LANDWIRTSCHAFTLICHES ZENTRUM
für Rinderhaltung, Grünlandwirtschaft, Milchwirtschaft, Wild und Fischerei Baden-Württemberg (LAZBW)
Atzenberger Weg 99, 88326 Aulendorf

Use of the PistenBully 300 (Kässbohrer) on grass silage Effects on density, silage temperature and fermentation quality - Project 2009 -

Created by:

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1.Test question

How are the compaction, silage temperature and fermentation quality of grass silage affected by use of a snow groomer as the spreading and rolling vehicle?

The LAZBW (Baden-Württemberg agricultural centre for ruminant production, grassland management, dairy management, wildlife and fisheries) has performed laboratory analyses on the harvested crop and all silage samples for its own interest and at its own cost. These results are also presented in this report.

2. Material and methods

2.1 Firm: Martin Huber
Geißbühlhof
72469 Meßstetten
Tel.: +49 (0)743 196 1150

2.2 Silage crop:
The first growth of permanent grassland was mowed at Martin Huber in Meßstetten on 27th and 28th May, left to wilt and then ensilaged on 28th May for further use in the firm's own biogas silage. The firm's own chaff chopper (John Deere 7300) was used for the harvest and predominantly two (shortly also three) tippers (average load around 11 t FM/tipper). Please refer to the appropriate DLG e.V. report for details. The short-cut (theoretical cut length 5-10 mm) harvested crop was exclusively spread and compacted with a snow groomer (PistenBully 300, Kässbohrer). The DLG (German agricultural society) test centre at Groß-Umstadt and the LAZBW were represented and participated in the harvest and ensilaging. Monitoring and recording the harvest progress was the remit of the DLG test centre in line with contractual provisions, whilst the LAZBW was responsible for sampling and certifying the silage.

The wilted crop from the 46 tippers, which were each tested by the LAZBW, had a mean dry mass content of 32.6 % (spread of 21.1 to 46.6 % DM). 10 of the 46 tipper samples were completely analysed in the lab. They had a mean 33.2 % DM (spread 28.5 to 37.9 % DM) (Table 1). With crude fibre levels of 28 % in DM, the harvested crop was slightly above the ideal level (25 % in DM) and this indicates a slightly delayed cut point. This is also reflected in the slightly below average mean crude protein content of 15.5 % in DM. The mean crude ash content was 9.9 % in DM (spread of 8.6 to 12.2 % in DM). The aim is a crude ash level of less than 10 % in DM. The mean energy level on harvesting was 5.8 MJ NEL/kg DM (spread of 5.1 to 6.3 MJ NEL/kg DM). The analysed values reflect the different parcels of land with different botanical composition and physiological development that were ensilaged on this day. The harvested crop had good silage ability with a mean 6.9 % sugar in DM. The cultivator treated the silage with a silaging agent that contains homofermentative lactic acid bacteria. The grass silage was also ensilaged in a separate silo ("dairy cattle silage") directly before the "biogas silage" with the same technology and also using the silaging agent for stall feeding.

Around 501 tonnes of harvested crop (fresh mass) were unloaded in around 10 hours according to the DLG e.V. This results in a mean output of 50 t FM per hour.
Table 1: Content of the harvested crop (10 of 46 samples were analysed)

Load serial no.	Crude protein	Crude fibre	Crude ash	Energy MJ/kg DM ME	NEL	DM %	Sugar % in DM
	% in DM						
7	18.0	24.5	8.6	9.93	5.88	28.5	7.5
8	14.7	27.5	12.2	8.80	5.14	32.7	4.8
15	14.2	29.5	9.0	9.66	5.70	37.2	6.6
16	16.1	31.2	9.6	9.31	5.46	30.5	4.3
24	16.9	27.8	9.7	9.71	5.74	31.0	5.1
25	14.9	28.3	9.4	9.93	5.89	35.1	7.3
32	15.5	27.4	10.2	10.36	6.21	29.4	8.4
36	14.8	27.6	10.0	10.08	6.01	35.2	8.6
37	14.0	27.2	9.7	10.10	6.02	34.6	8.4
44	16.1	28.6	10.5	10.52	6.33	37.9	7.7
Mean	**15.5**	**28.0**	**9.9**	**9.8**	**5.8**	**33.2**	**6.9**
Min	**14.0**	**24.5**	**8.6**	**8.8**	**5.1**	**28.5**	**4.3**
Max	**18.0**	**31.2**	**12.2**	**10.5**	**6.3**	**37.9**	**8.6**

2.3 Silo type: Bunker silo with mainly fixed side walls, covered with tarpaulin
2.50 m wall height,
17.45 m length with walls, additional slant up to 8.00 m without walls
13.40 m silo width

2.4 Local sampling dates:

1. **D1** 15th September 2009 at approx. 15.5 m from the back and 2.0 m from full wall height from the front
2. **D2** 28th September 2009 at approx. 7.0 m from the back and approx. 10 m from the front
3. **D3** 5th October 2009 at approx. 4.0 m from the back and approx. 13.5 m from the front

2.5 Sampling position:

1. **P1** on the right-hand side approx. 0.50 m from the side wall (**edge 1**)
2. **P2** on the right-hand side approx. 1.00 m from the side wall (**edge 2**)
3. **P3** in the middle of the silage pile, 7.0 m from the right-hand wall **(middle)**

2.6 Layers:

1. **L1** approx. 0.30 m from the access edge starting from the top
2. **L2** approx. 1.00 m from the access edge starting from the top
3. **L3** approx. 0.50 m above the silo floor

2.7 Analyses:

1. Density using Pioneer borer in kg FM/m³ and kg DM/m³
2. DM content using drying at 60°C and 105 °C; for the silage dry mass corrections acc. WEISSBACH (1994); figures then in % in DMc
3. pH values using rapid determination on site (indicator paper Macherey & Nagel, no. 095300) and additionally using measuring equipment in the lab
4. Sensory evaluation of the silage on site
5. Raw nutrients: acc. VDLUFA
6. Energy content: calculated using HFT (formula for grass silage acc. STEINGASS and MENKE, 1987)
7. Fermentation acid and residual sugar: using HPLC, modified acc. SIEGFRIED et al. 1984
8. Sugar content in the harvested crop acc. VDLUFA (Volume III Book of Methods) by the LTZ Augustenberg

2.8 Process

The silo was opened on 8th September 2009 after 3.5 months of storage (105 days). Removal took until 12th October 2009 (5 weeks). This resulted in a mean rate of around 4 metres per week.

The first sampling (silo start) was effected on 15th September 2009 at around 15.5 metres (measured from the back silo wall) after reaching the full access height. The second (silo middle) and third samplings (silo end) were performed on 28th September and 5th October 2009 respectively.

Sampling was effected at three positions in each case (P1 to P3) and three layers (L1 to L3) using a sample borer (Pioneer). Core samples (3 bores per position and layer; diameter 4.5 cm, 45 cm long) were removed and weighed (Figure 1). Mixed samples were created from the three core samples from the individual positions and layers. The mixed samples were tested immediately using sensory analysis for faulty fermentation and using indicator paper for the pH value. The samples were then weighed on site (500 g fresh material in crisp packs) to determine the dry mass content (Mettler PM 54). The samples were transported to Aulendorf in a cool box and dried out to a constant weight for at least 24 hours at 105 °C in the drying chamber.

Fresh material from each mixed sample was deep frozen to analyse feed value and fermentation quality.

The temperature was measured using two temperature probes (Testo) at three depths (15 cm, 50 cm, 150 cm from the front edge of the bore hole) in each bore hole (Figure 2).

