# The Influence of Chop Length on Compactability, Ensiling and Undesirable Temperature in Maize Silage

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*Quality losses in maize preservation due to undesirable rises in temperature still cause considerable problems in the practice of dairy cattle feeding. These problems must be assumed to grow still more severe in the future. The aim of the present study has been to determine the quantitative interrelations between maize breed, chop length, and the degree of mechanical processing. This article presents the experimental design, the methods and the first results of extensive research conducted in the context of a doctoral dissertation.*

**Keywords**
Maize silage, chop length, compactibility, ensiling, undesirable rises in temperature

## Introduction

Studies published over the last few years have shown that there are several arguments for increasing the forage ratio in dairy cattle feeding. An increased proportion of maize silage in the ration has the following advantages:

- A guarantee of a suitable ruminant ration due to increased rumination [1];
- Improvements in the energy metabolization of starch due to the lower degree of ruminal starch degradability as compared to starch from other grain crops [1];
- Improvements in economic efficiency due to fewer purchases of supplementary feed concentrates [2];
- Improvements of environmental conservation in the sense of the natural cycle by reducing nutrient imports to the farm in the form of purchases of supplementary feed [3].

High maize quality is a prerequisite of a higher proportion of this basic feed in the ration. However, quality losses in maize preservation due to undesirable rises in temperature still cause considerable problems in the practice of feeding. The consequences of undesirable rises in temperature due to metabolic activity of undesirable microbes in the silo are losses in palatability, mycotoxin infestation and especially energy losses. For example, a 10°C rise in temperature leads to daily feed energy losses of 0.1 MJ NEL per kg DM [4].

As a result of the following developments, the problem of undesirable rises in temperature must be assumed to grow still more severe in the future:

- As a consequence of an increasing tendency towards round-the-year indoor keeping and towards the feeding of livestock with silage throughout the year, the demands on the long-term stability of silage are still rising.
- The compaction of silage, an important measure to avoid undesirable rises in temperature, is becoming a bottleneck in the ensiling chain because of the increasing field capacities of forage harvesters.
- Greater chop lengths, which are currently being discussed as a means of improving the physical structural value of silage [1], are another impediment to adequate compaction.
- An increasing dissemination of breeds with a "greening effect" (slower maturation of the rest of the plant) raises the question about the ensilability of such varieties.

## Objectives

The objective of the present study has been to determine the quantitative interrelations between maize breed, chop length, and the degree of mechanical processing. Accordingly, the following questions must be settled:

- How can compaction be optimised without unreasonable effort?
- Provided satisfactory compaction is possible at chop lengths of 20 mm or more, how much additional compaction does this require?
- With what degree of precision can varieties with a “greening effect”, as opposed to established varieties, be comminuted and compacted?

## General State of Research

With regard to the above-mentioned questions a number of experiments concerning forage quality have already been conducted. However, in many of these experiments the focus was on isolated aspects.

From the point of view of nutrition physiology, the predominant interest currently lies on structural value [5]. For reasons of ruminal physiology, by increasing the physical structural value of maize silage it is possible to raise the proportion of this high-energy basic feed, which is usually farm-derived, in the ration. Chop length is the key parameter in physical structure.

However, feed quality is generally known to be the outcome of a variously interlinked process chain, and it must not be evaluated by examinations of isolated aspects alone.

Studies of the influence of physical structure tend to disregard decisive influencing factors such as maize breed and the quality of the ensiling process.

At the same time, studies of the influence of chop length on ensiling properties only sporadically include information on the influence of maize breed or on the consequences of chop length for animal physiology.

What is required, therefore, is a systematic analysis of the entire process which takes all influencing factors into account.

## Plant Material

### *Effects of the maturation behaviour of maize breeds on ensilability*

The statements made in the research literature with regard to maturation behaviour and ensilability are contradictory.

According to the Chamber of Agriculture Weser-Ems [6], maize populations with early leave, cob and stem maturation must be regarded as problematic as far as compactibility and ensilability are concerned. This hypothesis, however, was not borne out by research conducted by the Chambre of Agriculture Rhineland [7]. A comparison of breeds with different maturation characteristics did not reveal significant differences in ensilability. However, in all the maize breeds tested there were problems with undesirable rises in temperature.

### *Effects of the maturation behaviour of a maize breed on animal physiology*

In an experiment with fistulated cattle, Höner et al. [8] determined the digestibility of maize silages prepared from four different maize hybrids, using the nylon bag method as well as ruminal and duodenal cannulas. Revealing significant differences in digestibility between the varieties, this study illustrates the fact that the choice of an appropriate maize breed is a key prerequisite of a basic feed with good digestibility properties.

Böhm et al. [9] describe a decreasing ability of cattle to digest organic matter in silage produced from maize at later stages of maturation. New "stay green" varieties were bred in an attempt to solve this problem by reducing to a minimum the genetic link between generative and vegetative maturation [10]. Hartmann et al. [11] observed an increased energy value in "stay green" varieties as compared to varieties with a more rapid maturation of the rest of the plant. Above all, this was due to high levels of water-soluble carbohydrates and a greater digestibility of the rest of the plant. Hepting [12] found no evidence of increased digestibility or of an increased feed value in "stay green" varieties.

These results do not admit of clear conclusions concerning the digestibility or the feed value of "stay green" varieties.

