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Density determination of grass silage – Comparison of five measurement methods

In practice silage blocks are frequently measured and weighed to determine the density of grass silage. Scientific studies of density and silage quality were carried out to compare this variant with four other measurement methods. “Big blocks” are inherently relatively heterogeneous and hence cannot be used for the fast, precise determination of density. “Small blocks” represent density well, but their handling makes them unsuitable for quick sampling. The three measurement methods - “PioneerTM drilling jig”, “inclined drilling cylinder” and “vertical drilling cylinder” - gave comparable results. The “inclined drilling cylinder” was identified as the preferred variant on the basis of results and manageability.

Keywords
grass silage, density, measurement methods

Abstract
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Good forage compaction is essential for the production of high quality grass silage. It minimises reheating and the energy loss accompanying the opening of a silo. Good compaction reduces oxygen diffusion in the forage pile, which should not exceed 20 l/m^2 • h [1]. Under these conditions the area of silage favouring the activity of harmful aerobic organisms such as acetic acid bacteria and mould fungi is minimal, and the silage remains stable.

As the efficiency of cylinder choppers and silage trailers improves, compacting work in horizontal silos increasingly leads to hold-ups in the silaging process. Thus far there have been no methods of determining bulk density during silo filling, so an assessment of compaction quality can only be made after a silo is opened. Silage blocks are often used to determine compaction as they are easy to extract, weigh and measure, but this type of sampling does not include problem zones at ramps, silage edges and surfaces [2-4]. Drilling cylinders such as those used to determine the density of maize silage can be used for this [5]. Due to the fibrous structures of grass silage, however, this method produces mechanical disturbance in the samples. An existing “Apparatus for obtaining an undisturbed core of silage” [6] has not become widespread to date. There is, moreover, no standard sampling procedure.

The relationship between bulk density and silage quality is therefore being studied in a research project at the Swiss Federal Research Station Agroscope Reckenholz-Tänikon (ART). Within this framework sampling by means of hand-held devices is compared with the “silage block” method.

Material and methods

Two silage blocks were taken from different horizontal silos for comparison. The average DM content of the blocks was 26.6 and 30.7 %. The theoretical cutting length of the silage trailer involved was 40 mm. The stored green material originated from both natural grassland and temporary ley. Compaction was carried out by a standard ballasted tractor with a laden weight of 10 230 kg and an internal tyre pressure of 2.5 bar.

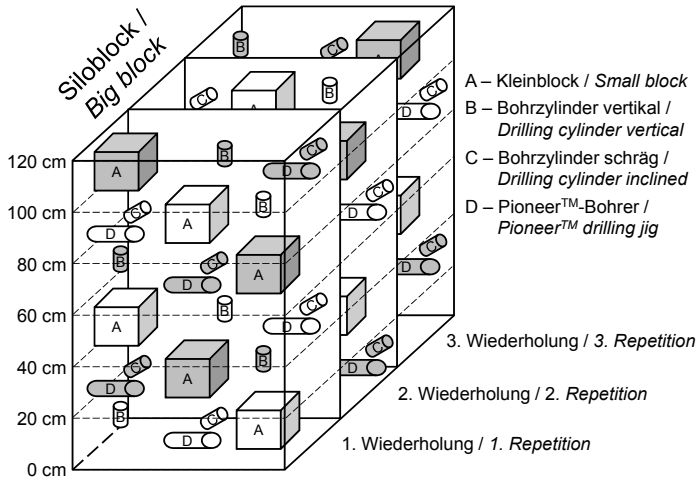
A comparison was made between the “big block”, “small block” and “Pioneer^{TM} drilling jig” variants and a “drilling cylinder” developed in-house, which was used in an inclined and vertical drilling direction. The sampling devices are shown in **Figure 1**.

The silage blocks were extracted with a Trioliet type TU 145 block cutter (Oldenzaal, NL) (width x depth: 1.75 x 0.75 m). A hand-held electric silage cutter (OMC, type AS/85, Correggio, IT) was used to cut out small blocks (0.2 x 0.2 x 0.015 m^3). The volume of the samples taken with the Pioneer^{TM} drilling jig (Pioneer, type Hi-Bred, Buxtehude, DE) was determined by the drill hole diameter (45 mm) and the measured drill hole depth. The volume of the stainless steel drilling cylinder (internal diameter 56 mm, wall thickness 2 mm) developed by ART was calculated, core drilling being limited to a defined length of 100 mm by slots in the drilling cylinder. The drilling cylinder was driven electrically at 120 rpm. Coarse teeth were

Abb. 1

Sampling devices used in the trial: 1 – Silage block cutter; 2 – Drilling cylinder (ART); 3 – Electric silage cutter; 4 – Pioneer™ drilling jig

Fig. 2



Scheme of the silage block with the spatial allocation of the four different sampling methods in three repetitions

notched into the chamfered cutting edge in order to chop the grass silage thoroughly.

