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Bulk Density Determination of Solid Biofuels

Several test methods and procedures for calculating the bulk density of solid biofuels were analysed. Cylindrical measuring containers proved to more advantageous than a cuboid shape. A 50 l volume seems to be sufficient for most fuels, while smaller containers are not recommendable. A defined application of shaking increases the bulk density value by 6 % (wood pellets) and 18 % (chopped miscanthus). When fuel moisture is below 25 % (w.b.), measurements with varying moisture content are only comparable, if the shrinkage is accounted for by a correction factor.

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Keywords

Bulk density, moisture content, solid biofuels, wood chips

Literature

[1] *Böhm, T., und H. Hartmann*: Wassergehalt von Holzhackschnitzeln Ein Vergleich der Bestimmungsmethoden. Landtechnik 55 (2000), H. 4, S. 280-281

Bulk density is an important quality parameter for determining storage and transportation room demands of pourable biofuels. Also the design of feeding systems depends on the fuel's bulk density. Furthermore it is a key property for volume based payments and it influences the readings from many physical principles for rapid moisture content determination [1].

Bulk density is calculated by the quotient of mass of a sample material filled into a measuring container and its known volume. Although bulk density is mostly regarded as an easily determinable parameter, the applied methods are highly inconsistent in practice. E.g. the shape and size of the measuring container often vary. Moreover the application of shock impact on the material filled container and the fuel's moisture content (MC) can influence the bulk density result. In the following the mentioned influencing factors are analysed.

Influencing factors

Four containers of different sizes (15, 50, 100l) and shapes (cube, cylinder) were tested in a European round robin (*Table 1*). The container was filled by pouring the sample material from a shovel until a cone of maximum possible height was formed. The pouring height was 100 to 200 mm above the upper rim of the container. Surplus material was removed using a scantling, which was shuffled over the container's edge in a sawing-like movement. The samples were weighed to the nearest 10 g on a platform balance. All measurements were conducted in two variants with three replications each, first by simple container filling („without shock“) and second by dropping the material filled container three times from 150 mm height („with shock“).

In order to evaluate the influence of shrinkage effects with decreasing moisture contents, several fresh wood chip samples were dried down stepwise. Thus, uniform fuel samples with six to eight approximately equidistant moisture content steps were produced covering the natural fuel moisture range. All original bulk density data were initially calculated to a dry matter basis (0 % moisture).

Work plan

The biofuel samples were coniferous (14), deciduous (16) and mixed wood chips (4); also bark (3), wood pellets (2), herbaceous pellets (4), sawdust (2) and three other fuels (chopped miscanthus, grain kernels, peat) were applied. A total number of 8184 bulk density measurements using 341 samples were conducted in six European laboratories.

Influence of container shape and size

For wood chips the shape of the container was accountable for around 1,5 % differences in the measured bulk density, where the 100-l-cube produced always lower values than the 100-l-cylinder (*Fig. 1*). The observed deviation was consistent for all tested fuels, but it was higher for bark (2,0 %) and lowest for high density fuels with a more homogeneous size distribution such as grain kernels (0,9 %) or wood pellets (0,7 %).

The results are also influenced by the container size. However, the differences between the 50 and 100-l-container (cylinder) were small and statistically not significant (deviations of only +0,4 to - 0,5 %), a further reduction of the container size to only 15l leads to an obvious underestimation of the bulk density (-1,4% for wood chips and -3,0 % for bark). Even for fuels with a more homogeneous size distribution such as grain kernels or wood pellets this observation was made (*Fig. 1*).