The ambient temperature was 8.5 °C on 15th September 2009, 23.3 °C on 28th September 2009 and 15.2 °C on 10th December 2009.

On the first sampling date, samples were also removed from another silo at the site, which was filled with grass silage for dairy cattle feeding, from two layers in the silo middle following the same plan. The silo was almost half empty at this stage. There was also grass silage (1st growth) in the silo, which was harvested in the customary way like the biogas silage. The harvest date was 2 days before the biogas silage and a wheel loader of around 18 tonnes total weight was used for rolling.

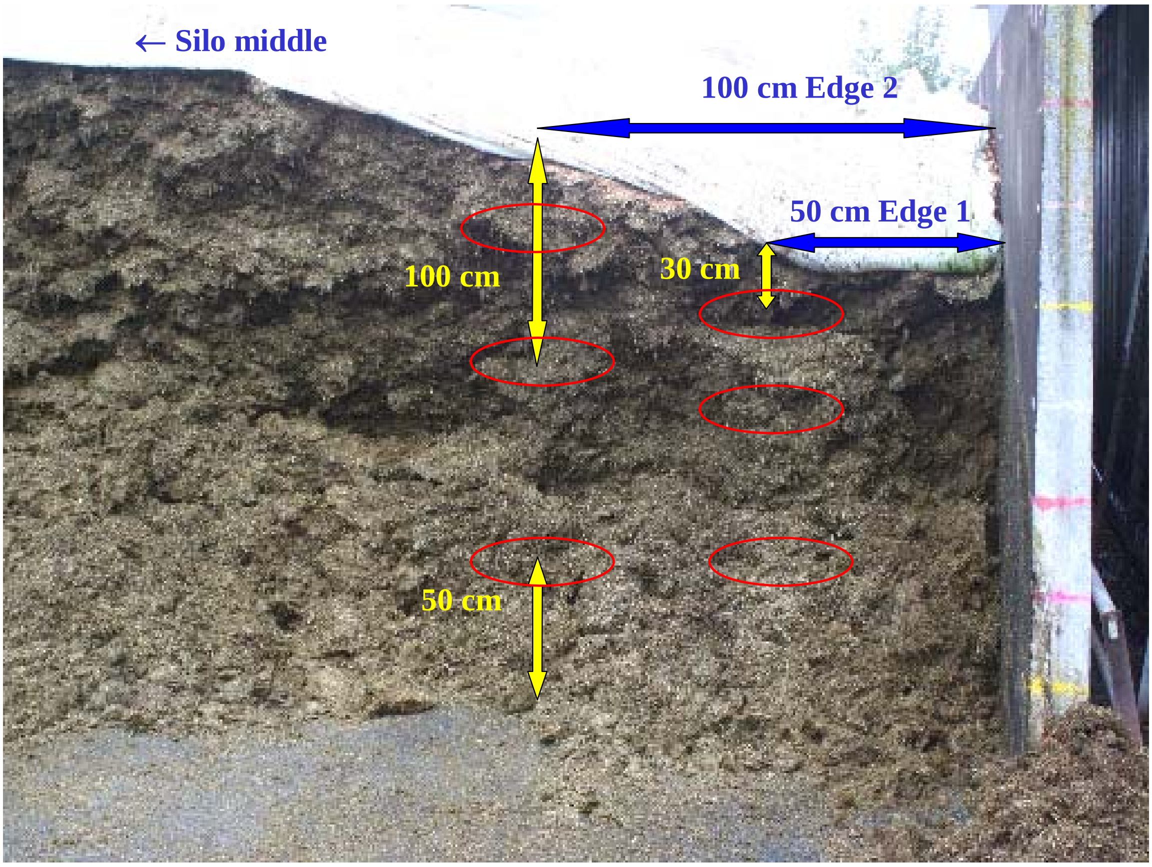

Figure 1: Schematic arrangement of the bore holes around the edge of the grass silage (illustration not to scale)

Figure 2: Temperature measurements in the bore holes

3. Results

3.1 DM content

The 27 silage samples had a mean 33.4 % DM with a spread of 26.5 % DM to 42.3 % DM (Table 2). This corresponds fairly well to the mean value of 32.6 % DM when the 46 tippers were unloaded, although there was a spread of 21.1 % DM to 46.6 % DM then because of the higher number of samples. The mean DM content is in the target range for good maize silage of 30 to 40 % DM.

The mean DM content was 34.7 % at first sampling, 32.2 % in the silo middle and 32.8 % at the silo end. The slight variation is due to the fact that the bunker silo was filled in even layers from the back to the front.

Slightly lower DM content with a mean 31.4 % DM was detected in edge section 1, i.e. right next to the silo wall, than the 34.8 % in edge section 2 (1 metre from the wall) and the 33.5 % DM in the middle of the silo (Table 2). Some rainwater probably seeped into this area, although the silage was very carefully covered with tarpaulin and undersheet. The fact that the tarpaulins were butted up against the wall certainly contributed to this. It was not possible to pull the tarpaulins over the silo wall because of the type of construction.

The DM content in the silo decreased from the top downward from a mean 38.2 % DM to 31.7 % DM, to 29.8 % DM (Table 4). This effect was also observed on the individual dates and positions and is because more heavily wilted grass was unloaded as filling progressed.

The test results showed that the PistenBully had no effect on the DM content of the silage as expected. The two grass silage types from the silo for the dairy cattle had a mean 33.5 % DM.

3.2 Density

Grass silage with around 33 % DM should have a density according to RICHTER (2009) of at least 200 kg DM/m^3 and around 600 kg FM/m^3. This target was achieved in the dairy cattle silage with a mean 250 kg DM/m^3 (top 243 kg DM/m^3, middle 257 kg DM/m^3). This indicates that the dairy cattle silage was extremely well compacted. Densities of this level are normally only achieved under practical conditions when the output and rolling are very well matched to one another and rolling is done very carefully, without a break and evenly with a very high rolling weight.

The grass silage unloaded by the PistenBully showed a lower compaction with an arithmetic mean of 173.1 kg DM/m^3 (and 520 kg FM/m^3) (Table 2). It was around 13.5 % below the target of 200 kg DM/m^3 and around 30 % below the very well compacted dairy cattle silage from the Huber firm. The spread within the silo was high from 130 to 207 kg DM/m^3. Effects were noted between the layers and positions (Tables 3 and 4). However, the mean density hardly changed from the front (date 1) with 173 kg DM/m^3 to the silo middle (date 2) with 175 kg DM/m^3 to the back (date 3) with 170 kg DM/m^3. Thus, the harvested crop was unloaded and compacted very evenly from the back to the front in the silo.

