Managing Aerobic Stability in Silages and High Moisture Corn

Patrick C. Hoffman and David K. Combs
Department of Dairy Science, University of Wisconsin-Madison

I. Introduction

Aerobically unstable corn silage and high moisture corn at feedout is a common problem on dairy operations in the upper Midwest region of the United States. Aerobically unstable corn silage and high moisture corn is defined by heating, mold growth, or mustiness occurring a few inches to several feet on the face or surface of the silo during feedout. Surpisingly little research is available that specifically defines negative nutritional effects associated with feeding aerobically unstable corn silage on high moisture corn, but reduced feed intake, milk production, and/or growth are commonly cited. This paper will explore the mechanisms and new tools to manage aerobic stability in corn silage and high moisture corn.

II. Mechanism

While not completely understood, it appears that yeasts are the major culprit associated with aerobic instability of corn silage and high moisture corn (Mahanna, 1991). Corn silage and high moisture corn can have high endemic yeast populations. Species of yeast include the non-fermenting species *Cryptococcus, Rhadotorala*, and *Sporabolomyces*. *Sacchromyces* can ferment sugars, but of greatest concern are the species *Candida* and *Hansenula* which can metabolize lactic acid. The degree or extent of which yeast can metabolize lactic acid is of great concern because high production of lactic acid is presumed to be the goal of silage fermentation. The theorized mechanism of yeast and aerobic instability of corn silage and high moisture corn is as follows:

1. High endemic yeast populations are ensiled.
2. During fermentation, moderate growth of yeast occurs until oxygen is expired in the silage.
3. At feedout, yeasts are re-exposed to oxygen.
4. Yeast growth becomes exponential.
5. Lactic acid is consumed.
6. Heating occurs.
7. Silage acids are volatized.
8. Silage pH rises.
9. Molds with low oxygen requirements (Mucor) invade the silage.
10. Aerobic instability.

The effects of yeast populations on aerobic stability of corn silage were observed by Kung, et al. (1998), and are presented in Figure 1. Kung, et al. define aerobic instability as a 4° F temperature rise. It is clear from Figure 1 that silage containing low yeast populations (10^3 CFU/g) are more stable than silages containing high yeast populations (10^6 CFU/g). In our laboratory, we evaluated (Hoffman and Ocher, 1997) the milk production and feed intake of lactating dairy cows fed aerobically unstable high moisture corn. The feeding protocol was to remove a 14 d supply of high moisture corn and lay it 1 ft deep on a concrete floor and continuously feed it for 14 d. This was compared to removing high moisture corn from the silo daily and feeding it to the cows. Surprisingly, we did not observe a depression in feed intake. In our study, the high moisture corn was included and fed as a total mixed ration which may have masked problems associated with feed intake. We did, however, observe a reduction in milk production over time in the cows fed the aerobically unstable high moisture corn, which is presented in Figure 2. Milk production was related to pH rise, lactic acid decline, and mold count (graphed relationship). Milk production losses were not related to yeast populations because yeast activity was essentially expired after 3 d of exposure to oxygen. It was our conclusion that metabolism of the lactic acid and volatilization of other organic acids reduced the energy content of the high moisture corn, resulting in the chronic loss of milk production. While data are limited, it does, however, appear that yeast populations can have a negative effect on aerobic stability of corn silage and high moisture corn. Likewise, aerobic instability of corn silage and/or high moisture corn can have a serious negative impact on milk production of lactating dairy cows.

III. Managing to Improve Aerobic Stability

1. Proper Silage Making Procedures

This paper will make only brief mention of the importance of proper silage making management practices and their relationship to aerobic stability of corn silage and high moisture corn. It should be remembered that oxygen is the ultimate enemy of the ensiling process because most molds and yeasts are aerobic and require air (oxygen) for growth. Thus any management practice that helps exclude oxygen from the silage or corn mass is helpful. Managing practices, such as harvesting at proper moisture contents, rapid filling, plastic covers, and extensive packing, are all related and necessary to exclude oxygen from the silage which promotes rapid fermentation by anerobic hetero- and homofermentative bacteria, thereby reducing time in which yeast and mold populations can grow during the initial stages of fermentation. The practical aspects of employing all of the best silage management techniques are often challenging and even when perfectly executed, aerobic instability can still sometimes occur. Therefore, using additional management aids may be required to help assure aerobic stability of corn silage and high moisture corn.

