecal samples were dried at 105°C for 24 h to determine DM and ashed in a muffle furnace at 500°C for 5 h to determine OM. Dried feces and forages were subsequently ground through a 1-mm screen for analysis of NDF without additional additives (38) and determination of N (in a Carlo Erba NA 1500 Carbon-Nitrogen elemental analyser, Carlo-Erba Srumentazione, Milan, Italy). Chromium-mordanted alfalfa fiber and Co-EDTA were prepared as described by Udén et al. (37).

Ruminal fluid. Samples of rumen contents taken from the sheep 1, 4, 6, and 8 h after feeding in the digestibility study were diluted with four volumes of methyl green-formalin-saline to fix and stain rumen protozoa for counting (28). Additional undiluted ruminal fluid was centrifuged at 100 × *g* for 8 min, then viscosity was determined using a cone plate viscometer model DV-11+ (Brookfield Engineering Laboratories Inc., Stoughton, MA). Soluble protein N was estimated as the difference between total N in ruminal fluid supernatant (20,000 × *g*, 30 min, 4°C), and the NPN content of the supernatant following precipitation of protein with TCA (final concentration 6.5%, wt/vol). Concentrations of Co and Cr were determined by atomic absorption spectrophotometry according to AOAC (1), VFA concentrations were determined as described by Wang et al. (41) with a Hewlett Packard 5890 gas-liquid chromatograph equipped with a 15-m NUKOL fused silica capillary column (Supelco Canada, Mississauga, ON). Ammonia was assayed by the phenol-hypochlorite method (42).

Statistical Analyses

Data from the confined animal digestibility trial were analyzed using the GLM procedure of SAS (34) with the following model:

$$Y_{ijk} = \mu + T_i + S_{j(i)} + E_{ijk}$$

where:

μ = overall mean,
T_i = treatment effect (AEPD or control),
$S_{j(i)}$ = sheep nested within treatment, and
E_{ijk} = residual error.

The mean square for sheep nested within treatment was used as the error term to test treatment effect by the least squares means comparison. Fluid and solid passage rates were determined by regressing the natural logarithms of Co and Cr concentration, respectively, against time after dosing using the REG option of SAS. For analysis of ammonia, VFA and viscosity variables in the confined sheep, the following model was used:

$$Y_{ijklm} = \mu + T_i + S_{j(i)} + H_k + D_l + HD_{kl} + TD_{il} + E_{ijklm}$$

where:

μ = overall mean,
T_i = treatment effect (AEPD or control),
$S_{j(i)}$ = sheep nested within treatment,
H_k = time (in hours) after feeding,
D_l = day of rumen sampling,
HD_{kl} = interaction of time after feeding with day of rumen sampling,
TD_{il} = interaction of treatment with day of rumen sampling, and
E_{ijklm} = residual error.

The mean square for sheep nested within treatment was used as the error term to test treatment effect by the least squares means comparison.

Analysis of data from the three cattle grazing trials was performed using a chi-square (44) weighed by animal grazing days. Data collected in the crossover grazing sheep and cattle studies were analyzed using the following model:

$$Y_{ijk} = \mu + T_i + A_j + TA_{ij} + D_k + TD_{ik} + H_l + AH_{jl} + E_{ijklm}$$

where:

μ = overall mean,
T_i = treatment effect (AEPD) or control,
A_j = animal,
TA_{ij} = interaction between animal and treatment,
D_k = day of period,
TD_{ik} = interaction between treatment and day,
H_l = time of observation (morning, mid-day, afternoon),
AH_{ji} = interaction of animal and time of observation, and
E_{ijklm} = residual error.

The mean square for animal × treatment interaction was used as the error term for treatment, while the mean squares for animal × treatment interaction and animal × time after feeding were used as the error term to test animal effects by the least squares mean hypothesis test. Period of study was not included in the final model as preliminary testing revealed that it did not affect ($P > 0.10$) incidence of bloat.

Table 2. Effects of treatment with alcohol ethoxylate and pluronic detergents (AEPD) on ruminal parameters of wethers fed fresh early bud alfalfa harvested daily.