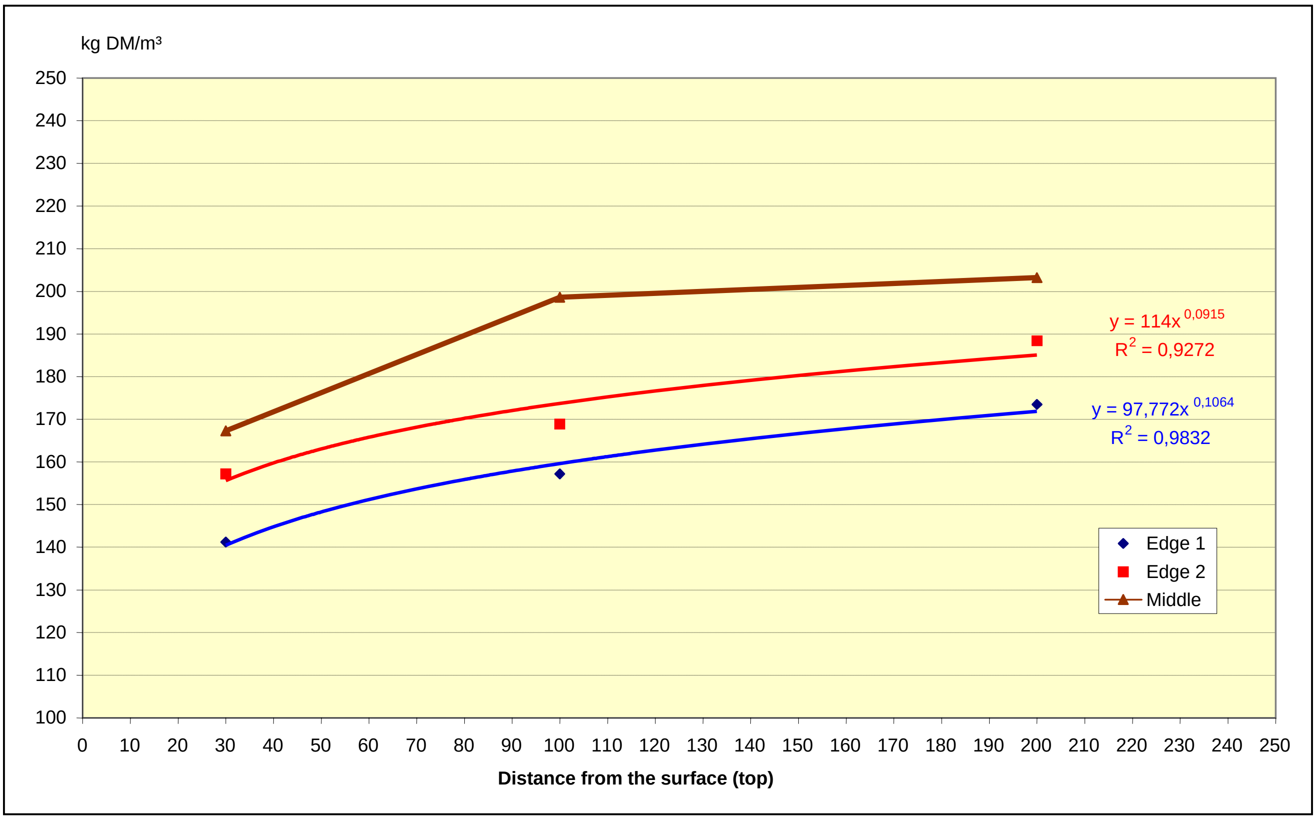

Figure 3: Density (kg DM/m³) depending on position (edge, middle) and location (distance in cm from the silo top surface). The measured values (points) and trend lines at the edge sections are shown.

The less well compacted edge sections take a smaller proportion than the better compacted silo middle. Therefore, presentation of the arithmetic compaction calculated from the nine measured values does not sufficiently reflect the actual ratios in the silo. Consequently, a trend line (R^2= 0.98 edge 1; R^2=0.93 edge 2) was laid through the measured values of the edge sections (Figure 3) and further compaction was calculated for each layer of 50 cm. As an almost even compaction was recorded from the measured values for the silo middle at a distance of 100 cm from the wall (Figure 3), the arithmetic mean of the actual measured values was used for the compaction of the 50-cm layers (Figure 4).

50 cm	100 cm	1,040 cm	100 cm	50 cm	
120.6	142.3	168.5	142.3	120.6	50 cm
149.2	170.0		170.0	149.2	50 cm
161.6	175.6		175.6	161.6	50 cm
170.0	184.4	200.9	184.4	170.0	50 cm
176.6	190.6		190.6	176.6	50 cm

Figure 4: The compaction (kg DM/m³) of the individual layers (each 50 cm) and sections (width of the layers) calculated from the measured value and trend lines in the silo.

A weighted mean of 183.2 kg DM/m³ results from the volume shares of the individual layers and sections (Figure 4). This mean was around 8.5 % below the target of 200 kg DM/m³ and almost 27 % below the maximum compaction of dairy cattle silage.

The lowest compaction was measured at the silo wall (edge 1) with a mean 157 kg DM/m³ (Table 3). The spread there ranged from 130 (-35 %) to 178 kg DM/m³ (-11 %). In comparison to the target value of 200 kg DM/m³, this is lower compaction by around 21 % in comparison to the 37 % of the dairy cattle silage. The mean density around a metre from the silo wall (edge 2) was 171.5 kg DM/m³ and, thus, was around 14 % lower than the target. The spread in the “edge 2” section ranged from 171 kg DM/m³ (-15 %) to 196 kg DM/m³ (-2 %). The best mean compaction of 190 kg DM/m³ was measured in the middle of the silo. The compaction there was only around 5 % below the target of 200 kg DM/m³, but still around 24.5 % below the density of the dairy cattle silage. The target value was exceeded at times in the silo middle by up to 3.5 %.

The compaction increased from the top downward in the silo from 155 kg DM/m³ to 175 kg DM/m³ with a mean 188 kg DM/m³ (Table 4). Accordingly, the uppermost layer was around 22 % (50 cm from the top), layer 2 (100 cm from the top) around 12.5 % and the bottom layer (50 cm from the bottom) around 6 % below the target of 200 kg DM/m³. It is worth noting that higher densities were achieved at times in the uppermost layer with 177 kg DM/m³ and in the second layer with 205 kg DM/m³.

3.3 Temperatures

Grass silage in the silo should be less than 20 °C from a depth of more than 15 cm. Sunshine can also cause higher values directly beneath the tarpaulin and at access areas.

Measurements were always taken at a fresh access for these investigations. This means that at least one layer of 30 to 50 cm silage was removed directly before sampling and temperature measurement. As a result, the measured temperatures could not have been influenced by sunshine at the access.

Acceptable temperatures were recorded with a mean of all measurements of 20.1 °C, although the maximum recorded temperature of 32.6 °C was too high (Table 2). The silage temperature increased from edge 1 with a mean 17.1 °C (maximum 21.9 °C) to edge 2 with a mean 19.2 °C (maximum 22.2 °C) to the silo middle with a mean 23.4 °C (maximum 32.6 °C). Thus, the silage did cool down from the silo wall outward. On the first sampling date, temperatures slightly above the optimum level were also recorded in the dairy cattle silage in the silo middle with 23 to 24 °C. Thus, slow cooling did occur in the biogas silage at the silo walls. In contrast, if yeasts had been active in the silage resulting in feed heating, this would have had a negative effect on the less well compacted zones at the edges. However, this was noted at the points (silo end, top two layers) with the maximum recorded temperatures (around 30 °C). Very low compaction of 151 kg DM/m³ was recorded there. Accordingly, except for this measurement, all other recorded temperatures up to around 25 °C were not due to use of the PistenBully.

The mean temperature decreased from the upper two layers downward from around 21 °C to a mean of around 18 °C .