Without a comparison of "stay green" varieties and varieties with an earlier maturation of the rest of the plant it is impossible to recommend any one maize breed as a feed able to meet the performance requirements of ruminants.

## Harvesting technology and ensiling process

A streamlined ensiling process is a decisive precondition of the production of high-quality silage. This is the only way of minimizing losses while producing a basic feed which, thanks to its high energy and nutrient concentration, allows an above-average proportion of basic feed in the dairy cattle ration.

### *Effects of harvesting technology and ensiling process on successful ensilage and feed quality*

Quality losses in maize preservation due to undesirable rises in temperature still cause considerable problems. The compaction of the plant material at ensiling is an important parameter in avoiding undesirable rises in temperature. Successful compaction is highly dependent on the size of the particles and the compaction process (pressure, duration, number of repetitions).

Schwarz et al. [13] observed that the development of new maize breeds with faster kernel maturation and a slower maturation of the rest of the plant has resulted in new demands on processing technology. They also pointed out that the question of processing technology must be reconsidered with regard to new technical possibilities that have arisen since the 1980s. Due to these developments there is an urgent need for research concerning the optimal use of the technology available and the handling of the new maize breeds.

An evaluation of harvesting technology has to start by contrasting targeted (theoretical) chop length with effective chop length distribution.

An important criterion in this is the proportion of particles diverging from the desired chop length, especially the proportion of oversize particles.

Schwarz and Kirchgessner [14] conducted tests with theoretical chop lengths of 4 and 7 mm which resulted in oversize fractions of at least 20 %.

In cooperation with Bonn University, the Chamber of Agriculture Rhineland classified maize samples from 61 farms according to particle length, finding fractions > 15 mm of up to 10 % [15].

Other studies, too, have repeatedly stressed the need for a high degree of congruence between theoretical and effective chop length [16, 17].

According to Honig and Rohr [18] fine chopping leads to a rapid onset of bacterial acid production and, consequently, to an early conclusion of the microbial reduction of the oxygen between the plant particles. High bulk densities due to short particles limit the propagation of undesirable microorganisms, thus preventing undesirable rises in temperature in the silo. Johnson et al. [19] made similar findings.

### *Effects of harvesting technology and ensiling process on animal physiology*

In recent years there has been much discussion on increased chop lengths as a means of improving structural value. Experiments by De Brabander et al. [5] confirm the relationship between physical structure, mastication, salivation and, consequently, buffering capacity and fatty acid profile in the rumen. Mastication was measured to determine the structural value of the feed under scrutiny. In a comparison of maize silages with different chop lengths, mastication increased with increasing particle lengths.

In addition to chop length, mechanical processing techniques and dry mass content must also be taken into consideration [20].

# Materials and Methods

## Experimental design

In cooperation with the Chamber of Agriculture North Rhine-Westphalia, two maize breeds were cultivated on the fields of the agricultural training and research station "Haus Riswick" in the year 2003. These maize breeds were chopped at three different chop lengths (5.5, 14.0 and 21.0 mm) and two different clearance settings of the kernel processing unit (1.0 and 2.0 mm) and subsequently ensiled in surface silos and tube silos (**Figure 1**).

The variants were analysed for chopping and processing quality, compactibility, and the course of the temperature curve of the silage from ensiling to feedout. Analyses of the chemical and microbial composition and examinations of the aerobic stability and fermentation quality of forage ensiled in air-tight jars were conducted as further indicators of the quality of the forage.

The maize was harvested with a self-propelled forage harvester with a 24-blade chopping cylinder (constant r.p.m.). The chop length was set via the speed of the pick-up.

Six tube silos (two breeds, three chop lengths) with the same level of compaction were prepared for the tests. The advantage of tube silos is that they consti-

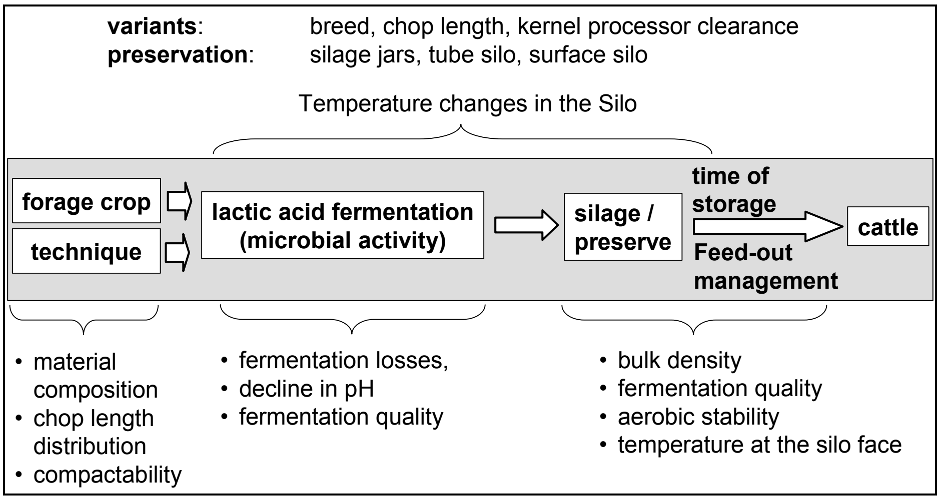


Figure 1: Investigated quality parameters in the harvesting chain of maize silage

tute small units (2.40 m in diameter, approximately 10 m long) suitable for testing at the same time as allowing direct comparisons concerning silage quality and long-term stability possible under practical conditions. They enable comparisons at a standardised degree of compaction.