	Control (n = 5)	AEPD (n = 5)	SEM
Passage rate, %/h			
Solid phase	3.1	3.8	0.9
Liquid phase	11.3	11.2	0.6
Time for 50% turnover, h[1]			
Solid phase	23.3	22.1	0.9
Liquid phase	6.3	6.3	0.7
Volatile fatty acids			
Total VFA, m*M*	76.2	73.1	1.4
Acetate, %	67.4	67.6	0.2
Propionate, %	20.6[b]	21.4[a]	0.2
Acetate:Propionate	3.2	3.1	0
Isovalerate, %	2.0[b]	1.7[a]	0
Branched-chain VFA, %	12.0[b]	11.0[a]	0.1
Ammonia N, mg/dl	35.8	33.6	0.9
Non-protein N, mg/dl	0.42	0.42	0.05
Soluble protein N, mg/dl	0.36	0.35	0.03
Protozoa × 10^5 per ml ruminal fluid	2.6	2.5	0.2
Ruminal pH	6.43	6.46	0.03
Ruminal fluid viscosity[2] (cP)	1.97[b]	1.79[a]	0.04
Ruminal fluid foam height[3] (mm)	2.82[b]	1.23[a]	0.15

[a,b]Within a row means with different superscripts differ ($P < 0.001$).

[1]50% turnover was calculated using the equation t = –k/ln (1/2), where k = decay constant and ln = normal logarithm.

[2]cP, centipoises.

[3]Measured from triplicate 10-g samples of rumen contents taken 4 h after AEPD dosing.

RESULTS AND DISCUSSION

Rumen Variables, Sheep in Confinement

Although Majak et al. (23) and Okine et al. (29) found that bloat-susceptible animals have a reduced rate of passage of the liquid phase, the liquid or solid passage rates in sheep fed fresh-harvested alfalfa were not affected by treatment with AEPD (Table 2). Complete turnover of the fluid phase would have occurred in less than 9 h for both AEPD-treated and control sheep, with 50% turnover of fluid in 6.3 h (Table 2). These results suggest that AEPD-dosing intervals exceeding 9 h might increase the risk of bloat in unrestricted grazing situations, although the risk of bloat is substantially reduced under unrestricted grazing compared with a 6-h grazing regimen (22). Further research is required to determine the degree of association of AEPD with the solid phase and whether or not AEPD is degraded by ruminal microbes before absolute recommendations could be made as to required frequency and timing of AEPD doses for bloat prevention.

Production of propionate was enhanced ($P < 0.001$) in AEPD-treated compared with control wethers, but total VFA production was similar between treatments (Table 2). Acetate production was unaffected ($P > 0.05$) by AEPD, but branched-chain VFA were reduced ($P < 0.001$) in the AEPD-treated wethers, relative to the controls. The most marked reduction occurred in the concentration of isovalerate in AEPD-treated sheep (Table 2). Branched chain VFA are produced from the deamination of AA (30), thus these results also suggest that treatment with AEPD may reduce proteolysis within the rumen. This effect has also been observed with monensin supplementation (4).

Ammonia concentration in ruminal fluid was greater ($P < 0.001$) for control than AEPD-treated wethers at 1 and 4 h after feeding (data not shown) and was elevated overall for control wethers in samples taken in the first 8 h after feeding (Table 2). These results are consistent with previously noted effects of AEPD on branched chain VFA. The reduced concentrations of NH_3 (as with branched chain VFA) in AEPD-treated wethers are likely indicative of reduced deamination within the rumen (4). Possibly, the lower NH_3 concentration in AEPD-treated wethers, compared with controls, could also be due to greater uptake of NH_3 for AA synthesis by ruminal microorganisms (39).

Altered VFA ratios have sometimes been attributed to changed protozoal numbers (25). Protozoa have also been suggested to promote bloat by stabilizing foam in the rumen (10). Whereas some pluronic detergents are lethal to ruminal protozoa (43), AEPD did not appear to affect protozoal populations in the present study. Numbers of protozoa were similar ($P > 0.05$) between AEPD-treated and control wethers (Table 2). The possibility remains, however, that the prevalence or activity of particular protozoal species may have been altered by AEPD.

Ruminal pH did not differ ($P > 0.05$) between the treatment groups on average (Table 2) or at any sampling time from 1 to 8 h after feeding (data not shown). Additionally, foam stability in bloating animals has been reduced at pH > 6.0 (16) and some of the bloat-preventative effects of monensin supplementation have been attributed to an increase in ruminal pH (4).