As silage blocks can expand vertically when extracted, the layers for testing (each 0.2 m) were pre-marked in the undisturbed silage. The height of the silage block was limited to 1.2 m for the trial. The precise measurements and weight of the silage blocks were determined following extraction. Samples were subsequently taken from these blocks with the hand-held devices (**Figure 1**).

Figure 2 shows the 18 designated sampling locations at six different levels and in three repetitions. The volume and weight of all the samples were calculated to determine density. The trial was supplemented by pairwise comparisons of each of the sampling devices effected in the same manner directly in the silage pile.

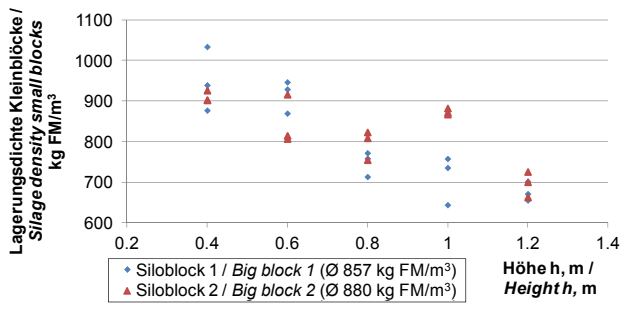
Statistical analysis was carried out using a pairwise linear regression model (Tibco Spotfire S+, Somerville, MA, USA).

Results and discussion

As a rule the bulk density of silage blocks is considered to be representative and is transferred directly to the silage as a whole. As part of this project the average overall bulk density of the horizontal silo investigated was also recorded on the basis of the harvested product introduced and the measured overall volume of the forage pile. The comparison yielded a not inconsiderable difference between the figures. At 857 kg FM/m^3 the first big block overestimated by 24 % the overall bulk density in the silo, calculated at 690 kg FM/m^3. The second big block (880 kg FM/m^3) overestimated overall bulk density (756 kg FM/m^3) by 16 %. An explanation for this difference may be that the big block was taken from a well compacted position in the silage pile. The nature of the system means that problematic silo zones like beginning and end, wall areas and silage surfaces cannot be taken into account because of the inclination. The target values for well compacted grass silage are given as 800 kg FM/m^3 for 20 % DM content and 560 kg FM/m^3 for 40 % DM content [7, 4]. On average, therefore, compaction of the big blocks (DM content 27 and 31 %) was rated as very good.

Figure 3 shows the density heterogeneity of the big blocks compared with the bulk density of the small blocks. Evaluation of the measurements confirms observations whereby density decreases as distance from the base plate increases [8, 9].

Fig. 3



Mean variation of silage density in big blocks determined by small block variant

Whole big blocks are therefore only suitable for a quick assessment of the average overall density of horizontal silos. The "small block" method was subsequently used as a reference for the comparability of selectively drawn samples.

Figure 4 shows the values for the three drilling variants with reference to the "small block" variant. The residual standard error (Res. SE), as a measure of the dispersion of the data points around the regression line, is comparatively close together in the three drilling variants. Here the "inclined drilling cylinder" variant compares favourably with the other two variants due to somewhat lower dispersion. But if, for example, the difference in the prediction accuracy of both drilling cylinder variants is calculated, these only differ by between 1 and 2 %. Both the gradient and the displacement of the regression lines to the x = y line were calculated for x = 869 kg FM/m³, but played a subordinate role in the given dispersion range of the values. All three variants underestimated the density of the reference "small block".

Kleinmans et al. [3] and Thaysen et al. [2] reported good results with the Pioneer™ drilling jig in maize silage. Analogously to the results shown here, they also reported that the Pioneer™ drilling jig tends to underestimate bulk density.

