Compression Characteristics of Wilted Grass

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ABSTRACT

Farm managers have been recommended to implement controlling measures in silo management (Spiekers, 2004). Quality analyses as well as density and temperature measurements are intended to help them assess their preservation work (*a posteriori*). To control the quality throughout the process chain, from harvest to feeding (*a priori*), online measurement systems which capture different process factors and parameters (e. g. mass flow, moisture content) are commercially available. In order to exert a purposeful influence on quality, online measurements must be linked with the corresponding measures (intensity of compression).

A minimal length of cut is necessary because grass silage must fulfil animal nutritional requirements with regard to the structural value. The aim of the present investigations is to investigate the influence of length of cut on compressibility at different moisture contents.

The results of compression tests show that in the case of high fiber concentrations the different lengths of cut have no influence on the density of the material after recovery. The effect of a difference of 9 percentage points in the moisture content showed 10% difference in density.

Keywords: silage, quality assurance, information management, compression characteristics

1. INTRODUCTION

Recent practical investigations have shown that problems with undesirable temperature increases in silage are on the rise (Spiekers et al., 2003). Due to the increased throughput and field capacities of harvesting machines, growing mass flow rates have to be dealt with at the silo, which makes it difficult to compress the harvested crops with adequate care. In practical dairy farming, the trend towards permanent housing adds to this problem in that silos are open for longer periods of time – even throughout the summer – and are thus exposed to the risk of aerobic thermophile processes.

"Factors affecting silage fermentation and storage include the composition of the crop, harvest, wilting, additives and silage system including loading, pressing and covering" (Lindgren, 1999).

For the purpose of process control, agricultural advisers give farm managers rule-of-thumb values for dry matter, theoretical length of cut, density, and feed-out rate. Thanks to the development of online sensors, information on the ACTUAL VALUES can be collected even during the harvest (Günther et al., 2004; Egbers et al., 2005).

Information on the necessity of adjustments that might follow from these values could make operative interventions possible even during the harvest (process control). A prerequisite of such process control is that the interconnectedness of the different quality-influencing factors should be known (Fig. 1).

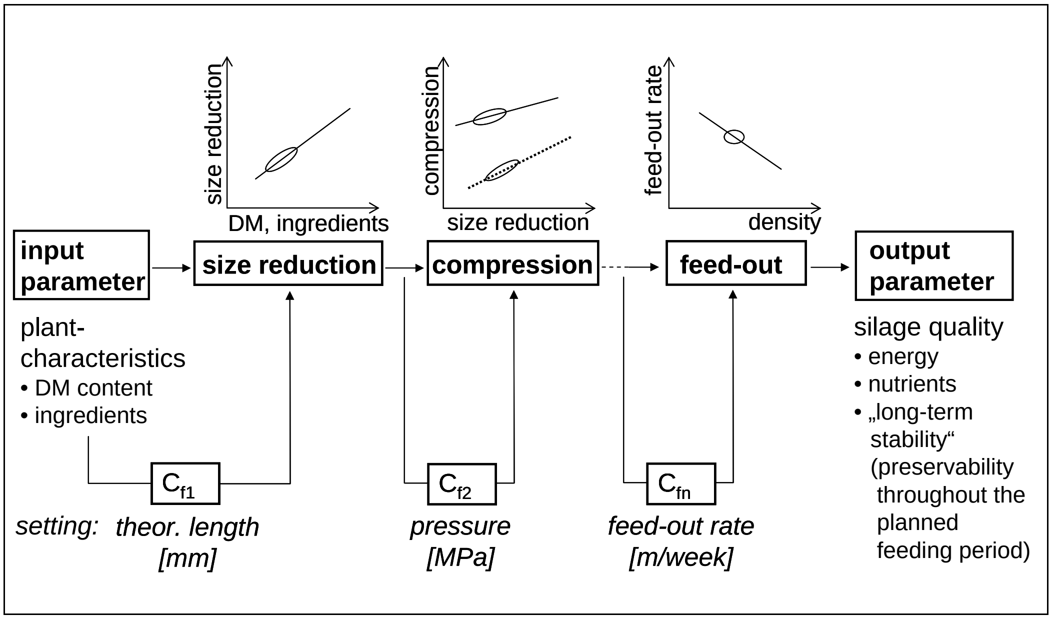

Figure 1. Control loop for quality assurance of silage (c = control, f = factor) (Wagner, 2005)

