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Temperature development and dry matter losses of grass silage in bunker silos

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Introduction

Ensiling is a preservation method for crops based on anaerobic fermentation where epiphytic lactic acid bacteria convert water soluble carbohydrates to lactic acid which decreases the pH. To store silage and protect it from oxygen, several structures, such as tower silos, bunker silos, tube silos and round bales, are used. Aerobic conditions are detrimental to silage quality and bunker silos are often difficult to keep hermetically sealed (Woolford, 1990). Air intrusion during the storage period, normally 2 to 10 months, results in deterioration of the silage already in the silo (Honig, 1991). After unloading, the silage is fully exposed to oxygen and aerobic deterioration processes start. Stability of silage during the feed-out period is an important factor determining quality and usability of the fodder (Wilkinson & Davies, 2012) and silage handling in warm climates require special attention in order to limit vast losses (Ashbell et al, 2002). The present paper consists of two independent parts: a) a laboratory method designed to mimic unloading of bunker silos is described and the effect of silage DM content on temperature development is reported, b) temperatures in 5 farm-scale bunker silos were logged throughout the ensiling period and total mass entering and leaving the silos were recorded.

Materials and Methods

a) Laboratory method

A grass forage crop was wilted to 30 and 50 % DM and packed into 2-m PVC tubes (diameter 0.16 m) at a density of 150 kg DM/m^3. The tubes were stored horizontally at 20ºC and insulated with 5 cm Styrofoam in order to mimic an environment inside a bunker silo (Figure 1). The tubes were fitted with temperature loggers every 0.15 m and 4 water filled gas locks to let out CO_2 but restrict air to enter. The forage consisted of a regrowth of *Poa pratensis* and *Festuca pratense* from a pasture that had been grazed earlier in the season. Before filling the tubes, half of each of the two crops (30 % DM and 50 % DM crop) was treated with two lactate assimilating species of the yeast genera *Candida* and *Hanensula (Pichia)* and the other half was left untreated. The four treatments were (30 and 50% DM with and without yeast) were duplicated, resulting in a total of 8 tubes. The tubes were stored 120 days after which they were opened by cutting off one of the ends. Thereafter, 0.15 m of each tube was cut 10 times at 7-day intervals using a saw and the content weighed and sampled.

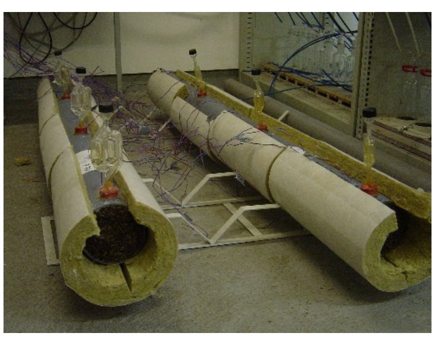

Figure 1. PVC tubes (Ø 0.16 m)

After sampling, samples were transferred to a storage stability test unit to monitor increase in temperature. Temperature in silages were measured in 1300 ml PVC containers covered at the bottom with a PE fiber net and filled with silage in relation to their DM contents, according to the equation: filling weight (g fresh matter) = -205.57 x ln(%dry matter) + 1061. The containers were placed in an insulating Styrofoam block and kept at 20ºC during 9 days and thereafter weighed before being discarded. The green crop and all silages were analysed for dry matter (DM) and as well as for presence of yeast and mould cultured aerobically at 25ºC on Malt Extract Agar (MEA, Merck) supplemented with Penicillin G (30 mg/L agar) and Streptomycine sulphate (30 mg/L agar) (Sigma).

b) Full scale silo measurements

Five farm scale silos were investigated. The dimensions were (length x width x height): 30x6x3 (2), 43x8x3 (2) and 42x12x3 (1) m and were located at three farms in central Sweden. The forage crops of grass and clover were weighed with a calibrated vehicle scale at loading and a sample was taken from each wagon load put into the silos. Each silo was fitted with temperature loggers recording and storing t temperature data at 4-h intervals throughout the ensiling and unloading period. The temperature loggers were placed in the centre of the silo and along one side and at two levels from the bottom. At unloading for feeding, total weights were recorded daily and samples were taken for analysis three times per week. At unloading, the temperature loggers were collected and temperature data was downloaded. Samples of crops at harvest and silages at unloading were analysed for DM, ash, crude protein (CP) and neutral detergent fibre (NDF), according to standard methods. Digestible organic matter was analysed with the Swedish 'VOS' method (Lindgren, 1979).

In both studies, the GLM procedure of SAS (SAS, 2014) was used for analysing statistical differences, where appropriate.

