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The Effects of Buffered Propionic Acid-Based Additives Alone or Combined with Microbial Inoculation on the Fermentation of High Moisture Corn and Whole-Crop Barley

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ABSTRACT

Buffered propionic acid-based additives (BP) alone or in combination with a microbial inoculant containing lactic acid bacteria (MI) were mixed with ground, high moisture corn or whole-crop barley and ensiled in triplicate laboratory silos to investigate their effects on silage fermentation and aerobic stability. The inoculant and chemicals were applied separately for treatments that included both additives. The addition of MI alone had no effect on DM recovery, fermentation end products, or aerobic stability of high moisture corn. However, treatments with 0.1 and 0.2% BP (alone and the combination) had more than 10- and 100-fold fewer yeasts, respectively, and they also had greater concentrations of propionic acid than did untreated corn. Corn treated with only 0.1 (161 h) and 0.2% (218 h) BP tended to be more stable when exposed to air than untreated corn (122 h). Treatment with MI + 0.2% BP markedly improved the aerobic stability (>400 h) of high moisture corn. With whole-crop barley, the addition of MI alone, BP alone, and combinations of MI and BP prevented the production of butyric acid that was found in untreated silage (0.48%). All barley silages that had MI in their treatments underwent a more efficient fermentation than treatments without MI, as evident by a greater ratio of lactic:acetic acid and more DM recovery than in untreated silage. Increasing levels (0.1 to 0.2%) of BP added together with MI improved the aerobic stability of barley (190 and 429 h) over the addition of MI alone (50 h). These data show that buffered propionic acid-based products are compatible with microbial inoculants and, in some circumstances when used together, they can improve the fermentation and aerobic stability of silages.

(**Key words:** propionic acid, aerobic stability, high moisture corn, barley silage)

Abbreviation key: BP1 = a liquid-buffered propionic acid-based additive used on high moisture corn, **BP2** = a dry-buffered propionic acid-based additive used on whole-crop barley, **HMC** = high moisture corn, **MI** = a mixture of lactic acid bacteria including *Lactobacillus plantarum, Lactobacillus acidophilus,* and *Lactobacillus bulgaricus*.

INTRODUCTION

Microbial inoculants have been added to silages to improve the efficiency of fermentation, whereas buffered propionic additives have been added to silages to improve the stability of silages when they are exposed to air. For example, classical microbial inoculants containing homolactic acid bacteria (e.g., *Lactobacillus plantarum*) are often added to silage because they produce large quantities of lactic acid very rapidly, which lowers the pH of silage (Muck and Kung, 1997). In some instances, aerobic stability has also been improved (Wohlt, 1989) in these treated silages. However, classical microbial inoculants can often have no effect or even make the aerobic stability of silages worse (Muck and Kung, 1997; Weinberg, et al., 1999) because high levels of lactic acid alone are not very antifungal. Propionic acid-based additives have been used to inhibit yeasts that assimilate lactic acid when silages are exposed to air and thus, they improve aerobic stability (Woolford, 1975). However, these products were not designed to increase the efficiency of fermentation. Thus, producers are often faced with a decision to use one or the other type of additive, realizing that each often has a shortcoming. Feedback from the field suggests that some producers have applied both buffered propionic acid additives and microbial inoculants on the same forage, but there is no published information to support this practice. The objectives of this study were to determine the effect of buffered propionic acid-based preservatives

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and a microbial inoculant added alone or in combination with each other on the fermentation and aerobic stability of high moisture corn (**HMC**) and whole-crop barley because these crops readily spoiled when they are exposed to air.