In the decision process there is an immediate temporal relationship of the dry matter content to the size reduction by harvesting equipment. The optimum wilting degree is quoted as 30 to 40% DM, with the recommendation that the optimal length of cut depends on DM and fibre content and, if applicable, on the kind of feeding technology used (Thaysen, 2004). The optimal length of cut ranges between 4 and 8cm (Thaysen, 2004). For animal nutritional reasons, a minimal length of cut of 2cm has been demanded (Brabander, de et al., 1999).

The compression properties of forage materials have been examined by a number of investigators. Zimmer (1967) observed that the effect of size reduction of cereal feeds increases with wilting intensity. According to Fürll (1972), the DM content and chop length (17.6mm and 35.2mm) of wilted meadow grass have a very small influence of 2-3% on material recovery. Investigations of t'Hart (1984) showed that for grass with a dry matter content higher than 30% the density of chopped material was greater than that of unchopped material under a given pressure, and density decreased with crude fibre content.

Pitt and Gebremedhin (1989) performed compression tests with grass at two chop lengths (6.4 and 12.7mm). There was an increase in stiffness (resistance of forage material to applied pressure) with longer chop length at lower DM concentrations ($200g*kg^{-1}$ and $270g*kg^{-1}$). From these results Pitt and Gebremedhin (1989) deduced that moisture concentration affects the material stiffness of forage. The density at saturation is also dependent on moisture concentration, because of differences in the specific gravities of water and silage dry matter (1.5 to 1.87) (Muck et al. 2003).

For settled silage, according to Segler und Winkeler (1955), the differences in specific gravity between various techniques of size reduction were only very small. McGechan (1990) showed that the density of grass silages in bunker silos decreased by approximately 20% as the median chop length increased from 20 to 100mm. The values are quite variable and are also affected by the fibre content.

The objectives of this study are to measure and describe the influence of cut length on density recovery after compression at a difference of 10 percentage points in moisture content.

2. EXPERIMENTAL METHOD

Investigations concerning the influence of dry matter content and length of cut on the compressibility of grass silage are presented in the following. The investigations took place in May 2004 on the Frankenforst experimental farm of Bonn University with a self-loading forage wagon (*Claas Quantum 3500 S*) with a 33-knife cutting and loading rotor. The shortest theoretical length of cut (l_{th}) of the forage wagon is 4.5 cm. There was no additional treatment of the grass by a conditioner. The material (first-growth crop, fibre concentration of $270g*kg^{-1}$DM) was collected at two different times of day with a half set of knives and with a full set respectively so that the dry matter contents of the harvested forage differed by 9 percentage points.

To assess the size reduction of the wilted material, 50g fresh material were fractionated with a fractionating tray (DLG test framework for pick-up balers) and converted into percentages by weight. This was carried out in four replications for each variant. The analysis of the results was based on the arithmetic mean and the mean error.

Figure 2. Materials testing machine

Compressibility was determined with a materials testing machine (*Zwick 1445*) (Fig. 2). The chopped material was filled loosely into a cylindrical plastic container with a height of 30 cm (11.5cm inner diameter) and compressed with a plunger at a rate of 90mm/min.

The maximum compression pressure achievable with the materials testing machine used was 0.45MPa. The force applied to compress the material is measured continuously with a force transducer and recorded over the whole path of the plunger (force-distance diagrams). For the purpose of assessing the collected data, pressure-density-diagrams were drawn up. In addition to maximum compressibility, the parameter of material recovery was included in the investigation, too. For this purpose, the fill level in the cylinder was measured one minute after compression. These measurements were carried out in six replications for each variant.