2. *Lactobacillus Buchneri*

Lactobacillus buchneri recently has been approved by the FDA for use as an inoculant in grass, corn, legume, and grain silages. This organism has been shown to dramatically improve aerobic stability of silages by inhibiting the growth of yeasts. The net result is that silages inoculated with *L. buchneri* resist heating when exposed to air.

This organism was originally isolated from naturally occurring aerobically stable silages. Is a heterofermentative bacteria that produces lactic and acetic acids during fermentation. Silages treated with an effective dose (10^6 CFU/gram of fresh material) of *L. buchneri* have higher concentrations of acetic acid and lower levels of lactic acid than untreated silages.

Most bacterial silage inoculants produce primarily lactic acid during the fermentation process. The most common lactic acid producing bacteria used in silage inoculants are *Lactobacillus plantarum, L. acidophilus, Pediococcus cervisiae, P. acidilactici,* and *Enteroccus faecium*. These organisms are known to increase the rate of pH decline during fermentation, decrease fermentative losses of DM, and in many cases, improve animal performance. However, silages produced as a result of homofermentative inoculants are often less stable when exposed to air than silages that have not been inoculated. As previously discussed, lactic acid can be readily metabolized by yeasts and molds upon exposure to oxygen. As a result, silages that contain high concentrations of lactic acid may be more susceptible to heating and spoilage once exposed to air.

When applied at the time of ensiling at the rate of 10^6 CFU per gram of fresh material, *L. buchneri* has increased aerobic stability of high moisture corn, corn silage, alfalfa silage, and small grain silages relative to untreated controls (Table 1). The beneficial impact of *L. buchneri* appears to be related to the production of acetic acid. Although the precise mechanism has not yet been determined, it is possible that aerobic stability is improved because acetic acid inhibits growth of yeasts (Driehuis, et al., 1999). It is also possible that the silages are more stable because there is less lactic acid for molds and yeasts to grow on. Yeast and mold counts of *L. buchneri* inoculated silages have generally been reported to be lower at feedout than for untreated control silages (Kung and Ranjit, 2001). Yeast and mold counts in silages inoculated with *L. buchneri* also do not increase as rapidly as in untreated controls when exposed to air. As a result, the temperature of silages inoculated with *L. buchneri* tend to remain similar to ambient temperature for several days, even in warm weather (Taylor, et al., 2000).

L. buchneri most likely would be beneficial under circumstances where problems with aerobic instability are expected. Corn silage, small grain silages, and high moisture corn are more susceptible to spoilage once exposed to air than legume silages and therefore may respond more favorably to inoculation with *L. buchneri* (Muck, 1996). Other factors that decrease aerobic stability are high ambient temperatures, low surface removal rate, and poor feed bunk management. *L. buchneri* is best suited to improve silage quality in circumstances where untreated silages or silages treated with lactic acid-producing bacteria have a history of heating before feedout. It is not likely that *L. buchneri* will improve silage quality in situations where heating and spoilage have not been encountered. In fact, under such circumstances, the potential reduction in dry matter recovery due to the heterolactic fermentation may actually make this organism undesirable as a silage inoculant, relative to homofermentative microorganisms. The increased DM losses in the silo (due to heterofermentative fermentation) must be outweighed by reduced DM losses associated with heating and spoilage during feed out.

It is important to note that acetic acid may reduce feed intake in ruminants. It is not clear at this time whether enough acetic acid is produced in silages treated with *L. buchneri* to affect feed intake. We found in a recently completed lactation trial that feed intake and milk production were similar when cattle were fed total mixed rations containing untreated or *L. buchneri*-inoculated high moisture corn (Figure 3). The corn inoculated with *L. buchneri* had higher concentrations of acetic acid and was more stable than the untreated corn. University of Delaware researchers (Ranjit and Kung, 2000) have also reported that acetate levels were elevated in alfalfa silage and barley silage inoculated with *L. buchneri* compared to untreated controls. Milk production and feed intake were not different when dairy cows were fed TMR's containing either treated or untreated alfalfa silage, or treated or untreated barley silage.

