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Effect of Feed Additives in Growing Lambs Fed Diets Containing Wet Brewers Grains

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ABSTRACT : The study was conducted to evaluate and compare the effects of feed additives on ruminal fermentation, nutrient digestibility and performance of lambs fed diets containing 60% wet brewers grains (WBG). In Experiment 1, two simultaneous trials were conducted. Fifty intact (20.2±0.8 kg BW) lambs were used in a feedlot trial and 10 (rumen cannulated; 32±1 kg BW) in a digestion trial. The pH, volatile fatty acids (VFA) and ammonia-N in lambs were also estimated. Lambs were randomly assigned to one of five diets: i) without additives (Con), ii) with 1% bicarbonate (Bic), iii) with 1% bentonite (Ben), iv) with 33 mg/kg monensin (Mon) and v) with 200 mg/kg fibrolityc enzymes (Enz). In Experiment 2, 120 Rambouillet×Pelibuey intact male lambs (19.5±1.5 kg BW) were used in a feedlot trial and randomly assigned to four diets: i) without additives (control), ii) with 1% Bic, iii) with 33 mg/kg Mon and iv) with 1% Bic and 33 mg/kg Mon. In Experiment 1, lambs fed diets containing Bic or Mon had significantly higher final weight, DMI, ADG than other lambs. However, apparent DM, OM, CP, NDF and ADF digestibilities and ruminal individual VFA content were similar ($p>0.05$) among treatments. Conversely, treatment×collection period interaction was significant for ruminal pH and NH_3. In Experiment 2, lambs fed diets containing a Bic and Mon combination had significantly higher final weight, DMI and ADG. It is concluded lambs fed Bic or Mon or Bic and Mon combination had better performance characteristics than lambs on Ben or Enz. (**Key Words** : Feed Additives, Sheep, Wet Brewers Grains)

INTRODUCTION

Brewers grains are by-products produced during beer production. These materials are acceptable sources of undegradable protein and water soluble vitamins (Westendorf and Wohlt, 2002). They have been used in animal feeding including ruminants and non ruminants (Younker et al., 1998). However, their nutritional content varies among brewing industries, type of substrate (barley, wheat, corn, etc.), and fermentative process (Murdock et al., 1981; West et al., 1994). Some industries will dry the brewers grains and sell it as dried brewer grains, while others sell as wet brewers grains (WBG; Crawshaw, 2001). Unfortunately, WBG need to be used in close proximity to the brewery plant, because transporting could become very expensive due to elevated water content (75-80%) (Westendorf and Wohlt, 2002). Nevertheless, water content may be very advantageous to livestock producers in areas, like the Central-North part of México, where water quality and provision are limited (Aguilera et al., 2007).

It seems that ruminants fed large amounts of WBG have fast ruminal fermentation rates and low pH (3.8-4.8) due to low particle size and high soluble carbohydrates Gierus et al. (2005). Owens (1959) reported that animals feeding on large amounts of WBG were susceptible to ruminal acidosis. Moreover, Kwatra et al. (1983) reported lactic acidosis in buffaloes consuming WBG diets, presenting with clinical signs such ataxia, dehydration, glazed eyes and diarrhea. Furthermore, Morel and Lehmann (1997) found latent ruminal acidosis in feedlot steers fed WBG. In addition, Okwee-Acai and Acon (2005), reported increased incidence of lameness when dairy cows were fed with WBG diets compared to non-WBG diets (47.8 vs. 24.0%).