For the statistical analysis, the mean values were compared using the Tukey test. The probability of error was $\alpha \leq 0.05$ in all calculations.

3. RESULTS AND DISCUSSION

This investigation is a comparison of the compression characteristics of material from a self-loading forage wagon with a half set of knives (l_{th} = 9,0cm) and a full set of knives (l_{th} = 4.5cm) respectively.

For the purpose of material characterisation, the results of the fractionation of the fresh material into different size classes are depicted in Table 1. The greatest differences between ‘short’ and ‘long’ can be found in the 4-8cm fraction, in which size reduction with a full set of knives leads to a percentage by mass that is 18.1 percentage points higher than in the case of size reduction with a half set of knives. In the 16-24cm fraction, however, the percentage by mass of the latter is 11.9 percentage points higher than the variant with more intense size reduction. Thus, a reduction by half of the number of knives leads to a shift of the greatest percentage by mass from the 4-8 cm fraction to the 16-24cm and 24-48cm fractions.

Table 1. Percentage by mass in different particle size classes with a complete and half knife-set of the loader wagon (dry matter content 33%)

particle size classes [cm]	theoretical length of cut [cm]	
	4.5	9.0
$x < 4$	6.7	4.8
$4 \leq x < 8$	46.8	28.7
$8 \leq x < 16$	34.6	36.7
$16 \leq x < 24$	8.9	20.8
$24 \leq x < 48$	3.0	9.0
$x \geq 48$	0.0	0.0

The results of the compression tests with wilted grass of different lengths of cut and dry matter contents are shown in a pressure-density diagram in Figure 3. With regard to fresh mass, the results show that the variants with a dry matter content of 33% have the highest degree of compressibility. In this respect, there is little difference between the lengths of cut 4.5 and 9cm. If these data are converted into dry matter density, the variants converge because at high dry matter content the low resulting water content compensates for the relatively low density.

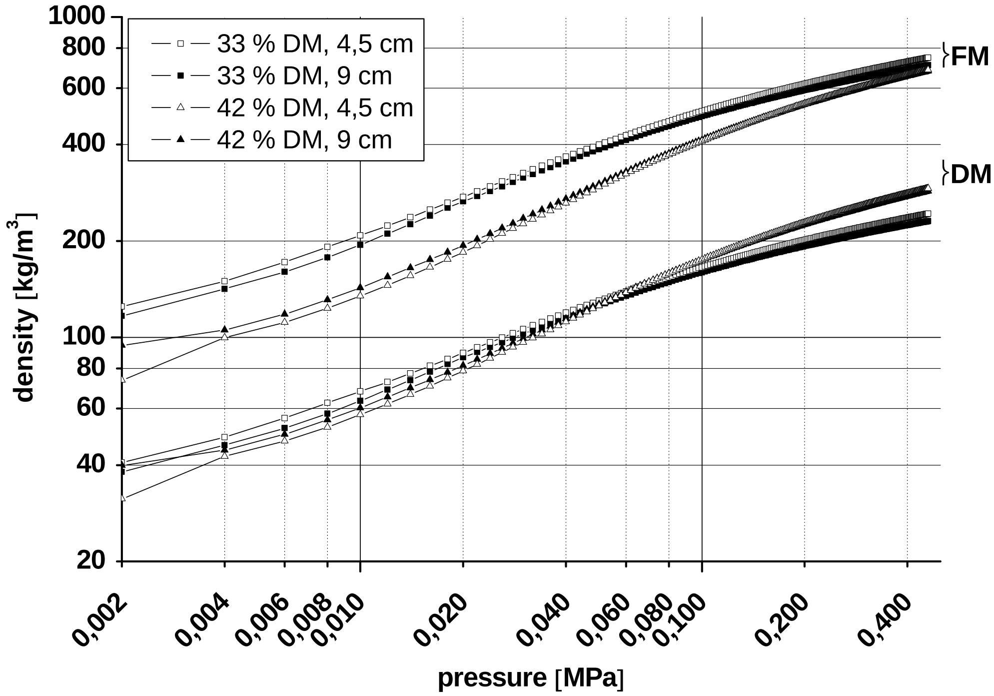

Figure 3. Influence of dry matter content and length of cut on the compressibility of wilted grass at one-time compression with 90mm/min (FM: fresh mass density, DM: dry mass density)

At 0.2MPa, which pressure is recommended by agricultural advisers (Thaysen, 2004), material with a dry matter content of 33% and a length of cut of 9mm is compressed to a density of 193kgDM*m^{-3}.

