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Investigations about the influence of press force, press duration and vibration on the compression of wilted grass

Wilted grass has to be compressed during the ensiling in bunker silos. An increasing number of farmers are using compactors with vibrating roller drums to achieve a higher compression effect. On the basis of a servo-hydraulic material testing system quasi static and vibrating compression cycles were carried out and compared with each other.
The oscillating movement of the roller drums cannot result in a higher compression performance which is observed in praxis. The observed increased compression performance is a result of the centrifugal force of the vibrating roller drums which can be several times higher than the weight of the vehicle.

Keywords
Wilted grass, silage, compression, vibration

Abstract
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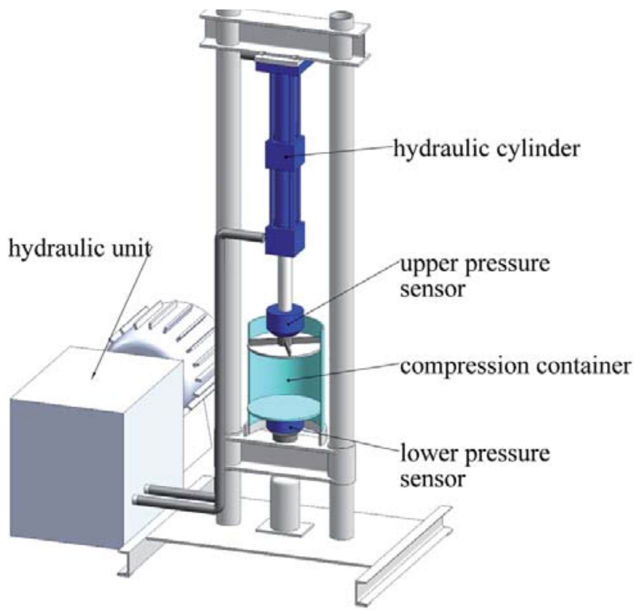
Silage from corn and wilted grass are important basal feed for ruminants. The production of high grade silages requires thorough, logistic coordination of the processes of harvesting, transport and storage. Harvesting and loading respectively is carried out with forage choppers or self-loading wagons. In recent years, forage choppers and loading wagons have been substantially improved in capacity of performance. Transport vehicles have been improved likewise, now featuring higher loading volumes and speed [1]. Once arrived at the bunker silo, the ensilaged crops have to be stored, compressed, and covered with silo film. Particularly the compressing process has become a performance bottleneck at this stage, since the available compressing vehicles have not been improved as much as harvesting systems and transport vehicles.
In order to achieve the highest possible compression effect, an increasing number of farmers are using compactors with vibrating roller drums. Often those are compactors designed and commonly used in road construction. The roller drums vibrate with frequencies ranging between 29 and 50Hz [2; 3]. Taking wilted grass as test medium, the impact of the vibrating roller drums on the compression of ensilaged crops was examined.

Compression Trials with Vibrating Compaction Pressure

Based on a servo-hydraulic material testing system by MTS Systems GmbH, a compression test bench was developed (**figure 1**). The test bench consists of a hydraulic power unit, a hydraulic cylinder with plunger, and a compression container. There is one load cell each installed under the bottom of the

Fig. 1



Servo-hydraulic material testing system for compression tests

compression container as well as at the pressing head of the plunger. The arrangement of both load cells facilitates determining the wall friction separately. Controlled by a computer program, the plunger can carry out defined sequences of movement, varying in applied force and depth of amplitude. A quasi static compression with two force loading cycles, like seen in two-axle vehicle, is used to simulate compressing with a tractor (**figure 2**). Compactors with vibrating roller drums are simulated by two cycles of sinusoidal pressure application (**figure 2**). The vibration frequency applied is 29Hz as common in road construction, and alternatively to that a frequency of 5 Hz was chosen for specific trial purposes.

