Reducing losses during storage and unloading of silage

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Introduction

Reducing losses during storage and unloading is the task of ensiling technology.

To meet this demand, it has to create favourable conditions for the ensiling process, and to avoid all negative effects, which might occur throughout the storage period. To this effect two main areas have to be covered:

Firstly: To judge the forage according to its substrate conditions and ensilability, and, if necessary, to take measures to improve it.

Secondly: To provide suitable storage conditions and ensure them until feedout.

Both items are also dealt with or mentioned as requirement in other papers of this conference. Now they shall be commented on from the point of view of in silo losses.

Improving ensilability.

Bad ensilability of the crop can be improved or compensated by ensiling technology mainly in four ways:

- Reducing water content by wilting
- Increasing homogeneity and substrate availability by chopping or laceration
- Use of additives
- Increasing insufficent epiphytic population of lactic acid bacteria by adding LAB-inoculants.

Without going into the "Why's", it has to be stated, that wilting is one of the most effective measures, to reduce in silo losses, as repeatedly reported and only a few years ago demonstrated on a very wide basis in the "Eurowilt" experiments (Fig 1; Zimmer and Wilkins, 1984).

How to minimize the risks incorporated with it, by a highly effective field treatment, has been shown impressively by Bosma, 1991.

In cases where the crop does not permit wilting or it is not possible for macro- or micro-climatical reasons, the use of absorbants helps effectively to reduce effluent losses. It has been discussed in more detail by Offer et al., 1991. The effect on losses is, e.g. proved by a Volkmendorf experiment. The application at ensiling of the same amount of dried sugar beet pulp, as normally used in the ration, saved 7% (Tab. 1). The net energy recovery was even improved by 10% (Honig et al., 1988).

![Figure 1: In-silo losses affected by DM content](image1)

![Figure 2: Chopping length and fermentation quality](image2)

![Table 1: Reduction of DM losses by use of absorbants in high moisture silage](table1)

The lacerating effect of flail harvesters, aggressive conditioners or the new matting system acts in the same direction.

Regarding this pronounced effect of a very short chop efforts should be made to put it into practise at reasonable costs.
The task of ensiling technique with respect to the use of silage aids is to secure an adequate even distribution. It is acknowledged that this can only be achieved by a suitable applicator attached to the harvesting machine, or a conveyor. Extensive Dutch investigations proved that the application on a forage chopper brings the best results. Dose rates have to be increased by 50% to get the same effect on any type of forage wagon with respect to homogeneous distribution as well as for fermentation results (Corporaal et al., 1989).

Critical points for additive application which need further attention are:

- application on unchopped forage as with loading wagon or baler
- flow adapted dosage of the additive, and, may be,
- dosage adapted to DM content.

The microbiological status of the forage is of great importance for satisfying fermentation as mentioned by Pahlow, 1991. So the monitoring of this status either directly or on a regional basis is the precondition for aimed use of LAB inoculants to secure optimum fermentation and avoid any risks. The necessity for inoculation e.g. became evident in both last spring seasons in the Braunschweig region, so that there was a pronounced effect to be observed by the LAB treatment (Fig. 3).

![Fig. 3: LAB inoculation and fermentation quality](image)

The fermentation was turned from mainly ethanol to lactic acid and the losses were reduced by 4% points (Honig and Dyckmans, 1990).

The development of a rapid test for epiphytic LAB or a permanent regional observation service for this matter could be targets for future research.

Storage and unloading

The provision and maintenance of anaerobic storage conditions is the main task of ensiling technology, as mineralisation due to air infiltration is the predominant source of losses, which may occur during all phases of silage conservation:

Filling, storage and feed out.

Filling

Ongoing plant respiration while filling the silo leads to losses caused by complete substrate degradation to CO₂ and water, as long as oxygen is available (Fig. 4).

![Fig. 4: DM losses after delayed sealing](image)

The oxygen trapped in the forage, only accounts for a negligible part of the mineralisation, as is shown by the loss values for the first three days without air influence. The greater amount of air is supplied by ongoing gas exchange. Respiration from plants and microorganisms will last as long as oxygen is supplied, as is clearly shown by the loss increase for 1 day and 3 days air influence (Wyss et al., 1991b).

Besides this, yeasts will have a chance to develop in presence of oxygen to levels which will cause problems at feed out (Fig. 5).