Viscosity of ruminal fluid followed a pattern similar to ammonia production. Overall, viscosity was reduced ($P < 0.001$) in AEPD-treated wethers, compared with controls, but this effect occurred primarily within the first 2 h after feeding (Figure 1). Digesta from bloating animals is usually more viscous than is digesta from nonbloating animals (6, 13), but the transitory nature of the AEPD-induced decrease in ruminal fluid viscosity is intriguing. Howarth et al. (13) noted that susceptible animals are most likely to bloat 2 to 3 h after consuming a bloat-inducing forage. Consequently, bloat control would likely be most crucial during the first 3 h after eating, i.e., the period during which AEPD-treatment had the largest effect on viscosity of ruminal fluid.

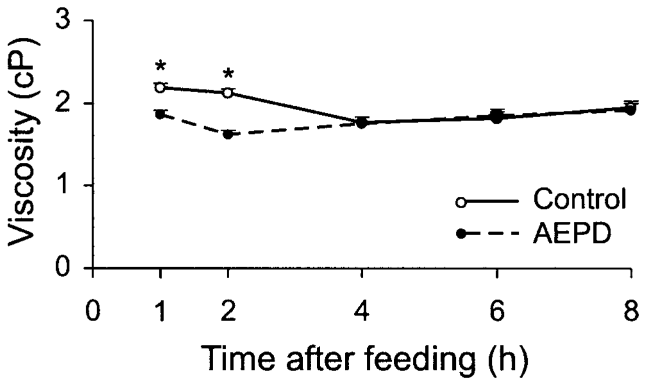

Figure 1. Viscosity of ruminal fluid (cP) of wethers receiving fresh-cut alfalfa in the 8 h following once-daily feeding and intraruminal dosing with 40 ml of water (control) or 50% (vol/vol) alcohol exthoxylate and pluronic detergents (AEPD). At a given time point, * indicates significant effect of treatment ($P < 0.001$). Bars indicate standard error. Where not visible, bars fall within data points.

In samples of rumen contents removed 4 h after dosing with AEPD, foam height was greater ($P < 0.001$) in controls than in AEPD-treated wethers (Table 2). Formation of foam is a key process in the development of bloat (6, 22) and pluronic detergents have reduced both formation and stability of foam in previous studies (12, 43). This difference in foam height between AEPD and control wethers may be linked to lipid metabolism. Lipids have reduced foam in the rumen (16) by coalescing gas bubbles in the foam (6), and Howarth (12) suggested that pluronic detergents function by increasing the effectiveness of dietary lipids as antifoaming agents. Further study is required to determine the effects of AEPD on ruminal lipid metabolism.

Along with an increased viscosity of ruminal fluid, increased concentrations of soluble protein N in the rumen can be linked to elevated susceptibility of ruminants to pasture bloat (12, 24). Moreover, in the development of legume bloat, the rate of release of soluble protein N may be as important as the amount of soluble protein N (40). Crude protein N values were high in the prebloom alfalfa used in this study (Table 1), comparable to those reported for lush wheat forage (4), but rumen soluble protein N did not differ ($P > 0.05$) between treatment groups (Table 2). Thus, the mechanisms by which AEPD controls bloat apparently do not include binding of soluble protein N, such as occurs in legumes containing condensed tannins (14, 26, 36).

Apparent Digestibility, Sheep in Confinement

Treating the wethers with AEPD did not change ($P > 0.05$) the digestibility of alfalfa DM, ADF, or NDF, or any of the N digestion/N retention variables measured (Table 3). As well, DMI did not differ ($P > 0.05$) between the AEPD-treated and control wethers. Consequently, milk production by AEPD-treated animals grazing alfalfa would likely equal that of controls. Advances in controlling legume bloat have been made by reducing the digestibilities of fiber and N, by including tannins in the diet (21, 26, 36), and by genetic selection of alfalfa to reduce the initial rate of DM digestion (9), but a significant reduction in any aspect of digestibility would likely limit the utility of AEPD for pasture-based production of meat and milk. If AEPD lowered digestibility, dairy and beef producers would likely avoid the cost of AEPD by accepting the lowered digestibility (10), nutritive value (6, 40), and forage yield (15, 32) of alfalfa-grass pastures compared with pure stands of alfalfa.