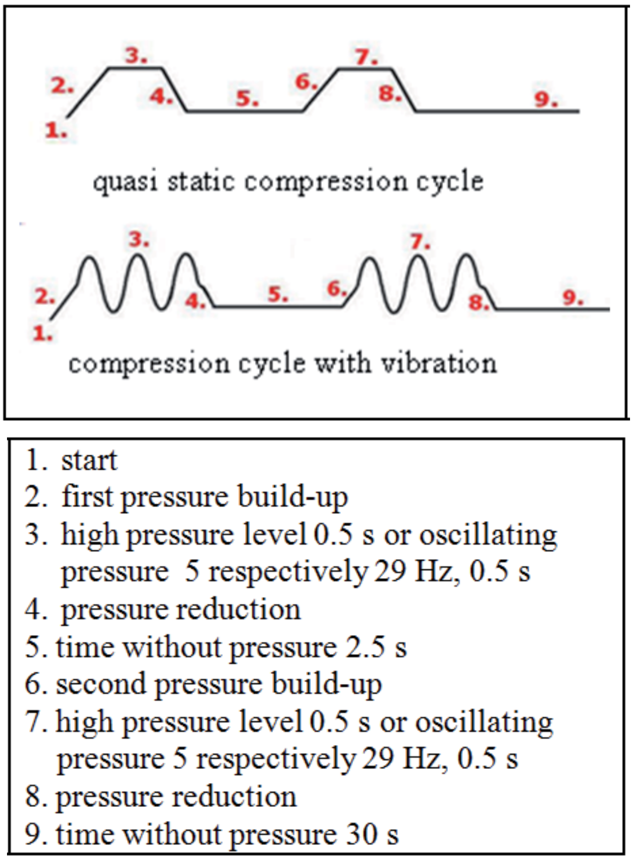
The load charge duration per force loading cycle of ca. 0.5 s, and the recovery period of 2.5 s between the force loading cycles result from the assumption of 4 km/h or 1.1 m/s respectively; a roller contact length of 0.6 m, and an axle base of 3 m. Such double loading cycle is repeated on the test bench 6 times with a time gap of 30 s, while in practice there are commonly 3 compaction rolls per shift. The 6 double cycles are carried out with a standard maximum load. This maximum load is varied between 1, 2, and 4 bar to simulate light, medium, and heavy compactor vehicles. An area pressure of approximately 2 bar occurs under a roller compactor with a weight of about 13 t.

Wilted grass with a dry mass (DM) content of ca. 24 % or 32 % was used in the test. As for the respective DM contents wilted grass with chop lengths (particle length HL) of 4, 9 and 17 mm was tested. All variants of compression were tested twice with each group of test matter.

Results

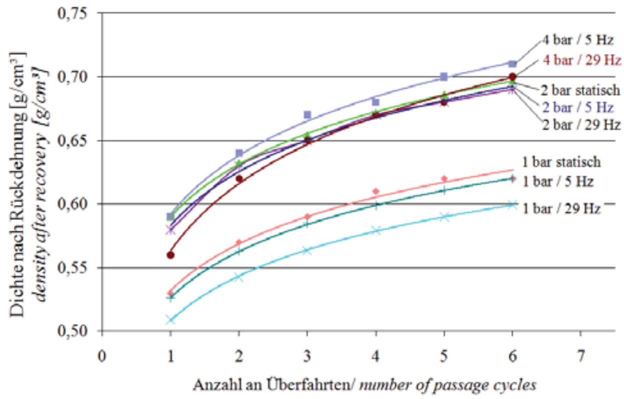
Generally, the typical progression of silage density in the compaction container over time shows that in the first compression process the highest gain in compaction is achieved. Typical progression of silage density in the compaction container over time using quasi static compression shows that the first force loading cycle causes the highest increase in density. Upon recovery between the two cycles the density decreases again, yet without falling back to the starting level. In the longer phase of recovery after a double cycle the silage material also recovers. This recovery process is finished after 8 to 10 seconds. Upon each further force loading cycle