Table 2: Test results, arranged by the sampling date

Date	Position	Location	DM %	Density kg FM/m²	Density kg DM/m³	Temp.°C at measured depth 15 cm	50 cm	150 cm
15.09.2009	Edge 1	30 cm from the top	30.9	504.3	155.9	18.4	17.7	16.7
	Edge 1	100 cm from the top	35.7	463.2	165.2	18.0	17.6	17.3
	Edge 1	50 cm from the bottom	29.6	556.9	164.7	16.8	16.8	16.3
	Edge 2	30 cm from the top	42.3	374.8	158.5	20.1	20.3	20.4
	Edge 2	100 cm from the top	40.1	420.3	168.7	19.8	19.6	19.0
	Edge 2	50 cm from the bottom	29.0	626.3	181.5	18.3	18.0	17.6
	Silo middle	30 cm from the top	37.6	460.6	173.4	23.7	24.4	25.3
	Silo middle	100 cm from the top	34.7	553.8	192.4	25.1	25.1	25.6
	Silo middle	50 cm from the bottom	32.6	607.9	197.9	19.7	19.7	19.7
Date 1	**n=9**	**Mean**	**34.7**	**507.6**	**173.1**	**20.0**	**19.9**	**19.8**
		Min	**29.0**	**374.8**	**155.9**	**16.8**	**16.8**	**16.3**
		Max	**42.3**	**626.3**	**197.9**	**25.1**	**25.1**	**25.6**
28.09.2009	Edge 1	30 cm from the top	36.4	379.1	137.9	21.9	17.1	17.0
	Edge 1	100 cm from the top	26.5	588.4	155.7	19.5	18.0	16.7
	Edge 1	50 cm from the bottom	27.5	648.0	177.9	17.1	17.0	16.8
	Edge 2	30 cm from the top	41.1	388.5	159.8	22.2	21.2	17.8
	Edge 2	100 cm from the top	29.0	576.4	167.3	22.2	21.2	20.3
	Edge 2	50 cm from the bottom	30.0	652.6	195.7	19.4	18.6	17.9
	Silo middle	30 cm from the top	39.0	454.9	177.3	26.3	23.9	24.2
	Silo middle	100 cm from the top	29.8	666.1	198.2	27.3	25.6	25.7
	Silo middle	50 cm from the bottom	30.5	672.6	205.0	21.5	20.6	20.1
Date 2	**n=9**	**Mean**	**32.2**	**558.5**	**175.0**	**21.9**	**20.4**	**19.6**
		Min	**26.5**	**379.1**	**137.9**	**17.1**	**17.0**	**16.7**
		Max	**41.1**	**672.6**	**205.0**	**27.3**	**25.6**	**25.7**
05.10.2009	Edge 1	30 cm from the top	36.7	353.6	129.8	16.0	16.5	16.3

	Edge 1	100 cm from the top	28.9	522.1	150.8	14.8	17.3	16.8
	Edge 1	50 cm from the bottom	30.5	583.0	177.7	15.1	16.2	15.9
	Edge 2	30 cm from the top	42.2	363.0	153.3	17.6	18.6	19.2
	Edge 2	100 cm from the top	30.1	566.5	170.6	16.8	20.9	20.8
	Edge 2	50 cm from the bottom	29.6	636.4	188.2	15.5	17.7	17.1
	Silo middle	30 cm from the top	37.4	404.4	151.2	22.6	32.6	29.7
	Silo middle	100 cm from the top	30.6	671.0	205.1	22.4	23.4	24.0
	Silo middle	50 cm from the bottom	29.4	703.4	206.7	17.4	18.8	18.3
Date 3	**n=9**	**Mean**	**32.8**	**533.7**	**170.4**	**17.6**	**20.2**	**19.8**
		Min	**28.9**	**353.6**	**129.8**	**14.8**	**16.2**	**15.9**
		Max	**42.2**	**703.4**	**206.7**	**22.6**	**32.6**	**29.7**
Total	**n=27**	**Mean**	**33.4**	**519.9**	**173.1**	**20.1**	**20.3**	**19.9**
		Min	**26.5**	**490.5**	**129.8**	**14.8**	**16.2**	**15.9**
		Max	**42.3**	**488.7**	**206.7**	**27.3**	**32.6**	**29.7**

Table 3: Test results, arranged by the sampling positions

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	Silo middle	**Mean**	**33.5**	**577.2**	**189.7**	**22.9**	**23.8**	**23.6**
		Min	**29.4**	**404.4**	**151.2**	**17.4**	**18.8**	**18.3**
		Max	**39.0**	**703.4**	**206.7**	**27.3**	**32.6**	**29.7**

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	Mean	**30 cm from the top**	**38.2**	**409.2**	**155.2**	**21.0**	**21.4**	**20.7**
	Min		**30.9**	**353.6**	**129.8**	**16.0**	**16.5**	**16.3**
	Max		**42.3**	**504.3**	**177.3**	**26.3**	**32.6**	**29.7**
15.09.2009	Edge 1	100 cm from the top	35.7	463.2	165.2	18.0	17.6	17.3
	Edge 2	100 cm from the top	40.1	420.3	168.7	19.8	19.6	19.0
	Silo middle	100 cm from the top	34.7	553.8	192.4	25.1	25.1	25.6
28.09.2009	Edge 1	100 cm from the top	26.5	588.4	155.7	19.5	18.0	16.7
	Edge 2	100 cm from the top	29.0	576.4	167.3	22.2	21.2	20.3
	Silo middle	100 cm from the top	29.8	666.1	198.2	27.3	25.6	25.7
05.10.2009	Edge 1	100 cm from the top	28.9	522.1	150.8	14.8	17.3	16.8
	Edge 2	100 cm from the top	30.1	566.5	170.6	16.8	20.9	20.8
	Silo middle	100 cm from the top	30.6	671.0	205.1	22.4	23.4	24.0
	Mean	**100 cm from the top**	**31.7**	**558.7**	**174.9**	**20.6**	**21.0**	**20.7**
	Min		**26.5**	**420.3**	**150.8**	**14.8**	**17.3**	**16.7**

	Max		**40.1**	**671.0**	**205.1**	**27.3**	**25.6**	**25.7**
15.09.2009	Edge 1	50 cm from the bottom	29.6	556.9	164.7	16.8	16.8	16.3
	Edge 2	50 cm from the bottom	29.0	626.3	181.5	18.3	18.0	17.6
	Silo middle	50 cm from the bottom	32.6	607.9	197.9	19.7	19.7	19.7
28.09.2009	Edge 1	50 cm from the bottom	27.5	648.0	177.9	17.1	17.0	16.8
	Edge 2	50 cm from the bottom	30.0	652.6	195.7	19.4	18.6	17.9
	Silo middle	50 cm from the bottom	30.5	672.6	205.0	21.5	20.6	20.1
05.10.2009	Edge 1	50 cm from the bottom	30.5	583.0	177.7	15.1	16.2	15.9
	Edge 2	50 cm from the bottom	29.6	636.4	188.2	15.5	17.7	17.1
	Silo middle	50 cm from the bottom	29.4	703.4	206.7	17.4	18.8	18.3
	Mean	**50 cm from the bottom**	**29.8**	**631.9**	**188.4**	**17.9**	**18.2**	**17.7**
	Min		**27.5**	**556.9**	**164.7**	**15.1**	**16.2**	**15.9**
	Max		**32.6**	**703.4**	**206.7**	**21.5**	**20.6**	**20.1**

3.4 Feed value

Use of the PistenBully had no negative effects on the feed value of the grass silage. No effects were detected on the crude protein, crude fibre, crude ash and energy content parameters (Table 5) by either the sampling position (edge sections, silo middle) or individual layers (top, bottom). The fluctuations in the material correspond to those in the primary material (Table 1).

In the comparison between biogas (n=2) and dairy cattle silage (n=27), the mean levels of crude protein, crude fibre and crude ash are the same (Table 6). However, the mean energy level in the biogas silage was 5.86 MJ NEL/kg DM; 0.3 units below that of the dairy cattle silage with a mean 6.16 MJ .NEL/kg DM. However, it must be remembered that only two samples were taken from the dairy cattle silage and energy levels in the biogas silo were detected up to 6.12 MJ NEL/kg. Therefore, the differences are more to do with the differences between the harvested crops (different land and plant stock). Additionally, the dairy cattle silage was ensilaged two days earlier. As a result, the harvested crop also only had a mean of 5.8 MJ NEL/kg DM on ensilaging (Table 1).

