Spoilage preventing additives in sorghum and maize

Spoilage is one of the most undervalued challenges with silage at farm level. Yeasts and moulds are ubiquitous and the presence of these microbes is usually high enough to generate spoilage.

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The process starts with ingressing air in the stock and a minimum amount of available metabolisable carbohydrate sources. So, mainly high quality and insufficiently compacted silages are susceptible to the phenomena.

A farm screening showed that for Germany, 70% of farms have this problem. Spoiled silages are characterised by heating and mould growth which results in a loss of dry matter (DM), digestibility and feed intake as well as increasing amounts of mycotoxins.

To avoid aerobic instability, silages must be compacted and sealed well, dry matter content should be between 30 and 45% and the feed-out should be as fast as air can penetrate the stock. If not all of these main necessities are covered well, silage additives may help to control the aerobic deterioration. To control spoilage, two main additive groups are best suited: the acetic acid producing hetero fermentative lactic acid bacteria and chemical silage additives.

Parameter	Treatment[1]							SED	P level
	C	LP	LB[1]	LB[2]	LB[3]	LB1 +LP	BS		
DM loss (% DM)	9.0^{c}	8.7^{bc}	8.7^{b}	9.0^{cd}	9.2^{cde}	9.5^{e}	6.1^{a}	0.09	<0.001
Lactic acid[2]	4.03^{b}	3.83^{b}	2.28^{a}	2.46^{a}	1.78^{a}	2.69^{a}	2.44^{a}	0.11	<0.001
Acetic acid[2]	2.73^{a}	2.20^{a}	3.70^{b}	4.55^{c}	5.18^{c}	2.28^{a}	2.79^{a}	0.08	<0.001
Ethanol[2]	3.42^{cd}	2.88^{c}	1.95^{b}	1.83^{b}	1.96^{b}	3.95^{d}	0.78^{a}	0.10	<0.001
1,2-propanediol[2]	1.34^{b}	0.29^{a}	2.47^{c}	3.57^{d}	5.11^{e}	1.22^{b}	1.21^{b}	0.05	<0.001
Ethyl lactate[3]	467^{b}	463^{b}	294^{ab}	237^{a}	193^{a}	453^{b}	195^{a}	51.6	<0.001
Ethyl acetate[3]	120^{b}	123^{b}	119^{b}	128^{b}	106^{ab}	105^{ab}	44^{a}	17.9	<0.05
Total ethyl esters[3]	587^{b}	586^{b}	414^{ab}	365^{ab}	299^{a}	559^{b}	239^{a}	67.5	<0.001

[1]C = Control, LP = L. plantarum DSM 3676/L. plantarum DSM 3677 (50%/50%, 1x10^{5} cfu/g forage; Kofasil LAC), LB[1] - L. buchneri DSM 13573 (1x10^{5} cfu/g forage; Kofasil S), LB2 - L. buchneri DSM 13573 (2.5x10^{5} cfu/g forage), LB3 - L. buchneri DSM 13573 (5x10^{5} cfu/g forage), LP+LB1 (2x10^{5} cfu/g forage; Kofasil Duo) and BS – 500 g/t sodium benzoate+300 g/t potassium sorbate (applied in 2l/t aqueous solution; Kofasil Stabil); [2]% of DM; [3]mg/kg DM; means in columns with different superscripts differ significantly.

Table 2. Effects of silage additives on DM losses, fermentation pattern, volatile organic compounds and aerobic stability of sorghum silage.

Table 1. Effects of inoculants on DM losses, fermentation pattern and aerobic stability of sorghum silage.

Parameter	Treatment[1]				SED	P level
	Control	LP	LB	LP+LB		
DM loss (% DM)	6.3^{a}	6.8^{b}	7.5^{c}	7.4^{c}	0.11	<0.001
pH	3.78^{b}	3.76^{ab}	3.75^{a}	3.78^{b}	0.01	<0.01
NH_3-N (% total N)	7.7^{b}	7.5^{b}	6.7^{a}	6.5^{a}	0.18	<0.001
Lactic acid (% of DM)	4.63^{b}	5.27^{c}	4.20^{ab}	3.91^{a}	0.20	<0.001
Acetic acid (% of DM)	1.33^{a}	1.28^{a}	2.73^{b}	2.91^{b}	0.07	<0.001
Ethanol (% of DM)	0.83^{b}	1.33c	0.43^{a}	0.40^{a}	0.06	<0.001
1,2-propanediol (% of DM)	0.13^{a}	0^{a}	3.81^{c}	4.26^{d}	0.10	<0.001
ASTA[2] (hours)	101^{a}	83^{a}	168^{b}	168^{b}	11.48	<0.001
ASTA[3] (hours)	199^{a}	194^{a}	336^{b}	336^{b}	3.13	<0.001

[1]LP = Lactobacillus plantarum (Kofasil LAC), LB = Lactobacillus buchneri (Kofasil S), LP+LB (Kofasil DUO);
[2]Aerobic stability (ASTA) measured after air stress and 57 days of fermentation for 168 hours;
[3]ASTA measured after 98 days of fermentation for 336 hours; means in columns with different superscripts differ significantly.