By comparison, the density of the material with a length of cut of 4.5mm is 8kgDM*m^{-3} higher. At both lengths of cut, material with a dry matter content of 42% that is picked up, chopped, and compressed at a pressure of 0.2MPa has a density of 227kgDM*m^{-3}.

Subsequent to compression at a pressure of 0.45MPa, the material recovery was determined by a reading of the fill level of the glass cylinders one minute after the pressure on the wilted grass was released. The density of the forage with a dry matter content of 33% (average 237kgDM*m^{-3}) differs by about 18% (Table 2) from the material with a higher wilting degree (average 289kgDM*m^{-3}). The density of the material after recovery ranges from 115 kgDM*m^{-3} (33% dry matter content, 9mm) and 130kgDM*m^{-3} (42% dry matter content, both lengths of cut) (standard error 10%). Thus, the once-through, quasi static compression of the material and the subsequent load release results in a 50% decrease in density in all variants.

Table 2. Influence of dry matter content and length of cut on the material recovery of wilted grass[1)]

l_{th} [2)] [cm]	DM concentracion [$g*kg^{-1}$]	density [kg $DM*m^{-3}$] compressed	recovered
4,5	330	244[b] +- 9	119[c] +-12
9,0	330	231[b] +- 14	115[c] +- 11
4,5	420	289[a] +- 5	130[c] +- 11
9,0	420	287[a] +- 5	130[c] +- 17

[1)] $\alpha \leq 0.05$; Tukey-Test [2)] theoretical length of cut

Because of the one-time, quasi static compression of the material by means of the plunger of the materials testing machine, the results of the compression graphs cannot be compared directly with agricultural practice, but it is possible to compare the material-dependent differences in compressibility and material recovery. A reduction of the three-material system (grass, water, air) to a two-material system consisting of grass and water leads to differences between lengths of cut that may be regarded as negligible.

At high dry matter content, the influence of length of cut is lower than at a low dry matter content. This tendency intensifies with increasing pressure. At the same pressure, the dry matter density of samples with a high dry matter content (44%) is lower than the dry matter density of samples with a low dry matter content (33%) because the pore-free grass has a higher density than water (Wolf-Regett, 1989).

There are significant differences between the DM-Contents, but not in case of the different l_{th}.

Agricultural advisers (Thaysen, 2004) recommend a reference density of $160kgDM*m^{-3}$ for wilted grass with a dry matter content of 20%; at a dry matter content of 40% the reference value is $240kgDM*m^{-3}$. Due to material recovery after the release of the load on the material, the density of the material is reduced by 50% to values below the reference value. A chop-length test for silage maize produced similar results (Wagner et al., 2004). Even after material recovery, the differences between lengths of cut tend to be greater than the differences between dry matter contents. The method of determining material recovery by means of readings has a higher systematic error in the case of grass (10%) than in the case of silage maize (3%); this requires further optimisation.

4. CONCLUSIONS

Compression tests were carried out in the laboratory in order to determine in what measure it is possible to influence the density of silage already in the field.

For the investigations, grass with different wilting degrees (33% DM, 42% DM) and different lengths of cut (4.5 cm and 9.0 cm) underwent quasi-static compression with a pressure of 0.45 MPa.

The results do not show any effects of cut length on compressibility and material recovery. By contrast, the DM content has a negative effect on compressibility, regardless of length of cut. The density after recovery of the compressed material with a lower DM content is approximately 10 % higher than the density of the variant with a higher DM content.

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