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Table 1. Ingredients and chemical composition of diets used in feedlot trial 1 and digestion and fermentation trial of Experiment 1

Concept	Diets (DM)				
	Control	Bicarbonate	Bentonite	Monensin	Enzyme
Ingredients					
Wet brewers grain (g/kg)	600.0	594.0	594.0	600.0	600.0
Corn ground (g/kg)	112.8	111.8	111.8	112.8	112.8
Molasses cane (g/kg)	82.0	81.0	81.0	82.0	82.0
Alfalfa hay (g/kg)	40.0	40.0	40.0	40.0	40.0
Oat hay (g/kg)	160.0	158.0	158.0	160.0	160.0
Sodium bicarbonate (g/kg)		10.0			
Sodium bentonite (g/kg)			10.0		
Monensin[1] (mg/kg)				33.0	
Fibrolytic enzymes[2] (mg/kg)					200.0
Calcium carbonate (g/kg)	5.0	5.0	5.0	5.0	5.0
Premix[3] (g/kg)	0.2	0.2	0.2	0.2	0.2
Chemical composition					
Dry matter (g/kg)	339.7	334.0	338.0	336.0	336.0
Ash (g/kg)	35.8	42.4	43.2	33.8	35.4
Crude protein (g/kg)	176.4	174.4	176.2	176.8	175.4
Neutral detergent fiber (g/kg)	359.4	359.4	359.9	359.2	359.7
Acid detergent fiber (g/kg)	182.2	182.4	182.1	182.7	182.4
Ether extract (g/kg)	45.5	45.4	44.8	43.2	45.6
EM[4] (Mcal/kg)	2.75	2.75	2.75	2.75	2.75

[1] Monensin sodium (Rumensin 200 Elanco Inc. Greenfield IN). [2] Fibrolytic enzymes (Cattle-Ase, Loveland Industries Inc., Greeley, CO, USA).
[3] Trace mineral and vitamin premix was composed by 5.6% Mg, 15,000 ppm Co, 50 ppm Se, 3,500,000 IU Vitamin A/kg; 862,500 IU Vitamin D3, 4,000 IU Vitamin E.
[4] Calculated using published values of feed ingredients (NRC, 2007).

Under certain conditions, WBG can be a source of contamination with toxic agents. *Aspergillus flavus* (Wadhwa et al., 1995) was isolated from diets containing WBG and provided to buffaloes diagnosed with hepatotoxicity. Moreover, Simas et al. (2007) found aflatoxins (1-3 g/kg) on one third of WBG samples collected at dairy farms.

Feed additives are a group of feed ingredients that can cause a desired animal response in a non-nutrient role such as pH shift, growth, or metabolic modifier (Hutjens, 1991). Particularly, monensin sodium is used to manipulate ruminal fermentation (Bergen and Bates, 1984). Fibrolytic enzymes can increase fiber digestibility (Sheppy, 2001). Whereas, sodium bentonite participates by shifting VFA patterns, slowing passage rates, exchanging mineral ions and inactivating mycotoxins (Kabak et al., 2006). On the other hand, sodium bicarbonate/sodium sesquicarbonate, has a buffer activity and it has been proved to increase dry matter intake and to stabilize rumen pH (Hutjens, 1991).

Knowledge of the practical use of WBG for animal feeding has been the aim of several trials previously conducted by Aguilera et al. (2007) who found that feedlot lambs can be fed diets containing 60% of WBG. Thus, the purpose of these trials was to evaluate and compare the effects of feed additives on ruminal fermentation, nutrient digestibility and feedlot performance of lambs fed diets with 60% WBG.

MATERIALS AND METHODS

Experiment 1

Fifty Rambouillet×Pelibuey intact male, recently weaned lambs (20.2±0.8 kg BW) were included in feeding trial 1. Vaccinated and dewormed lambs were randomly allotted to one of five diets (10 per treatment) as shown in Table 1. Dietary ingredients were mixed every two weeks and kept in a bunker silo. Additives were included in the diet prior to feeding, using a horizontal 100 kg-mixer. Lambs were adapted to diets for a period of 10 d; thereafter, they remained in the feeding trial for 90 d. Diets were offered twice a day (08:00 and 16:00 h), considering a 5% daily increase. Lamb intakes were determined by recording weight differences between offered and refused feed. Individual body weights of lambs were recorded every 30 d and initial body weight was used as a covariate for average daily gain (ADG) adjustments.