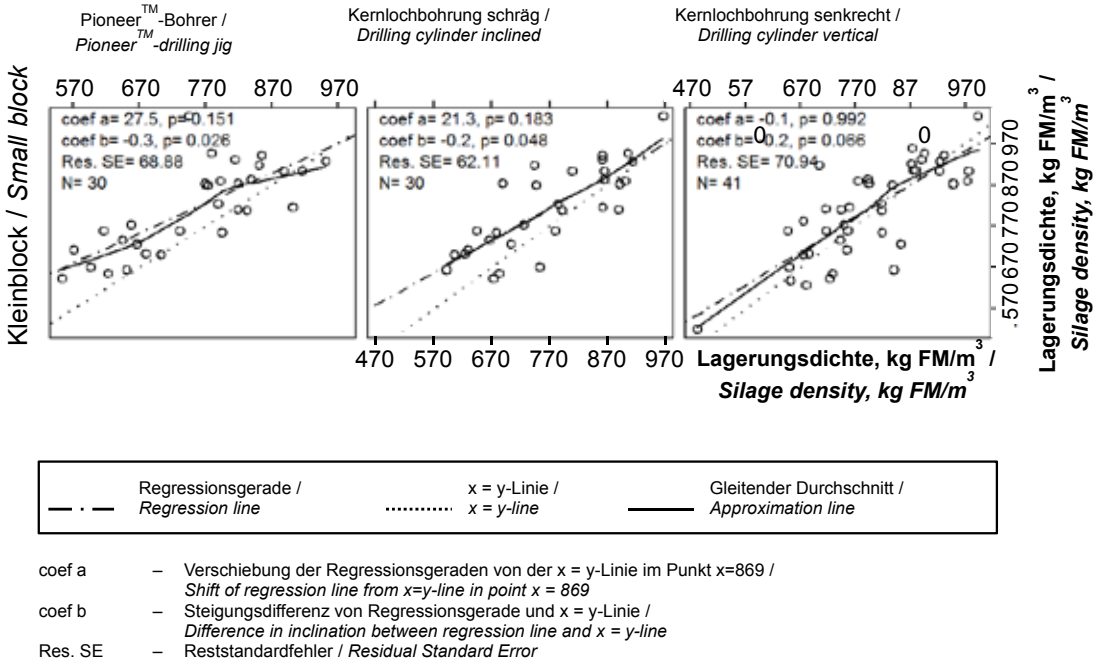
Horizontal drilling is recommended by Kleinmans et al. [3] for the extraction of maize with the Pioneer™ drilling jig. By comparison, the fibrous structure of grass silage results in the silage being pulled out of the drilling jig again during horizontal sampling and measurement of the drill hole depth reduces the calculated density. Drilling carried out at an angle to the horizontal bedding layers of the silage generally effects better separation of the grass silage fibres and the individual layers are no longer pulled out of the drilling jig.

The drilling cylinder used in this trial was driven by an electric drill. This represents a huge saving in labour, particularly when extracting a sizeable number of samples. An inclined drilling direction is preferable to a vertical one, as in this way samples can be taken at the cutting point of the silage.

Conclusions

The study shows that, due to the extraction point, the big blocks extracted overestimated the average overall density by up to 24 %, whereas the individual samples taken with handheld devices testified to the enormous heterogeneity of density conditions within the silage blocks. It was found that silage densities decreased as distance from the base plate increased. The same was true of the areas at the edge of the forage pile.

Fig. 4



coef a – Verschiebung der Regressionsgeraden von der x = y-Linie im Punkt x=869 / *Shift of regression line from x=y-line in point x = 869*

coef b – Steigungsdifferenz von Regressionsgerade und x = y-Linie / *Difference in inclination between regression line and x = y-line*

Res. SE – Reststandardfehler / *Residual Standard Error*

Silage density of the drilling variants with reference to the small block

This means that all areas of the silage must be examined when taking samples in horizontal silos. The important point here is that a sizeable number of small silage samples are more representative of density conditions in horizontal silos than a few large-volume samples.

A large number of samples can be taken quickly and efficiently with the aid of drilling cylinders. Less compacted layers, which conduct air and hence do not suppress the activities of aerobic and optionally anaerobic microorganisms, can be identified and appropriate countermeasures taken. The drilling direction should be chosen with care to ensure satisfactory filling of the drilling cylinder. Drilling should be carried out obliquely or vertically in relation to the bedding direction of the fibres in order to separate the fibrous structure of the grass silage.

In statistical analysis the variants tested showed only slight differences of between 1 and 2 % in density prediction accuracy, the tendency being to underestimate the density. Rather better statistical consistency with the reference "small block" and comparatively easier handling made the "inclined drilling cylinder" variant the preferred variant in this trial.

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