Results and Discussion

a) Laboratory method

Loss of DM during the 120-d storage period assumed that it consisted of only CO_2 exiting via the water locks. Accumulated weight loss during unloading was obtained by weighing all ten 0.15 m cuts during the 63-d emptying of the silos. Results are presented in Table 1 which shows that the dryer forage gave higher fermentation losses during the storage period. The addition of yeast did not make any difference. The losses after the unloading period of 63 days further increased total losses of the wetter silage by almost 5 times and of the dryer silage by more than 10 times

Table 1 Total DM loss after 120 days airtight storage and accumulated DM loss after a 63-d unloading time of the silos

	Weight loss at opening (% of crop DM)	Accumulated weight loss during a 63-d unloading (% of crop DM)
Untreated 30 %	6.1[a]	29.2[a]
Yeast 30 %	6.2[a]	29.2[a]
Untreated 50 %	1.6[b]	21.4[b]
Yeast 50 %	1.9[b]	19.3[b]

[a, b] Different superscripts in the same column differ at $p<0.05$

The temperatures recorded in the silo tubes during the storage period when silos were closed were similar to the ambient temperature. When unloading started by cutting off one end of the tube, the temperature in the wetter silages continued to be unaffected. The dryer silages were also unaffected during the first two weeks. Thereafter, the silage that was due to be unloaded started to show 2 to 4 degrees higher temperatures than the ambient about one week in advance.

Figure 1 illustrates the result of the storage stability test performed with silage unloaded the first day and the third week (day 22) after silo opening. All silages (30% and 50 % DM) tested after unloading on the first day after silo opening were stable throughout 48 hours. When unloading three weeks later, the dryer silages (50% DM), starting at a slightly elevated level as mentioned above, immediately increased in temperature, reaching 32ºC after approximately 44 hours while the wetter silages maintained their stability.

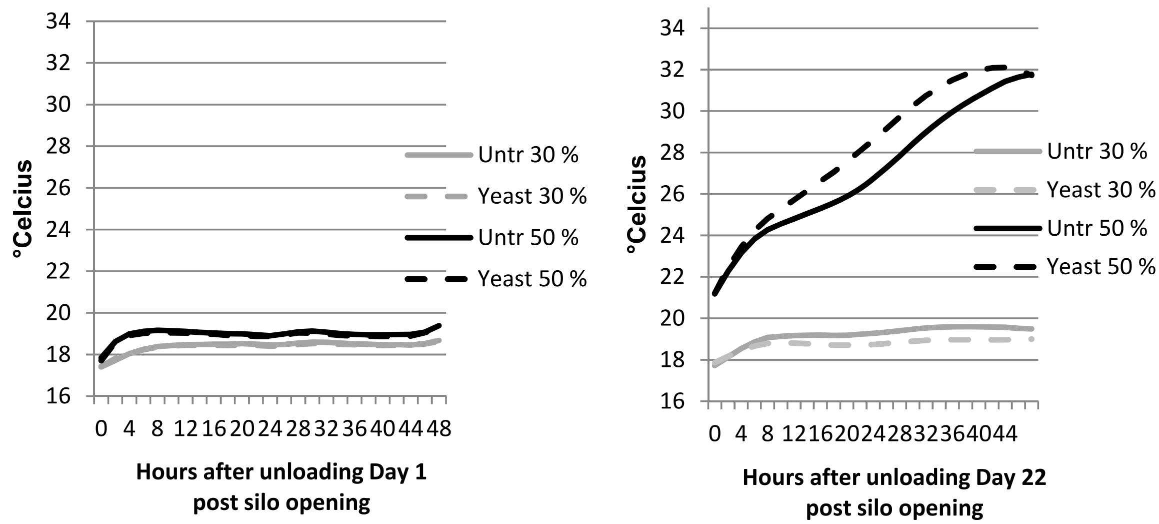

Figure 2 Storage stability after unloading silage Day 1 and Day 22 after opening the silos

The results from the 50% DM silage can be compared with a full size silo packed at a density of 150 kg DM/m^3. At opening, the porosity will allow air from the face to penetrate the silage. This will start up aerobic microbial processes and, when the silage is fully exposed to air at unloading, aerobic deterioration will be rapid. For the wetter silage, this does not seem to happen. The increased yeast counts found in the unloaded silage at week three supports this finding, < log 1.7 cfu/g in the 30% DM silages and log 4.4 cfu/g in the 50% DM silages. The yeast content in the green crop was 4.4 and 4.8 cfu/g in the 30 and 50% DM, respectively. No effect at all was observed for the addition of extra yeast to the green crops, probably because of an abundant occurrence of yeast present on the crop.

b) Full scale silo measurements

Recording temperatures in full scale silos typically show an initial rise in temperature followed by a slow decrease during the remaining storage and unloading periods. Figure 3 illustrates such a pattern in one of the silos. The silo was filled September 12, opened January 23 and was completely emptied May 19. In this silo, the temperature loggers were placed 1 meter above the bottom and the silo measuring 30x6x2.4 m (LxWxH). Note that the silo temperature was approximately 20ºC in January when the outdoor temperature was -15ºC.