To make a comparison with surface silos possible, one maize breed was chopped at chop lengths of 5.5 mm (1 mm clearance) and 21.0 mm (2 mm clearance) respectively. These two variants were ensiled seperately in surface silos and compacted conventionally with a wheel loader (15 t).

In order to guarantee the comparability of the forage used, its composition was determined in accordance with the methods of the Association of German Agricultural Experimental and Research Stations [21].

An analysis of the initial material (chemical and microbial composition, chop length distribution and compactibility) is vital for a meaningful interpretation of subsequent investigations of density and fermentation quality.

The chop length distribution was determined with a sieve stack (circular holes) by a standardized method in accordance with DIN 24041 [22]. For the purpose of comparing different methods, both fresh and dried material was sifted (sifting time 5 minutes, with 30 s running time alternating with 1 s rest). The initial weight in all cases was 100 g, After sifting, the reweighing of the different size classes made it possible to calculate the percentages of the following fractions:

$x < 2$ mm, $2 = x<3$ mm,
$3 = x <6$ mm, $6 = x < 10$ mm,
$10 = x < 15$ mm, $15 = x < 25$ mm,
$25 = x < 40$ mm and $x = 40$ mm.

Compactibility was determined with a materials testing machine (**Figure 2**). The chopped material was filled loosely into a cylindrical plastic container with a height of 30 cm (11.5 cm inner diameter) and compressed with a plunger at a rate of 90 mm/min. The height of the cylindrical container is the equivalent of the layer thickness of 30 cm officially recommend by agricultural advisers for the practical ensiling [23]. Bulk density was calculated on the basis of initial mass and cylinder volume.

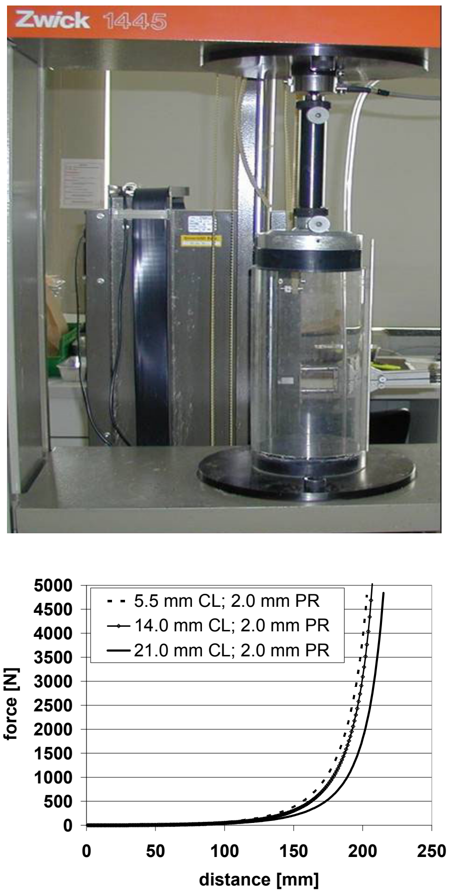


Figure 2: Materials testing machine and example of evaluation by a force/distance curve for maize with different theoretical chop lengths (CL); (PR = processing roll clearance)

The maximum compaction pressure achievable with the materials testing machine used was 0.45 MPa. The typical pressure in silos according to official recommendations by agricultural advisers is 0.2 MPa [23]. The force employed for compaction was measured and recorded continuously (with a force sensor) over the entire movement of the plunger, thus providing a basis for force/distance curves (Figure 2). The results were evaluated in pressure/density curves. In addition to maximum compaction, relaxation after compaction was also considered. To that purpose, the fill level in the cylinder was measured one minute after compaction. The measurements were repeated six times for each variant.

Tests to document the fermentation process of silage stored in air-tight jars were conducted by the training and experimental station North Rhine-Westfalia "Haus Riswick". Fermentation losses over a period of ninety days are an indicator of the fermentation process (DLG guidelines for the certification of silage additives) [24]. In addition, the material was analyzed for pH, and the concentrations of fermentation acids, $NH_3$ and alcohol were determined.

With the end ensiling process at an end (after 90 days), its quality was evaluated by analysing the chemical and microbiological composition of the samples, and by analyses of fermentation quality and aerobic stability.

To capture effective density in the tube silos and the surface silos, silage density was measured at the centre of the silo face with the help of a silage block cutter (three repetitions).

To record the development of the interior temperature of the silos, data loggers were integrated in the middle and at both ends of the surface silos and the tube silos during silo loading. The data loggers were retrieved with the silage at unloading. From the data thus acquired it is possible to draw conclusions on air infiltration at different chop lengths. In addition, temperature measurements were performed three times per week at different points of the silo face.

The surface silos were unloaded at a feed rate of 4 m per week between 13th February and 20$^{th}$ March 2004 (unloading equipment: rotary cutter). This period of time was characterised by low outdoors temperatures and night frost.

First results of experiments conducted in 2003/04

The maize was harvested in the autumn of 2003. Due to the comparatively hot and dry summer the dry matter content of the silage samples was extremely high (up to 48 % DM). Findings from Saxony, according to which one third of the maize silage harvested in 2003 had a dry matter content above 40 %, show that this value is typical given the weather conditions [25].

