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 homogenity and substrate availability by chopping or laceration
- Use of additives
- Increasing insufficient 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 impressivly 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 Völkenrode 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).

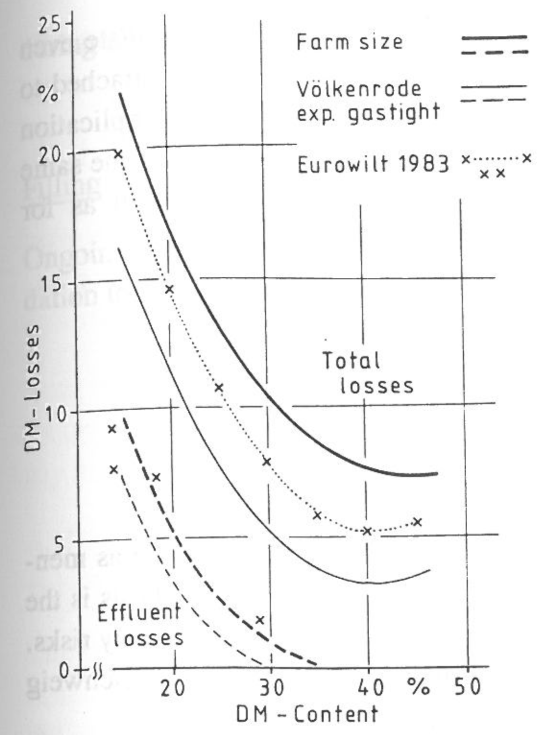

Fig. 1:
In-silo losses affected by DM content

Sugarbeet tops and leaves (SBTL), dried sugarbeet pulp (DSP), bunker silo 100 t

Stage	Text		SBTL alone	SBTL +DSP
At ensiling	SBTL DSP	dt DM dt DM	150 -	150 114
	Loss	%	23	6
At feeding	SBTL DSP	dt DM dt DM	116 114	248
	Total	dt DM	230	248
	Balance	dt DM %		+18 + 7

Table 1: Reduction of DM losses by use of absorbents in high moisture silage

Intensive disintegration, as achieved e.g. by precision chopping, even down to 10 mm medium chop length, improves fermentation conditions drastically. Spoelstra, 1991, commented on that as well. A lately run experiment, to determine the appropriate chop length for additive tests, shows again the very positive effect of fine chopping down to 5 mm set chop length on fermentation as well as on DM losses (Fig. 2). At 20 mm a similarly positive quality could only be achieved by using formic acid as an additive (El Himdy and Honig, 1991).

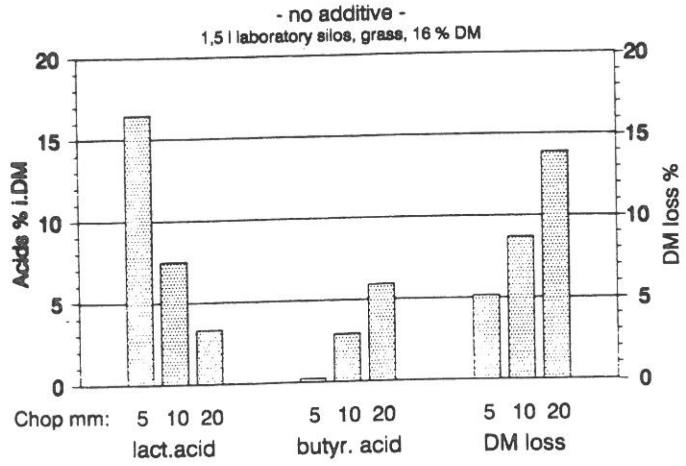

Fig. 2:
Chopping length and fermentation quality

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).

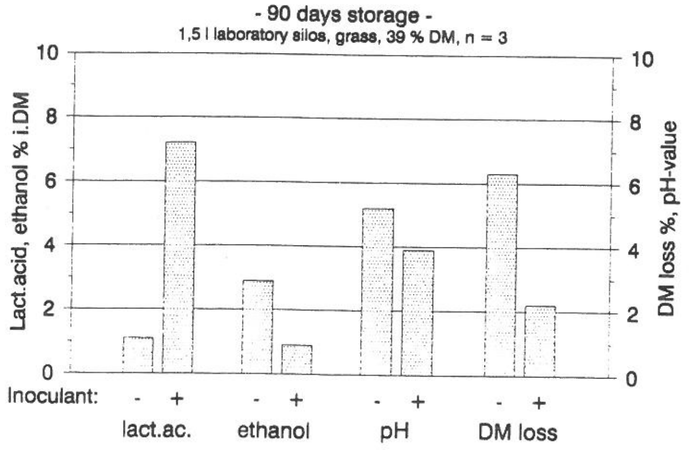

Fig. 3: LAB inoculation and fermentation quality

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 CO_2 and water, as long as oxygen is available (Fig 4).

