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# Vibratory Rollers for Compacting Ensiling Material

*Improved forage harvester capacities, larger means of transportation and silos, as well as rising silage quality requirements: storage and compaction are increasingly becoming the bottleneck. First systematic attempts with vibratory rollers resulted in recommended densities in spite of short compaction times. Further research needs to determine what effects are due to vibration and how to attain essential information during storage for process control and documentation.*

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## Keywords

Vibratory rollers, silage, density, compaction, pore volume

## Literature

[1] *Fürll, C., H. Schemel, C. Idler und V. Scholz*: Anforderungen an die Logistik zur Sicherung hoher Silagequalitäten. Agrartechnische Forschung 13 (2007), Nr. 6, S. 214-220

[2] *Baumgarten, W.*: Verdichtung bleibt ein Problem. Land & Forst (2007), Nr. 16, S.30-32

The goals of silo management are to minimize energy losses and costs. This applies to filling, the storage phase, and unloading. The minimization of losses requires sufficient compaction of the ensiling material. Due to growing mass flows in harvesting machines, compaction capacities in the silo must increase as well. These capacities must be provided by a small number of machines on small silo areas. On some farms in the eastern part of Germany, vibratory rollers are already being used on large silos. Especially near biogas plants, large silos needing efficient compaction solutions are also built elsewhere [1]. Practical investigations have shown that on more than 80% of the farms compaction in the upper part of the silos is insufficient [2].

As part of a research project, supported by the Federal Ministry of Education and Research, attempts have been made in the past two years to determine the effects of rollers as ensiling material compressors. In this project, both measuring methods and mathematical models for the characterization of the compaction are being sought.

### Material and Method

The examined farms in Brandenburg harvest ensiling material for fodder and raw material for biogas production on several thousand hectares every year. The vibratory rollers used weigh between 9.9 and 12.6 tonnes. The storage containers filled are 2 or 3-sided silos, whose walls are 3 and 5 metres high. Due to the high value of the materials to be ensiled and the machines used, the studies may not interfere with the storage process. The chopped material is wilted grass and forage maize. Wheel load and vehicle scales are used to determine the mass flow of chopped material. The surface of the compacted chopped material is measured with the aid of a laser theodolite, and the volume is calculated using the software "Surfer" from Golden Software. The methods applied for grid calculation are "triangulation with linear interpolation" for empty silos and "kriging" for ensiling material surfaces. The machinery operation time was determined based by video recordings of the storage processes. The dry matter content is measured hourly. For control, drill core samples are taken horizontally from the cutting surface after the completion of ensiling. The volume and the mass of the drill core samples allow the density of the silage to be ascertained. Drying at 105 °C shows the dry matter content. A specially developed air pyknometer is able to measure the compressible gas volume within the drill core sample. This allows compaction as the target value to be evaluated directly.

### Results

Based on examples, the results of the studies on forage maize and grass silage are presented (*Table 1*). For short periods, the average storage mass flow of about 107 t/h reaches peak values of 222 t/h. Per tonne of original substance, only 0.5 minutes are needed for compression by a vibratory roller. In maize silage, average densities of 250 kg DM/m$^3$ are attained. This corresponds to the recommendations. The maximum density of the core samples is 358 kg DM/m$^3$ in maize and 325 kg DM/m$^3$ in grass. Since this year´s grass silage often has very high dry matter

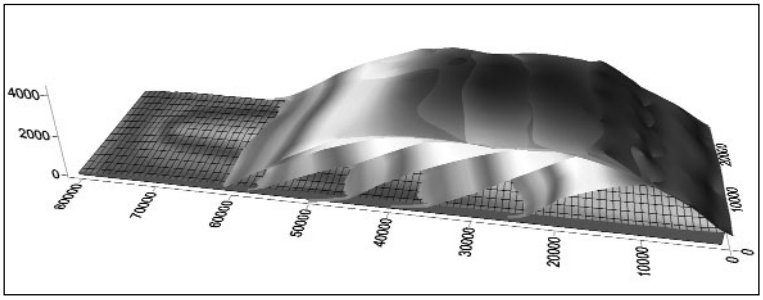


*Fig. 1: Silo chart in software surfer 8*

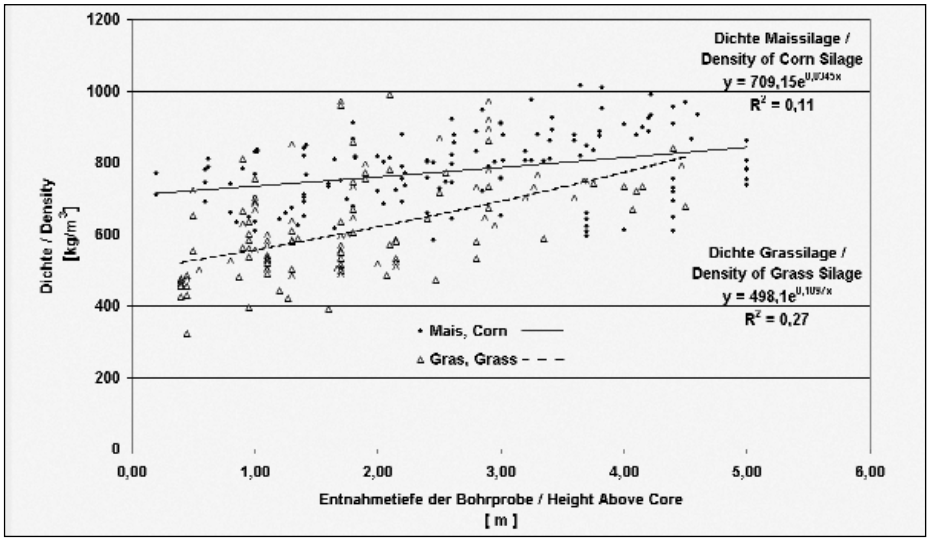


*Fig. 2: Density of silage as a function of the height of the silage, detirmined by core samples*

contents, a direct comparison is only possible with reservation.

