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.

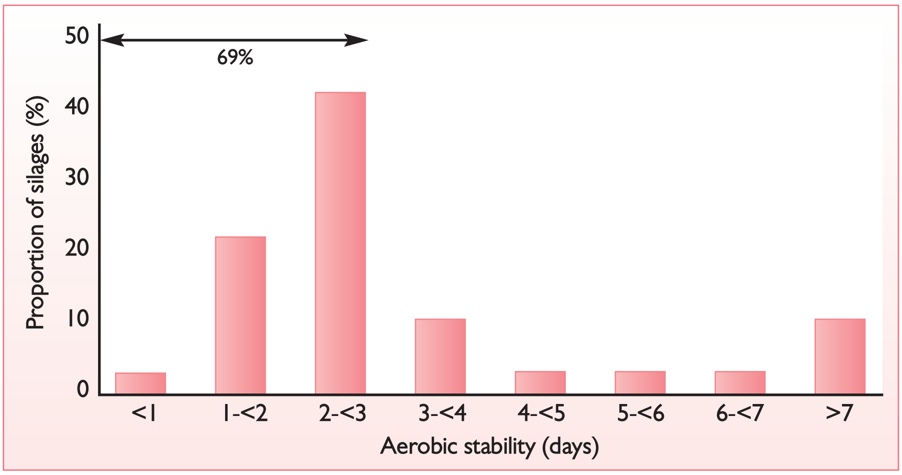

Fig. 1. Frequency of aerobically unstable maize silages in Australia (Kaiser and Piltz, 2002).

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.

During recent years, it was shown that even spores of the obligate anaerobic Clostridia were found at very high numbers in the upper layers of silages which underwent aerobic deterioration.

Nevertheless, yeasts initiate the aerobic spoiling as a consequence of air ingress during silage storage and after silo opening. These processes are well studied and documented.

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

DM content of silage (%)	Temperature rise above ambient (°C) 5	10°	15	20	25
	DM losses in % per day				
20	1.6	3.2			
30	1.2	2.3	3.5		
50	0.7	1.5	2.2	2.2	3.7

The predisposition of silage from maize and sorghum to aerobic deterioration proved to be created by the surplus of fermentable carbohydrates.

Preventing spoilage

To avoid the impact of air ingress into silage, or at least to reduce it, is the pre-requirement 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

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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 subsequently subjected to secondary fermentation and converted into acetate with forming 1,2-propanediol as a co-product. Later on, 1,2-propanediol can be metabolised to propionic acid.

Propionic acid is a more potent fungal inhibitor than acetic acid. The formation of this acid also contributes to stabilising the silage.

During the last few years, different researchers have tested different L. buchneri strains, which were shown to be very efficient in improving aerobic stability. Silage inoculants based on this species of LAB are now used successfully in many countries.

In contrast to hay-crop silages the use of homofermentative inoculants in maize and sorghum is neither necessary nor advisable. Occasionally postulated positive effects have not been consistent, or its magnitude has been marginal. Quite the contrary was observed. Stimulation of homolactic fermentation resulted in significant decreases in aerobic stability of these types of silages.

Nevertheless, the opinions about the best concept of inoculation of silages expressed by silage specialists have been controversial. One point of discussion is the forming of CO_2 during the production of acetic acid by the heterofermentative LAB, which increases the fermentation loss by some extent.

Treatment (DM = 26%)	pH	g/kg DMc				mg/ kg DMc	
		Lactic acid	Acetic acid	Ethanol	1,2-propanediol	Ethyl acetate	Ethyl lactate
Control	3.8	4.0	2.7	3.4	1.3	120	467
L. plantarum	3.8	3.8	2.2	2.9	0.3	123	463
L. buchneri	3.8	2.5	4.6	1.8	3.6	128	237
Benzate/Sorbate*	3.7	2.4	2.8	0.8	1.2	44	195

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

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

But this small additional loss of organic matter is even indirectly advantageous since for each kg of DM that is lost during fermentation, as much as 3kg of DM can be saved during feed-out upon exposure to air, which may otherwise be degraded during the process of aerobic deterioration.

Moreover, the metabolic end products of the heterolactic pathway are not only composed of acetate, but also of compounds like 1,2-propanediol and propionic acid which have higher energy contents per g than the lactic and acetic acids. In this way, the energy value per g of the silage DM is even increased.

Unfortunately, the volatile compounds which are lost during oven drying of silage samples are sometimes not determined and considered in feed evaluation. This, in turn, results in an incorrectly calculated, too low nutritional value of treated silages.

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.

Apprehensions 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 contents.

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.

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).