MATERIALS AND METHODS

High Moisture Corn

Whole corn, obtained from a commercial farm at silo filling, was processed with a mobile roller mill (model number ATG3600B, Automatic Equipment Manufacturing Co., Pender, NE) when the kernels contained 29% moisture, then 75-kg batches of ground-HMC were treated with: 1) nothing, 2) 0.1% (of wet forage weight) buffered propionic acid-based preservative, (**BP1**) (active ingredients containing ammonium and sodium propionate, acetic, benzoic, and sorbic acids; Kemin Americas, Des Moines, IA), 3) 0.2% BP1, 4) a microbial inoculant comprised of *Lactobacillus plantarum, Lactobacillus bulgaricus,* and *Lactobacillus acidophilus* (**MI**) (Kemin Americas) to obtain a final concentration of 100,000 cfu/g of fresh forage weight, 5) 0.1% BP1 and MI, or 6) 0.2% BP1 and MI. To add the targeted amount of lactic acid bacteria, the inoculant was plated on Rogosa SL agar (Difco-248020, Becton Dickinson, Sparks, MD) and based on the measured concentration of lactic acid bacteria; an appropriate amount was used to achieve the desired application rate. The microbial inoculant was solubilized in water and sprayed onto the HMC at a rate of 40 mL of liquid per 25 kg of corn. The buffered propionic acid was in a liquid form and was also sprayed onto the HMC. Both additives were applied sequentially within 5 min of each other for treatments 5 and 6. High moisture corn was packed into three 20-L silos (27 cm, diameter × 36 cm height) for each treatment and sealed immediately (covers with O-ring seals). Packing density was 700 kg of DM/m^3. Weights of empty and full macro silos were recorded. The silos were stored in the dark, where the ambient temperature ranged from 18 to 30°C.

Three samples of HMC were obtained after application of the appropriate additive but prior to ensiling from each treatment for analyses of d 0 samples. These samples were stored on ice (about 1.5 h) until they were returned to the laboratory for processing. In the laboratory, the DM content of each sample was determined in a forced-draft oven set at 60°C for 48 h, then 25 g of each d-0 sample was homogenized with 225 mL of sterile quarter-strength Ringer's solution (Oxoid BR0052G, Unipath, Basingstoke, UK) for 1 min. The pH of the blended mix was determined. A portion of this mix was filtered through Whatman 54 filter paper (Clifton, NJ) to obtain a water extract, acidified with 50% (wt/vol) H_2SO_4, and frozen prior to any further analysis. Water-soluble carbohydrates were determined as described by Nelson (1944). Ammonia-N was analyzed by the phenol-hypochlorite procedure described by Weatherburn (1967). Water extracts were also analyzed for acetic, propionic, and butyric acids as described by Kung et al. (2000). Next 50 g of HMC from each replicate sample for each treatment was pooled and mixed well. A single sample from this pooled mix from each treatment was analyzed for yeasts on 10-fold serial dilutions by pour plating on malt extract agar (Oxoid CM59). The agar was acidified by the addition of 85% lactic acid at a concentration of 0.5%, vol/vol, after autoclaving. Plates were incubated aerobically at 32°C for 48 h. The numbers of colonies on the plates were counted when they contained a minimum of 30 colonies but no more than 300.

Silos were opened for each treatment after 120 d of ensiling and processed as described for the fresh samples. In addition, the filtered and acidified water extracts were analyzed for D- and L-lactic acid isomers by an enzymatic procedure (kit 826-UV, Sigma, St. Louis, MO). For the analysis of D-lactic acid, L-lactic dehydrogenase was replaced with a similar amount of D-lactic dehydrogenase (Sigma L-9636). L-Lactic acid (Sigma L-2250) and D-lactic acid (Sigma L-1000) were used as standards for their respective assays. The sum of the L- and D-lactic acids was reported as the total lactic acid concentration. The concentrations of ethanol in HMC were determined using a YSI Analyzer (model 2700, Yellow Springs, Ohio, Ethanol Membrane Kit 2786).

Dry matter recovery was calculated from knowing the weight of the empty silos, the initial and final silo weights, and DM concentrations of the fresh and ensiled material. Aerobic stability was determined by returning 5 kg of each replicate to a clean 20-L silo without packing. Thermocouple probes were placed in the geometric center of each sample mass, and a double layer of cheesecloth was placed over each silo to prevent drying and contamination but to allow penetration of air. Ambient temperature, as well as the temperature from each bucket was recorded every minute and averaged after every 2 h by a data logger (model number CR10X, Campbell Scientific, Inc., Logan, UT). The samples were allowed to aerobically deteriorate at room temperature (22 to 24°C). Aerobic stability was defined as the number of hours before the temperature of the mass rose 2°C above the ambient temperature (Moran et al., 1996).