The bottom line is that it appears that *L. buchneri* will improve aerobic stability of ensiled feeds and may significantly reduce feed waste in circumstances where heating and molding of feeds are an ongoing problem. The economic benefit of using this product will depend on how much feed can be saved by reducing losses associated with aerobic instability.

3. Organic Acids

There are two philosophies of organic acid application for control of aerobic stability in corn silage or high moisture corn. The first philosophy is that of full preservation. To effectively preserve corn silage and/or high moisture corn for one year, 10 to 20 lbs (active ingredient) of organic acids are required per ton of corn silage and/or high moisture corn. A second philosophy is to apply organic acids at low rates of 2 to 5 lbs (active ingredient) per ton of corn silage and/or high moisture corn. These low application rates of organic acids are intended to aid in aerobic stability of corn silage and/or high moisture corn at feedout. The theory of this practice is to control yeast populations at feedout time. Normal corn silage and/or high moisture corn fermentation results in the production of lactic acid. At feedout, some yeast species can metabolize lactic acid and cause corn silage and/or high moisture corn to heat and mold. Yeast cannot assimilate propionic acid. Therefore, low application rates of propionic acid stabilize corn silage and/or high moisture corn at feedout by controlling buildup of yeast populations. It should be remembered, however, that low application rates of organic acids do not provide full preservation and high quality corn silage and/or high moisture corn is still dependent on normal fermentation. Therefore, when using low organic acid rates, it is advised to use an inoculant (specifically developed for corn silage and/or high moisture corn) at ensiling time to help insure adequate fermentation of the corn silage and/or high moisture corn. The use of organic acid stabilizers and *L. buchneri* has not been tested and their dual use appears to be illogical because they both seek the same resolution to aerobic instability. Studies comparing normally fermented corn silage and/or high moisture corn to organic acid treated corn silage and/or high moisture corn show no differences in palatability, intake, or animal performance.

4. Anhydrous Ammonia

Addition of anhydrous ammonia to corn silage alters the fermentation of corn silage. Anhydrous ammonia is basic in nature and immediately after application will elevate the pH of corn silage. Afterwards, the pH slowly declines via normal fermentation, but fermentation will not be as extensive as untreated corn silage. Because of a less extensive fermentation, some research has demonstrated a higher DM loss associated with adding anhydrous ammonia to corn silage. Anhydrous ammonia, however, has excellent anti-fungal properties and can effectively reduce yeast and mold populations within the silage. As a result, anhydrous ammonia-treated corn silage often has improved aerobic stability and lower DM losses at feedout. Anhydrous ammonia is applied at 6 to 8 lbs per ton of silage and requires specialized equipment to handle due to its caustic nature. Anhydrous ammonia is not recommended for dry corn silage or high moisture corn because excessive volitalization losses will occur. In an unpublished study in our laboratory, we examined rates on anhydrous ammonia on the cidlal effects of yeast populations. Low application rates of 1 to 5 lbs per ton are not effective in reducing yeast populations. Only the recommended rates of 6 to 8 lbs per ton are effective in reducing and/or eliminating endemic yeast and mold populations in the silage. Despite shortcomings, anhydrous ammonia can be a very effective tool in controlling aerobic stability in corn silage.

Conclusions

Aerobic stability can be a problem in corn silage and high moisture corn even when they are harvested and stored properly. New tools are available to manage aerobic stability and producers and consultants should take a more aggressive management approach to controlling the risk associated with aerobic instability of silages and high moisture corn.

REFERENCES

Driehuis, F., W. J. W. H. Oude Elferink, and S. F. Spoelstra. 1999. Anaerobic lactic acid degradation during ensilage of whole crop maize inoculated with *Lactobacillus buchneri* inhibits yeast growth and improves aerobic stability. J. Appl. Microbiol. 87:583-594.