Ten ruminal cannulated Rambouillet×Pelibuey weathers (32±1 kg BW) that were fed the same experimental diets used in feeding trial 1 (Table 1), were used in a replicated 5×5 Latin Square design, for a digestion and rumen fermentation trial. Every feeding period lasted 21 d (14 d of adaptation and 7 d of collection). Animals were housed in metabolic crates with free access to water. Diets were offered *ad libitum* twice daily (08:00 and 16:00 h). Feed consumption of lambs was determined by recording daily

Table 2. Composition of diets used in feedlot trial 2 of Experiment 2

Item	Diets (DM)			
	Control	Bicarbonate	Monensin	Bicarbonate:Monensin
Ingredient				
Wet brewers grain (g/kg)	600	594	600	594
Barley grain (g/kg)	275	272	275	272
Oat hay (g/kg)	76.8	76.8	76.8	76.8
Tallow (g/kg)	30.0	30.0	30.0	30.0
Fish meal (g/kg)	13.0	12.0	13.0	12.0
Sodium bicarbonate (g/kg)		10		10
Monensin[1] (mg/kg)			33	33
Calcium carbonate (g/kg)	5.0	5.0	5.0	5.0
Trace mineral and vitamin premix[2] (g/kg)	0.2	0.2	0.2	0.2
Chemical composition				
Dry matter (g/kg)	346.4	342.5	345.7	342.3
Organic matter (g/kg)	964.2	952.4	962.7	950.8
Ash (g/kg)	36.4	48.1	38.2	45.7
Crude protein (g/kg)	178.4	174.7	177.1	173.2
Neutral detergent fiber (g/kg)	378.9	379.6	373.8	383.2
Acid detergent fiber (g/kg)	195.1	194.4	197.3	195.9
Ether extract (g/kg)	63.8	64.4	63.2	63.7
EM[3] (Mcal/kg)	2.75	2.75	2.75	2.75

[1] Monensin sodium (Rumensin 200 Elanco Inc. Greenfield IN).

[2] Trace mineral and vitamin premix was composed by 5.6% Mg, 15,000 ppm Co, 50 ppm Se, 3,500,000 IU Vitamin A/kg; 862,500 IU Vitamin D3, 4,000 IU Vitamin E.

[3] Calculated using published values of feed ingredients (NRC, 2007).

offered and refused feed. Diet samples and orts were collected daily, dried at 55°C for 48 h, and ground (1-mm screen) in a Wiley mill. Samples and composites were classified by period and stored for further analyses.

At d 15 of each period, after the morning feeding, rumen fluid samples were obtained at 0, 1.5, 3, 4.5, 6 h. Immediately after the first sampling, ruminal fluid pH was measured using a portable pH meter (Cornning, Model 340 Acton, Massachusetts USA), afterwards, those rumen samples were strained through two layers of cheesecloth. Subsequently, 30 ml samples were acidified by adding 8 drops of sulphuric acid 97% and stored frozen (-12°C). Furthermore, samples were analyzed for VFA and ammonia-N was determined following FAO (1986) procedures.

Total fecal collections of individual animals were carried out from d 16 to 21. A 10% aliquot of total feces was collected daily, stored frozen (-12°C) and later thawed and dried at 55°C for 48 h. Dry samples were ground through a 1-mm screen and analyzed for DM, Ash, CP (AOAC, 1997), NDF and ADF (Van Soest et al., 1991). Chemical analyses of diet and ort samples were determined by the same procedures as for feces. Digestion coefficients for DM, OM, CP, NDF and ADF were calculated by procedures and formulas for apparent digestibility, as described by Van Soest (1994).

Initial and final weight, total gain, DMI and feed efficiency data were statistically analyzed using a randomized block design. Monthly ADG data were analyzed with a repeated measurements design with effects of treatment, lambs within treatment, month, and treatment× month interaction. Rumen pH, ammonia-N and VFA data were analyzed with a replicated 5×5 Latin square repeated measures design by the General Linear Model (GLM) procedure of SAS (SAS, 2000). Tukey's test was used to adjust for multiple comparisons (Steel and Torrie, 1980).