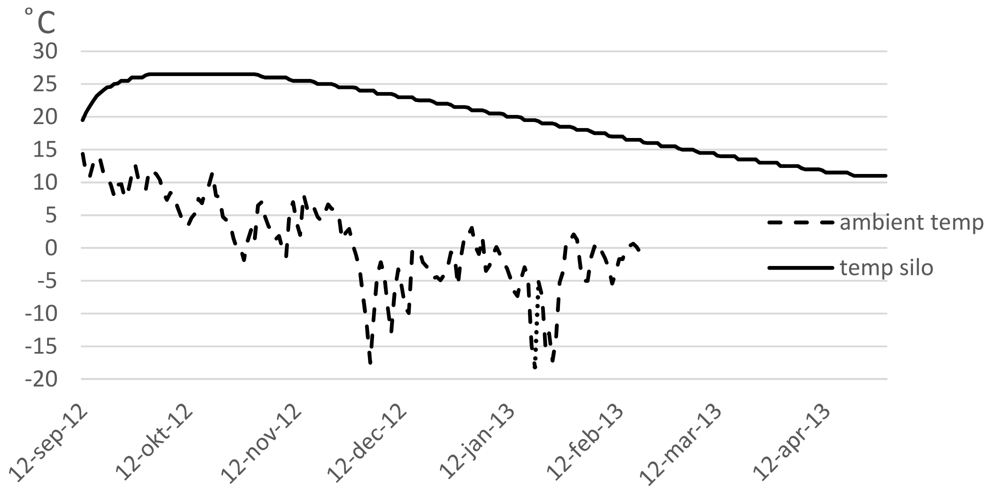

Figure 3 Ambient and the in-silo temperature at 1.0 m from the bottom

Figure 4 illustrates a silo where the loggers were placed close the bottom (0.5 m) and close to the top (1.90 m) in a silo measuring 43x8x2.55 m (LxWxH). This silo was filled July 9, opened and emptied October 16 the same year. The temperature in the upper layer soon exceeded the lower layer which may indicate some aerobic activity due to air leakage from poor sealing.

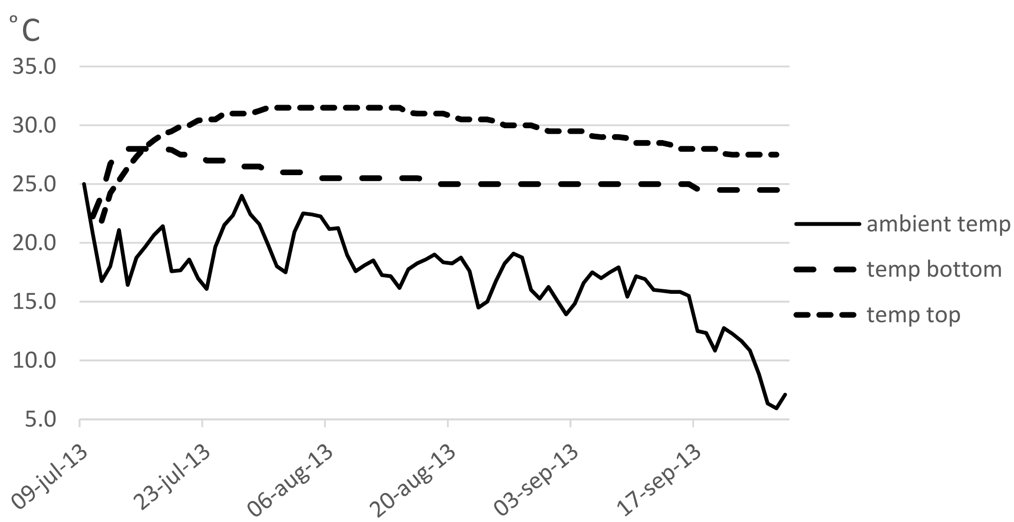

Figure 4 Ambient and in-silo temperature in the bottom (0,5 m) layer and top (1,90 m) layer.

Figure 5 illustrates temperature development in a silo where a second harvest (July 22) filled half the silo. In September, the plastic film was removed and a third harvest was loaded on top of the second harvest, where after the silo was re-sealed. January 8, the silo was opened and stayed open until May 20 for unloading. The temperature in this silo elevated to about

40ºC. The logger close to the surface of the second harvest was heated a second time when the third harvest entered.