The extensive tests described here were conducted as part of a doctoral dissertation. The results presented in the following refer only to "Oldham" maize with chop lengths (CL) of 5.5; 14.0 and 21.0 mm at kernel processing roll clearance settings (PR) of 1.0 and 2.0 mm, respectively. The bulk densities of the two extremes in the surface silos, 5.5 mm CL with 1.0 mm PR and 21.0 mm CL with 2.0 mm PR, have already been compared. Results of the analyses for the tube silos will follow in a later article.

Heat stress during the harvesting period resulted in marked variations in DM content of up to 11 % (**Table 1**). Especially samples chopped at PR 2.0 revealed high DM contents with a coefficient of variation between 1.3 and 3.6 %. Therefore, an analysis of the influence of chop length and processing roll clearance for a number parameters related to compaction must not disregard the influence of DM content.

The results of the sieve analyses suggest that theoretical chop length has a considerable influence on chop length distribution. In **Figure 3**, mass percentages are assigned to the different size classes in the form of a histogram.

The typical shape of the histogram shows that at a theoretical chop length of 5.5 mm more than 40 % of the sample are in the fraction 3=x<6 mm. The mass percentages of the longer particles increase as chop length increases. An influence of the kernel processing unit is especially apparent in the 21 mm variants. A kernel processing roll clearance of 1 mm results in comminution of the kernels as well as the rest of the plant. With regard to their weight, a large proportion of the kernels is in the 3-6 mm fraction. With a greater mass than particles from other parts of the plant, they affect the result of the sieve test.

As regards cumulative frequency (**Figure 4**), in the fractions < 3 mm the differences in the variants are below 10 % proportional mass. The variant 5.5 mm CL und 2.0 mm PR has the greatest proportional mass in this fraction. In the fraction < 10 mm the variations between the variants are 26 %. In general, a processing roll clearance setting of 1.0 mm results in smaller differences in mass distribution than does the 2.0 mm setting.

Table 1: Average dry matter content of maize chop samples

| material prepared for: | variant | | DM content [%] |
|---|---|---|---|
| | chop length [mm] | clearance [mm] | |
| materials testing machine | 5.5 | 1.0 | 37 |
| | 14.0 | | 36 |
| | 21.0 | | 41 |
| | 5.5 | 2.0 | 46 |
| | 14.0 | | 47 |
| | 21.0 | | 48 |
| surface silo | 5.5 | 1.0 | 39 |
| | 21.0 | 2.0 | 43 |

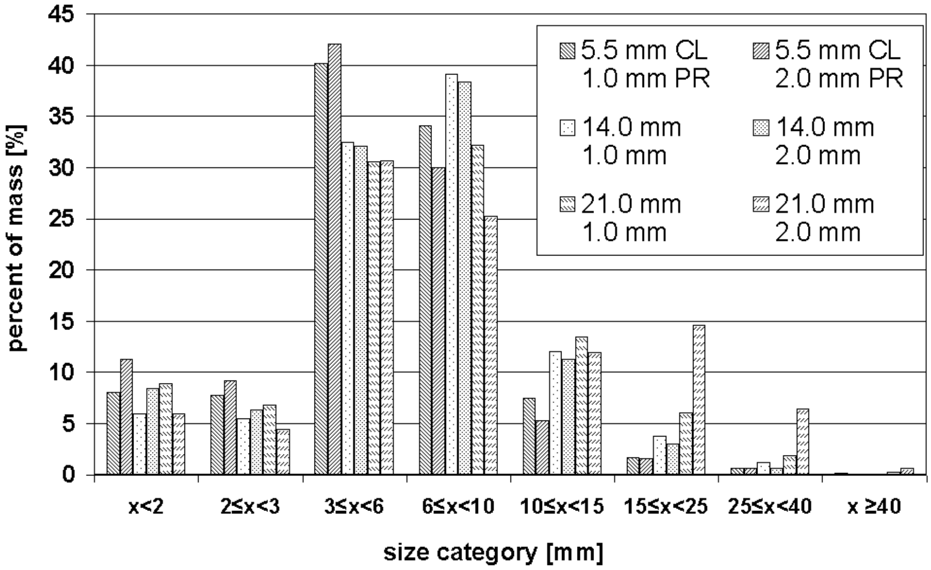


Figure 3: Influence of theoretical chop length (CL) and processing roll clearance (PR) on chop length distribution (histogram)

