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The effect of propionic acid on the fermentation and aerobic stability of maize silage

T. Fu[1,2] and Q.Y. Diao[2]

[2] College of Animal Husbandry and Veterinary, Henan Agricultural University,
[1]Institute of Feed Research, Chinese Academy of Agricultural Sciences
Beijing 100081, P.R. China

ABSTRACT

The effect of propionic acid on fermentation and aerobic stability of whole-plant maize silage was evaluated using laboratory silos. Whole-plant maize silage was treated with 2 l/tonne propionic acid; silage with no additives served as the control. The results showed that application of a low rate of propionic acid could influence the ratio of organic acids and reduce NH_3-N in fermentation and improve aerobic stability by 40 h in maize silage. It also accelerated yeast multiplication at the early stage of fermentation but restricted it at the late stage.

KEY WORDS: maize silage, propionic acid, fermentation process, aerobic stability

INTRODUCTION

High level of propionic acid (1 to 2% of the DM) have been beneficial in controlling silage fermentation, the main effects are improved bunk life, aerobic stability and reduced DM losses, but a high percentage of acid often restricts fermentation (McDonald et al., 1991). Furthermore, the cost of adding sufficient propionic acid is relatively high and usually is not cost-effective. Propionic acid added at low rates did not affect fermentation, but was effective in the reduction of heating in silage (Kung et al., 1998). However, most studies evaluated the effects on fermentation end-products, data are lacking on the fermentation process itself.

Aerobic stability of maize silage can be a major problem for farmers particularly in warm weather (Muck, 2004). The two most effective products for increasing aerobic stability of maize silage are propionic acid and *Lactobacillus buchneri* inoculant. The mechanisms by which *Lactobacillus buchneri* improves aerobic

[1] Corresponding author: e-mail: diaoqiyu@mail.caas.net.cn

stability are still unclear. Propionic acid and its salts are worth considering as silage additives. Thus, the objective of this study was to evaluate a low application rate of propionic acid on fermentation and aerobic stability of maize silage.

MATERIAL AND METHODS

Whole-plant maize was harvested during the dough-dent stage of maturity at about 27% DM (Table 1). The plant was cut by a conventional forage harvester to a length of 1-2 cm, treated with propionic acid at an application rate of 2 l/tonne of fresh forage; maize with no additives served as the control. The additive was applied uniformly with constant mixing. The forage was then packed into glass laboratory-scale silos (2 l capacity) and sealed with agglutinant for each treatment. All silos were packed to a density of 600 g/l of fresh forage and stored at ambient temperature (20 to 27°C).

Table 1. Chemical composition (DM basis) of whole-plant maize before ensiling

Whole-plant maize	$g\ kg^{-1}$
Dry matter	27.3
Crude protein	7.7
Neutral detergent fibre	52.7
Acid detergent fibre	27.9
Water-soluble carbohydrates	13.1
Ash	7.6
pH	5.80

Samples from three mini silos of each treatment were collected and analysed for chemical and microbial composition after 1, 2, 4, 8, 21, 56 and 91 d of ensiling. When silos were opened on d 91, the maize silage was analysed for pH, temperature and total yeast counts after 24, 48, 96,144,192 and 240 h of exposure to air.

Yeasts were counted by the method described by Taylor and Kung (2001), lactic, acetic, propionic and butyric acid concentrations were analysed by ion chromatography (ISC2500, Dionex, USA). Ammonia-N was estimated in water extracts by the phenol-hypochlorite procedure described by Weatherburn (1967). Aerobic stability was defined as the number of hours the silage remained stable before rising more than 2°C above the ambient temperature.

The data were subjected to analysis of variance using the *t*-test of the Statistical Package for the Social Science (SPSS 11.0, SPSS, Inc., Chicago, IL). An α level of $P<0.05$ was deemed significant.

RESULTS

Changes of the concentration of lactic acid and acetic acid and their ratio observed during silage fermentation are listed in Table 2. The concentration of acetic acid was lower in the propionic acid treatment than in the control after 1, 2, 4, 8, 21, 56 and 91 d of ensiling ($P<0.05$), but the ratio of lactic to acetic acid was higher in this treatment ($P<0.05$). No significant differences were observed in the concentration of lactic acid after 1, 2, 8, 21 and 91 d of ensiling ($P>0.05$).The change of the concentration of NH_3-N was similar to that of acetic acid.

