The reduction of volatile organic compounds in silages using inoculants

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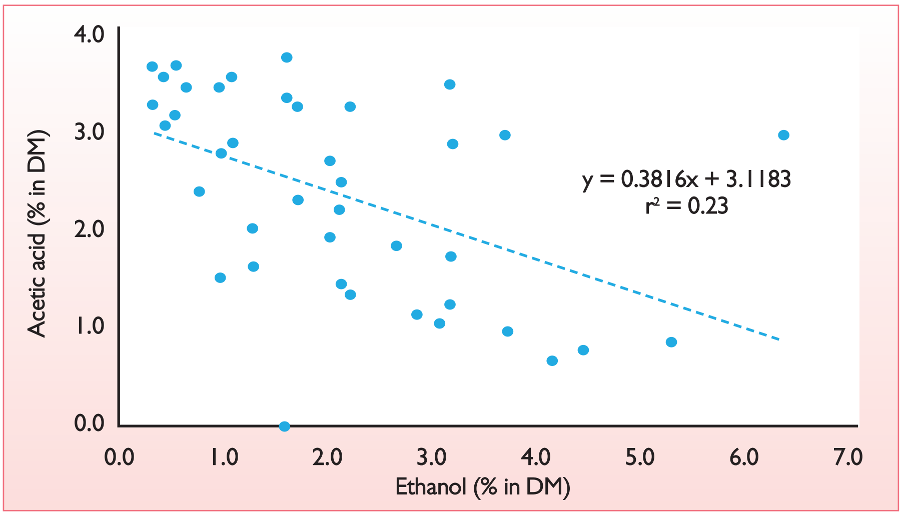

Fig. 1. Relationship between acetic acid and ethanol in corn silages.

Volatile organic compounds (VOCs) are emitted as gas from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short and long term adverse health effects, which evaporate relatively easily.

Regulations in different countries define VOCs as substances with a boiling point of up to 250°C. Of course, their concentration in the air is much higher indoors than outdoors.

Many studies about the dangerous effects on human health and the environment have been carried out in the past. VOCs surround us. Normally they do not act acutely but long term. They are considered to be air pollutants and often symptoms like allergies, respiratory diseases, irritation, immune depression, nausea, and many others, have been reported. An example is the high level of ozone in Central California, USA which is caused by the reaction between VOCs and nitrogen oxides in the presence of sunlight, which leads to new ozone standards.

Research in animal production has been focusing on VOC emissions from agricultural sources and its impact on, for example, feed intake. The impact on animal health has been less investigated due to the obvious difficulties regarding an adequate trial design.

However, more research is needed in this area as high yield animals are kept indoors most of the time and air quality could be a limiting factor to achieving optimal performance.

Production of VOCs

VOCs are mainly produced by plants, as well as animals and micro-organisms. In order to reduce the production of VOCs it is important to monitor their concentrations and correlate them with other physical factors such as temperature, sunlight and decomposition of organic matter.

The reduction of ozone contamination, for example, was more effective in urban areas than in rural areas, because in urban areas the VOCs are a limiting factor, whereas in rural areas it is the opposite.

Over the last year the scientific community has been paying more and more attention to silage as a source of VOCs. Silages are considered to produce more than 700 substances which are potentially dangerous for the formation of ozone. One of the major problems is the countless possible combinations of factors which can contribute to an increased production of VOCs.

As explained before, the term 'VOCs' is a common term for thousands of substances which could represent a potential damage and this fact leaves us with very costly quantitative analysis.

There are several sources of VOCs in dairy production: crops, feed production, preserved feed through fermentation, in silos, due to decomposition of organic material, during digestion, oxidation lagoons, manure, etc. Several VOCs have been identified in silages including:

- Isoprene (C_5H_8).
- Monoterpenes ($C_{10}H_{16}$).
- Oxygenated VOC.
- Sesquiterpenes ($C_{15}H_{24}$).
- Alcohol (ethanol, methanol, propanol, butanol).
- Esters (hexyl-, butyl-, propyl-, methyl- and ethyl- acetate; propyl-, ethyl- propionate; butyl-, propyl-, ethyl- butyrate; propyl-, ethyl- hexanoate).
- Aldehydes.
- Ketones.
- Carbonyl compound emissions.

However, the identification of those VOCs of major significance in silage production, as indicators of pollution from a practical point of view, is a must.

Researchers mainly discovered emissions of alcohols (mainly ethanol), volatile fatty acids, esters and aldehydes. Even when ethanol has not had a major effect as a VOC, the amounts produced in unstable silages can be relatively high (8-10% in DM in silages with aerobic instability). Other dangerous substances were also found, such as alkenes, alkynes and esters as the majority of VOCs in silages.

