Grass silage compaction in horizontal silos

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Abstract

Keywords: grass forage, bulk density

1 Introduction

Horizontal silos are still popular because they are low-cost to build and need modest mechanisation for filling and removal of the silage. Good compaction is a premise for high quality silage. Nevertheless year after year huge amounts of silage and so real financial values vanish into thin air because of poorly compacted silages.

Quality of grass silage compaction depends on forage characteristics as well as on technical conditions of silage filling and compaction. Crude fibre content, dry matter content and cutting length influence the silage compactibility. The most important technical factors are layer thickness, forage dispersal, weight of the compacting tractor and compacting time.

Starting with the opening and feeding of the sealed silos, oxygen diffuses into the silage and aerobic microorganisms begin to metabolise. This process leads to deterioration and can easily be detected by the heating of the silage. The lower compaction is, the easier oxygen can diffuse into the silage and the quicker deterioration goes on. To stabilise silage as long as possible, Honig (1991) defined minimal compaction values with gas exchange rates of $< 20 \text{ l m}^{-2}\text{ h}^{-1}$.

Practice-oriented literature releases technical reference values to reach the necessary compaction. For example, the weight of the compacting tractor should be as high as one-third of the hourly forage quantity (Miller, 2006; Nußbaum, 2007). The compacting time should be 3-3.5 minutes per incoming tonne of wilted grass (Edner, 1985). Layer thickness should be at most 30 cm to guarantee a sufficient depth effect in compaction. Therefore, the usage of grass silage spreader is recommended. Compacting tractor’s tyre pressure should be 2.5 bar and higher. In spite of this recommendations there are a lot of bad compacted silage piles as a german study of Thaysen, Ruser, and Kleinmanns (2006) shows. In this study only one third of the silages reached the requested compaction rates. Own investigations in Switzerland showed, that one third of swiss grass silages were deficient or of bad fermentation quality (Latsch & Sauter, 2012).

The aim of this study was to identify the influence of the parameters compacting time, weight of compacting tractor and tyre section width on the achievable compaction rate in grass silage.

2 Materials and methods

The filling and compacting of four horizontal silos (W x L x H: 6 x 25.6 x 1.8 metres) with grass was examined in this project. For each incoming wagonload, the fresh matter masses and the dry matter content was registered. The ballasted compacting tractor (John Deere
6920; weight of 10.1 tons) was equipped with standard tyres on the left side and tyres with a 20% smaller maximum width on the right side of the vehicle to identify potential differences in compaction performance. Consequently contact pressure of the smaller tyres increased by 20% at the rear tyre and by 30% at the front tyre (Table 1). Accordingly there were three areas in the silo where only the left (area A) or the right tyres (area C) or both of them (area B) were rolled over. In area B compacting time is almost twice as high as in area A and C. All collected data were allocated to the compacting areas (Figure 1).

![Ultrasonic sensors](image_url)

**Figure 1: Sketch of the test design with ultrasonic sensors, different tyre section width and compacting areas A, B and C.**

**Table 1: Tyre dimension, width of compacting area and contact pressure of the compacting tractor**

<table>
<thead>
<tr>
<th>Tyre dimension</th>
<th>650/65R38</th>
<th>540/65R28</th>
<th>20.8R38</th>
<th>16.9R28</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>rear left</td>
<td>front left</td>
<td>rear right</td>
<td>front right</td>
</tr>
<tr>
<td>Compacting area</td>
<td>A (1.89 m)</td>
<td>C (1.77 m)</td>
<td>B (2.11 m)</td>
<td></td>
</tr>
<tr>
<td>Tyre section width [mm]</td>
<td>642</td>
<td>520</td>
<td>553</td>
<td>429</td>
</tr>
<tr>
<td>Tyre diameter [mm]</td>
<td>1838</td>
<td>1420</td>
<td>1828</td>
<td>1420</td>
</tr>
<tr>
<td>Wheel load [kg]</td>
<td>2980</td>
<td>2130</td>
<td>2910</td>
<td>2170</td>
</tr>
<tr>
<td>Tyre pressure [bar]</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Contact area [cm²]</td>
<td>4667.6</td>
<td>4346.6</td>
<td>3720.0</td>
<td>2977.2</td>
</tr>
<tr>
<td>Contact pressure [%]</td>
<td>0.638</td>
<td>0.490</td>
<td>0.782</td>
<td>0.729</td>
</tr>
</tbody>
</table>

1 Pre-test data recorded 2008 and analysed with TASC 2.0 (Diserens, 2010)

The position of the compacting tractor inside the horizontal silo was recorded every second by RTK-GNSS-data logger (Trimble, Sunnyvale, CA, USA). Using a geographical information system (Quantum GIS Lisboa 1.8.0) the position and hence the compacting time could be related to the compacting areas.
The storing of forage was done with a self-loading wagon with feeding-out conveyor (Agrar Bison 452, GVS, Schaffhausen, Switzerland). The mean wagon load of the four silos lay between 3300-3900 kg original substance. Further forage dispersal was manually made by hay fork.