Six grass silage records were available for comparison from the Aulendorf “Fodder Report” database for 2009. These had almost identical parameters of feed value as those in the test samples (Table 6).

3.5 Fermentation quality

Mould formation and reheating can occur if silage is not optimally compacted. Mould formation and decomposed sections (decay) were only observed on 15th September right at the edge (layer approx. 50 cm wide, 15 cm high) and on 28th September at individual points (up to 10 cm high) in the uppermost layer directly beneath the tarpaulin. Otherwise, there was no mould in the grass silage. No mould could even be seen on 5th October. Light heating was only seen in places (see chapter 3.3).

The grass silage was all well fermented and only contained some butyric acid at the edge on the first sampling date (Table 5). Therefore, the limit value in the DLG key for very good silage of 0.3 % in DMc was not exceeded. The silage with butyric acid was outside the optimum pH range because of the slightly higher pH values (Figure 5). The silage in the silo middle was all below the critical pH level.

In contrast to the dairy cattle silage, the biogas silage had slightly lower levels of lactic acid (7.2 compared to 8.8 % in DMc) and slightly higher levels of acetic acid (1.3 compared to 0.9 % in DMc). Therefore, the pH value in the dairy cattle silage was lower by 0.2 units (4.2 compared to 4.4). The slightly lower levels of residual sugar in the biogas silage also fit with this. The ethanol levels in the dairy cattle silage were slightly higher (0.9 compared to 0.6 % in DMc). Overall however, it is clear that the fermentation quality of the biogas silage was only slightly worse at the edge section than that of the dairy cattle silage.

Following page:
Table 5: Feed value and fermentation quality of grass silage, arranged by sampling date

Date	Position	Location	DMC %	CP	CF	CA	Energy MJ/kg DM ME	NEL	pH	NH3N:N_t %	Lactic acid	Acetic acid	Butyric acid	Ethanol	Sugar
				% in DMc							% in DMc				
15.9.09	Edge 1	30 cm from the top	30.91	15.88	32.78	10.81	10.15	6.07	4.39	5.08	8.38	1.23	0.10	0.10	1.39
	Edge 1	100 cm from the top	35.66	15.73	28.43	10.30	10.16	6.07	4.43	5.14	6.87	1.15	0.14	0.14	0.95
	Edge 1	50 cm from the bottom	29.58	16.32	29.50	10.45	10.13	6.05	4.52	7.86	8.89	1.35	0.20	0.47	0.10
	Edge 2	30 cm from the top	42.30	15.34	27.63	10.70	10.22	6.12	4.48	5.19	9.05	0.66	0.21	0.43	1.65
	Edge 2	100 cm from the top	40.14	15.96	26.47	9.92	10.23	6.12	4.35	4.23	7.85	0.90	0.02	0.27	1.62
	Edge 2	50 cm from the bottom	28.98	14.72	27.80	11.36	9.85	5.87	4.46	6.12	10.94	0.97	0.07	0.41	1.14
	Silo middle	30 cm from the top	37.64	14.88	27.13	11.41	9.97	5.95	4.46	5.23	7.33	0.98	0.00	0.96	4.01
	Silo middle	100 cm from the top	34.74	14.60	26.76	12.16	9.90	5.91	4.38	4.83	7.25	1.04	0.00	0.78	4.00
	Silo middle	50 cm from the bottom	32.56	14.54	28.18	10.72	9.79	5.82	4.40	6.41	8.05	1.69	0.00	0.89	2.27
15.9.09	**n=9**	**Mean**	**34.7**	**15.3**	**28.3**	**10.9**	**10.04**	**6.00**	**4.4**	**5.6**	**8.3**	**1.1**	**0.1**	**0.5**	**1.9**
		Min	**29.0**	**14.5**	**26.5**	**9.9**	**9.79**	**5.82**	**4.4**	**4.2**	**6.9**	**0.7**	**0.0**	**0.1**	**0.1**
		Max	**42.3**	**16.3**	**32.8**	**12.2**	**10.23**	**6.12**	**4.5**	**7.9**	**10.9**	**1.7**	**0.2**	**1.0**	**4.0**
28.9.09	Edge 1	30 cm from the top	36.37	15.82	26.68	9.69	9.83	5.83	4.54	4.44	5.91	1.21	0.16	0.05	1.15
	Edge 1	100 cm from the top	26.46	14.88	27.94	10.62	9.41	5.55	4.44	7.16	6.05	3.21	0.08	0.30	0.04
	Edge 1	50 cm from the bottom	27.46	17.25	25.64	10.63	9.41	5.55	4.50	6.97	8.12	1.17	0.00	0.36	0.00
	Edge 2	30 cm from the top	41.12	15.73	26.35	9.63	10.02	5.96	4.39	4.49	6.23	0.90	0.00	0.19	2.12
	Edge 2	100 cm from the top	29.02	15.99	24.57	10.12	10.01	5.96	4.41	6.53	6.62	1.41	0.03	0.65	1.21
	Edge 2	50 cm from the bottom	29.98	17.58	26.50	9.22	9.70	5.73	4.48	6.57	7.87	1.67	0.00	1.07	0.33
	Silo middle	30 cm from the top	38.98	16.29	28.45	10.80	10.14	6.07	4.51	5.37	6.80	0.80	0.05	0.77	1.26
	Silo middle	100 cm from the top	29.76	16.08	28.86	10.39	9.82	5.83	4.26	5.59	7.73	1.24	0.00	0.81	0.40
	Silo middle	50 cm from the bottom	30.48	17.38	27.01	9.64	9.65	5.71	4.37	6.54	8.17	1.87	0.00	2.13	0.10
28.9.09	**n=9**	**Mean**	**32.2**	**16.3**	**26.9**	**10.1**	**9.78**	**5.80**	**4.4**	**6.0**	**7.1**	**1.5**	**0.0**	**0.7**	**0.7**

		Min	**26.5**	**14.9**	**24.6**	**9.2**	**9.41**	**5.55**	**4.3**	**4.4**	**5.9**	**0.8**	**0.0**	**0.1**	**0.0**
		Max	**41.1**	**17.6**	**28.9**	**10.8**	**10.14**	**6.07**	**4.5**	**7.2**	**8.2**	**3.2**	**0.2**	**2.1**	**2.1**
5.10.09	Edge 1	30 cm from the top	36.70	15.34	27.82	10.28	9.73	5.77	4.42	7.05	5.56	0.74	0.03	0.71	0.54
	Edge 1	100 cm from the top	28.89	15.36	26.98	10.12	9.54	5.63	4.49	7.01	7.89	1.77	0.07	0.73	0.14
	Edge 1	50 cm from the bottom	30.48	16.90	25.93	8.96	9.87	5.85	4.41	6.19	4.49	1.08	0.00	1.31	0.03
	Edge 2	30 cm from the top	42.24	15.35	27.10	9.31	10.07	6.00	4.46	4.91	6.01	1.07	0.00	0.52	0.38
	Edge 2	100 cm from the top	30.12	15.57	27.88	10.60	9.44	5.57	4.46	7.42	5.08	0.93	0.03	0.63	0.46
	Edge 2	50 cm from the bottom	29.57	17.03	25.79	8.24	9.76	5.76	4.31	6.41	5.41	1.22	0.00	0.54	1.01
	Silo middle	30 cm from the top	37.39	16.56	25.83	10.27	10.03	5.98	4.48	6.02	8.53	1.42	0.00	0.43	0.67
	Silo middle	100 cm from the top	30.57	15.39	27.64	10.07	9.77	5.79	4.21	6.16	8.28	1.21	0.00	0.69	0.36
	Silo middle	50 cm from the bottom	29.39	16.58	28.74	8.47	9.67	5.70	4.22	7.16	5.65	1.50	0.00	0.54	0.03
5.10.09	**n=9**	**Mean**	**32.8**	**16.0**	**27.1**	**9.6**	**9.76**	**5.78**	**4.4**	**6.5**	**6.3**	**1.2**	**0.0**	**0.7**	**0.4**
		Min	**28.9**	**15.3**	**25.8**	**8.2**	**9.44**	**5.57**	**4.2**	**4.9**	**4.5**	**0.7**	**0.0**	**0.4**	**0.0**
		Max	**42.2**	**17.0**	**28.7**	**10.6**	**10.07**	**6.00**	**4.5**	**7.4**	**8.5**	**1.8**	**0.1**	**1.3**	**1.0**