Table 2 shows the changes of the concentration of total organic acid including and excluding the addition of propionic acid before ensiling. The concentration of total organic acid was significantly lower in the propionic acid treatment than in the control ($P<0.05$), although no significant differences occurred in the concentration of total organic acid that including the addition of propionic acid before ensiling after 2, 4, 8, 21, 56 and 91 d of ensiling ($P>0.05$).

Table 2. Chemical (DM basis) and microbial composition ($\log_{10}$) of untreated maize silage and maize silage treated with propionic acid after 1, 2, 4, 8, 21, 56 and 91 d of ensiling, g kg^{-1}

Indices		1	2	4	8	21	56	91
pH	control[1]	4.22^{a}	3.94^{a}	3.85^{a}	3.80^{a}	3.74^{a}	3.70^{a}	3.76^{a}
	PA[2]	4.16^{b}	3.84^{b}	3.76^{b}	3.71^{b}	3.69^{b}	3.61^{b}	3.70^{b}
Lactic acid, g kg^{-1}	control	25.4	48.6	63.2^{a}	69.4	72.6	76.2^{a}	76.2
	PA	24.3	48.1	59.8^{b}	67.0	71.8	73.4^{b}	75.8
Acetic acid, g kg^{-1}	control	7.3^{a}	11.1^{a}	13.0^{a}	15.8^{a}	17.0^{a}	18.1^{a}	19.6^{a}
	PA	4.3^{b}	6.6^{b}	7.7^{b}	9.2^{b}	10.0^{b}	11.0^{b}	12.1^{b}
L/A[3]	control	3.48^{b}	4.37^{b}	4.88^{b}	4.40^{b}	4.26^{b}	4.21^{b}	3.90^{b}
	PA	5.69^{a}	7.30^{a}	7.79^{a}	7.29^{a}	7.16^{a}	6.65^{a}	6.28^{a}
Total organic acid, g kg^{-1}	control	32.6^{aA}	59.7^{a}	76.2^{a}	85.2^{a}	89.7^{a}	94.3^{a}	95.8^{a}
	PA	28.6^{b}	54.7^{bA}	67.5^{bA}	76.2^{bA}	81.9^{bA}	84.5^{bA}	87.9^{bA}
	PA[4]	35.7^{B}	62.2^{B}	75.7^{B}	84.4^{B}	90.0^{B}	92.3^{B}	96.3^{B}
NH_3-N, g kg^{-1}	control	0.37^{a}	0.44^{a}	0.47^{a}	0.51^{a}	0.61^{a}	0.73^{a}	0.77^{a}
	PA	0.28^{b}	0.31^{b}	0.34^{b}	0.44^{b}	0.56^{b}	0.60^{b}	0.65^{b}
Yeast, cfu/g	control	ND[5]	2.24	4.61	3.76	3.39	4.49	4.2
	PA	5.92	6.07	6.02	3.36	2.24	ND	ND

^{a,b,A,B} means in columns with unlike superscripts differ ($P<0.05$); [1] control - untreated control; [2]PA- treated with 2 l/tonne propionic acid of fresh forage weight; [3] L/A - lactic acid/acetic acid; [4]includes the addition of acid before ensiling; [5]not detectable, <2.00 log cfu/g

Treatment with propionic acid resulted in a relatively low pH of the fermentation process, which was lower than the control on the different observation days ($P<0.05$). Yeast could not be detected in the control on the first day of the experiment (Figure 1), but multiplied rapidly between d 2 and 4 after ensiling. In the propionic acid treatment, large numbers of yeast were detected during the initial 2 days after ensiling but disappeared on d 21.

When silage was exposed to air, the change of pH and the number of yeasts in each treatment is shown in Figures 1 and 2. There was no significant change in pH within 48 h after the silage was exposed to air. But the pH increased rapidly after 48 h in the untreated silage. By contrast, the propionic acid treatment increased slowly. pH remained lower, acidic, 240 h after exposure to air. Yeast could be detected at 24 h but with slower growth than in untreated silage.