![Fig. 5: Lactate assimilating yeasts after delayed sealing](image)

Every measure to speed up the filling process will reduce these losses. So it is mainly a matter of management to keep the losses low - like provision of sufficient labour force, the adaption of the area harvested to silo size and to the working capacity.
Also the use of acid additives directly lowering the pH-value will reduce these respiration losses by killing plants and reducing microbial population.

If unavoidable interruptions or protractions delay the finishing of the silo, an intermediate seal is advisable.

![Diagram of Bunker silo, 30 cm below cover](image)

**Fig. 6:** O₂ concentration with and without intermediate cover

Figure 6 illustrates the effect on the oxygen concentration in the top forage layer during one night. Sealing the front half of the silo reduced oxygen concentration to zero, whereas its concentration did not change in the uncovered half, thus causing additional temperature rise and losses (Honig, 1987b).

**Information and education** are the main remedy against this type of losses, and, may be, some more detailed quantification by model calculation. This aspect will need growing attention to improve conservation technology in future.

**Storage**

In the storage phase - in addition to the unavoidable fermentation losses, mainly controlled by substrate parameters, - air infiltration is a markable source of losses. Aeration losses often may exceed those due to fermentation (McGechan, 1990).

In this context the following matters have to be observed:

- The motive forces for air infiltration
- Factors influencing its intensity, such as leakages and resistance of the forage to gas flow
- Practical measures to reduce gas flow, such as consolidation and sealing.

**Motive forces** of the gas exchange leading to air infiltration are diffusion and gas flow due to pressure differences between the fermentation gas and the ambient atmosphere.

The **diffusion** relies on concentration differences between the inner and the outer and is influenced by the permeability of the silo walls, the sealing cover and the permeability of the forage itself. Weise et al., 1975, showed this very clearly.

The **gas flow** due to pressure differences is primarily caused by the difference in the specific weight between CO₂ and air. It is modified by the CO₂ concentration and temperature. Flow intensity again depends on the permeability of or leakages in the silo wall and cover and the resistance against gas flow in the forage.

Both forces will always be active in silos, and both have been used for modelling the gas exchange processes. The pressure difference model was able to explain the gas flow pattern more satisfactorily in a comparison by McGechan, 1989, 1991.

A third special situation is given in **hermetic silo systems**, where gas exchange is caused by gas volume changes in the silo due to barometric pressure and temperature changes.

The **validity of the gas flow hypothesis** is clearly demonstrated by the Völkenrode pilot plant experiments (Honig and Zimmer, 1985, Honig, 1987a), which also point at the most relevant factors for the extent of gas exchange: leakages or permeability of silo wall and cover and consolidation of the forage. (Fig. 7)

![Graph of DM (CO₂) losses and silo technology](image)

**Fig. 7:** DM (CO₂) losses and silo technology

The losses are nearly the same for a gastight silo and for one with conventional sheet cover. They start rising - and creating "surface waste" - if there is a leak, especially in the bottom part of the silo, allowing CO₂ to escape. The increase of forage resistance to gas flow by better consolidation (curve 4) reduces the losses markedly.

Factors influencing the resistance of the forage against gas flow have been investigated by Parsons and Hoxey, 1988, Bosma, 1984, Honig, 1987.
The consolidation in tower silos is reached by the forage weight itself. Provided the silo body is tight, the reached density is of minor importance for gas exchange. Most vulnerable is the surface layer, as it is least consolidated. All technical systems to overcome this in top unloading silos by application of additional weight, as waterbags, concrete covers etc., have shown very positive effects on fermentation but proved to be too impractical and expensive. Some improvement has been achieved by using special top unloaders, for the distribution of the forage and some consolidation during filling.

In horizontal silos active consolidation by tractors or shuffle loaders is necessary.

The forage characteristics to ease consolidation are:

- young, low fibre material, short chopping length, and laceration as after flail harvesting, intensive conditioning or matting.

They become the more important the higher DM contents are reached in the crop.

A very important item, when asking for a short, precise chop, is the permanent care for sharp and precisely set knives. Fechner et al., 1988, determined a doubling of medium chopping length comparing blunt to sharp, well set knives. In addition the energy consumption is increased by 10 to 20%.

The rolling practices are more or less empirical till now, defining the necessary rolling capacity by tractor weight/DMh, or number of rollings or rolling time/DM. Taking up former work on dynamic consolidation by Müller, 1970, Bosma, 1990 Dernedde, 1990, a systematic investigation has been started in Kiel, (Lau, 1990) to differentiate the factors influencing the rolling effect using model bunker silos.