Because the alfalfa fed in the present study was relatively immature (Table 1), its DM digestibility approached that of the fresh, third-cut alfalfa fed to sheep by Kudo et al. (19). Similarly, digestibility of ADF in the fresh, prebloom alfalfa used in the present study was 4 to 7% higher than that reported for cattle receiving alfalfa silage cut in early bloom (2).

Rumen Variables, Grazing Sheep

Although sheep are less susceptible than cattle to legume bloat (7), the 4-h alfalfa grazing regimen resulted in eight incidents of bloat among the control wethers, whereas none of the AEPD-treated animals bloated either during or after grazing (Table 4). Restricted grazing was used to increase the incidence of bloat and provide a rigorous test of AEPD effectiveness. Control animals that bloated during grazing were severely affected; mean bloat scores approached 4. Also,

Table 3. Effects[1] of intraruminal dosing of mature wethers with 20 ml of alcohol ethoxylate and pluronic detergents (AEPD) per day on apparent nutrient digestion of early bud alfalfa harvested on a daily basis.

	Control (n = 5)	AEPD (n = 5)	SEM
DM intake, g/d	1408	1474	85
Digestibility, %			
DM	64.5	65.4	1.6
ADF	54.2	57.3	1.5
NDF	58.6	62.6	1.8
N intake, g/d	48.0	50.2	2.9
Urinary N, g/d	19.6	21.0	2.0
Fecal N, g/d	9.2	9.6	1.0
N digested, %	81.2	80.8	1.5
N digested, g/d	38.8	40.6	2.3
N retained, g/d	19.2	19.6	2.2
N retained, % intake	40.6	38.8	4.2
N retained, % digested	49.8	47.8	4.5

[1]Treatment effects were not detected ($P > 0.05$) among any of the characteristics measured.

Table 4. Effects of treatment of mature wethers grazing early to midbud alfalfa with 0.1% (vol/vol) alcohol ethoxylate and pluronic detergents (AEPD) in drinking water on viscosity of ruminal fluid and apparent digestibility of DM, N, ADF and NDF.

	Control (n = 5)	AEPD (n = 5)	SEM
Incidents of bloat during grazing	8[b]	0[a]	NA[1]
Subjective post-bloat bloat score[2]	3.8	NA	0.2
Subjective bloat score 1 hr post-grazing	2.5[b]	1.1[a]	0.1
Ruminal fluid viscosity[3], cP	1.31[b]	1.18[a]	0.01
Ruminal fluid VFA			
Total VFA, mM	125.1	127.5	2.4
Acetate, %	64.5	63.9	0.4
Propionate, %	21.4[b]	22.5[a]	0.2
Acetate:propionate	3.04[b]	2.86[a]	0.04
Branched chain VFA, %	5.7	5.7	0.1
Digestibility, %			
DM	72.3	72.2	0.6
ADF	58.6	58.0	0.4
NDF	57.5	58.6	0.5
N	79.8	79.9	0.7

[a,b]Within a row, means with different superscripts differ ($P < 0.001$).

[1]NA, not applicable.

[2]Measured immediately upon removal from paddock using the scale of Majak et al. (22).

[3]Expressed in centipoises measured 1 h after grazing.

1 h after grazing, bloat scores were greater ($P < 0.001$) in controls, compared with AEPD-treated sheep. Treated sheep had scores of 1, indicating no froth or distension of the rumen, whereas the mean score for control animals was 2.5, indicating froth in the rumen and variable degrees of rumen distention. As with the digestibility study, ruminal fluid was less viscous ($P < 0.001$) in AEPD-treated compared with control wethers, but viscosity was only measured 1 h after grazing. Ruminal fluid viscosity measured 1 h after feeding in the digestibility trial was greater than in the grazing trial, possibly due to different patterns of intake under grazing versus confined conditions.

Differences in VFA in control versus AEPD-treated sheep were generally similar to those reported for the digestibility study although total concentration of VFA was greater in grazing compared with confined sheep. The differences in VFA between the grazing and digestibility studies were likely due to dietary differences arising from selective grazing (36), altered sampling times, or different feeding habits (one major meal in confinement versus multiple small meals while grazing).