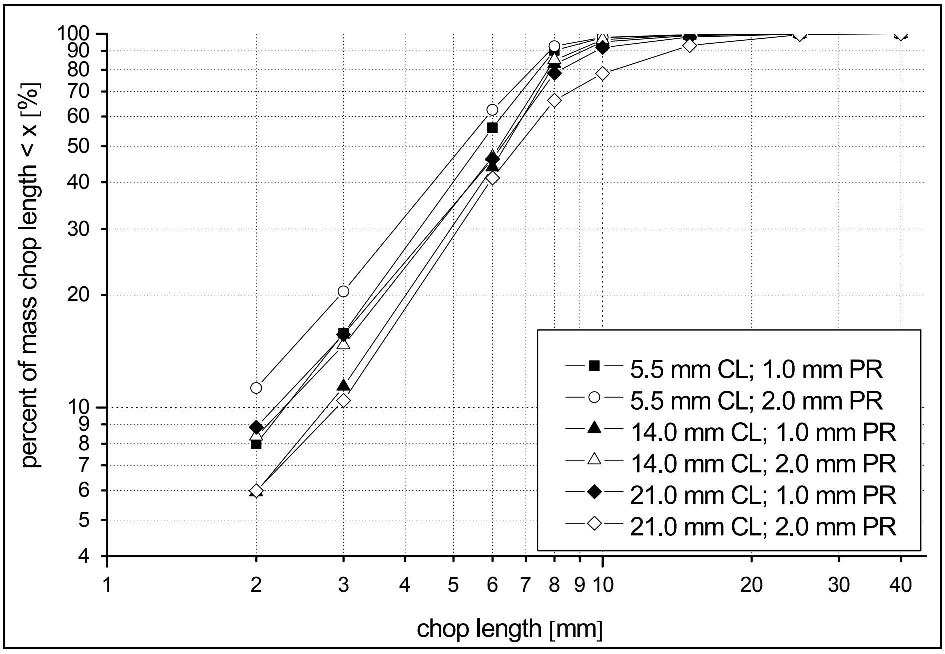


Figure 4: Influence of theoretical chop length (CL) and processing roll clearance (PR) on chop length distribution (cumulative frequency)

The bulk density of chopped maize of different chop length (CL) and mechanical processing (PR) settings lies between 74 and 102 $kg_{DM}/m^3$, with a coefficient of variation between 2 and 9 % (**Table 2**).

As regards bulk density, there are great

Table 2: Influence of theoretical chop length and mechanical processing on the bulk density of chopped maize

| **clearance [mm]** | | **1.0** | | | **2.0** | | |
|---|---|---|---|---|---|---|---|
| **chop length [mm]** | | **5.5** | **14.0** | **21.0** | **5.5** | **14.0** | **21.0** |
| **bulk density** | **[$kg_{FM}/m^3$]** | 207 | 219 | 217 | 223 | 213 | 154 |
| | **[$kg_{DM}/m^3$]** | 76 | 80 | 88 | 102 | 99 | 74 |

differences not only between the degrees of mechanical processing but also between the different chop lengths: Whereas at 1 mm PR there is a 16 % increase in bulk density on a DM basis between CL 5.5 mm and CL 21.0 mm, there is a 28 % decrease in bulk density between these chop lenghts at 2.0 mm PR. At both processing roll settings there are only minor differences in bulk density between CL 5.5mm and CL 14.0 mm. Raising PR from 1.0 to 2.0 mm, with CL staying the same, results in a 34 % increase in density on a DM basis (5.5 mm CL) and in a 16 % reduction (21.0 mm CL), respectively. Calculated on an FM basis, the differences are much smaller, with 5 % (5.5 mm CL), and much greater, with > 29 % (21.0 mm CL), respectively.

The findings concerning compactibility tend to follow those concerning bulk density (**Figure 5**): Taking DM content into account, chopping at 5.5 mm CL, or 14 mm CL, and compaction with a pressure of 0.2 MPa and results in a relatively low degree of compaction (275 $kg_{DM}/m^3$) at a DM content of 37 %. At 5.5 mm CL and 14 mm CL (PR 2.0 mm), compression with a pressure of 0.2 MPa results in a 30 % higher bulk density (350 $kg_{DM}/m^3$), whereas with the 21 mm variant (PR 1.0 or 2.0 mm and 40 and 48 % DM content) a 13 % higher density of 310 $kg_{DM}/m^3$ can be achieved.

Maximum compaction with a pressure of up to 0.45 MPa compresses material chopped to 5.5 and 14 mm CL (PR 1.0 mm) to 330 $kg_{DM}/m^3$. By contrast, density is 14 % higher (375 $kg_{DM}/m^3$) at a chop length of 21.0 mm (PR 1.0 and PR 2.0 mm) and 26 % higher (415 $kg_{DM}/m^3$) at chop lengths 5.5 and 14 mm (PR 2.0 mm).

Whereas, on a DM basis, the density difference between 5.5 and 14.0 mm CL decreases for the two degrees of mechanical processing, the difference between the degrees of mechanical processing (PR) increases for these CL. This does not apply to the 21.0 mm variant: in this case the difference between the degrees of mechanical processing, which is 16 % initially, disappears completely with increased pressure.

Because of the great variations in dry matter content, the differences in compactibility cannot be attributed exclusively to chop length or degree of mechanical processing. A comparison of compactibility on a fresh matter basis reveals that, with increasing pressure, the variant with a theoretical chop length of 21.0 mm and a 2.0 mm processing roll clearance has a lower density than the other variants (Illustration 5), with the differences growing smaller as pressure increases. A pressure of 0.2 MPa results in 645 $kg_{FM}/m^3$ in the variant with the greatest length of chop; with pressure rising to 0.4 MPa, density increases by 20 %. In the other variants, the average density at a pressure of 0.2 MPa is 763 $kg_{FM}/m^3$, rising by 20 % FM if the pressure is raised to 0.4 MPa.