For the evaluation of the compression capacity of the vibratory rollers in several silos with different designs, the influence of the height of the stored material on compaction must be known. The material column above the sample results in self-compaction. The effect of this autocompaction is obviously more significant in grass silage than in maize silage (*Fig. 2*).

The relationship between the density of the silage and the pneumatically measured pore volume is close and corresponds to theoretical expectations (*Fig. 3*). Deviations can be explained based on the different degrees of moisture of the samples. The linear course over a wide range of the gas-filled pore volume is proof of the preservation of the structure of the compacted material.

## Conclusions

With regard to compression capacity, vibratory rollers are a good alternative to the traditional tractor or wheeled loader. For large farms with long ensiling periods and contractors, a special vehicle may be worthwhile, in particular if the heavy tractors are needed on the field during the relevant time.

As compared with tractors having comparable weights, vibratory rollers are even cheap.

Some manufacturers can realize the required greater climbing ability of the rollers on loose chopped material by adapting oil pressure distribution in the case of slippage. In addition, silo rollers should be equipped with well-profiled rear wheels. Transferring rollers from one silo location to another increases costs. For rollers, permission for road transport is granted up to a mass of 25 t. For longer distances and padfoot drums, a flat bed trailer is recommended.

## Outlook

One goal of current research is the development of a testing system for estimating compressor efficiency. Therefore, the theodolite is used for the automatic registration of the compressor path. Software developed by the University of Heidelberg is able to calculate the silo volume from the vehicle coordinates at any time. Thus, the compaction effect can be determined based on volume reduction. This is expected to provide reliable information about the efficiency of vibration during compression.

For practical application, a driver information system is being developed, which shows the driver of the compressor the currently attained surface density and leads him to the insufficiently compacted spots. At the end of storage, documentation (e.g. in the form of a 3-D chart) is provided, which shows all improperly compacted spots in colour.

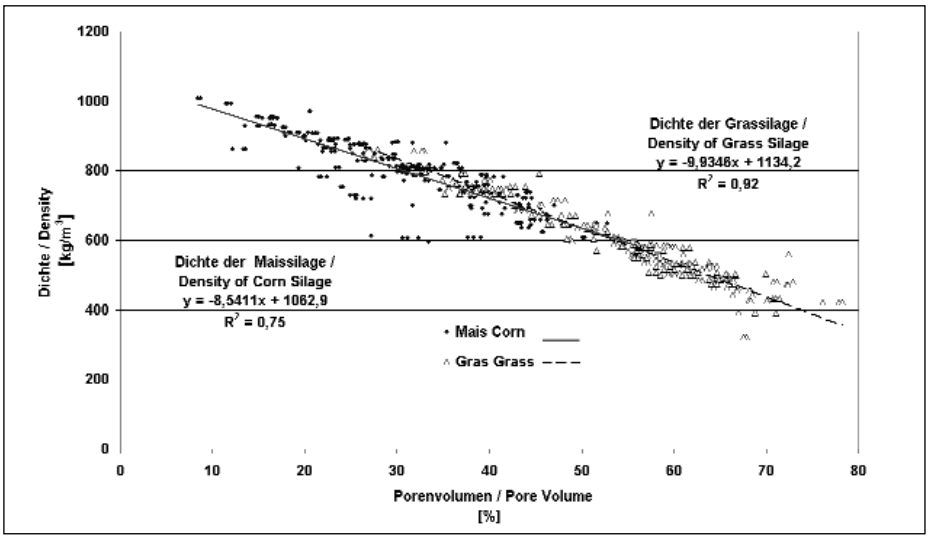


*Fig. 3: Density of silage in relation to gas filled pore volume*

*Table 1: Compaction of ensiling material with vibratory roller Hamm 3412HT with a smooth drum and 12.2 t operating weight and distribution with wheel loader with 12.5 or 13.3 t weight*

| | | | | Masse | | | | mittlere Dichte | | Verdichtung | | Verdichtung/ Masse OS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Erntegut | Beginn | Dauer | TS-Gehalt | frisch (OS) | TS | Massestrom | Volumen | frisch (OS) | TS | Walze | Radlader | alle Fahrzeuge | davon Walze |
| | | Tage | % | t | t | t/h | m³ | kg /m³ | kg /m³ | min | min | min/t | min/t |
| **Mais** | 11.09.06 | 2 | 34,4 | 1.830 | 630 | 120 | 2.642 | 693 | 238 | 914 | 350 | 0,69 | 0,50 |
| | 17.09.07 | 7 | 34,3 | 8.892 | 3.050 | 130 | 12.091 | 735 | 252 | 4.115 | 1.708 | 0,65 | 0,46 |
| | 04.10.07 | 5 | 39,7 | 3.766 | 1.495 | 116 | 5.727 | 658 | 261 | 1.942 | 498 | 0,65 | 0,52 |
| **Gras** | 14.05.07 | 6 | 45,2 | 2.165 | 979 | 60 | 3.429 | 631 | 285 | 2.153 | 581 | 1,26 | 0,99 |