### Table 2: Necessary consolidation ranges to reach an acceptable low gas flow level

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<th>DM density range kg/m³</th>
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<td>150...500</td>
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<td>150...500</td>
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### Table 3: Tractor effects on rolling efficiency

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<tr>
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<th>Pressure at rolling bar N</th>
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<td>2</td>
<td>90</td>
</tr>
<tr>
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<td>2</td>
<td>2</td>
<td>160</td>
</tr>
<tr>
<td>4500 kg twin tire</td>
<td>2</td>
<td>1</td>
<td>90</td>
</tr>
<tr>
<td>Speed</td>
<td>4500 kg single tire</td>
<td>4</td>
<td>160</td>
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Good sealing in lower silos means mainly optimum tightness of the walls and doors, especially in the lower part of the structure, to avoid gas flow. The proportion of surface to be covered until feed out is relatively small.

In oxygen limiting steel silos a compensation volume of about 7% of the total silo volume is necessary, to prevent excessive air ingress by "breathing" (Jiang et al., 1989).

In bunker silos the surface to be covered is large in relation to the silo content, therefore the quality of the cover is of deciding importance, as is proved as well by the posters by Kaiser, 1991, and by Dickerson, 1991, stating the huge amount of losses up to total spoilage if no cover is used.

The common, well established procedure is the use of PE-Film as cover.

The basic demands of sufficient impermeability for oxygen and mechanical stability are fulfilled at 0.15 to 0.2 mm thickness.

This value has also resulted from a model calculation by Savoie, 1988, setting costs for the sheet against the value of the losses.

A further demand is the UV resistance of the film. This has to be guaranteed by the supplier.

The colour of the film is of minor importance, as the foil normally should be weighted and covered to fix it best possible to the stack.

A problem still not fully solved is the connection of the cover to the wall of bunker silos.

Therefore normally the highest losses occur at the "shoulder" of the silo, degressing downward and to the center. The amount varies strongly with the quality of the connection to the wall. Best results are achieved by putting an additional film 1 to 2m deep between wall and forage, and then over the forage, before the main sheet is attached.

In clamp or pit silos the use of a ground sheet is inevitably necessary, if they are set up on sandy soil of high permeability. Table 4 shows the enormous increase of surface losses, due to permanent gas flow off into the soil, where the sheet is missing (Pedersen et al., 1976).

Experimental pit silos, cover PE sheet + sand
Source: Pedersen

<table>
<thead>
<tr>
<th>Bottom</th>
<th>Fermentation loss %</th>
<th>Surface loss %</th>
</tr>
</thead>
<tbody>
<tr>
<td>with PE sheet</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>without PE sheet</td>
<td>4</td>
<td>36</td>
</tr>
</tbody>
</table>

Table 4: Bottom permeability and DM loss

From all systems of bale ensiling the wrap system for round bales gives the most promising results, as a very tight enclosure of the forage is achieved, reducing gas exchange and, if punctures occur, restricting the spoilage to the direct surrounding of the holes. The different consolidation pattern in the bales from the different baler types, does not greatly affect the losses (Tab. 5), neither with the tight nor with a punctured film (Wyss et al. 1991a).

<table>
<thead>
<tr>
<th>Film</th>
<th>fixed chamber</th>
<th>Baler type</th>
<th>variable chamber A</th>
<th>variable chamber B</th>
</tr>
</thead>
<tbody>
<tr>
<td>tight</td>
<td>10.0</td>
<td>8.8</td>
<td>9.4</td>
<td></td>
</tr>
<tr>
<td>with 2 holes</td>
<td>11.5</td>
<td>13.8</td>
<td>11.8</td>
<td></td>
</tr>
</tbody>
</table>

A = wide core; B = narrow core

Table 5: DM losses (%) in wrapped bale silage

Unload

Losses during unloading depend on the aerobic stability of the silage and the exposure time to air, which may initiate new deterioration.

High aerobic stability is reached by a good ensiling technique as discussed before, achieving intensive, fast acidification and avoiding critical yeast development. A risk is involved even at optimum air exclusion at all stages of storage, if the pH value has not been lowered satisfactorily, e.g. due to insufficient LAB population. In such cases the high availability of residual nutrients may increase the intensity of deterioration.