Experiment 2

In feeding trial 2, 120 recently weaned Rambouillet× Pelibuey male lambs (19.5±1.5 kg BW) were randomly allotted into 12 pens (3 pens per treatment diet and 10 lambs per pen) receiving 1 of the 4 experimental diets. Ingredient proportions of diets used in Experiment 2 are shown in Table 2. Preparation, storage and addition of additives to experimental diets, adaptation and collection periods, feeding procedures, collection of feeds, orts and feces samples and weighing periods of lambs were performed as in feeding trial 1 in Experiment 1 of this study.

Initial and final weight, total gain, DMI and feed efficiency data were statistically analyzed using a randomized block design. Monthly ADG data were analyzed with a repeated measurements design using the General Linear Model (GLM) procedure of SAS (2000). Tukey's test was used to adjust for multiple comparisons (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Experiment 1

Lambs fed diets containing Bic or Mon had

Table 3. Mean lamb performance in feeding trial 1 of Experiment 1

Concept	Diets					SEM	p<
	Control	Bicarbonate	Bentonite	Monensin	Enzyme		
Initial weight (kg)	20.34	20.38	20.38	20.39	20.34	0.3	0.9
Final weight (kg)	39.78[b]	42.21[a]	39.92[b]	41.82[a]	40.00[b]	0.3	0.04
Total gain (kg)	19.44[b]	21.83[a]	19.54[b]	21.43[a]	19.66[b]	0.3	0.03
DMI (g/d)	1,092[b]	1,267[a]	1,066[b]	1,084[b]	1,092[b]	27.2	0.03
ADG (g)							
0-30 d	185.7	204.7	193.3	208.7	194.3	4.2	0.2
30-60 d	218.3[b]	248.4[a]	224.2[b]	237.6[a]	215[b]	3.5	0.1
60-90 d	244.4[b]	274.7[a]	234.6[b]	268.5[a]	246.4[b]	3.3	0.01
ADG (0-90 d)	216.2[b]	242.6[a]	217.5[b]	240.8[a]	218.4[b]	1.7	0.001
Feed efficiency[1]	5.1[a]	5.2[a]	4.9[a]	4.5[b]	5.0[a]	0.1	0.02

[a, b] Means in a row with different letter superscripts are significantly different.
[1] Feed efficiency = DMI (0-90 d)/ADG (0-90 d).

significantly higher final weight and DMI than lambs fed the other diets (Table 3). Because treatment×month interaction was significant, ADG is discussed by weighing time. The ADG significantly varied throughout all measurement periods (0-30, 30-60 and 60-90 d) being higher ($p<0.05$) in those lambs that were fed Bic or Mon (Table 3). Furthermore, lambs fed diets containing Bic or Mon had better feed efficiency because 8% less feed was necessary per unit of gain when Bic or Mon was added to diets. It has been reported that Bic (Jacques, 1986) or Mon (Goodricht et al., 1984) added to high concentrate diets controlled acidity and were effectively utilized for growth and body weight gain. In this study, an effect on palatability through neutralization of acidity of lamb diets might have been responsible for the intake response to Bic or Mon.

It appears that inclusion of Ben in the diet caused no effect on performance of lambs. Similar findings were reported by Ivan et al. (1992) when 0.5% of Ben was added to lamb diets; however, when Ben doses were higher (0.75% DM of diet), lambs had higher DMI and ADG compared to lambs fed diets without additives (Walz et al., 1998). In this study, addition of Enz caused no effect on DMI, ADG or feed efficiency of lambs. Similar results were reported in lamb studies that used Enz added to barley (McAllister et al., 2000) or sorghum (Lee-Rangel et al., 2006) based diets. Recently, Miller et al. (2008) also found no significant differences for DMI, ADG or feed efficiency in lambs when Enz was used at three inclusion levels. Conversely, Beauchemin *et al.*, (1995) reported that when Enz was added to a high-grain feedlot finishing diet it resulted in an increment of 11% in feed conversion ratio and 6% in weight gain, and a 5% decrease in feed intake. It seems that an enzyme mixture added to diets enhanced growing animal responses (Beauchemin et al., 1999). These authors reported that growing feedlot heifers increased average daily gain by 9% and numerically improved feed to gain ratio by 10% but there was no effect on DMI. Gomez-Vázquez et al. (2003) also reported similar DMI in grazing steers fed sugar cane-urea as a supplement and Enz at recommended and twice recommended levels, even though steers had higher ADG than those fed the same diets without additive. In addition, Titi and Lubbadeh (2004) reported no significant differences for DMI or birth weight, when supplemented with Enz by the end of pregnancy and the first 60 d of lactation of ewes and goats. Enz is used to improve forage digestion by reducing dietary ADF and NDF concentrations (McAllister et al., 2001). In this study, low levels of dietary ADF and NDF might explain why Enz did not affect lamb performance.