Addcon has carried out numerous experiments to obtain knowledge about the different ways to control aerobic stability.

Plant material and additives

Sorghum (Sorghum sudanense, Sorghum bicolor) is considered an easily ensilable plant. That results from a sufficient DM content (280-350g/kg), an uncritical buffering capacity (BC) (30-35g LA/kg DM) and a quite high amount of sugar (S) (100-85g/kg DM).

The S/BC ratio is thus around 3-6 and the fermentation coefficient (FC = DM (%) + (8xS/BC)) is 50-80. Crops like silage maize or sorghum that are characterised by an FC >45 are best suited for ensiling. But crops that are easy to ferment tend to be aerobically instable.

In the case of sorghum and maize, we tested the effect of different inoculants. Beside the controls (no additive, only fresh water added), the following treatments were included: LP - Lactobacillus plantarum DSM 3676/L. plantarum DSM 3677 (50%/50%, 1x10^{5} cfu/g forage; Kofasil LAC); LB - Lactobacillus buchneri DSM 13573 (1x10^{5}

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cfu/g forage; Kofasil S); LP+LB (2x10^{5} cfu/g forage 50%/50%; Kofasil Duo), all diluted in tap water and applied at 10 ml/kg fresh plant material.

As chemical silage additives we used salts of benzoic, sorbic and propionic acids in a range between 2-4 litres/t.

Methods of analysis

The harvested crops and silages were analysed chemically using routine methods of the LUFA standards for feed evaluation, Germany. The DM content of the silages was measured and corrected for the loss of volatiles during drying according to Weissbach and Strubelt (2008).

Determination of pH was done potentiometrically using a calibrated pH electrode. Lactic acid was analysed by HPLC; volatile fatty acids, alcohols and volatile organic compounds (VOC) were determined by gas chromatography as described by Weiss (2001).

Losses of DM during fermentation were calculated according to Weissbach (2005). The aerobic stability was measured at the end of strict aerobic storage as well as after one or two 24 hours air stress challenges during storage and at the end of storage using the temperature method described by Honig (1990).

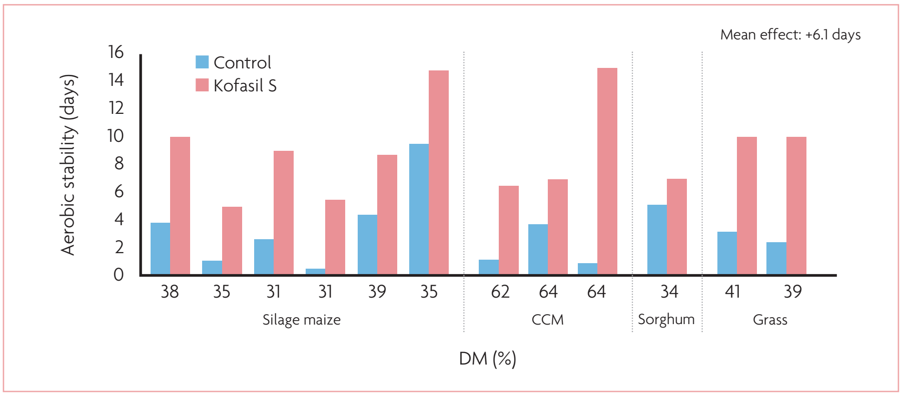

Fig. 1. Effect of Kofasil S (L. buchneri DSM 13573) on aerobic stability of different silages (Spiekers 2001, Hertwig 2001, Pflaum 2003, Chamber of agriculture Lower-Saxonia 2007-2010, Humboldt-University Berlin 2008, McGill University Montreal 2007).

Results and discussion

Since Driehuis et al. 1999 we know the effects of Lactobacillus buchneri on the aerobic stability of silages. The acetic acid formed by the post fermentation of lactic acid is mainly responsible for restricting the growth of yeasts and moulds.

Silage inoculated with Lactobacillus buchneri, alone or in combination with Lactobacillus plantarum, improved the aerobic stability in all cases (see Table 1). This improvement comes from the elevated content of acetic acid. Typically, with L. buchneri, the amount of 1,2 propanediol is increased. Due to the different possible origins of acetic acid, 1,2 propanediol may help to explain L. buchneri as the source and may help to predict the effect of acetic acid on feed intake.

As acetic acid enhances the aerobic stability, its increase is often discussed in the context of decreased feed intake.

However, results from Hutchinson and Wilkins (1971) raised the possibility that not acetic acid but some byproducts, such as those of enterobacterial fermentation, may disturb feed intake. If Lactobacillus buchneri is used in silage, feed intake seems to be unaffected. Furthermore, DM intake is reduced by heating and can then be improved by acetic acid in silages.