Table 6: Comparison of feed value and fermentation quality of grass silage for biogas and dairy cattle

Type			**DMC**	**CP**	**CF**	**CA**	**Energy MJ/kg DM**		**pH**	**NH3N:N$_t$**	**Lactic acid**	**Acetic acid**	**Butyric acid**	**Ethanol**	**Sugar**
			%	**% in DMc**			**ME**	**NEL**		**%**	**% in DMc**				
Biogas Silage	**n=27**	**Mean**	**32.9**	**15.9**	**27.4**	**10.2**	**9.86**	**5.86**	**4.4**	**6.0**	**7.2**	**1.3**	**0.0**	**0.6**	**1.0**
		Min	**26.5**	**14.5**	**24.6**	**8.2**	**9.41**	**5.55**	**4.2**	**4.2**	**4.5**	**0.7**	**0.0**	**0.1**	**0.0**
		Max	**42.2**	**17.6**	**32.8**	**12.2**	**10.23**	**6.12**	**4.5**	**7.9**	**10.9**	**3.2**	**0.2**	**2.1**	**4.0**
Dairy cattle silage bottom			31.9	16.5	28.3	10.3	10.20	6.10	4.2	7.2	6.8	1.3	0.0	0.9	0.6
Dairy cattle silage top			35.0	16.9	27.1	10.6	10.34	6.21	4.2	5.0	10.9	0.6	0.0	0.8	3.4
Dairy cattle silage mean (n=2)			**33.5**	**16.7**	**27.7**	**10.5**	**10.27**	**6.16**	**4.2**	**6.1**	**8.8**	**0.9**	**0.0**	**0.9**	**2.0**
Comparative value “Heuberg” (n=6)			**32.2**	**14.0**	**25.0**	**9.6**	**9.90**	**5.88**	**4.5**						

Slight effects were noted within the biogas silo with regard to individual fermentation quality parameters. The levels of lactic acid decreased slightly from the front (8.3 % in DMc) backward (6.3 % in DMc) in the silo (Table 5). The edge sections had slightly lower levels of lactic acid with a mean 6.9 % in DMc and, therefore, some higher pH levels than the grass silage in the silo middle with a mean 7.5 % in DMc. Only small effects on the lactic acid level were observed within the layers. The levels increase from the top downward from a mean 7.1 % in DMc to a mean 7.5 % in DMc.

The acetic acid levels fluctuate between 0.7 and 3.2 % in DMc. According to the DLG key, silage should not be more than 3.0 % in DMc. This limit value was exceeded once in the edge section, whilst the rest of the silage was lower.

The mean ethanol content was 0.6 % in DMc with a spread of 0.1 to 2.1 % in DMc. There are no fixed limit values for the ethanol level. However, silage should not normally be more than 1 % in DMc. In total, this level was only exceeded twice and, thus, did not pose a problem.

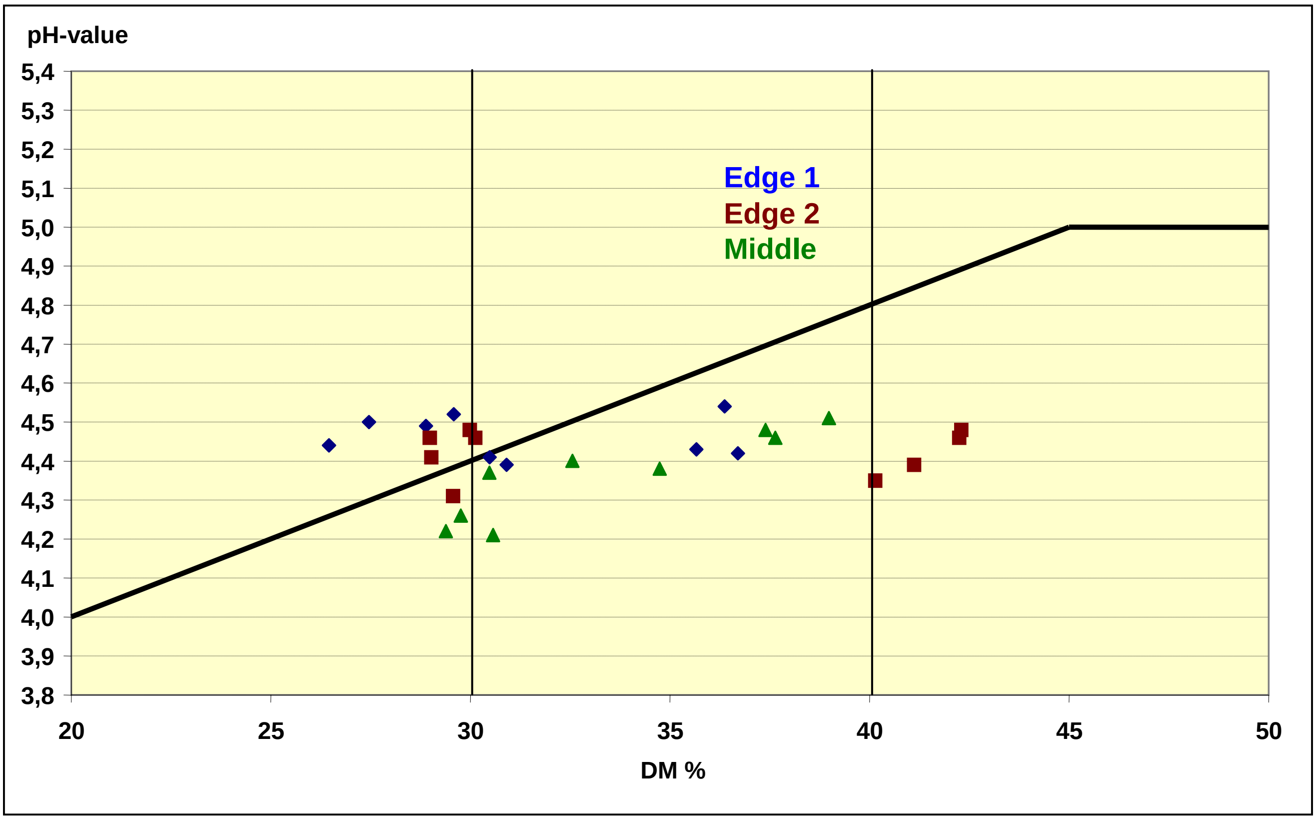

Figure 5: Grading the fermentation quality of the silage by DM content and pH value. The ideal is silage that is beneath the “critical pH value” (black line) and between 30 and 40 % DM.