Hoffman, P. C. and S.M. Ocher. 1997. Quantification of milk yield losses associated with aerobically unstable high moisture corn. J. Dairy Sci. 80(Suppl. 1):234 (Abstr.).

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

Kung, Jr., L. and N. K. Ranjit. 2001. The effect of *Lactobacillus buchneri* and other additives on the fermentation and aerobic stability of barley silage. J. Dairy Sci. 85:1149-1155.

Manhanna, W. C. 1991. Silage fermentation and additive use in North America. NFIA Feed Ingredient Institute.

Muck, R. E. 1996. A lactic acid bacteria strain to improve aerobic stability of silages. *P*. 42-43 *in* U.S. Dairy Forage Res. Center 1996 Res. Summaries. Madison, WI.

Muck, R. E. 2001. Corn silage inoculants that work. *P*. 1 *in* Proceedings of the Forage Teaching and Technology Conference. University of Wisconsin Extension, Madison, WI.

Ranjit, N. K. and L. Kung, Jr. 2000. The effect of *Lactobacillus plantarum* and *L. buchneri* on the fermentation and aerobic stability of corn silage. J. Dairy Sci. 83:526-535.

Taylor, C. C., J. M. Neylon, J. A. Lazartic, J. A. Mills, R. M. Tetreault, A. J. Whither, R. Charley, and L. Kung, Jr. 2000. *Lactobacillus buchneri* and enzymes improves the aerobic stability of high moisture corn. J. Dairy Sci. 83(Suppl. 1):111.

Table 1. The effect of *L. buchneri* on aerobic stability of corn silage (Muck, 2001).

Treatment	Stability, hr[1]
Control	75
Inoculant 1	91
Inoculant 2	71
Inoculant 3	50
L. buchneri 1	217
L. buchneri 2	178
Inoculant + chemical inhibitor	151

1 Time required for corn silage temperature to rise 2° C.

Figure 1. Effect of yeast on aerobic stability of corn silage (Kung et al., 1998)