An obvious side effect of L. buchneri is the increase of DM losses during fermentation. Table 2 shows that with an increasing inoculant density of L. buchneri, this not only increases the DM losses slightly, but also acetic acid and the aerobic stability (data not shown).

If we take into account the DM losses by heating (a temperature increase of 10-15°C leads to DM loss of 2-4%) the overall effect of L. buchneri is more than positive and its stabilising effect is well documented (Fig. 1).

However, application of sodium benzoate and potassium sorbate (BS) always resulted in the lowest losses (Table 2).

With high contents of easy fermentable carbohydrates and in the presence of yeasts the fermentation of alcohol may increase. High alcohol contents are also well known in sorghum silage. In the late 1990s, farmers in Germany reported increasing chemical smells within silages.

Now, we know that alcohol and fermentation acids form esters which cause this smell. More than 500 experiments with different crops were reanalysed by Weiß (2012). If reasonable amounts of alcohol were detected, esters were also present. Ester concentrations are strongly positively correlated with the ethanol content.

The effect of ester formation is especially obvious in well compacted and sealed silages.

This VOC may detrimentally affect feed intake by dairy cattle.

As sorghum represents an important forage source for ruminants in warm climates, and its production often carries the risk of excessive ethanol fermentation, high concentrations of these VOC are also to be expected in sorghum silage.

Weiß (2011) showed that L. buchneri, at different inoculation rates, reduced ethanol in sorghum silages (Table 2). The use of L. plantarum alone or in combination with L. buchneri did not affect ethanol when compared with control silages.

Application of L. buchneri (regardless of inoculation rate) and benzoate/sorbate caused the lowest ester contents (ethyl lactate and ethyl acetate).

No differences were found between the control, L. plantarum and the combination of L. plantarum and L. buchneri (Table 2).

These observations are in line with the results of Tobacco et al. (2009) and Thomas et al. (2013). The combination of sodium benzoate and potassium sorbate showed the lowest VOC in whole-crop maize silages and outperformed other chemical silage additives, such as mixtures of formic and propionic acids and their sodium salts.

In the case of ethanol, ester and aerobic stability chemical additives seem to be more effective. This might be explained by the time lag in fermentation.

The LAB must first adapt, grow and only later will the fermented acids reach the necessary concentrations. Therefore LAB are also not a viable option if the silo is closed for less than eight weeks.

If, furthermore, difficult environmental conditions for the LAB, like high DM contents or bad compaction (more air in the silo) and for the treatment of the upper layers, which are particularly prone to deterioration due to lower compaction, the L. buchneri effect is shortened.

In these cases, antimycotic chemicals must be applied, of which sorbates and benzoates are the most efficient against fungi, while propionates are somewhat less so.

Experiments done in cooperation with the Humboldt-University Berlin, Germany, show the stronger effect of benzoate and sorbate on aerobic stability compared to propionate (Table 3).

However, as chemical silage additives may differ in composition and application rates, it is difficult to clarify their efficacy.

The work of Nadeau (2013), aimed at investigating the effects of two chemical additives and varying application rates on whole crop maize silage traits like aerobic stability, showed with increasing amounts of the chemicals used, aerobic stability was also improved.

In the case of parameters important to fermentation quality, like ammonium nitrogen (as % of total nitrogen) the nitrite, benzoate and sorbate-containing additive tend to be better suited.

However, to improve aerobic stability,

	Control	KS		KG pH5	PA
		1l/t	2l/t	3l/t	4l/t (95%)
DM (%)	33.1	33.7	33.9	32.5	34.1
pH	3.7	3.7	3.6	3.7	3.7
Lactic acid (%)	4.67	515	6.24	5.51	4.45
Acetic acid (%)	1.00	1.06	1.22	0.85	0.84
Propionic acid (%)	0	0	0	0.34	0.95
Ethanol (%)	1.42	1.06	0.71	1.25	0.45
Aerobic stability (days)	18	28	28	25	15

Kofasil Stabil (KS) 1 = 483, Kofasil Stabil (KS) 2 = 966, Kofa Grain (KG) = 1140, Propionic acid (PA) = 1900.

Table 3. Effect of additives on fermentation pattern and aerobic stability of silage maize after 28 days fermentation (Humboldt-University Berlin 2010).

sodium benzoate and potassium sorbate in appropriate compositions are more effective.

In contrast to propionate, sorbate and benzoate differ quite strongly in their impact on spoilage microbes and so on aerobic stability (Table 3).

Conclusion

High quality and high sugar containing silages tend to spoil easily. When problems arise, management techniques like compaction, sealing, speed of feed-out should be checked first and if necessary improved. Silage additives can also help to overcome spoilage.

Effective and economic control of aerobic stability is possible using Lactobacillus buchneri, but the silage has to be closed for more than six weeks. The ester phenomena also seem to be controllable.

If ensiling is accompanied by agro-technical and environmental deficiencies or ethanol fermentation followed by ester formation is dominant, then chemical additives like benzoate and sorbate are much more secure options than the use of lactic acid bacteria. ■