Barley Silage

Spring barley (*Hordeum vulgare*) interseeded with about 5% hairy vetch (*Vicia villosa*) was cut with a

Table 1. Chemical composition and yeasts (wet weight basis) of fresh high moisture corn after treatment but before ensiling.[1]

Item	Control	BP1, 0.1%	BP1, 0.2%	MI	MI + BP1, 0.1%	MI + BP1, 0.2%	SE
DM, %	70.9[bc]	71.3[a]	71.1[ab]	70.6[c]	70.8[bc]	71.4[a]	0.1
pH	6.11[a]	5.80[b]	5.62[bc]	6.21[a]	5.80[b]	5.53[c]	0.05
Water-soluble carbohydrates, %[2]	1.61	1.99	1.85	1.82	2.06	1.63	0.19
Ammonia-N, %[2]	0.003[c]	0.007[b]	0.013[a]	0.004[c]	0.009[b]	0.013[a]	<0.001
Propionic acid, %[2]	0.01[c]	0.17[b]	0.33[a]	0.01[c]	0.18[b]	0.34[a]	0.01
Yeast, $\log_{10}$ cfu/g	6.02	6.48	4.70	5.36	5.34	5.40	. . .[3]

[a,b,c]Means in columns with unlike superscript differ ($P < 0.05$).

[1]BP1 = a liquid-buffered propionic acid-based additive used on high moisture corn; MI = a mixture of lactic acid bacteria including *Lactobacillus plantarum, Lactobacillus acidophilus,* and *Lactobacillus bulgaricus*.

[2]DM basis.

[3]Analyzed from a single pooled sample for each treatment.

mower-conditioner in the late boot stage of maturity and allowed to wilt before being harvested with a New Holland 1985 Crop Cruiser (New Holland, PA) at a theoretical cut length of 0.95 cm. Vetch was almost nondetectable in harvested forage. Treatments were: 1) nothing, 2) barley treated with 0.1% (fresh forage weight) of a propionic acid-based additive (**BP2**) (active ingredients containing ammonium and sodium propionate, ethoxyquin, BHA, and BHT; Kemin Americas), 3) 0.2% of BP2, 4) lactic acid bacteria (**MI**) (*L. plantarum, L. bulgaricus,* and *L. acidophilus;* Kemin Americas) to obtain a final concentration of 100,000 cfu/g of fresh forage weight (to add the targeted amount of lactic acid bacteria, the inoculant was plated on Rogosa SL agar and adjustments were made to the formulation to achieve the desire application rate), 5) 0.1% BP2 + MI, 6) 0.2% BP2 + MI. Microbial inoculants were applied to treatments 4, 5, and 6 about 5 min after the addition of BP2. Three silos (as previously described) were prepared for each treatment and packed at a density of 230 kg of DM/m^3. Silos were opened after 98 d of ensiling and sampled, processed, and analyzed as described for HMC.

Statistical Analysis

All microbial data were transformed to $\log_{10}$ and are presented on a wet weight basis. Chemical data are presented on a DM basis. Data from each experiment were analyzed using the general linear models procedure of SAS (1998) for a completely randomized design. Differences among means were tested using Tukey's Test (Snedecor and Cochran, 1980). An α level of $P < 0.05$ was deemed significant.

RESULTS AND DISCUSSION

We did not analyze our samples for the usual nutrient composition (e.g., ADF, NDF, and starch) because past studies from our laboratory have shown that buffered propionic acid additives and microbial inoculants have few effects on these nutrients (Kung et al., 1998, 2000, 2001). The application rates of similar buffered propionic acid-based additives used in this study have improved the aerobic stability of silages in previous studies from our laboratory (Kung et al., 1998, 2000).