To investigate the elasticity of the material, the fill height in the compaction cylinder was measured once again one minute after compaction with the materials testing machine, and as a result density after relaxation could be calculated. Although compaction with a pressure of 0.4 MPa effects densities of up to 954 $kg_{FM}/m^3$, the density values drop again by up to 50 % (21.0 mm CL, 2.0 mm PR) due to material relaxation (elasticity) (**Figure 6**). Relaxation increases with increased chop length at both degrees of mechanical processing. Accordingly, at the end of the compaction process, after material relaxation, the variant with the highest degree of mechanical processing (5.5 mm CL and 1.0 mm PR) has a density of 227 $kg_{DM}/m^3$, whereas the variant with the lowest degree of mechanical processing (21 mm CL and 2.0 mm PR) has a density of 196 $kg_{DM}/m^3$.

The findings of an investigation of bulk density in the surface silos by measuring and weighing blocks of silage (silo block cutter) resemble the findings of the compactibility tests conducted with the materials testing machine: 215 $kg_{DM}/m^3$ for material with a high degree of comminution (5.5 mm CL at 1.0 mm PR) and 192 $kg_{DM}/m^3$ at a low degree of comminution (21 mm CL mit 2.0 mm PR).

Silage quality in the surface silos was judged (VDLUFA) to be "good" ("2.0") in the case of the silage chopped at 21 mm CL and "very good" ("1.0") in the case of the silage chopped at 5.5 mm CL. Minor differences in silage quality between the silos were due to acetic acid leading to minor fermentation losses in the variant with the greater CL.

Similarly, only minor differences were revealed by investigations concerning the temperature development in the surface silos after they had been opened for the first time. Whereas there was a slight decrease in temperature in the 5.5 mm CL variant, there was a slight increase in temperature in the 21 mm variant (**Figure 7**).

Temperature measurements at the silo face revealed differences in temperature between the surface silos of up to 5°C at the top and up to 3°C at the core of the silo (**Figure 8**). A comparison of temperatures at a depth of 0.5 m with those at a depth of 1.0 did not reveal any differences.

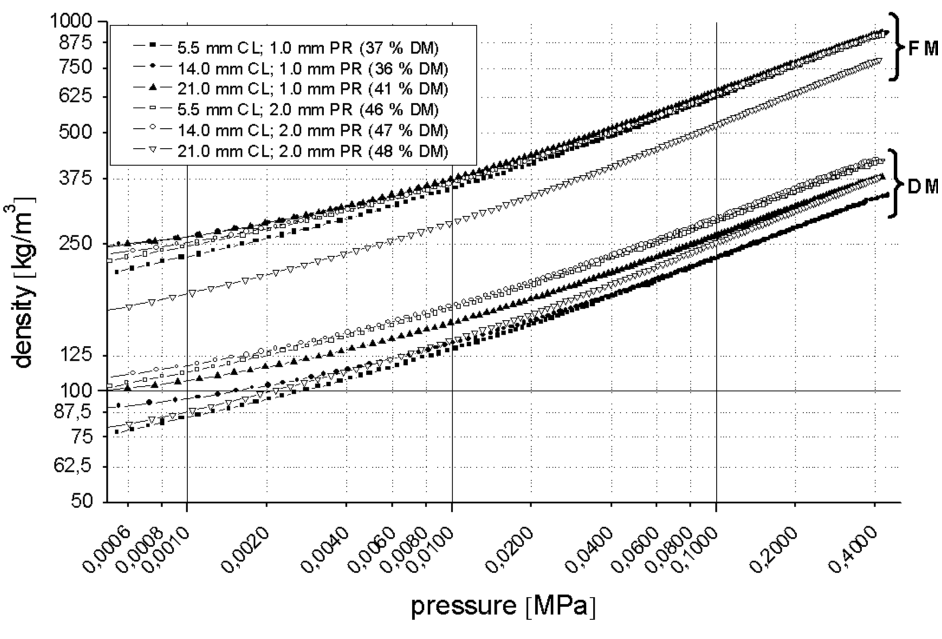


Figure 5: Effect of theoretical chop length and mechanical processing on the compactibility of chopped maize. Density on a DM basis as compared to density on an FM basis

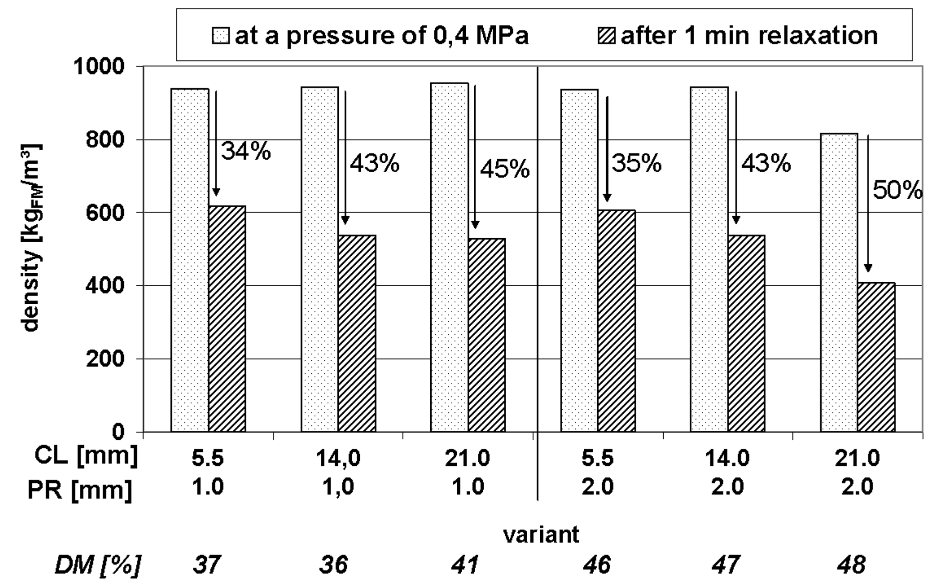


Figure 6: Bulk density after compression with a materials testing machine with a pressure of 0.4 MPa and after one minute relaxation