The residual sugar content indicates whether there was sufficient fermentation substrate for the fermentation process. If the levels approach zero, then the fermentation substrate may be limited for fermentation. At best, the critical pH value was just achieved with the scarce substrate. Some low residual content did occur in this test. Despite this, the pH level was mainly below this critical level due to intensive lactic acid fermentation. Accordingly, the fermentation substrate was rather scarce, but was sufficient to achieve optimum fermentation with low pH values. The silage that had low residual sugar levels was precisely where high levels of lactic acid were recorded. Use of the silaging agent, which contained the homofermentative lactic acid bacteria, certainly also contributed to this and, thus, encouraged the intensive lactic acid fermentation. Additives of this kind encourage the formation of lactic acid and typically reduce the formation of acetic acid. Consequently, the predominantly low levels of acetic acid also fit into the overall picture.

4. Evaluating the results

The bunker silo was filled in even layers from the back to the front and layering was effected in a wedge shape. Accordingly, the fill level was reached first in the back section. As the harvested crop's level of wilting increased slightly from the beginning of unloading in the morning to the end in the late afternoon, the mean **DM content** at first sampling was slightly higher at the front of the silo (+2.0 % absolute) than at the back. As a result, the upper layers had higher DM content. The mean DM levels right next to the silo wall (50 cm distance) were slightly beneath those further from the wall (100 cm distance) and those in the silo middle. However, this effect is due to rainwater that had penetrated and not to use of the PistenBully. It always occurs when the tarpaulin is flush to the silo wall rather than being pulled over the wall.

Grass silage with around 33 % DM should have a **density** according to RICHTER (2009) of at least 200 kg DM/m³ and around 600 kg FM/m³. This target was exceeded in the dairy cattle silage by 25 % with a mean 250 kg DM/m³. This indicates that the dairy cattle silage was extremely well compacted. Densities of this level are normally only achieved under practical conditions when the output and rolling are very well matched to one another and rolling is done very carefully, without a break and evenly with a very high rolling weight. Additionally, the grass silage must be cut very short, which was also done here with 10 to 15 mm cut length.

The grass silage spread by the PistenBully had a lower compaction with a weighted mean of 183.2 kg DM/m³. It was around 8.5 % below the target of 200 kg DM/m³ and around 27 % below the very well compacted dairy cattle silage from the Huber firm.

The spread within the silo was high from 130 to 207 kg DM/m³, particularly between the edge sections and the silo middle. Thus, right next to the wall (edge 1) a mean of just 157 kg DM/m³ and, thus, just 78.5 % of the target was achieved. The spread in this area from 130 to 178 kg DM/m³ was the biggest (minus 11 to minus 35 %). The mean compaction of the whole silo of 173.1 kg DM/m³ was achieved one metre from the wall (edge 2) with a mean 171.5 kg DM/m³. The compaction in this zone was around 14 % below the desired compaction. The spread here ranged from 171 to 196 kg DM/m³ (minus 2 to minus 15 %). Accordingly, the PistenBully was in a position to compact this area better than edge zone 1. The fact that the PistenBully was not able to drive along directly and parallel to the silo wall because of the overhanging blade had a negative effect. The edge zone was regularly compacted though by reversing along the wall. However, this was insufficient to achieve optimum compaction right at the wall. As a result, thought should be given to how the blade can be constructed so that the PistenBully is able to drive along directly and parallel to the silo wall and compact accordingly. The fact that the silo in this test was relatively narrow and short also made things difficult.

The minimum compaction of 200 kg DM/m³ was almost achieved in the silo middle with a mean compaction of 189.7 kg DM/m³ (minus 5 %). The best compaction was achieved there with 207 kg DM/m³ (plus 3.5 %).

All tippers were weighed by the DLG test centre on unloading and the volume of the filled silo was measured by an independent surveyor. A mean compaction of 228 kg DM/m³ resulted from the overall tonnage of 501 tonnes of fresh mass and the overall volume of 716 m³ and the individual DM content of each tipper load (mean value 32.6 % DM). This density was not achieved on any occasion when sampling the grass silage. Several things may be responsible for this. Other tests by the DLG e.V. show that the mean DM content when sampling tipper loads with just one sample per tipper can deviate by an absolute 1 to 2 % from repeated sampling per tipper. It should be noted seriously that sampling with boring stock only produces a relatively small (45 mm x 450 mm) and, above all, point-like sample. Small quantitative displacements in the boring stock can clearly affect calculations on a cubic metre of silage. Three borings were used per measuring point in an attempt to counter this. However, it remains possible that the type of sampling has affected the overall result. Unfortunately, there is no precise evidence on the accuracy of this type of sampling. Nevertheless, starting with a fluctuation range of 5 to 10 %, and this tends to vary downward for grass silage due to unavoidable material deviations in the pipe (deviations in the feed), the calculated densities are within the range of the overall compaction calculated by the DLG. DM loss may be a further reason for the variations, which occur due to the fermentation liquid and the fermentation process. Fermentation liquid occurs up to a DM content of 30 %. The DM content was less than 30 % for 20 of the 46 loads (each around 11 t FM). The unavoidable fermentation losses amount to at least 7.5 % in ideal conditions and may also be higher than 10 % in practice.

If the effects of the PistenBully on the different zones in the silo are taken into account, however, then the density comparison is significant in any case. Accordingly, the edge sections are less well compacted than the samples from the silo middle. The proportion of well (+), moderately (0) and less well (-) compacted silage in the whole silo can be calculated from Figure 4. The less well compacted areas (less than 150 kg DM/m³) account for a maximum 2.5 % of the silo volume. Around 50 % of the silo was moderately compacted (150 - 200 kg DM/m³) and around 47.5 % was well compacted silage (over 200 kg DM/m³).

The increase in compaction from the top downward from a mean 155 kg DM/m³ (minus 22 %) to 175 kg DM/m³ (minus 12.5 %) to a mean 188 kg DM/m³ (minus 8 %) is seen in any silo with a similar method. The reasons for this are, firstly, the more frequent traversing of the lower layers and, secondly, the increase in dry mass content of the parts unloaded later. This can be countered by extended rerolling (up to an hour after the last tipper). The PistenBully in this test had around half an hour for this.

Mould formation and **decay** only occurred in isolated incidents and right at the edge of the uppermost layer. No mould was detected in the deeper layers. Thus, use of the PistenBully had no negative effect. The **temperature** of silage should not exceed 20 °C except for sections exposed to direct sunlight (silo access) and directly beneath the heated tarpaulin (in summer). The grass silage in this test was a mean 20 °C. Therefore, except for a few areas (end of removal, upper layer), reheating cannot be assumed. Temperatures of 20 to 25 °C were recorded in places, but these temperatures also occurred on 15th September (with ambient temperatures of 8.5 °C) in the highly compacted dairy cattle silage.

Use of the PistenBully and the compaction that was an average of 8.5 % beneath the target did not have a negative effect on the **feed value** and the **fermentation quality** of the grass silage. The 27 samples from the biogas silo (test silo) had almost identical ingredients compared with the two lots of silage from the dairy cattle silo, except for the energy content (minus 0.3 MJ NEL/kg DM). The levels are also at the same level as other silage from the "Heuberg" region. There were fluctuations in the feed value within the silo, but these were less to do with the type of rolling vehicle and far more to do with fluctuations in the harvested crop (see Table 1). This may also have been the reason for the slightly lower energy level in the biogas silage, especially as the dairy cattle silage was ensilaged one to two days earlier. The silage was very well compacted particularly in the silo middle. The pH levels were only outside the optimum range in the edge zones (see Figure 3). Butyric acid was also analysed there in individual samples, although the maximum level at 0.2 % in DMc never exceeded the limit value according to the DLG key of 0.3 % in DMc. The target level of over 5 % in DMc was definitively surpassed with a mean 7.2 % in DMc thanks to use of a silaging agent that contains lactic acid bacteria. Therefore, there were also low levels of residual sugar in the silage. Accordingly, the sugar level in the harvested crop was sufficient for good fermentation.