The chemical compositions of the fresh HMC are shown in Table 1. The DM concentration of the HMC ranged from 70.6 to 71.4%, and, although there were differences among treatments, these differences were biologically small. We applied the microbial inoculant and buffered propionic acid additive sequentially to ensure viability of the former. We have not studied the effects of potentially applying the 2 additives simultaneously, which would certainly be desirable under many circumstances. The pH ranged from 5.53 to 6.21 and was lowered by the addition of BP1, presumably due to the addition of the buffered propionic acid, which is mildly acidic (pH of about 5.5). The concentrations of ammonia-N and propionic acid in HMC were also increased by the addition of BP1, which was predictable because the buffered propionic acid is in the form of ammonium propionate. The absolute effect of BP1 on these measurements cannot be determined because manufacturers of these products seldom divulge the concentration of buffered propionic acid and other active ingredients. However, measurable increases in propionic acid (0.1 to 0.3%, wt/wt) from buffered propionic acid additives have been reported in other studies (Kung et al., 1998), and the increase suggests that this acid is the primary active ingredient. No other VFA were detected in fresh samples. As expected, treatment with MI alone had no effect on the initial pH or concentrations of ammonia-N or propionic acid when compared with untreated corn. Numbers of yeasts did not differ among treatments and was similar to findings reported in a previous study with high moisture corn by our group (Taylor and Kung, 2002).

Table 2. Composition of high moisture corn after 120 d of ensiling.[1]

Item	Control	BP1, 0.1%	BP1, 0.2%	MI	MI + BP1, 0.1%	MI + BP1, 0.2%	SE
DM, %	69.7[b]	70.3[a]	70.3[a]	69.7[b]	69.7[b]	69.8[b]	0.06
pH	4.13	4.12	4.17	4.23	4.16	4.14	0.03
Water-soluble carbohydrates, %[2]	1.29	1.52	1.39	1.23	1.39	1.49	0.09
Ammonia-N, %[2]	0.031	0.029	0.030	0.031	0.030	0.030	<0.001
Lactic acid, %[2]	1.23	1.15	1.10	1.21	1.13	1.23	0.05
Acetic acid, %[2]	0.52	0.48	0.54	0.46	0.56	0.51	0.04
Propionic acid, %[2]	<0.01[c]	0.14[b]	0.29[a]	0.01[c]	0.17[b]	0.30[a]	0.01
Ethanol, %[2]	2.84[bc]	2.83[c]	2.83[c]	2.85[b]	2.86[a]	2.85[ab]	<0.01
DM recovery, %	93.1	94.3	94.1	93.1	93.6	93.0	0.5
Yeast, $\log_{10}$ cfu/g[3]	4.16[a]	1.96[abc]	0.57[c]	3.92[a]	2.87[ab]	1.01[bc]	0.48

[a,b,c]Means in columns with unlike superscript differ ($P < 0.05$).

[1]BP1 = a liquid-buffered propionic acid-based additive used on high moisture corn; MI = a mixture of lactic acid bacteria including *Lactobacillus plantarum, Lactobacillus acidophilus,* and *Lactobacillus bulgaricus*.

[2]DM basis.

[3]Wet weight basis.

After 120 d of ensiling, inoculation with MI alone did not affect the end products of fermentation or numbers of yeasts when compared with untreated corn (Table 2). In previous studies, inoculation with lactic acid bacteria has had variable effects on the fermentation of HMC. For example, Fellner et al. (2001) reported that microbial inoculation with *L. plantarum* and *Enterococcus faecium* resulted in HMC with a lower pH and concentration of acetic acid than in untreated corn. Inoculation with MI alone also had no effect on the aerobic stability of HMC (101 h) when compared with untreated HMC (121 h, Figure 1), but Phillip and Fellner (1992) reported that HMC treated with a microbial inoculant remained cooler with a lower pH when exposed to air. In contrast, Phillip and Fellner (1992) reported that several microbial inoculants failed to affect the fermentation of HMC.