Ethanol emission rate is affected by several factors in the silage. Ethanol is the main product of yeast metabolism and represents a fermentation process in which approximately 40% of the energy is lost.

Good agricultural practices (right harvest time, good compaction, proper silo sealing using sheets with low permeability, sufficient weights on the silo covering, adequate silo design, adequate advance in the silo in the feed out phase (which decreases the exposed silage layer), certain levels of acetic acid, clean-cut surface) should diminish the presence of ethanol in the silage. High con-

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tribution to total ozone formation from different types of silages (corn, alfalfa, cereal) has been associated with the alcohol content, especially ethanol, which is considered a dominant silage VOC.

Focus on reduction of VOCs

The reduction of ethanol from silages is a major issue, not only for the reduction of an important source of VOCs but also to increase the profitability of a farm. As discussed before, the secondary fermentation by yeasts and formation of ethanol causes enormous losses due to aerobic instability in the silage.

Therefore, not due to its qualitative importance as a VOC, which is relatively low, but because of the huge quantities of ethanol produced, this should be focused on more in the silage production and use process.

An estimation of ethanol production from silages in Western Europe, based on the silage production (500 million tons), 30% of DM and an ethanol content of 1% (in unstable silages this quantity is higher) amounts to 1.5 million tons of ethanol per year.

Ethanol emission depends on exposure time, ambient temperature and air velocity. Another important factor is the porosity of the silages, whose density and structure was disrupted, resulting in a lower density and higher porosity, as occurred in the feed out phase. As discussed before, the amount of VOCs is higher indoors than outdoors. This would mean that when unstable silage is brought to the stable it would be more dangerous for animal health because of the duration of exposure at increased rates. Even when the evidence is not fully corroborated, and mostly in animal bioassays, it is considered that many organic compounds are associated with or suspected to cause cancer in animals.

Many VOCs are identified as carcinogenic substances in humans, therefore there is also a risk to animals.

The interaction between different VOCs can increase the risk for animals which have a longer productive cycle, for instance, dairy cows. There is evidence regarding high correlations between esters and ethanol found in corn silages (r^2 = 0.52 and 0.78 for ethyl acetate and ethyl lactate x ethanol respectively). It is perfectly viable that other VOCs can be also correlated or come in contact with those from silages in the stable.

Table 1. Effect of acetic acid on different yeasts.

- **Saccharomyces rouxii and Torulopsis versatilis.** Acetic acid has an increased toxic effect on yeasts in brine fermentation of soy sauce from pH 5.5 to 3.5 (Noda et al. 1982).

- **Candida krusei and Pichia sub-pelliculosa.** Acetic acid has the greatest inhibitory effect on yeast growth. 20g litre^{-1} of acetic acid in the test mixture was enough to completely inhibit the growth of the selected yeasts at pH 4 (Danner et al. 2003).

- **Silage yeasts.** High levels of formic or acetic acid reduce survival of yeasts during storage (in silages) (Driehuis and van Wikselaar Oude 1996, Elferink et al. 1999).

- **Silage yeasts.** Lactic acid is degraded anaerobically to acetic acid and 1,2-propanediol, which in turn causes a significant reduction in yeast numbers (Driehuis et al. 1997, Oude Elferink et al. 1999).

Silage inoculants

Meanwhile, the use of silage inoculants is a common practice in silage production. Homolactic lactic acid bacteria (LAB) are used as fermentation enhancers, whereas heterolactic LAB are mainly included for preventing aerobic instability in the feed out phase. Alcohol (ethanol) is produced primarily by yeast in that phase. It is already very well known and documented that acetic acid from heterolactic LAB inhibits the growth of yeast under aerobic conditions (Table 1).

In some studies the correlation coefficient between ethanol and acetic acid was negative, middle-low, however, highly significant (r^2 = -0.23). This relationship is shown in Fig. 1 on the previous page.

Even though acetic acid is also considered a VOC, its use shows many advantages which are described throughout scientific literature. Its use is therefore supported by a cost – benefit relationship.

Conclusions

As discussed above, interest in the research on VOCs as air pollutants and their negative effects on human health is increasing.

Silages are an important source of VOCs in animal production. Alcohols, especially ethanol, are major VOCs in silages.

Ethanol emissions from silages on farms are increased by silage characteristics (type of silage, compacting, covering), ambient conditions (higher temperatures, increased air velocity, elongated time of silage exposure) and management practices.

The prevention of ethanol formation is based on the inhibition of yeasts in the feed out phase of the silos. For this purpose, the use of heterolactic LAB is a good ensiling practice to increase the acetic acid content of the silage. ■

References are available from the author on request