It has been established that sodium bicarbonate functions as a ruminal pH stabilizer favoring DMI improvement. In this study, ADG, DMI and FE of lambs were also improved by addition of Bic in diets. Increased DMI and ADG were also reported by Tripathi et al. (2004) by added Bic at 0.75 or 1.5% in diets for lambs compared to 0 or 2.25%. Moreover, Sormunen et al. (2006) found an increment of 8 to 20% in DMI when Bic was added to grass silage prior to feeding lambs. In addition, Chaturvedi et al. (2003) used 1.5% Bic on a 75:25 concentrate:forage diet and obtained a 27 kg increment of lamb weight in a 90 d feeding trial. Recently Sarwar et al. (2007a) added 1.15% Bic and found increment of 27% in DMI in growing lambs, and 29% by 1.5% Bic addition in Nili Ravi Buffaloes (Sarwar et al., 2007b). Conversely, Mandebvu and Galbraith (1999) and Kawas et al. (2007a) did not report improvement of DMI or ADG for lambs fed 1.5% Bic in barley grain or sorghum grain based diets, respectively. They argued that lack of effect of sodium bicarbonate on ruminal pH or animal performance was probably because buffering capacity of bicarbonate was in excess for all treatments.

In this study, compared to control lambs Mon inclusion improved feed efficiency and ADG, without changes in DMI. Improvement in feed efficiency was also reported by Poos et al. (1979) who evaluated Mon inclusion in dried brewers grains (DBG) or urea as protein sources for feedlot cattle. They reported that Mon increased feed efficiency only in the DBG diet. Moreover, Goodrich et al. (1984)

Table 4. Dry matter intake and digestibility parameters of lambs in digestion trial of Experiment 1

Items	Diets					SEM	p<
	Control	Bicarbonate	Bentonite	Monensin	Enzyme		
Dry matter intake							
g/d	1,503.1^{b}	1,729.2^{a}	1,577.5^{b}	1,588.5^{b}	1,537.7^{b}	15.7	0.03
g/kg BW d	28.9^{b}	33.3^{a}	30.7^{b}	27.5^{b}	29.9^{b}	0.3	0.04
g/kg $BW^{0.75}$ d	77.6^{b}	89.3^{a}	82.1^{b}	83.1^{b}	80.0^{b}	0.8	0.03
Fecal DM excretion (g/d)	487.8^{b}	534.3^{a}	501.7^{b}	503.6^{b}	481.4^{b}	4.9	0.05
Apparent digestibility coefficients (% DM)							
Dry matter	67.5	69.1	68.2	68.3	68.7	2.3	0.8
Organic matter	68.2	68.8	67.9	68.5	68.3	1.2	0.7
Crude protein	70.4	71.5	69.8	69.7	70.2	1.9	0.6
Neutral detergent fiber	64.3	66.7	65.2	64.5	67.1	1.5	0.3
Acid detergent fiber	52.1	54.1	53.2	52.6	54.1	2.2	0.5

$^{a, b}$ Means in a row with different letter superscripts are significantly different.