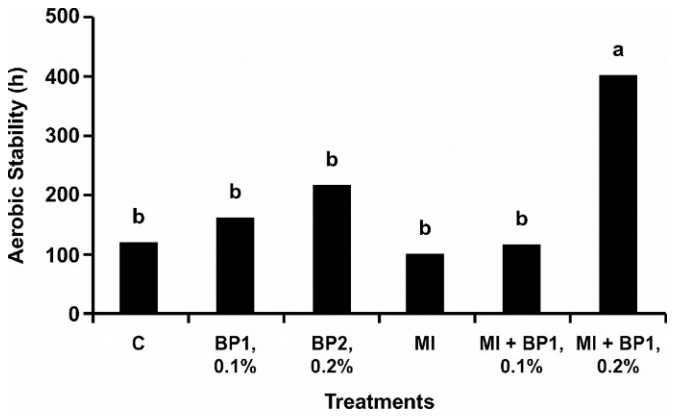

Figure 1. The aerobic stability of untreated high moisture corn (C) or high moisture corn treated with a microbial inoculant (MI), a buffered propionic acid additive (BP1; added at a rate of 0.1 and 0.2% of fresh forage weight), or the combination of both. The active ingredients in BP1 were propionic, acetic, benzoic, and sorbic acids (Kemin Americas, Des Moines, IA). The active ingredients in MI were *Lactobacillius plantarum, Lactobacillius bulgaricus, and Lactobacillius acidophilus* (Kemin Americas) added to obtain a final concentration of 100,000 cfu/g of fresh forage weight. Bars with unlike letters are different ($P < 0.05$). SE = 38.

In the current study, concentrations of propionic acid were greater in HMC treated with BP1 (alone and together with MI) and numbers of yeasts were markedly lower in these treatments (Table 2). In HMC treated with BP1 alone, there was a trend ($P < 0.10$) for improved aerobic stability for the low (161 h) and high (218 h) level of additions, respectively. Unexpectedly, the combination of 0.1% BP1 + MI had no effect on aerobic stability (116 h), whereas the combination of 0.2% BP1 + MI resulted in HMC with the greatest aerobic stability (>390 h) of all the treatments. Propionic acid was added at 1% of fresh weight in the studies of Fellner et al. (2001) and Sebastian et al. (1996), which was substantially more than the levels of propionic acid-based additives used in the current study (0.1 to 0.2%). However, the additives used in our studies contained other antifungal compounds. In recent studies, additions of low levels of buffered propionic acid-based preservatives (0.1 to 0.2%, wt/wt) similar to those used in the current study improved the aerobic stability of corn silages (Kung et al., 1998, 2000). Treatments did not affect DM recovery after ensiling, which generally supports the fact that they did not affect fermentation.

The chemical composition and numbers of yeasts in chopped barley forage after treatment but before ensiling are shown in Table 3. Similar to our findings with HMC, numbers of epiphytic yeasts were not affected by initial treatment of BP2, even though the low and high level of this additive increased the concentration of propionic acid in forage to an average of 0.25 and 0.87%, respectively. Similar findings have been reported in freshly treated corn forage (Kung et al., 1998, 2000)

Table 3. Composition of barley forage after treatment but before ensiling.[1]

Item	Control	BP2, 0.1%	BP2, 0.2%	MI	MI + BP2, 0.1%	MI + BP2, 0.2%	SE
DM, %	36.0[b]	36.3[ab]	37.1[ab]	35.8[b]	37.4[ab]	37.8[a]	0.3
pH	6.05[b]	6.05[b]	6.05[b]	6.07[ab]	6.10[a]	6.11[a]	0.01
Water-soluble carbohydrate, %[2]	4.00	3.97	4.40	4.00	4.06	3.71	0.15
Ammonia N, %[2]	0.03	0.03	0.03	0.03	0.03	0.03	<0.01
Propionic acid, %[2]	0.00[d]	0.25[c]	0.93[a]	0.01[d]	0.25[c]	0.82[d]	0.02
Yeast, $\log_{10}$ cfu/g[3]	4.45	4.75	4.11	3.98	4.29	4.71	. . .[4]

[a,b,c,d]Means in columns with unlike superscript differ ($P < 0.05$).

[1]BP1 = a liquid-buffered propionic acid-based additive used on high moisture corn; MI = a mixture of lactic acid bacteria including *Lactobacillus plantarum, Lactobacillus acidophilus,* and *Lactobacillus bulgaricus*.

[2]DM basis.

[3]Wet weight basis.

[4]Analyzed from a single pooled sample for each treatment.

and is most likely due to the fact that most of the propionic acid is in dissociated (less active) form when the pH is high, as it is in fresh forage.