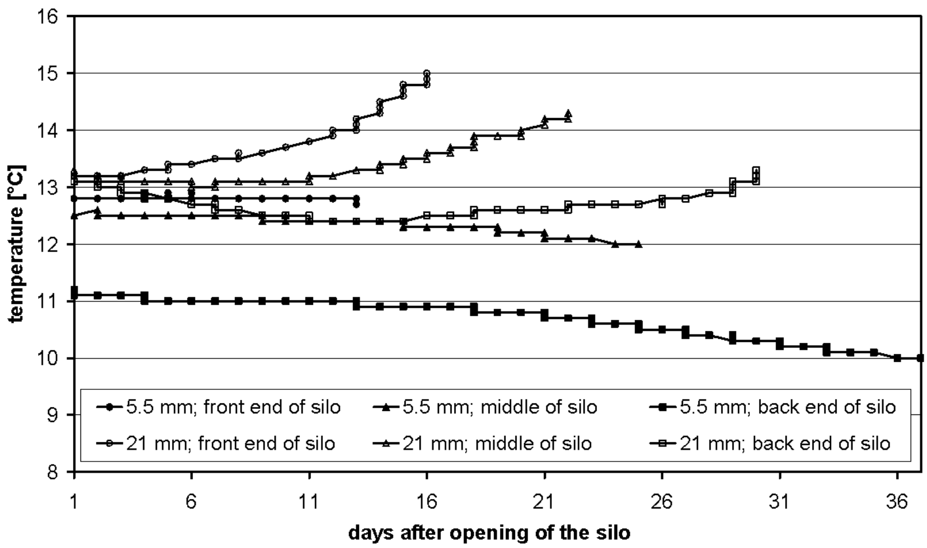


Figure 7: Development of silo interior temperature after the beginning of the feed-out phase

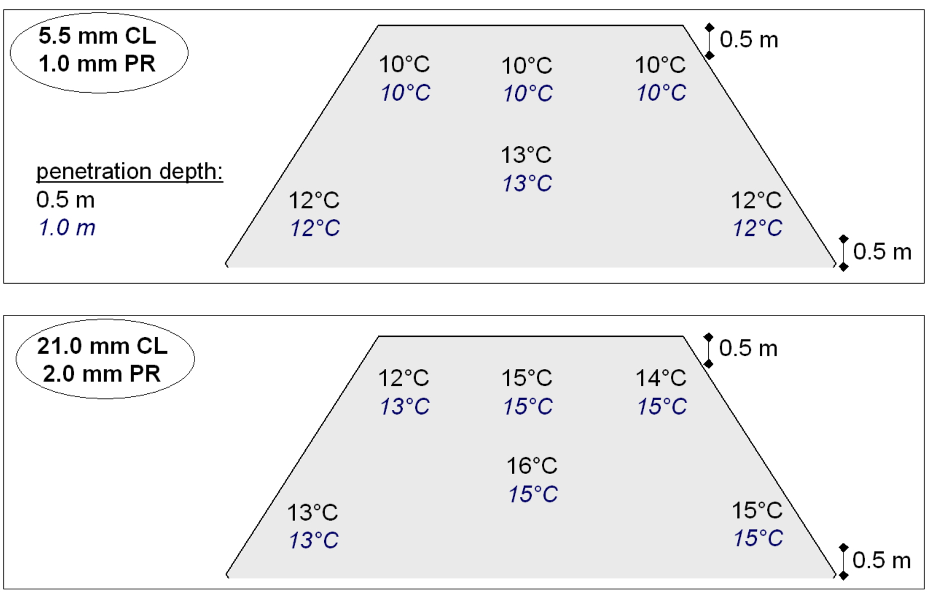


Figure 8: Temperatures at the silo face

## Discussion

The effect of the kernel processor on chopped forage is a reduction in size. According to Schurig [26] this process results in a 15-30 % reduction in particle sizes. At the same time, mechanical processing is accompanied by higher power consumption.

A sieve analysis with four sifting repetitions is marked by great statistical errors in the oversize fraction. Still, it is evident that material chopped at 5.5 mm CL has a higher proportion of fractions < 6 mm in material processed with a PR of 2.0 mm than in material processed with 1.0 mm PR, whereas the proportion of fractions between 6 and 15 mm is higher for the 1.0 mm PR variant than for the 2.0 mm PR variant. In the case of the 5.5 mm variants, this higher proportion in the coarse fraction, combined with the lower proportion in the fine fraction, unexpectedly results in lower densities at PR 1.0 mm than at PR 2.0 mm. In addition, differences in density might be explained by a roughening or splicing of the silage at a tight 1.0 mm roll clearance, which prevents a tight packing of the particles.

