Christian Fürll, Hartmut Schemel and Dietmar Köppen, Potsdam-Bornim

Principles for measuring density in silages

Silage density influences silage quality significantly. To develop an online measurement procedure, various physical principles were analysed. The procedures of georadar and microwave measuring technology were experimentally examined.

Prof. Dr.-Ing. habil. Christian Fürll heads the „Processing, Storage and Preservation Department" at the Leibniz Institute of Agricultural Engineering Potsdam-Bornim, Max-Eyth-Allee 100, 14469 Potsdam; e-mail: *cfuerll@atb-potsdam.de*.
Dr.-Ing. Hartmut Schemel works in this department as a scientist. Dietmar Köppen as student at the University of Rostock was working on a diploma thesis at ATB Potsdam-Bornim.

Keywords

Silage, compaction, density, density measurement

Literature

[1] *Köppen, D.*: Entwicklung eines kontinuierlichen Messverfahrens für die Oberflächendichte von Siliergut. Diplomarbeit am ATB Bornim, Potsdam-Bornim, 2002

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

[3] *Häbler, J., R. Tölle, und J. Hahn* : Vibrationswalzen zur Verdichtung von Siliergut. LANDTECHNIK 63 (2008), H. 1, S. 28 - 29

Among the process engineering parameters, the density of silage has a major influence on silage quality. It is physically expedient to state the necessary surface densities of the original substance (fresh matter). One criterion for the level of storage intake density of the original substance is that the gas exchange may not be greater than the gas formation in the material to be ensiled. This means that for wilted ensiling matter, assuming a free ensiling matter surface without any cover, the density should be > 750 kg OM/m^3. If the whole surface is covered with plastic sheeting, a storage intake density of only 400 to 500 kg OM/m^3 is necessary (Rettig 1972, cited in [2]).

Density measurements conducted on silos in practice revealed, however, that in more than half the cases the recommended density values were not achieved (Thaysen 2006, cited in [2]). The main reason for this is insufficient compaction during storage intake. In order to achieve the required minimum densities, it is necessary to compact carefully with tractors or other suitable vehicles [2, 3]. The time required for compaction depends on the compaction technique applied and essentially on the dry matter content. It is a major disadvantage that there are no reliable density measuring instruments for practical farmers that work online during storage intake.

Principles for measuring density

A series of principles were analysed and assessed as regards their suitability for online measuring of the silage density (*Table 1*). It is not possible to describe the physical principles on which they work in detail here.

The measuring procedures set out in lines 5 to 9 of *Table 1* enter into question to a cer-

Table 1: Compiling and assessing possible measuring methods for online density measurement of silage material

		contact-free	during travel	of the surface	silage influenced	depth of penetrationn[m]	installtin outlay	safety outlay	weighting
1	Geo-Radar	yes	yes	yes	no	up to 5	comp.	small	**XXX**
2	Microwave scatter field probe	no	yes	yes	no	up to 0.3	costly	medium	**XX**
3	High-frequency moisture sensor	no	yes	yes	no	up to 0.03	costly	medium	**X**
4	Measuring wheel (depth of sinking in)	no	yes	yes	yes	exp.	costly	small	**X**
5	Ultrasonic thickness sensor	no	yes	yes	no	exp.	very costly	medium	**(X)**
6	Film pressure/force measuring system	no	yes	yes	no	exp.	costly	small	**(X)**
7	Isotope probe Cs 137	no	yes	yes	yes	up to 0.8	comp.	medium	**(X)**
8	Measuring the depth to which the tractor sinks in	yes	yes	yes	no	exp.	comp.	small	**(X)**
9	Penetrometer	no	no	no	yes	up to 5	very costly	high	**(X)**
10	Near infrared spectroscopy (NIR)	yes	yes	yes	no	up to 0.01	compact	small	**0**
11	Flow measurement	no	no	yes	yes	exp.	very costly	medium	**0**
12	DC current electrics	no	no	yes	no	exp.	costly	high	**0**
13	Ultrasonic spacing sensor	yes	yes	yes	no	no	comp.	small	**0**
14	Laser measuring 3-D	yes	yes	yes	no	no	costly	medium	**0**

exp. = to be determined experimentally; XX - worth investigating
comp. = compact construction within the contest of specifications; X - can be used
costly = costly construction method; (X) - can be used conditionally
XXX = preferred solution; 0 - no application

tain extent, with consideration being given to various aspects.

The *penetrometer* has been designed and tested for determining density. It supplies very precise results for a wide variety of densities and moisture contents.

The method of recording the *depth to which the tractor sinks* in by comparison with non-compacted matter is only suitable to a limited degree. It would not be a major problem to record the actual measurements if sufficiently different contours are available. As the measured value is not related directly to the density, it is influenced by interference parameters.

The *radiometric probe* has been tested for determining densities in and on the feed stock. The studies conducted [2] revealed a very precise signal that could be processed well for evaluation. This measuring procedure is also used in other branches of industry.