The chemical and microbial compositions of barley silage after 98 d of ensiling are shown in Table 4. The addition of MI alone resulted in silage with a lower pH; higher concentration of lactic acid; and lower concentrations of acetic acid, butyric acid, and ammonia-N than in untreated silage, which is indicative of a more dominant homolactic acid fermentation. Untreated silages had the highest concentration of water-soluble carbohydrates, followed by silages treated with the inoculant, and it was lowest in silages treated only with BP2. All treatments containing MI had a higher ratio of lactic:acetic acid (about 6:1) than did untreated silage and silage treated only with BP2 (about 3:1). The addition of BP2 alone at 0.1 and 0.2%, also resulted in silage with a lower pH, less butyric acid, and ammonia-N and higher lactic acid than in untreated silage, but they increased the concentrations of acetic acid and propionic acids. The concentrations of ethanol were only decreased in silages treated with the combination treatments of MI and BP2. Silage treated with 0.1% BP2, MI, MI + 0.1% BP2, and MI + 0.2% BP2 improved the recovery of DM when compared with untreated silage. Treatment with 0.2% BP2 had a DM recovery that was numerically, but not statistically, different from untreated silage. The consistent improvements in DM recovery from silages treated with MI agree with the shift towards a more homolactic acid fermentation and with previous findings that showed inoculation with similar organisms improved the efficiency of fermentation (Muck and Kung, 1997).

The numbers of yeasts were highest in silage treated only with MI (4.67 log cfu/g) and MI + 0.1% BP2 (4.07 log cfu/g) and were substantially lower (<3.00 log cfu/g) in all other treatments. Specifically, the aerobic stability of untreated barley silage (containing 2.59 log cfu

Table 4. Composition of barley silage after 98 d of ensiling.[1]

Item	Control	BP2, 0.1%	BP2, 0.2%	MI	MI + BP2, 0.1%	MI + BP2, 0.2%	SE
DM, %	34.3[e]	35.3[cd]	35.7[bc]	34.8[de]	36.4[ab]	36.7[a]	0.2
pH	4.14[a]	3.89[bc]	3.97[b]	<3.88[c]	3.82[c]	3.88[bc]	0.02
Water-soluble carbohydrate, %[2]	2.73[a]	1.18[d]	1.88[c]	2.20[bc]	2.61[b]	2.65[b]	0.01
Ammonia N, %[2]	0.152[a]	0.131[b]	0.123[bc]	0.113[c]	0.087[d]	0.088[d]	0.003
Lactic acid, %[2]	4.77[c]	6.27[b]	6.86[a]	6.91[a]	6.97[a]	6.84[a]	0.09
Acetic acid, %[2]	1.32[b]	1.94[a]	2.01[a]	1.11[c]	1.03[c]	1.06[c]	0.02
Lactic:acetic	3.60[c]	3.23[c]	3.41[c]	6.21[b]	6.79[a]	6.46[ab]	0.09
Propionic acid, %[2]	0.01[c]	0.21[b]	0.74[a]	0.01[c]	0.24[b]	0.76[a]	0.01
Butyric acid, %[2]	0.48[a]	0.01[b]	0.01[b]	0.01[b]	0.01[b]	0.01[b]	0.01
Ethanol, %[2]	3.10[a]	3.09[a]	3.05[a]	3.07[a]	2.79[b]	2.62[b]	0.03
DM recovery, %	93.9[b]	96.2[a]	95.4[ab]	96.6[a]	96.6[a]	96.3[a]	0.4
Yeast, $\log_{10}$ cfu/g[3]	2.59[b]	2.87[b]	2.75[b]	4.67[a]	4.07[a]	1.73[b]	3.44

[a,b,c,d,e]Means in columns with unlike superscript differ ($P < 0.05$).

[1]BP1 = a liquid-buffered propionic acid-based additive used on high moisture corn; MI = a mixture of lactic acid bacteria including *Lactobacillus plantarum, Lactobacillus acidophilus,* and *Lactobacillus bulgaricus*.

[2]DM basis.

[3]Wet weight basis.