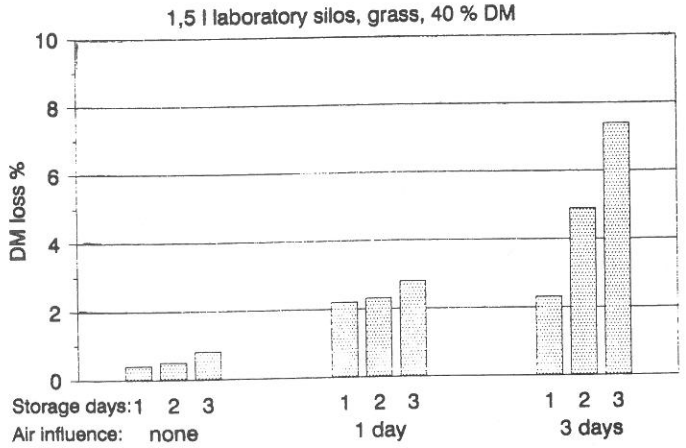

Fig. 4: DM losses after delayed sealing

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).

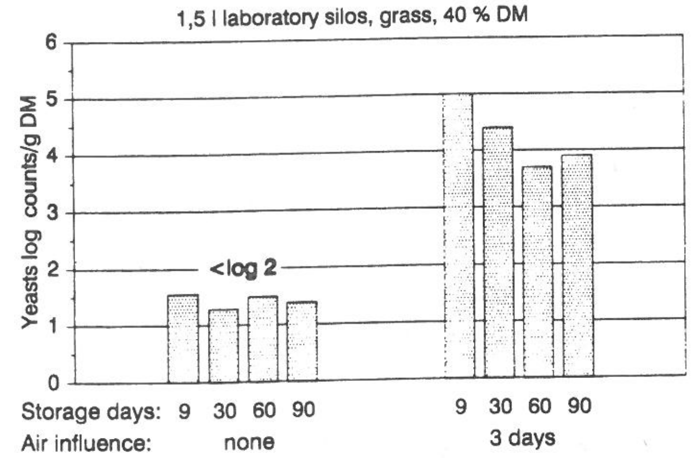

Fig. 5: Lactate assimilating yeasts after delayed sealing

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.

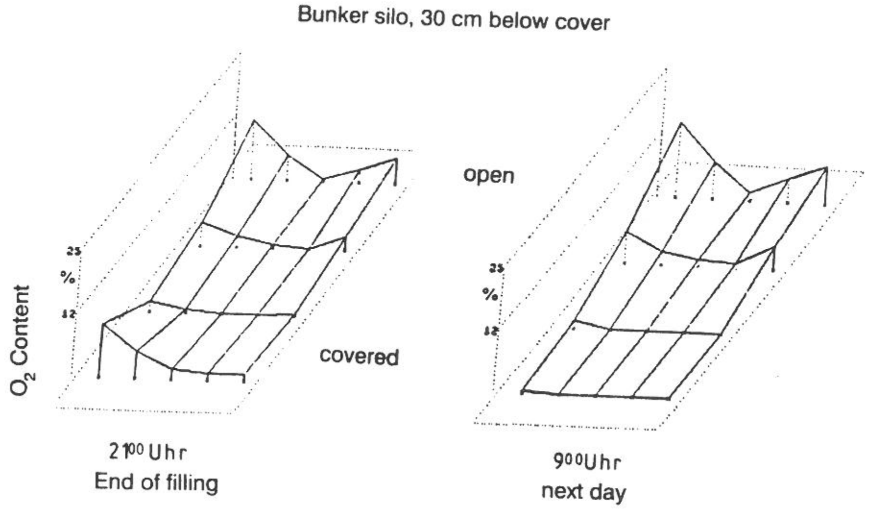

Fig. 6: O_2 concentration with and without intermediate cover

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 CO_2 and air. It is modified by the CO_2 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)