Fig. 2



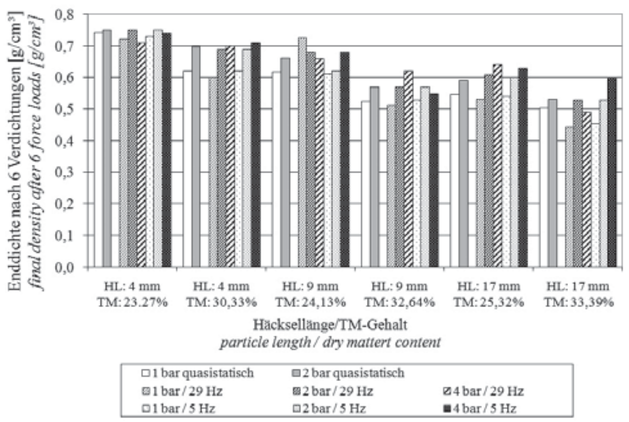
Force load cycles with quasi static and vibrating compression

Fig. 3



Final density after recovery of quasi static and vibrating compression (wilted grass, particle length 4 mm, DM-content 30.33 %)

Fig. 4



Final density of wilted grass after 6 force loading cycles depending on the particle length (HL) and the DM-content (TM)

the final density increases by a continuously smaller amount.

Applying either quasi static compression or vibrating compression, the density of the silage increases digressively with each compressing cycle (**figure 3**). Upon increasing compaction pressure the final density increases as well. There is only an insignificant difference between the compression variants in the final density after 6 compression cycles when applying the same pressure, whereas the densities in the variants of vibrating compression are even slightly lower compared to the quasi static variants. Although there are no values available for quasi static compression at 4 bar, there is no different trend to be expected.

The higher frequency of 29 Hz does obviously not lead to higher final density than the vibration at 5 Hz.

Silage with a particle length of 4 mm can be better compressed than silage with particle lengths of either 9 or 17 mm (**figure 4**). Within the same group of particle length the final density in dry mass contents of ca. 24 % is higher than in such with 30 to 33 %.

Final densities in groups with equal particle length and dry mass content only show insignificant differences between quasi static compression and vibrating compression. Existing differences can mainly be ascribed to the different compaction pressures of 1, 2, or 4 bar.

Conclusions

Upon equal dry mass contents, higher final densities are achieved in shorter particle lengths. Upon equal particle lengths a lower dry mass content leads to higher densities. Thus, results from other trials are confirmed [4; 5], whereas the particle length has less effect on the final density upon high dry mass content [4].

As to their effect on the final density, the dry mass content and the particle length interfere with each other. Silage with longer chop lengths (17 or 9 mm) and less dry mass content shows nearly the same final densities as shorter chopped silage (9 or 4 mm) with higher dry mass content. Thus, if the dry mass content of a given type of plants does not meet the requirements for effective ensiling, it can be levelled out to a certain degree by adjustment of particle length.

Vibration compression compared to quasi static compression of wilted grass does not lead to higher final density. On the contrary, the compaction pressure in quasi static compression remains at maximum during the entire force loading time of 0.5 s. The lower medium compaction pressure caused by the sinus wave of vibration compression is taken as the assumed reason for that.

In contrast to that, observations in practice have shown that compression work can significantly be reduced when using vibrating rollers [6]. Based on own trials, the conclusion can be drawn that vibration in itself does not improve compression, but higher vertical force due to unbalanced masses in the roller. According to information by manufacturers, the occurring vertical forces may amount to two or three times of the actual vehicle mass [2; 3].

A further advantage of vibrating roller compactors is that the roller body contacts the silage raw material in over the full width of the vehicle, causing compression. The effective work width can be up to 2.10m, while using tractors or wheel-type loaders it does normally not exceed 1m (double tire width). In peripheral areas of silo walls the tracks of wheel-type tractors can not be made overlaying, thus it is not possible to work systematically with the same number of rollovers there.

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