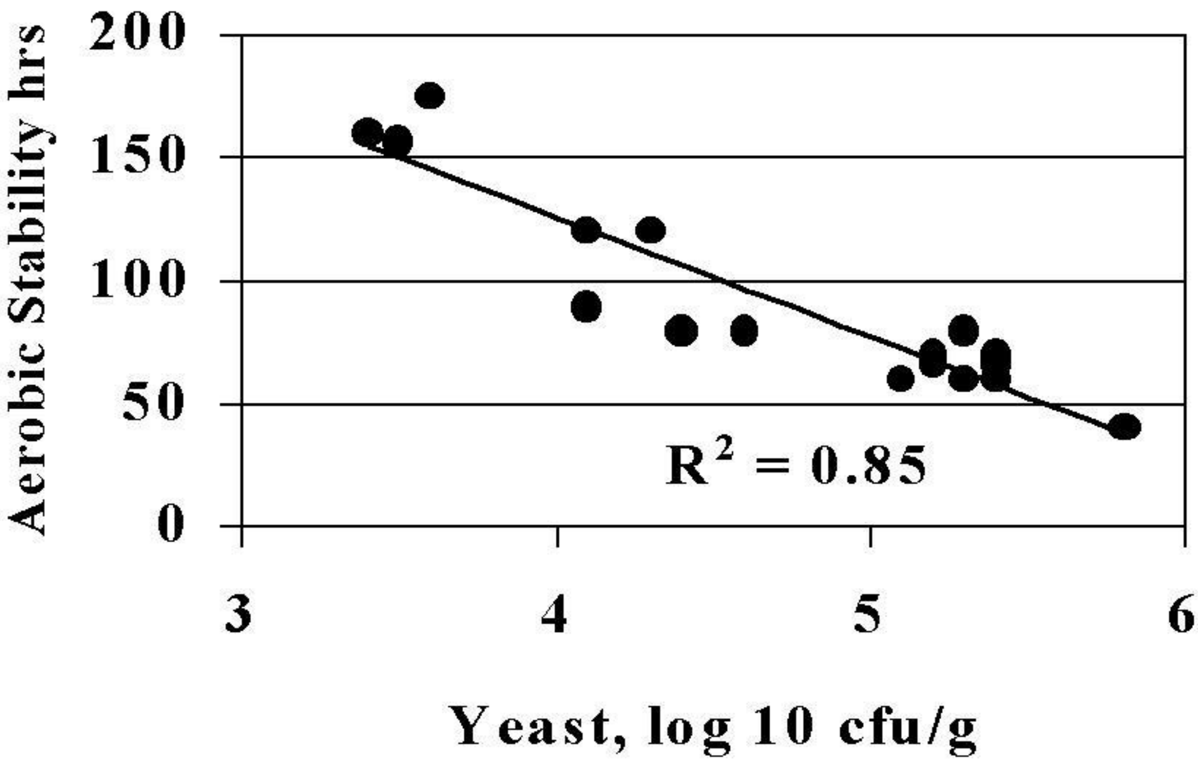

Figure 2. Effect of aerobically unstable high moisture corn on milk yield (Hoffman et al., 1997).

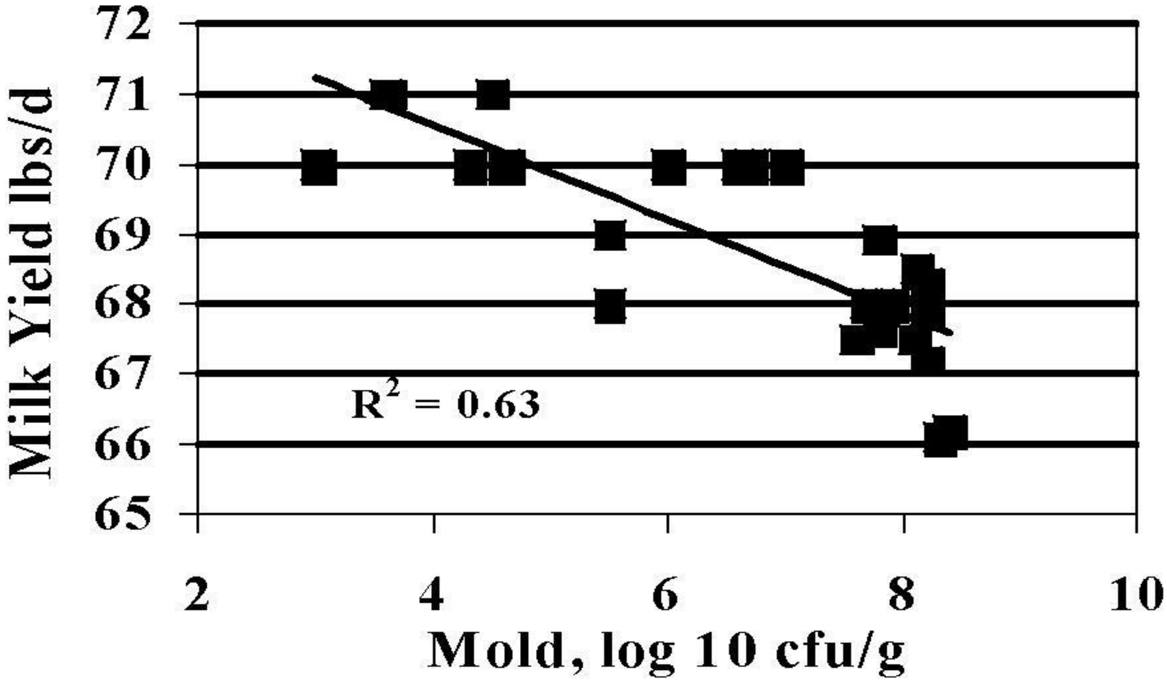

Figure 3. Effects *L. buchneri* and aerobic deterioration of HMC on 3.5% FCM yield (Combs et al., 2001)