found that Mon addition improved feed efficiency by 7.8% and 1.8% in feedlot steers fed true protein or urea, respectively. Furthermore, Owaimer et al. (2003) reported a 10% DMI reduction and 8.3% increment in feed efficiency by Mon inclusion in 25:75 forage:concentrate lamb diets. It seems that increments in feed efficiency in animals fed Mon are due to increases in energy supply to the animals (Lana et al., 1998). Reduction in DMI and improvement in feed efficiency, in response to Mon supplementation is well documented (Hutjens, 1991). However, Martini et al. (1996) did not find improvements in lamb feedlot when they included Mon for a period of 100 d. Maas et al. (2001) also reported DMI reduction by Mon addition in sheep grazing during autumn or spring. Moreover, Muwalla et al. (1994) obtained a 16% increment in ADG and reduction in DMI when Mon was included in diets for feedlot lambs. Furthermore, Wang et al. (2004) supplemented Mon to steers on backgrounding (60:40 forage:concentrate) and finishing (7:93 forage:concentrate) barley grain diets and obtained increments in ADG during both periods, but similar DMI. Improvement of energy utilization of ruminants fed Mon even with the same level of DMI was also reported by Daenicke et al. (1982), who calculated 15.3% higher daily energy retention and 5.1% better FE and no differences in DMI of steers fed diets with or without Mon. In addition, Granzin and Dryden (2005), Martineau et al. (2007), Al-Zahal et al. (2008) Grainger et al. (2008), and Genhman et al. (2008) found no differences in DMI in dairy cattle fed Mon.

The DMI (g/d) and relative intakes (g/kg BW d and g/kg $BW^{0.75}$ d) of cannulated lambs were significantly higher in lambs fed Bic than other lambs (Table 4). Concomitantly, an increase ($p<0.05$) in fecal excretion appears to be related to increases in DMI ($p<0.05$) in those lambs fed the Bic diet (Table 4). Nevertheless, apparent DM, OM, CP, NDF and ADF digestibility were similar ($p>0.05$) among treatments

Table 5. Mean ruminal pH and ammonia-N content of lambs at different post-feeding times (Experiment 1)

Time (h)	Diets				
	Control	Bicarbonate	Bentonite	Monensin	Enzyme
	----------	----------	pH	----------	----------
0	6.3^{a}	6.3^{a}	6.1^{a}	6.1^{a}	6.1^{a}
1.5	6.1^{ab}	5.9^{b}	5.9^{ab}	6.1^{ab}	6.1^{a}
3	6.0^{ab}	5.8^{b}	5.7^{ab}	5.9^{b}	6.2^{a}
4.5	5.9^{ab}	5.9^{b}	5.7^{b}	5.8^{bc}	5.8^{b}
6	5.8^{b}	5.6^{c}	5.5^{bc}	5.7^{c}	5.7^{b}
Mean	6	5.9	5.8	6	6
SEM	0.1	0.1	0.1	0.1	0.1
p<	0.01	0.01	0.01	0.01	0.01
	----------	----------	NH_3-N (mg/dl)	----------	----------
0	16.1^{a}	16.6^{a}	16.7^{a}	18.2^{a}	17.4^{b}
1.5	16.4^{a}	16.3^{a}	16.5^{a}	17.1^{a}	18.0^{ab}
3	16.1^{a}	16.5^{a}	16.4^{a}	16.8^{ab}	17.0^{b}
4.5	15.4^{b}	15.3^{b}	15.9^{b}	15.8^{b}	16.0^{c}
6	14.5^{b}	14.7^{b}	16.2^{ab}	16.7^{ab}	17.4^{b}
Mean	15.6	15.8	16.3	16.9	17.1
SEM	0.4	0.4	0.4	0.4	0.4
p<	0.01	0.01	0.01	0.01	0.01

$^{a, b, c}$ Means in a row with different letter superscripts are significantly different.