In the grazing study, the increased ($P < 0.001$) propionate production in the AEPD-treated wethers, compared with the controls, led to a reduced acetate to propionate ratio in the treated group. A similar shift in fermentation products from acetic to propionic acid also occurs with monensin supplementation (20, 33); the resulting improvements in ruminant feed conversion efficiency have been linked to reduced energy loss from production of methane (34).

In accordance with the results of the digestibility trial conducted with confined sheep, treating grazing sheep with AEPD did not alter ($P > 0.17$) any of the digestibility variables measured (Table 4). Estimates of ADF and NDF digestibility were generally similar between the confined and grazing sheep, although digestibilities of alfalfa DM and N were higher in grazing sheep likely because of their increased opportunity for selection of high-quality leaf material compared with the sheep fed chopped forage.

Forage Consumption and Selection, Grazing Sheep

Consumption of alfalfa and total forage did not differ ($P > 0.05$) between AEPD-treated and control sheep (Table 5). Although intake is reduced in bloating animals compared with nonbloaters (22), the short grazing period allotted to the wethers, together with their ensuing hunger, likely encouraged appetite, even in the presence of subclinical or clinical bloat. Furthermore, the 20-h period between grazing bouts was likely sufficient to allow the majority of the foam to dissipate, which is consistent with the suggestion by Majak et al. (24) that withdrawing feed for 24 to 48 h may eliminate ruminal conditions that predispose cattle to bloat.

As determined by DM composition of the clipped pre- and postgrazing quadrats, the only difference in forage intake between treatment groups was the higher ($P < 0.05$) proportion of weeds (mostly dandelion, *Taraxacum officinale*) consumed by the AEPD-treated wethers than by the controls. However, the amount of weeds consumed was similar between treatment groups. In previous studies (W. Majak, unpublished), dandelion was found to be a bloat-neutral forage, unlikely to influence predisposition to bloat in grazing animals.

Table 5. Effects of treatment of mature wethers with 0.1% (vol/vol) of alcohol ethoxylate and pluronic detergents (AEPD) in drinking water on forage consumption and forage preferences while grazing early to mid-bud alfalfa.

	Control (n = 5)	AEPD (n = 5)	SEM
Total forage produced, kg/ha	14,400	13,164	800
Total forage consumed, kg/ha	5,972	6,000	709
Proportion total forage consumed, %	41.0	43.6	4.3
Alfalfa produced, kg/ha	9,175	8,814	775
Alfalfa consumed, kg/ha	3,475	3,202	712
Proportion alfalfa consumed, %	31.6	25.9	9.9
Weeds[1] produced, kg/ha	5,225	4,350	450
Weeds consumed, kg/ha	2,425	2,825	327
Proportion weeds consumed, %	44.3[b]	62.0[a]	5.4

[a,b]Within a row, means with different superscripts differ ($P < 0.05$).

[1]The majority of weeds noted were dandelion (*Taraxacum officinale*).

Table 6. Effect of alcohol ethoxylate and pluronic detergents (AEPD) administered in the drinking water (0.06%, vol/vol) on incidence of bloat for cattle grazing pure stands of pre-bloom alfalfa in 1998.[1]

	Control (no AEPD in water)			AEPD in drinking water[1]		
Location[2]	No. of animals	No. of animal days	Incidents of bloat	No. of animals	No. of animal days	Incidents of bloat
Lethbridge	10	80	38[a]	29	232	0[b]
Lacombe	8	112	26[a]	20	280	0[b]
Kamloops	10	70	38[a]	29	203	0[b]
Totals	28	262	102[a]	78	715	0[b]

[a,b]Treatment effect was significant ($P < 0.001$).

[1]Cattle in the treated group began receiving AEPD in the drinking water 2 d before grazing commenced. All cattle were allowed to graze from 0900 to 1400 h daily.

[2]Dates of studies: Lethbridge, AB, Aug. 20 to 27; Lacombe, AB, Aug. 28 to Sept. 14; Kamloops, BC, Sept. 24 to 30.