The pile height was linearly scanned by 6 ultrasonic sensors (Pepperl & Fuchs UC-6000-30GM-IUR2-V15, Mannheim, Germany) that were installed in a mobile measuring bridge, moving on two rails (Figure 1). The measurement was done along the length of the silo in continuous distances of 40 cm each time the compaction was done. The resultant 3-dimensional net was used to calculate the volume of the pile.

After the silo was opened, evenly spaced core drilling samples with vertical distances of 20 cm were taken at different sites. The statistical analysis with a logistic regression was performed with a generalised linear mixed model (GLMM). The following parameters were aggregated and differentiated between the compacting areas: location and density of drilling samples, retention time and number of passages of the compacting tractor per wagonload, compacting time and quantity of wagonloads per drilling sample and increase in forage height between drilling samples.

3 Results

Comparing the silos dry-matter bulk density (Table 2) with the minimal compaction values of Honig (1991) shows the good to very good compacting work quality of our silos. In 2009 the calculated bulk density is almost identical to the median drilling sample density. In 2010 there are differences of 12.5% and 16.5% up- and downwards, which can be explained with the huge data variation.

<table>
<thead>
<tr>
<th></th>
<th>Original substance (OS) total</th>
<th>Mean dry-matter content (DM)</th>
<th>Dry-matter substance (DM) total</th>
<th>Volume total</th>
<th>Bulk density¹ OS</th>
<th>Bulk density¹ DM</th>
<th>Median drilling sample densities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Silo</td>
<td>143700</td>
<td>26.6</td>
<td>38192</td>
<td>208.3</td>
<td>690.0</td>
<td>183.4</td>
<td>185.3</td>
</tr>
<tr>
<td>2. Silo</td>
<td>85356</td>
<td>47.1</td>
<td>39651</td>
<td>154.3</td>
<td>553.0</td>
<td>256.9</td>
<td>250.6</td>
</tr>
<tr>
<td>2010</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Silo</td>
<td>126410</td>
<td>34.7</td>
<td>44055</td>
<td>210.9</td>
<td>599.3</td>
<td>208.9</td>
<td>183.4</td>
</tr>
<tr>
<td>2. Silo</td>
<td>133090</td>
<td>33.0</td>
<td>43509</td>
<td>176.0</td>
<td>756.2</td>
<td>225.3</td>
<td>258.3</td>
</tr>
</tbody>
</table>

¹ calculated bulk density in relation to original substance OS and calculated silage volume

Figure 2 shows the bulk density of one silo according to its height position. For a better presentation, data points of compacting areas at the same height are scattered. There is an enormous heterogeneity in bulk density in one and the same height. Statistical analysis showed, that no spatial structuring within the layers of the same height inside the silo occurred. A general trend shows the highest bulk density at the bottom of the silage pile with decreasing values in higher layers. The lowest values at the very bottom of the pile (0.2 m) depend on the way of silage unloading. Extracting the silage with a front loader silage grab fork always loosens up the silage pile by pulling out forage material.

There are no significant differences between the bulk density in compacting area A, B or C. Under given conditions the different tyre dimensions show no verifiable effects on bulk density.
Statistical analysis showed no significant interaction between bulk density and compacting time. Mean compacting time per tonne original substance and load was 1 min. 49 sec. at compacting area A and 2 min. 22 sec. at compacting area C. At compacting area B compacting time was 5 min. 35 sec. and thus more than twice as long (Figure 3).

Compacting time in compacting area C is in every case a bit longer than in area A (Figure 4). This fact can be explained with the individual influence of the tractor driver. Compacting area B has the longest compacting times due to the fact that it is overrun from both tractor sides. The extra compacting time in area B does yet not lead to better bulk density values.
4 Discussion

Under given conditions, the silage pile was obviously not more compactable. Neither smaller tyres nor longer compacting time led to significantly higher bulk density. The suggestion of the Bundesarbeitskreis Futterkonservierung (2006) to overrun each place of the silage at minimum three times was fulfilled and maybe this fact interfered with the positive effects that smaller tyres definitely have. In comparison to statements in scientific literature, where compacting times of 2-3.5 minutes are recommended (Bundesarbeitskreis Futterkonservierung, 2006; Edner, 1985; Grünig, 2007; Miller, 2006; Nußbaum, 2007), measured compacting times lay at the lower end of this range.

Thaysen, et al. (2006) describe explicit differences in bulk density between the dense inside of the silage pile and its looser outside. A density gradient from bottom to top was also found in this study, but no spatial structuring within the layers of same height inside the silo occurred. The extreme heterogeneity of bulk density in this investigation could also be found in a separate study that was performed within the same silos (Latsch & Sauter, 2013). The declining bulk density from bottom to top was clearly visible, but within the same layer, there was a huge variance of density values.

5 Conclusion

The investigation showed, that one main problem in compacting work of grass silage in bunker silos seems to be the heterogeneity of bulk density. This problem occurs, when forage is not well distributed after unloading and peaks and troughs of grass lie directly side by side. To solve this problem, forage distribution should be improved by creating thin even layer.

6 References