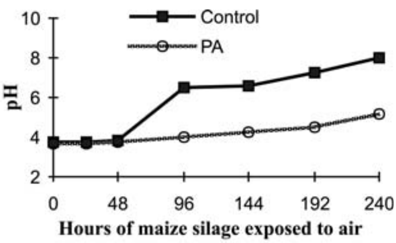

Figure 1. Changes in pH of maize silage exposed to air after 91d of ensiling

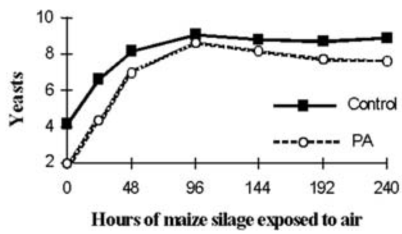

Figure 2. Changes in yeasts (log_{10}) of maize silage exposed to air after 91d of ensiling

The aerobic stability of maize silage treated with propionic acid and untreated silage were 48 and 88 h, respectively.

DISCUSSION

The ratio of lactic acid and acetic acid was higher in the propionic acid treatment than in the control. This shows that the addition of propionic acid may affect fermentation by influencing the dominant lactic acid bacteria during fermentation.

In our study, no significant difference in lactic acid and total amount of organic acid on fermentation in treated and untreated silage was found, but the pH of the propionic acid treatment was significantly lower than in the control. This may be contributed to the pH of acetic acid being higher than that of propionic acid at the same concentration.

The treatment with propionic acid all along had a lower concentration of acetic acid and NH_3-N than the untreated silage during fermentation, suggesting that the addition of propionic acid maybe restrains fermentation by acetic acid bacteria and NH_3-producing bacteria. Those substances are commonly considered to have a negative influence on silage fermentation (McDonald et al., 1991). Ammonia itself does not adversely affect silage fermentation it is often included in silage additives as ammonium tetraformiate. However, increased ammonia N is an indication of poor fermentation.

Large differences in the trend of yeast growth were observed between the control and propionic acid treatments. The addition of propionic acid at the peak of fermentation could not inhibit yeast growth. This may be due to propionic acid increasing the osmotic pressure, and as a result, the respiration of plant cells was reduced. This prolonged oxygen environment allowed the multiplication of yeast after packing in the silo. The added propionic acid was not enough to inhibit the growth of yeast at this stage. But with the accumulation of organic acids and pH decline, the growth of yeast gradually stopped. After 8 days of ensiling, the yeast counts declined significantly in the propionic acid treatment, possibly due to undissociated propionic acid being responsible for the antifungal properties of this acid. The ratio of undissociated (COOH) to dissociated (COO-) acid is highly dependent on pH (Lambert and Stratford, 1999). At the same time there was no significant difference of the amount of lactic acid and total organic acid between the treated and untreated silages.

Yeasts are the most frequent initiators of heating in silages. The opening of a silo can aid the yeast at rest to multiply and decompose lactic acid, release heat and cause rapid spoilage of silage (Woolford, 1990). This study showed that the addition of propionic acid inhibited yeast growth and delayed the increase in pH after exposure of maize silage to air. Despite the limited application rate, the aerobic stability of the propionic acid treatment was enhanced by 40 h. This is similar to the result described by Kung et al. (1998).

CONCLUSIONS

The addition of a low rate propionic acid influenced the ratio of organic acids, reduced the NH_3-N concentration and pH during fermentation and improved the aerobic stability of maize silage. It also accelerated yeast multiplication at the early stage of fermentation but restricted it at the late stage.

REFERENCES

Kung Jr. L., Sheperd A.C., Smagala A.M., Endres K.M., Bessett C.A., Ranjit N.K., Glancey J.L., 1998. The effect of preservatives based on propionic acid on the fermentation and aerobic stability of maize silage and a total mixed ration. J. Dairy Sci. 81, 1322-1330

Lambert R.J., Stratford M., 1999. Weak-acid preservatives: Modeling microbial inhibition and response. J. Appl. Microbiol. 86, 157-164

McDonald P., Henderson N., Heron S.J.E., 1991. The Biochemistry of Silage. 2nd Edition. Chalcombe Publications, Bucks (UK)

Muck R.E., 2004. Effects of corn silage inoculants on aerobic stability. Trans. ASAE 47, 1011-1016

Taylor C.C., Kung Jr. L., 2001. The effect of *Lactobacillus buchneri* and other additives on the fermentation and aerobic stability of barley silage. J. Dairy Sci. 84, 1149-1155

Weatherburn M.W., 1967. Phenol-hypochlorite reaction for determinations of ammonia. Anal. Chem. 9, 971-974

Woolford M.K., 1990. A review: The detrimental effects of air on silage. J. Appl. Bacteriol. 68, 101-112