Cattle Grazing Studies

Lethbridge, Lacombe, Kamloops. Climatic conditions varied among the three sites selected for conducting grazing trials in the fall of 1998 (Table 6). Lethbridge is located on the short-grass prairie of southwestern Alberta, Lacombe is in the parkland region of central Alberta, and Kamloops is in the semiarid interior of British Columbia. In Kamloops, alfalfa was grown under irrigation, whereas the other sites were not irrigated. Regardless of variations in climate among these sites, administering 0.06% AEPD in the drinking water for cattle grazing alfalfa effectively eliminated ($P < 0.001$) the occurrence of bloat (Table 6). In contrast to the AEPD-treated cattle, 102 cases of bloat were recorded among the control animals over the course of these trials, demonstrating that conditions were conducive for bloat in all three locations.

The results of these cattle and sheep-grazing studies demonstrate that compared with other pasture bloat preventatives available in North America, AEPD has the potential to equal or possibly exceed the reported 80% effectiveness of the monensin controlled-release capsule (27), poloxalene (12, 21), or bloat-safe alfalfa (9). Although 6-h grazing periods are more likely to trigger bloating than was unrestricted grazing (22) and were used to challenge the effectiveness of AEPD, the promising results of these sheep and cattle grazing studies need to be confirmed under continuous grazing conditions.

Kamloops Crossover Study. Results of the crossover study conducted with cannulated Jersey steers in Kamloops are shown in Table 7. As with the three replicate studies, adding 0.06% (vol/vol) AEPD to drinking water eliminated ($P < 0.001$) bloat in cattle grazing alfalfa. Significant ($P < 0.05$) animal effects were found, indicating that the animals differed in their propensity to bloat without AEPD treatment. Sixty percent of steers crossed from AEPD treatment in period 1 to control in period 2 bloated during the first day of period 2. These results confirmed those of Majak et al. (22) and the sheep digestibility trial in the present study. The rapid rate of passage of digesta in ruminants grazing alfalfa likely washed the majority of the AEPD out of the rumen within 24 h of administration. If grazing animals did not drink AEPD-treated water at least once in a 24-h period, due to heavy dew, rain, or access to sources of water not treated with AEPD, the animals could be susceptible to bloat. Conversely, control steers that bloated frequently during period 1, did not bloat again in period 2, when grazing commenced after only 18 h of access to AEPD-treated water. This demonstrates the potential for alleviation of bloat storms after only short-term administration of AEPD.

Table 7. Effects of alcohol ethoxylate and pluronic detergents (AEPD) administered in the drinking water (0.06%, vol/vol) on incidence of bloat in ruminally cannulated Jersey steers grazing pure stands of pre-bloom alfalfa for 6 h daily.[1]

	Period 1		Period 2	
Animal no.	Treatment group	Incidents of bloat	Treatment group	Incidents of bloat
A12	Control	17[b]	AEPD	0[a]
A13	Control	7[b]	AEPD	0[a]
A19	Control	9[b]	AEPD	0[a]
B23	Control	4[b]	AEPD	0[a]
B24	Control	18[b]	AEPD	0[a]
Total bloats for treatment group		55[b]		0[a]
A14	AEPD	0[a]	Control	6[b]
A16	AEPD	0[a]	Control	6[b]
A17	AEPD	0[a]	Control	6[b]
B21	AEPD	0[a]	Control	11[b]
B22	AEPD	0[a]	Control	9[b]
Total bloats for treatment group		0[a]		38[b]

[a,b]Within a row, values bearing different superscripts differ ($P < 0.001$).

[1]The study, designed as a crossover, comprised two grazing periods (9 and 7 d).

CONCLUSIONS

Pasture bloat is a complex phenomenon resulting from the interaction of numerous plant, animal, and climatic factors. Consequently, there are likely many ways to control this condition. The formulation and dosing of AEPD used in this study led to complete control of pasture bloat during short-duration grazing of alfalfa by cattle and sheep, and several effects of AEPD on ruminal fermentation were observed. Possible modes of action of this agent include reduced deamination of AA by rumen microbes, enhanced lipid metabolism by rumen microbes leading to reduced viscosity of rumen contents, altered fermentation to favor production of propionate over acetate, or altered activity of selected ruminal protozoa. Administration of AEPD did not alter intake or apparent digestibility of nutrients. Although the underlying mechanisms of bloat prevention by AEPD are not yet clear, the results of this study demonstrate the possible utility of alcohol ethoxylate and pluronic detergents for controlling legume bloat in grazing animals.

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