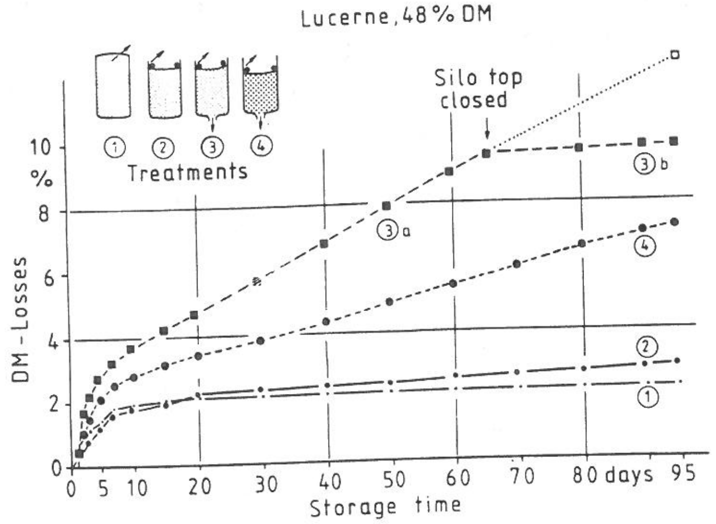

Fig. 7: DM (CO_2) losses and silo technology

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 CO_2 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.

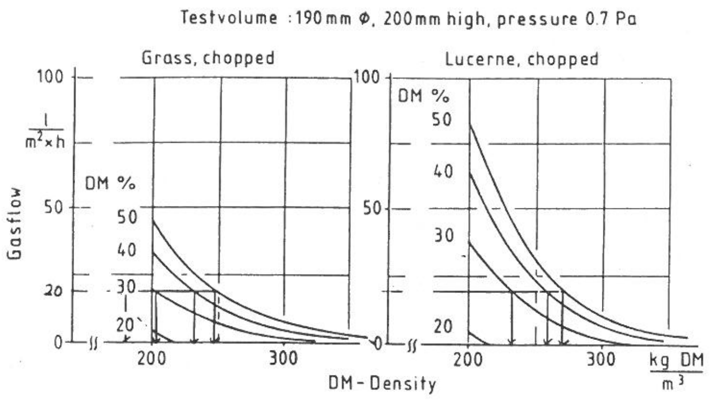

Fig. 8: Gasflow in silage

Fig. 8 shows Völkenrode results. The main factors determining the porosity of the forage are density, here expressed as DM-density, DM content and forage structure, as given by forage species, stage of maturity, and chopping length. Increasing DM content needs a markedly higher density to keep porosity or gas flow at the same level. Growing coarseness of the forage structure acts in the same direction.

The consolidation ranges, nessary to reach the gas flow level of 2ol/(h x m^2) as marked in Figure 8 are compiled in Table 2 for different forages and DM ranges. For wilted material as well as maize they should be well above 200kg DM/m^3.

- 20 l / (h*m²) -

Crop	DM range g/kg	DM density range kg/m³
Grass	150...500	140...260
Lucerne, whole crop cereals	150...500	160...280
Maize	250...350	210...290
CCM	500...600	400...480

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

The gas flow is very sensitive to forage density changes. Its reduction by 20kg DM/m^3 from the stated level will double the gas flow rate in coarser crops and increase it 1,5 fold in finer, wilted forages. A parallel increase of aeration losses is to be expected.

> To define these relationships more precisely will need extensive model calculations, as they have been carried out e.g. by Pitt,1986, or McGechan, 1989, 1991 from whom we will hear more about this matter in a seperate paper.

The consequence, to be drawn from these results for the practical ensiling technology is to achieve best possible consolidation, and to secure a good sealing of the silo.

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/t DM/h, or number of rollings or rolling time/t of DM. Taking up former work on dynamic consolidation by Müller, 1970, Bosma,1990 Dernedde, 1990, a systematic investigation has been started in Kiel, (Laue, 1990) to differentiate the factors influencing the rolling effect using model bunker silos.

Model bunker silo, 4 layers, 80 cm consolidated hight
Source: Laue

Tractor parameters		Speed km/h	Pressure 10 cm under tire bar	Density at ensiling kg/m³
Load	2500 kg singl tire	2	1	90
	4500 kg single tire	2	2	160
	4500 kg twin tire	2	1	90
Speed	4500 kg single tire	4	2	160
Depth effect of rolling:		20 to 40 cm from surface		

Table 3: Tractor effects on rolling efficiency

Preliminary results (Tab. 3) confirm, that a high specific pressure on thin forage layers is the most important factor. So the use of twin tire or caterpillar tractors will reduce effectivity. Rolling speed seems - in a certain range - to be of minor influence.

> Further work has to be done to set up a reliable scheme.

Good sealing in tower 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 exessive 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 clamps 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: Peddersen

Bottom	Fermentation loss %	Surface loss %
with PE sheet	7	6
without PE sheet	4	$\boxed{36}$

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).