Specific chemical and also microbiological additives can increase the aerobic stability. A promising result was achieved last year by using an inoculant containing propionic acid producing bacteria in addition to LAB (Fig. 9). Due to faster acidification this silage was stabilized even earlier than by sorbate (Wyss et al. 1991b).

Fig. 9: Additive effect on aerobic stability

The air ingress into the silo face depends again on the density of the forage. So a good consolidation of the forage is also of great importance to reduce the risk of aerobic deterioration.
To maintain this consolidation state also during feedout and avoid any loosening of the remaining silage is the demand to a satisfactory unloading technique (Fig. 10).

![Graph showing CO2 concentration before unloading](image)

Fig. 10: Intensity of secondary fermentation when unloading a trench silo in different ways

Otherwise air could penetrate more deeply into the forage, and would increase the risk of deterioration, as is shown on the diagram. The development of unloading machinery has fulfilled this aim to a great extent.

Whereas block cutters allow storage of the forage blocks for several days, the completely loosened material from augers and scrapers has to be fed within a day, as the stability is strongly reduced by the intensive aeration.

Finally the air stress during unloading is determined by the progression of the silo face through the silo.

The penetration depth of air in a normally consolidated silo is around 1 m, as is shown on Figure 10. So at a progression of 1 m/week, all silage will be exposed to oxygen for 1 week. At 2 m/week this time is halved, reducing the risk drastically. Therefore feed demand and silo width have to be adapted well to each other.

![Graph showing CO2 concentration before unloading](image)

Fig. 11: CO2 concentration before unloading

Looking for possibilities to improve aerobic stability, the following may be stated:

- There is still more information necessary to predict the risks for aerobic instability.
- The development of specific additives to increase aerobic stability showed promising results and should go on.
- Of high importance remains as ever, a good knowledgeable management of ensiling and unloading technique.

Conclusion

Summing up, the following conclusion can be drawn:

Looking at the factors influencing losses during ensiling, it is possible, to show single factor relationships. But as the different processes are interdependent, it will only be possible, to determine the system losses in concise model calculations. These will also define the factors, still necessary to be evaluated in more detail.

Some can already be identified:

- Technical ones, such as improving Chopper care and chopping economy or Additive applicators or sealing technique in bunkers

- Procedures, such as rolling practice

And last but not least, to improve management at all stages of the process, which means to intensify the knowledge transfer to the person directly concerned:

The farmer.

References


**Spoebner, S. (1991).** Chemical and biological additives in forage conservation.


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**MANAGEMENT OF SILAGE EFFLUENT**

**Offer, N.W.**, Chamberlain, D.G. and **Kelly M.**

1 Scottish Agricultural College, Ayr, Scotland.

2 Hannah Research Institute, Ayr, Scotland.

**INTRODUCTION**

Silage effluent pollution is the main environmental problem arising from the shift from hay to silage conservation that has occurred over the past 25 years. Current annual UK silage production is approximately 42 million tonnes of which 14% is baled (Petchy, 1990). Taking an average clamp size of 800 tonnes, this gives a total of approximately 45,000 silage clamps, the majority of which leak effluent to a greater or lesser extent. Yet, the development and adoption of new silage technology has mostly failed to consider the consequences for effluent output. Instead, researchers into forage conservation have energetically pursued marginal improvements in efficiency leading to changes that have often exacerbated the effluent problem. This is untenable in the present era of public concern for the environment.

**SILAGE EFFLUENT AND THE ENVIRONMENT**

**Composition and yield of effluent**

Effluent arises from the expulsion of plant juices from the ensiled herbage mass. Its high content of fermentation acids and soluble carbohydrates (Table 1) makes it extremely polluting with a very corrosive effect on common building materials. Values for five day Biological Oxygen Demand (BOD5) for silage effluent range up to 80,000 mg/l making it more than twice as polluting as farm slurry and up to 200 times as polluting as domestic sewage.

<table>
<thead>
<tr>
<th>Composition of dry matter (g/kg)</th>
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</thead>
<tbody>
<tr>
<td>ash</td>
</tr>
<tr>
<td>crude protein</td>
</tr>
<tr>
<td>ammonia-N (g/kgN)</td>
</tr>
<tr>
<td>amino acid-N (g/kgN)</td>
</tr>
</tbody>
</table>

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* Quotations marked with * refer to this conference.