Maize silage and the problem of its aerobic stability

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The increasing cultivation of forage maize and its use for silage production have contributed substantially to the high animal performance level achieved in Europe and Northern America. It also offers chances to increase silage production and feed inventories in other countries. The same applies to sorghum which is particularly suitable for warm countries.

Forage maize and sorghum are generally easy to ensile. They always contain much more water soluble and thus fermentable carbohydrates (WSC) in relation to the buffering capacity (BC), and also the epiphytic lactic acid bacteria (LAB) counts are very high in most cases.

Therefore, in comparison to hay-crop silages, no risk of clostridial fermentation exists here. However, the surplus of WSC creates a completely different quality problem when silages are produced from those crops. This problem is caused by proliferation and metabolism of yeasts.

Aerobic instability

During anaerobic storage yeasts will thrive on utilising sugar to produce ethanol. Upon subsequent exposure of silage to air, yeasts switch over to respiratory metabolism and excessive cell multiplication linked with head generation.

Subsequently, lactic acid is degraded so that pH increases, thereby creating environmental conditions which allow other undesirable micro-organisms to develop. Silages made from forage maize, but also those produced from sorghum, tend to be susceptible to aerobic spoilage. The proportion of aerobic unstable silages from these crops is typically high. An example for that is given in Fig. 1.

It is well known that aerobic spoilage of silages is associated with dramatic losses in nutrients (Table 1) and with the deterioration of palatability and hygienic quality of silages as well.

Table 1. DM losses by aerobic deterioration of silages upon exposure to air (Honig and Woolford, 1979).

<table>
<thead>
<tr>
<th>DM content of silage (%)</th>
<th>Temperature rise above ambient °C</th>
<th>5</th>
<th>10'</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>DM losses in % per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td></td>
<td>1.6</td>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>1.2</td>
<td>2.3</td>
<td>3.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>0.7</td>
<td>1.5</td>
<td>2.2</td>
<td>2.2</td>
<td>3.7</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Frequency of aerobically unstable maize silages in Australia (Kaiser and Piltz, 2002).

Preventing spoilage

To avoid the impact of air ingress into silage, or at least to reduce it, is the pre-requisite for any efficient ensiling technology. Suitable technical measures, which lead to improvements regarding this aspect, like better compaction and sealing, are very effective and highly economic.

Even so, the particularly high risk of aerobic instability of silages from sensitive crops remains and measures need to be taken to minimise this risk.

But not all individual silage batches are unstable. Unfortunately, there is no method for reliable prediction of the aerobic stability of a given silage possible as yet.

However, what is well known is the inhibiting effect of high concentrations of undissociated acetic acid on yeasts and its beneficial effect on aerobic stability. Fig. 2 presents the result of an evaluation of numerous experimental data obtained from silages of different crops.

Data clearly demonstrate that silages containing less than 3g/kg FM are mostly unstable, whereas those having more than 8g/kg

Continued on page 13
Continued from page 11

FM of undissociated acetic acid are almost always stable. The undissociated proportion of a weak acid like acetic acid depends on pH. The lower the pH level, the greater the proportion. Consequently, to secure aerobic stability, the two criteria must be met, namely sufficiently high acetic acid content and sufficiently low pH.

In the late 1990s, it could be demonstrated that inoculation of crops with specifically selected strains of the heterofermentative species Lactobacillus buchneri resulted in elevated acetic acid concentrations and higher aerobic stability of silages.

These LAB produce lactic acid during the first stage of fermentation. Part of lactate is formed 1,2-propanediol as a co-product. In the late 1990s, it could be demonstrated that inoculation of crops with specifically selected strains of the heterofermentative species Lactobacillus buchneri resulted in elevated acetic acid concentrations and higher aerobic stability of silages.

The consequence of aerobic deterioration of silages which is most obvious on farms is the potentially dramatic decrease of the animal’s feed intake. Production of aerobically stable silages by the use of biological or chemical silage additives prevents not only additional nutrient and energy losses, but also preserves a good palatability of the silage.

Aphrophsions that inoculation with heterofermentative LAB could lead to a higher acetic acid concentration in silages than is tolerable by cattle are not confirmed by practical experience. At least, the risk of emergence of less palatable silages caused by aerobic deterioration is always much greater than by excessive acetic acid content.

Another problem, which just very recently became obvious, is also associated with volatile fermentation end-products. There have been reports from commercial farms of odd-smelling maize silages which are not taken in well by dairy cows, or silages are even refused. These silages were not treated with additives as the rule.

Analyses of samples taken on farms as well as numerous studies on laboratory scale could shed light on the causal agents. The odd smell was associated with the spontaneous formation of esters from the fermentation products.

The highest concentrations were consistently found for ethyl lactate and ethyl acetate. The content of these esters was mainly influenced by the concentration of ethanol and only to a smaller extent by the concentrations of the organic acids.

The higher ethanol level, the more ethyl esters of the respective acids were found. Therefore, if ester accumulation is to be reduced, then ethanol forming must be lowered and, thus, yeasts development suppressed during the anaerobic storage of silage.

Table 2 summarises the results of a laboratory scale ensiling trial on sorghum, in which the effect of different additive types was studied on ester accumulation.

Although L. buchneri could reduce the levels of ethanol and forming of ethyl lactate if compared with untreated silages and those treated with a homofermentative L. plantarum additive, only the combination of sodium benzoate and potassium sorbate in the tested chemical additive dramatically restricted ethanol fermentation as well as the formation of ethyl esters of lactate and acetate. As a consequence of these new findings it can be stated that yeast should be generally inhibited in making silage from maize and sorghum. When aerobically stable and well palatable silages from maize and sorghum are reliably produced the use of an adapted silage additive is essential.

Table 2. Fermentation pattern of sorghum silage made with different additives (Weiss and Auerbach, 2011).

<table>
<thead>
<tr>
<th>Treatment (DM = 26%)</th>
<th>pH</th>
<th>Lactic acid g/kg DMc</th>
<th>Acetic acid g/kg DMc</th>
<th>Ethanol 1,2-propanediol mg/kg DMc</th>
<th>Ethyl acetate mg/kg DMc</th>
<th>Ethyl lactate mg/kg DMc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>3.8</td>
<td>4.0</td>
<td>2.7</td>
<td>3.4</td>
<td>1.3</td>
<td>120</td>
</tr>
<tr>
<td>L. plantarum</td>
<td>3.8</td>
<td>3.8</td>
<td>2.2</td>
<td>2.9</td>
<td>0.3</td>
<td>123</td>
</tr>
<tr>
<td>L. buchneri</td>
<td>3.8</td>
<td>2.5</td>
<td>4.6</td>
<td>1.8</td>
<td>3.6</td>
<td>128</td>
</tr>
<tr>
<td>Benzate/Sorbate</td>
<td>3.7</td>
<td>2.4</td>
<td>2.8</td>
<td>0.8</td>
<td>1.2</td>
<td>44</td>
</tr>
</tbody>
</table>

Liquid preparation containing sodium benzoate and potassium sorbate DMc = DM corrected for volatile organic compounds

Ensuring good palatability

The consequence of aerobic deterioration of silages which is most obvious on farms is the potentially dramatic decrease of the animal’s feed intake. Production of aerobically stable silages by the use of biological or chemical silage additives prevents not only additional nutrient and energy losses, but also preserves a good palatability of the silage.

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Chemical silage additives based on benzoate and sorbate are even more effective than LAB inoculants.

Fig. 2. Risk of aerobic instability as influenced by acetic acid and pH (Wolthusen et al., 1989).