Grass, 37 % DM, n=3

Film	Balertype fixed chamber	 variable chamber A	 variable chamber B
tight	10.0	8.8	9.4
with 2 holes	11.5	13.8	11.8

A = wide core; B = narrow core

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

Unloading

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 exclosure at all stages of storage, if the pH value has not been lowered satisfactorily, e.g. due to unsufficient 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).

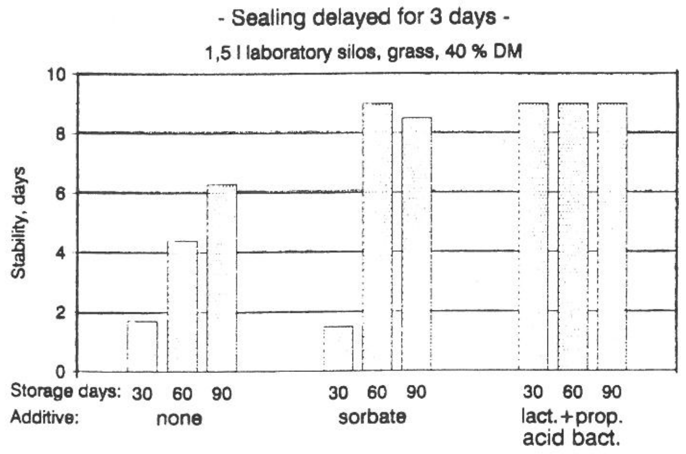

Fig. 9: Additive effect on aerobic stability

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).

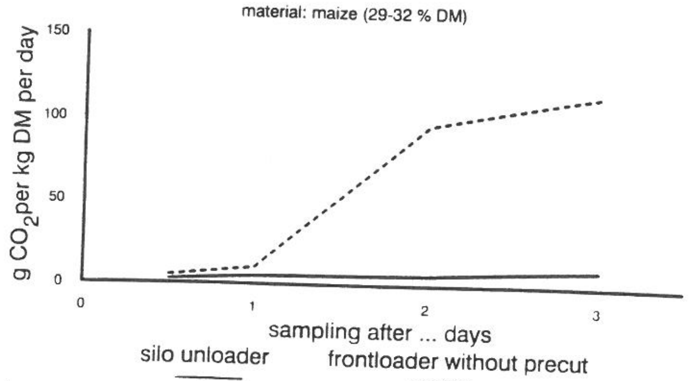

Fig. 10: Intensity of secondary fermentation when unloading a trench silo in different ways

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 fedt 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.

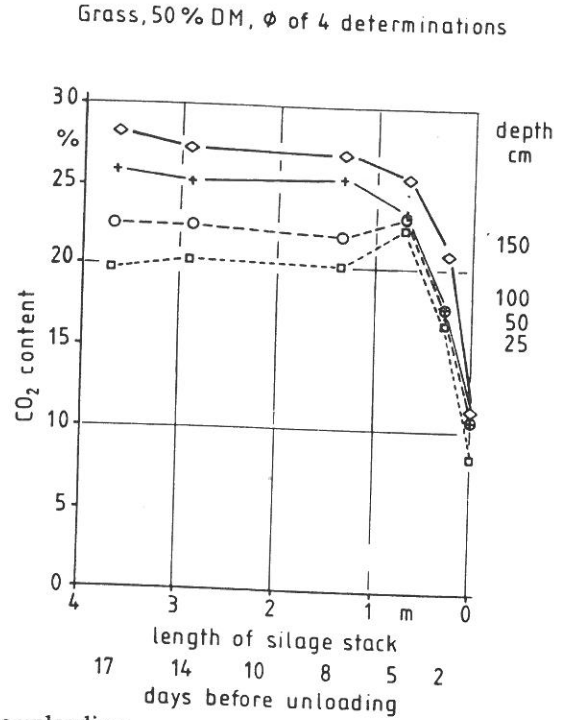

Fig. 11: CO_2 concentration before unloading

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

- There is still more information necessary to predict the riks 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 knowledgable 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.

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* Quotations marked with * refer to this conference.

MANAGEMENT OF SILAGE EFFLUENT

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INTRODUCTION

Silage effluent pollution is the main environmental problem arising from the shift from hay to silage conservation that has occured 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 Biochemical Oxygen Demand (BOD_5) 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 1. Chemical composition of effluent from grass silage.

Dry matter (g/kg)	40 - 110
pH	3.2 - 3.5
BOD_5 (mg/l)	20,000 - 80,000
Composition of dry matter (g/kg)	
ash	180 - 350
crude protein	200 - 310
ammonia-N (g/kgN)	20 - 400
amino acid-N (g/kgN)	500 - 750