The level of acetic acid in the silage was probably reduced to a mean 1.3 % in DMc by using the homofermentative silaging agent. This should be between 2 and 3 % in DMc. Low acetic acid levels increase the risk of reheating. However, as a high average removal rate of four metres per week was achieved in this test, the low level of acetic acid could not have a negative effect.

5. Summary

Wilted meadow grass (1st growth) was harvested in Meßstetten using a chaff chopper on 28th May 2009 and spread and compacted in a bunker silo using a PistenBully 300. The harvest process was completely documented by the DLG test centre by weighing the 46 tippers (501 t FM) and certifying the rolling work and does not constitute part of this report. Samples were taken by the LAZBW Aulendorf from each tipper to determine the dry substance content. The feed value of 10 samples was also tested. In total, 501 tonnes of fresh mass were ensilaged within 10 hours and covered with tarpaulin on the same day.

After a fermentation and storage period of 3.5 months (105 days), the grass silage was removed for feeding in a biogas plant and completely used as fodder within 5 weeks. The silage was sampled three times during the removal period (15th, 28th September, 5th October 2010) and analysed with regard to compaction, fermentation quality and temperature. Three core samples were removed at three positions (edge 1, edge 2, middle of the silo) and layers (0.30 m, 1.00 m from the top; 0.50 m from the bottom) on each occasion and the temperature in the bore holes was measured at three depths (15 cm, 50 cm, 150 cm).

On the first sampling date, grass silage from another silo was also sampled for comparison at two points. This was filled two days before the test silo with a comparable harvested crop (1st growth) using the same harvesting technology, but was rolled with a wheel loader (18 t). Silage data for the region from the LAZBW fodder database was available for further comparison.

The results of silage sampling can be summarised as follows:

1. The 27 silage samples had a mean 33.4 % DM (26.5 – 42.3 %) and reflect the content on unloading with a mean 32.6 % DM (21.1 - 46.6 %).

2. The DM content in the silo decreased from the top downward from a mean 38.2 % DM to 31.7 % DM, to 29.8 % DM. This effect is because more heavily wilted grass was unloaded as filling progressed in the afternoon.

3. Slightly lower DM content with a mean 31.4 % DM was detected in edge section 1, i.e. right next to the silo wall, than the 34.8 % in edge section 2 (1 metre from the wall) and the 33.5 % DM in the middle of the silo. Some rainwater probably seeped into this area, although the silage was very carefully covered with tarpaulin and undersheet. The fact that the tarpaulins were butted up against the wall certainly contributed to this. It was not possible to pull the tarpaulins over the silo wall because of the type of construction.

4. The test results showed that the PistenBully had no effect on the DM content of the silage as expected. The two lots of grass silage from the silo for the dairy cows had a mean 33.5 % DM, whilst the “Heuberg” region grass silage was also at the same level with 32.2 % DM.

5. The grass silage spread by the PistenBully had a mean compaction of 183.2 kg DM/m³. It was around 8.5 % below the target of 200 kg DM/m³ and around 27 % below the very well compacted dairy cattle silage from the firm (250 kg DM/m³). This indicates that the dairy cattle silage was extremely well compacted. Densities of this level are normally only achieved under practical conditions when the output and rolling are very well matched to one another and rolling is done very carefully, without a break and evenly with a very high rolling weight.

6. The mean compaction of 183.2 kg DM/m³ differed from the mean compaction of 228 kg DM/m³ recorded by the DLG on unloading. Causes of this are the unavoidable DM losses through fermentation liquid (up to 30 % DM) and the fermentation process itself (at least 7.5 %). The DM content was less than 30 % for 20 of the 46 loads. Possible variations may also be due to the point-like and small samples using sample borer, where quantitative displacements in the boring stock can clearly affect calculations.

7. There was a large range of compaction within the silo from 130 to 207 kg DM/m³ and effects were clear between the layers and positions. These effects are also due to use of the PistenBully. Around 47.5 % of all the grass silage was well (over 200 kg DM/m³), a further 50 % moderately (150 - 200 kg DM/m³) and around 2.5 % was less well (under 150 kg DM/m³) compacted.

8. The lowest compaction was measured at the silo wall with a mean 157 kg DM/m³. In comparison to the target of 200 kg DM/m³, this means lower compaction by around 21 %. The mean density around a metre from the silo wall was 171.5 kg DM/m³ and, thus, around 14 % beneath the target. The best mean compaction of 190 kg DM/m³ was measured in the middle of the silo. The compaction there was only around 5 % lower than the target of 200 kg DM/m³.

9. Edge effects were also noted with other techniques. The closer the rolling vehicle was able to work along the wall, the smaller these effects were. The fact that the PistenBully was not able to drive along directly and parallel to the silo wall because of the overhanging blade had a negative effect at the silo wall. The edge zone was regularly compacted though by reversing along the wall. However, this was insufficient to achieve optimum compaction right at the wall. Accordingly, in our opinion the design

should be amended so that the vehicle can drive along and compact right next to the wall in future.

10. The compaction increased from the top downward in the silo from 155 kg DM/m³ to 175 kg DM/m³ with a mean 188 kg DM/m³. Effects of this kind are observed frequently in all silos regardless of the rolling technique.

11. Mould formation and decay only occurred in isolated incidents and right at the edge of the uppermost layer. No mould was detected in the deeper layers. Thus, use of the PistenBully had no negative effect.

12. The temperature of the grass silage was a mean 20 °C. Therefore, except for a few areas with up to 32.6 °C (end of removal, upper layer), reheating cannot be assumed. Temperatures of 20 to 25 °C were recorded in places, but these temperatures also occurred at the same time in the highly compacted dairy cattle silage.

13. The reduced compaction has not had a negative effect on the fermentation quality of the grass silage because of the high removal rate of 4 metres per week.

14. The 27 samples from the test silo had almost identical ingredients compared with the two lots of silage from the dairy cattle silo except for the energy content (minus 0.3 MJ NEL/kg DM). The levels are also at the same level as other silage from the "Heuberg" region.

15. There were fluctuations in the feed value within the silo, but these were less to do with the type of rolling vehicle and far more to do with fluctuations in the harvested crop. This may also have been the reason for the slightly lower energy level in the biogas silage, especially as the dairy cattle silage was ensilaged one to two days earlier.

16. The silage was very well compacted particularly in the silo middle. The pH levels were only outside the optimum range in the edge zones. Butyric acid was also analysed there in individual samples, although the maximum level at 0.2 % in DMc never exceeded the limit value according to the DLG key of 0.3 % in DMc.

17. High levels of lactic acid were achieved with a mean 7.2 % in DMc, but low levels of acetic acid (1.3 % in DMc), thanks to use of a silaging agent that contains lactic acid bacteria. This should be between 2 and 3 % in DMc. Low acetic acid levels increase the risk of reheating.

18. The grass silage had low levels of ethanol (0.6 % in DMc) and ammonia nitrogen (6 % of the total N). Thus, there was no protein breakdown and only slight alcoholic fermentation.

These results show that use of the snow groomer (PistenBully 300) to ensilage meadow grass (1st growth, 32.6 % DM, finely cut) had no negative effect on the feed value of the silage and utilisation in the biogas plant, despite a weighted mean compaction of 183.2 kg DM/m³, which was around a mean 8.5 % beneath the target of 200 kg DM/m³.

6. Responsible for the results

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