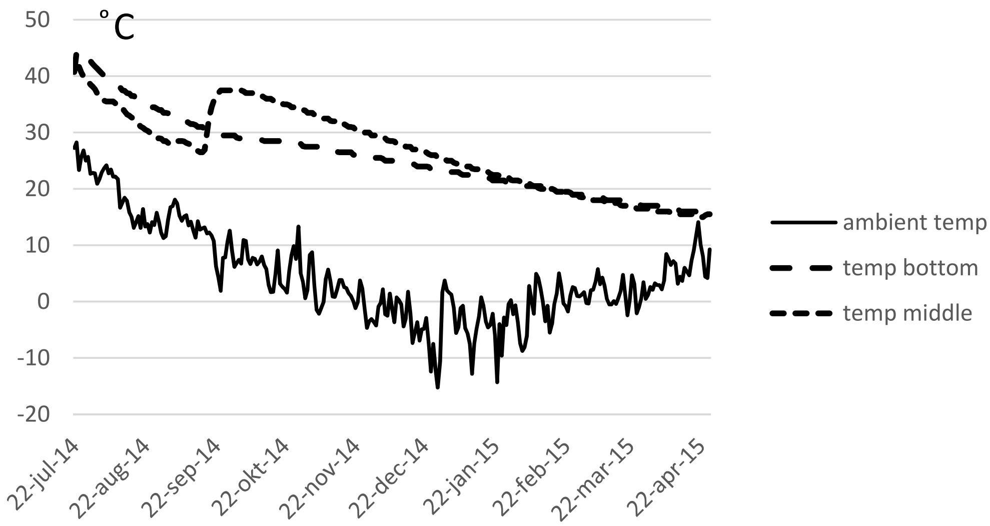

Figure 5 Ambient and in-silo temperature

The calculated silo balances, kg DM unloaded from the silo minus kg DM filled into the silo, are presented in Table 2. Temperature recordings do not seem to have the potential to indicate losses in the silos investigated in this study. In some farms, the discarded quantity of silage was higher due to farmer preferences. Therefore, it could be a better criterion to use DM losses where discarded silage is not included. Dry matter loss, excluding the discarded quantity, is therefore also included in the table. In this case however, the difference was not significant and no relation was found between the in-silo temperature and losses recorded. Daytime temperature sum (DTS), the sum of the daily average silo temperatures, were also tested as an alternative to finding a relationship between temperature and losses. Furthermore, an index of the difference between in-silo DTS and ambient DTS divided by silo surface area was also tested as an indicator of silage losses. However, neither of these alternative variables improved the correlation between the temperature and recorded DM losses.

Table 2 Mean and maximum temperature and DM loss recorded in 5 silos at three farms.

				Mean temperatur (°C)				Max temp (°C)		DM loss (%)	
		Date of			Silo			Silo			Excl.
Silo	Farm	Filling	Empty	Ambient	Mean	Lower	Upper	Lower	Upper	Total	discard
1	A	09-sep	08-apr	1	22,6	22,6	-	26,5	-	3,1	1,5
2	B	12-sep	19-maj	-0,1	19,8	18	21,7	25,5	28,5	18,1	15,3
3	A	15-jul	04-dec	16,1	26,7	24,2	28,7	28	30,5	3,4	2,7
5	B	10-jul	16-okt	10,9	23,1	20,8	25,3	30,1	34,9	16,0	12,4
8	C	22-jul	20-maj	4,7	26,2	25,6	26,8	44,5	41,7	6,4	5,6

There was, however, a clear effect of farm on DM losses. Farm A differed from other farms by displaying very low DM losses. At this farm, filling of the silos was done very slowly resulting in a long packing time with a tractor. The practice on this farm was also to not close the silo immediately when full. Instead, packing continued the day after with the visible effect of pressing the surface another 0.2 meter downwards. The silos were finally covered with 0.15 m of sand on top of the plastic film.

Conclusions

A laboratory method is presented where the pattern of unloading bunker silos can be mimicked and monitored. Porous silages, due to a high DM content or poor compaction, were sensitivity to oxygen intrusion during the unloading period. This resulted in a silage with poor stability, heating up fast after unloading and leading to considerable DM losses. Temperature recording in full-scale silos did not prove to be a valid indicator of DM losses. However, large differences in losses among farms were observed, indicating that thorough and meticulous compaction of the silo may be more important to minimize losses than rapid sealing. Controlled experiments are required to establish if this indication can be verified.

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