Table 6. Mean ruminal VFA concentrations of lambs obtained at 0, 1.5, 3, 4.5, 6 h post-feeding (Experiment 1)

Concept	Diets					SEM	p<
	Control	Bicarbonate	Bentonite	Monensin	Enzyme		
Total VFA (mM)	136	137	135	138	143	3.2	0.6
Acetate (mM)	87	85	87	82	91	2.0	0.5
Propionate (mM)	31	36	34	39	34	0.8	0.1
Butyrate (mM)	11	9	7	11	11	0.2	0.2
Iso-butyrate (mM)	3.4	3.3	3.5	3.4	3.5	0.1	0.7
Valerate (mM)	1.9	1.8	1.9	2.1	2.0	0.04	0.6
Iso-valerate (mM)	1.2	1.4	1.2	1.5	1.6	0.03	0.7
Acetate:propionate ratio	2.8	2.4	2.6	2.1	2.7	0.04	0.2

[a, b] Means in a row with different letter superscripts are significantly different.

(Table 4). Because the sampling time×treatment interactions were significant ($p<0.05$), data for ruminal pH and ammonia-N are shown by each period of sampling in Table 5. However, because the sampling time×treatment interactions were not significant ($p>0.05$), only main effects of ruminal total and individual VFA content are shown in Table 6. Numerically, acetate content was lower and propionate higher in those lambs fed Bic or Mon diets, resulting in lower acetate:propionate ratios than lambs fed Ben or without additives (Table 6). It is well documented that lower acetate:propionate ratio enhances energy retention, because propionate fermentation is more energetically efficient and theoretically reduces the methane production associated with the production of acetate and butyrate (Van Soest, 1994). Thus, Bic and Mon diets could have promoted more energy for lambs fed WBG.

In this study, feed additives showed variable responses in rumen digestion parameters of sheep (Tables 5 and 6). Similar findings were reported in several studies. Galyean and Chabot (1981), Ivan et al. (1992) and Jacques et al. (1986) reported no influence of Ben on ruminal fermentation characteristics. However, Walz et al. (1998) and Colling et al. (1979), respectively, found increments in total VFA and acetate and butyrate by Ben addition to lamb diets. As in diets of feedlot steers (Adams et al., 1981) and grazing lambs (Mess et al., 1985), addition of Bic appeared not to alter ruminal fermentation and digestion characteristics. However, Mandebvu and Galbraith (1999) found that Bic increased molar proportion of propionate and reduced ammonia-N. Kawas et al. (2007b) reported similar pH and higher propionate by the inclusion of Bic in lamb diets. Santra et al. (2003) argued that total VFA increased and ammonia-N decreased in response to Bic addition.

In this study, Mon reduced acetate:propionate ratio without affecting other rumen parameters. Similar findings were reported in other studies carried out with sheep fed high grain diets (Mbanzamihigo et al., 1996; Garcia et al., 2000) or salinomycin on high roughage diets (Fujita et al., 2007). Mass et al. (2001) also found that addition of Mon in grazing sheep did not affect ammonia-N content, decreased acetate:propionate ratio and increased rate of rumen outflow which is usually associated with increased propionate content. In this study, fermentation and digestion parameters were unaffected by Enz supplementation. Similar results were reported by Gomez-Vázquez et al. (2003) in steers, Assoumaya et al. (2007), Lee-Rangel et al. (2006) and McAllister et al. (2000) in lambs and Baah et al. (2005) in dairy cattle supplemented with fibrolytic enzymes. Conversely, Beauchemin et al. (1995), Lewis et al. (1996) and Yang et al. (1998) using enzyme additives in ruminant diets containing mainly forages reported improvements in digestibility of nutrients. Moreover, Feng et al. (1996) argued that addition of a fibrolytic enzyme mixture to grass hay before feeding improved digestibility of beef steers. Furthermore, Hristov et al. (1998) indicated that addition of fibrolytic enzymes to ruminant diets increased ruminal and total tract digestibility of DM and NDF. Miller et al. (2008) reported lower NDF and higher ADF total tract digestibility for ewe lambs fed barley and sorghum grain-based diets.