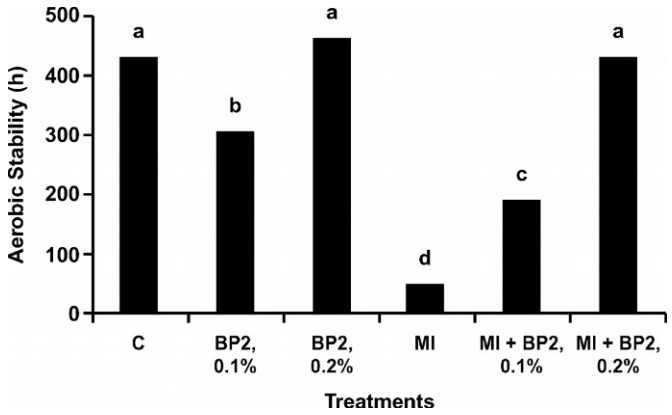

Figure 2. In experiment 2, the aerobic stability of untreated barley silage (C) or barley silage treated with a microbial inoculant (MI), a buffered propionic acid additive (BP2; added at a rate of 0.1 and 0.2% of fresh forage weight), or the combination of both. The active ingredients in BP2 were propionic acid, ethoxyquin, BHA, and BHT (Kemin Americas, Des Moines, IA). The active ingredients in MI were *Lactobacillius plantarum, Lactobacillius bulgaricus,* and *Lactobacillius acidophilus* (Kemin Americas) added to obtain a final concentration of 100,000 cfu/g of fresh forage weight. Bars with unlike letters are different ($P < 0.05$). SE = 11.

of yeasts/g) was extremely good (430 h, Figure 2), but this finding was confounded by the fact that this silage contained 0.48% butyric acid, which is known to have strong antifungal properties (Woolford, 1975). Clostridial fermentations are more commonly found in silages with high moisture contents (>70% moisture), but butyric acid has been observed in silages with lower concentrations of moisture. For example, Driehuis and van Wikselaar (2000) reported that butyric acid concentrations averaged 0.4% and ranged from 0 to 1.87% in grass silages whose DM contents ranged from 36.8 to 67.4%. We hypothesize that if untreated silage had not undergone a clostridial fermentation, its aerobic stability would have been more similar to that of silage treated with MI, which had the poorest aerobic stability (50 h) of all the treatments. In past studies by our group, treatment with inoculants containing *L. plantarum* have resulted in silages that have either been as stable as control silages (that did not contain butyric acid) (Ranjit and Kung, 2000; Taylor et al., 2002) or have reduced the aerobic stability of silages (Kung and Ranjit, 2001). In the current study, because aerobic stability was improved for barley silage when MI was combined with increasing levels of BP2 (190 and 429 h, respectively, for 0.1% BP2 + MI and for 0.2% BP2 + MI), an argument could be made that if untreated silage had no butyric acid and was stable for about 50 h, then increasing levels of BP alone probably improved stability (about 300 and 450 h for 0.1 and 0.2% BP alone, respectively) over untreated silage.

CONCLUSIONS

Microbial inoculation was not effective in improving the fermentation, DM recovery, or aerobic stability of HMC. However, in barley silage, inoculation prevented the accumulation of butyric acid and resulted in silages that had undergone a more homolactic acid fermentation (higher ratio of lactic:acetic acid and lower ammonia-N). This was true regardless if the inoculant was applied alone or with buffered propionic acid. Aerobic stability was improved in HMC with an addition of 0.2% of a buffered propionic additive together with MI when compared with untreated HMC. Addition of 0.2% of a buffered propionic acid-based additive with MI improved the aerobic stability of barley silage when compared with silage treated only with MI. Barley silage that had been treated with MI alone and with buffered propionic acid had a greater recovery of DM than did untreated silage. In our study, the microbial inoculant and chemical additive were applied sequentially rather than simultaneously, as direct contact of the buffered propionic acid might have been detrimental to viability of the inoculants. Further studies to address this issue may be warranted. These data suggest that buffered propionic acid-based products are compatible with microbial inoculants, and, in some circumstances when used together, they can result in improvements in silage fermentation and aerobic stability.

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