The *film - pressure/force measuring* system is also only useful to a limited extent, as there is not yet any matured measuring system ready for series installation in tractors. However, in principle it is conceivable that the compaction condition could be determined in this way.

Ultrasonic density measurement is known as a low-cost and precise method of determining density and depths. The measuring procedure is widely used in many branches of industry. The major differences explained between the sonic transmission in solid and liquid materials and transmission in air is avoided in all cases of application by air compensation. However, it is not possible to use this to determine silage densities.

Measuring the depth to which a vehicle sinks in with the aid of a *measuring wheel* is the cheapest and simplest option for determining differences in density. However, this method does not provide any direct values regarding the storage density. It is relatively easy to record the actual measurements, and if developed further, this method could represent a potential solution.

With *high-frequency moisture sensors* it is possible to detect the moisture in products. As moisture determination is always influenced by the density of the matter being measured too, calibration on the basis of density would be conceivable. However, as practical applications have shown, it is so far only possible to consider a small depth of penetration and only to measure the moisture content.

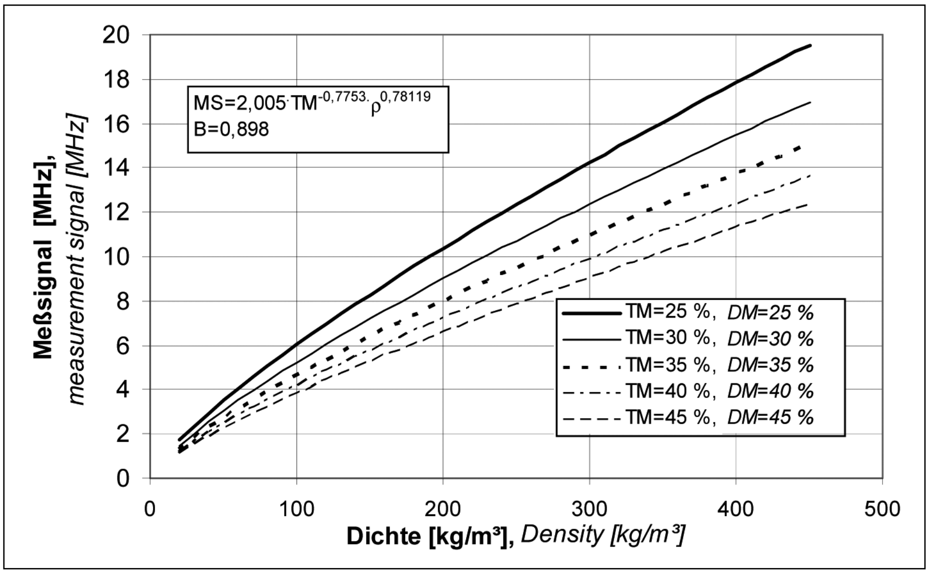

Fig. 1: Effect of the parameters density ρ and dry matter content DM on the measuring signal MS of a microwave sensor during measuring the density of eleven silage samples (forage maize and gras)

Microwave scatter field probes are characterised by a higher depth of penetration than the high-frequency moisture sensors, whereby this depth of penetration depends strongly on the density and moisture content of the matter being measured. Experiments will have to demonstrate whether the microwave scatter field probes are suitable for recording density, or only for measuring moisture content. One disadvantage is the direct contact needed between the measuring head and the surface.

A preferred solution is the *georadar* „Ground Penetrating Radar“. The advantage over all the other methods is that it combines a high depth of penetration, direct determination of density and online recording of measurements. The georadar works in a lower frequency range. It is widely used in geophysics. Reasons for this include the further development of the processor capacity and the relatively low prices. Its suitability specifically for maize, grass or other silages with a wide variety of densities and moisture contents will have to be explored in experiments.

Test results

Alongside radioactive density probes, the preferred solutions are considered to be the use of georadar and the microwave scatter field probes. Experiments were conducted with the latter. As the results obtained with georadar are not yet satisfactory because further development of the software and higher-frequency antenna are necessary, this paper only discusses the results of experiments with microwave scatter field probes.

The experiments were conducted with five maize silages in the dry matter (DM) range DM = 26% to 37%, and six grass silages with DM = 22% to 67%. The microwave probe was a planar sensor from Messrs. TEWS, Hamburg. The analysis provided statistically significant results [1]. The measuring signal is influenced both by the density and by the dry matter content (*Fig. 1*). The standard deviations are distinctly lower at higher DM contents than at lesser contents.

Conclusions

Some physical principles appear to be suitable for continuous (online) or discontinuous density measuring of matter to be ensiled and silages. The selection of the measuring methods analysed and partly examined distinguishes between direct or indirectly determinable density values, error magnitude, handling, outlay and price. The results obtained make it worth continuing the examinations in order to provide farmers with an option for checking an important process parameter during silage storage intake.