Experiment 2

Feedlot performance data of lambs in Experiment 2 are given in Table 7. Lambs receiving the combination of Bic and Mon treatment had significantly higher final weight and total gain than lambs in other treatments. The DMI of lambs was enhanced ($p<0.05$) by Bic addition and reduced by Mon, but not affected by Bic and Mon combination or Con. Because the treatment×month interaction was significant ADG is discussed by weighing time. At the first 30 d of the feeding trial, ADG was similar ($p>0.05$) in lambs fed Con or Bic, and higher ($p<0.05$) in Mon or Bic and Mon combination group. During the 30-60 d period, ADG of lambs was significantly different among treatments being higher in those lambs fed Bic and Mon combination. A similar pattern was observed in the 60-90 d period. Feed efficiency of lambs remained unchanged ($p>0.05$) among periods of measurement. However, in general, when Bic and Mon combination or Mon, respectively, were added to diets 15% and 8% less feed was necessary per unit of gain of lambs (Table 7).

It is well known that ionophores such as Mon and buffers such as Bic can improve feedlot performance of

Table 7. Weight gains, dry matter intake and feed efficiency of lambs in feeding trial 2 of Experiment 2

Concept	Diets				SEM	p<
	Control	Bic	Mon	Bic:Mon		
Initial weight (kg)	19.4	19.3	19.4	19.3	0.4	0.9
Final weight (kg)	40.4	42.8	42.7	44.4[a]	0.4	0.001
Total gain (kg)	21.0	23.5	23.3	25.2[a]	0.3	0.01
DMI (g/d)	1,170.9	1,297.2	1,114.2	1,226.4	29.4	0.01
ADG (g)						
0-30 d	205.8[c]	213.6[bc]	224.3[b]	232.8[a]	5.8	0.01
30-60 d	237.9[c]	267.5[b]	258.3[b]	289.1[a]	7.0	0.01
60-90 d	258.2[c]	309.7[b]	292.4[b]	322.3[a]	5.0	0.01
ADG (0-90 d)	234.0[c]	267.4[b]	254.7[b]	281.1[a]	3.8	0.01
Feed efficiency[1]	5.0[a]	4.9[a]	4.4[b]	4.4[b]	0.1	0.01

[a, b] Means in a row with different letter superscripts are significantly different.
[1] Feed efficiency = DMI (0-90 d)/ADG (0-90 d).

livestock, even though their mechanisms of action may be different. Mon has particularly high affinity for Na^+ (Pressman, 1976). Increasing levels of Na^+ when Bic is included in diets as a buffer may influence the response to Mon (Zinn and Borques, 1993); in fact, only a few digestion and metabolism studies (Rogers and Davis, 1982; Zinn et al., 1994) have examined this issue. Phy and Provenza (1998a) determined sheep preferences for barley and barley with ionophores and/or Bic; both additives were effective in improving barley intake and there was an interaction between lasolacid and Bic. Moreover, these studies also demonstrated that lambs prefer solutions containing Bic or lasolacid in order to maintain rumen homeostasis. Food preference involves interactions between taste and post-ingestive feedback which are determined by physiological condition of the animal and chemical characteristics of the food (Provenza 1995, 1996). Animals prefer foods that meet needs and they limit or avoid consumption of food with high levels of nutrients or toxins (Phy and Provenza, 1998b).

Although, there were similar management and environmental conditions and chemical composition of diets, in general, heavier lambs were observed in feeding trial 2 of Experiment 2 (Table 6) than in feeding trial 1 of Experiment 1 (Table 3). Differences in diet composition might have influenced performance of lambs. Alfalfa hay, corn grain and molasses used in Experiment 1 (Table 1) were replaced by barley grain, tallow and fish meal (Table 2). While fiber content was similar on both diets, degradation pattern could have been changed by corn and barley differences and by tallow inclusion. Moreover, higher rumen by-pass protein from fish meal addition might also have had a positive influence.

CONCLUSIONS

It is concluded that inclusion of additives to lamb diets, containing 60% WBG, produced different responses on digestion and fermentation parameters because ruminal pH and ammonia-N content were altered and total and individual VFA, and digestibility of nutrients were unaltered. However, Bic or Mon or Bic and Mon combination produced higher performance than lambs on Enz or Ben. Moreover, lambs on Bic and Mon combination or Mon required less feed per unit of gain of lambs (15% and 8% respectively).

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