The compactibility tests, in which the material was compressed once with a pressure of 0.4 MPa, reveal a span of about 110 $kg_{DM}/m^3$ between the variants at lower pressures. At higher pressures this difference decreases to approximately 60 $kg_{DM}/m^3$. At lower pressures, material with a theoretical chop length of 5.5 mm and a clearance of 1.0 mm tends to achieve lower pressures than does material with a theoretical chop length of 14.0 mm or 5.0 mm and 2.0 mm PR under the same pressure. Material with 21.0 mm theoretical chop length and 2.0 mm processing roll clearance, with a relatively high proportion of oversize material, has a low bulk density.

The compactibility tests conducted with the materials testing machine produced no evidence that chop length has a clear influence on compactibility at maximum compaction. An influence of processing roll clearance is evident at chop lengths between 5.5 and 21 mm and 2.0 mm PR.

There is an analogy between the compactibility and the bulk density of chopped forage, both on a DM basis and on an FM basis. Even at low pressures a theoretical chop length of 21.0 mm and a processing roll clearance of 2.0 mm results in a steeper pressure-density curve. This is because due to greater particle sizes there is a larger proportion of air in the interstices between the particles, and this air is the first to be pressed out upon compaction.

Density after relaxation decreases with increasing chop length. A high degree of mechanical processing augments this effect.

A comparison of the two extreme variants (5.5 mm CL with 1.0 mm PR and 21.0 mm CL with 2.0 mm PR) summarizes the parameters analysed in this study (**Table 3**).

At a pressure of 0.4 MPa, a high DM content combined with a low degree of comminution, results in a higher DM based density during compaction than does a low DM content combined with a high degree of comminution. Due to relaxation, however, this higher density value decreases more extremely after compression than does the density value for material with a high degree of comminution. Further research will have to show whether the strong relaxation of the 21 mm variant is to be explained by its chop length or its high DM content.

The results of the compactibility tests with the materials testing machine (0.4 MPa) reveal a difference in density of about 31 $kg_{DM}/m^3$. The differences in the surface silo (compaction with a wheel loader, 0.2 MPa) are 23 $kg_{DM}/m^3$. Recommended values for the density of maize silage are 230 $kg_{DM}/m^3$ at a DM content of 28 % and 270 $kg_{DM}/m^3$ at a DM content of 33 %. The rule of thumb for DM contents exceeding 33 % is that with every percentage point of DM content the density of the silage should increase by approximately 10 $kg_{DM}/m^3$ [23]. This is supposed to prevent later oxygen infiltration even after the silo has been opened.

As regards fermentation quality, both surface silo variants produced good results, which confirms the good fermentation properties of maize. The influence of chop length on undesirable rises in temperature after the silo has been opened for the first time must also be regarded as very low - which must, of course, be seen in connection with the feed rate of 4 m per week and with the low outside temperatures during unloading.

Table 3: Comparison of different parameters of compactibility at different chop lengths and processing roll clearances

| parameter | unit | chop length [mm] clearance [mm] | |
|---|---|---|---|
| | | 5.5 1.0 | 21.0 2.0 |
| **sieve analysis** | | | |
| mass fraction > 15 mm | [%] | 2.4 | 23 |
| mass fraction > 25 mm | [%] | 0.77 | 7.03 |
| **materials testing machine** | | | |
| dry matter content | [%] | 37 | 48 |
| bulk density | [$kg_{FM}/m^3$] | 207 | 154 |
| | [$kg_{DM}/m^3$] | 76 | 74 |
| density at 0.2 MPa | [$kg_{FM}/m^3$] | 755 | 645 |
| | [$kg_{DM}/m^3$] | 277 | 309 |
| compactibiliy at 0.4 MPa | [$kg_{FM}/m^3$] | from 150 to 890 | from 150 to 790 |
| | [$kg_{DM}/m^3$] | from 55 to 326 | from 72 to 379 |
| | [$kg_{DM}/m^3$ difference] | 271 | 307 |
| relaxation | [$kg_{FM}/m^3$] | from 939 to 618 | from 817 to 408 |
| | [$kg_{DM}/m^3$] | from 327 to 227 | from 376 to 196 |
| | [% der DM ] | 31 | 47 |
| **surface silo** | | | |
| dry matter content | [%] | 39 | 43 |
| density at beginning of the „feed-out-phase" | [$kg_{DM}/m^3$] | 215 | 192 |

## Conclusions

An increased physical structural value for maize silage is being discussed for nutritional considerations. Such an increase is connected with increased chop lengths. In the process chain of forage harvesting and preservation compaction already is a bottleneck. Increased chop lengths might aggravate this problem.

Tests concerning compactibility and ensilability were conducted on a conducted in the lab and on the farm. In this context, maize with chop lengths of 5.5 mm and 21.0 mm respectively was ensiled in surface silos. A third chop length of 14.0 mm was included in the research for the purpose of compactibility tests in the lab. Despite a high average DM content of 40 % the tests revealed a high degree of ensilability for both surface silo variants. Even after the silos had been opened for the first time, unloading at the high feed rate of 4.0 m per week did not result in quality losses or in a marked rise in temperature at the silo core.

Work on this project is being continued. Findings concerning tube silos unloaded at a feed rate of 1.5 m per week at high outdoors temperatures may be expected to be published in one of the next numbers.

## List of Abbreviations

| | | |
|---|---|---|
| FM | - | fresh matter |
| NEL | - | net energy lactation |
| DM | - | dry matter |
| DM content | - | dry matter content in % |
| CL | - | theoretical chop length in mm |
| PR | - | kernel processing roll clearance in mm |

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