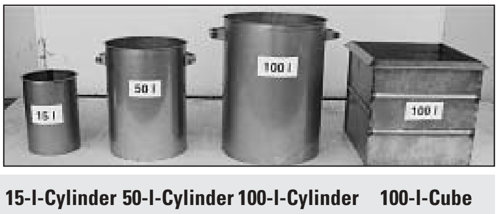

Table 1: Description of the tested measuring containers

Description	15-l-Cylinder	50-l-Cylinder	100-l-Cylinder	100-l-Cube
Volume (l)	15,01	49,86	99,68	100,68
Weight (kg)	2,72	5,44	10,37	13,61
Ratio of side square to volume	19,70	13,18	10,40	10,69

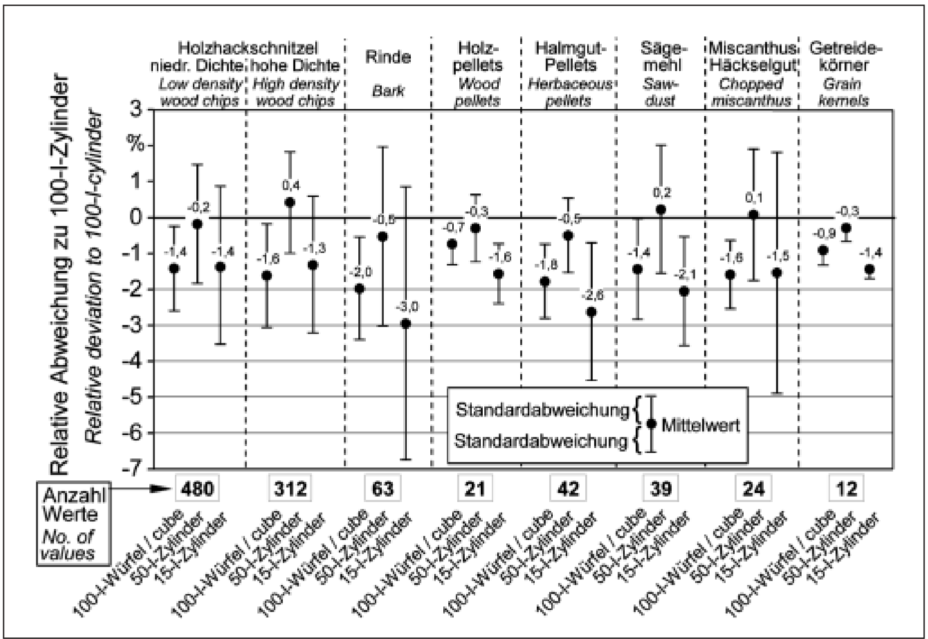

Fig. 1: Relative deviations of bulk densities (dry base, measured in three tested containers compared to the reference container (100-l-cylinder = zero-line).

For most fuels reproducibility improved with the application of a 100-l-cylinder instead of a 100-l-cube. Regarding the container size, reproducibility is better with bigger containers.

Influence of shock impact

The effect of shock impacts on the sample accounted for an increase in bulk density which ranged between 6 % (wood pellets) and 18 % (chopped miscanthus). For wood chips an 11 % increase was measured (*Fig. 2*). Obviously the observed compaction was highest for all fuels which are susceptible towards bridging. By shock application the attempt is made to account for effects of vibrations during transportation or for compacting effects during shipment and storage.

Influence of moisture content (MC)

From a specific test series with wood chips each of the measured bulk densities (dry basis) was calculated relative to a reference bulk density (determined by interpolation) at a uniform moisture content of 30 % (zero line). The results are demonstrated in *Fig. 3*. For the lower MC range a clear correlation between moisture and the measured bulk density (BD) is given. This observation can be explained by the fact that any shrinkage of wood particles is known to take place mostly below the fibre saturation point. This point is usually between 18 and 26 % moisture (wet basis). Due to shrinkage the container can house more individual particles, which leads to higher dry matter weights of the sample. Above the fibre saturation point no further correlation was found.

For a better comparability of different sample moisture contents it can be useful to apply a general correction factor in practice. According to the function in *Figure 3* it is suggested to adjust the bulk density by 0,712 % for each 1 % moisture difference between the measured MC of the samples that shall be compared. This factor should however only be applied for any moisture differences below the MC-level of 25 % (w.b.).

Conclusions

A measuring container size of 50 l is acceptable for all tested solid biofuels. For practical reasons a cylindrical container shape shall be preferred. A defined shock impact on the filled container increases the measured bulk density of wood chips by about 10 to 12 %. The fuel's moisture content is of high importance because of the comparability of different measurements at varying moisture contents. This comparability can be improved by the application of the here suggested correction factor.

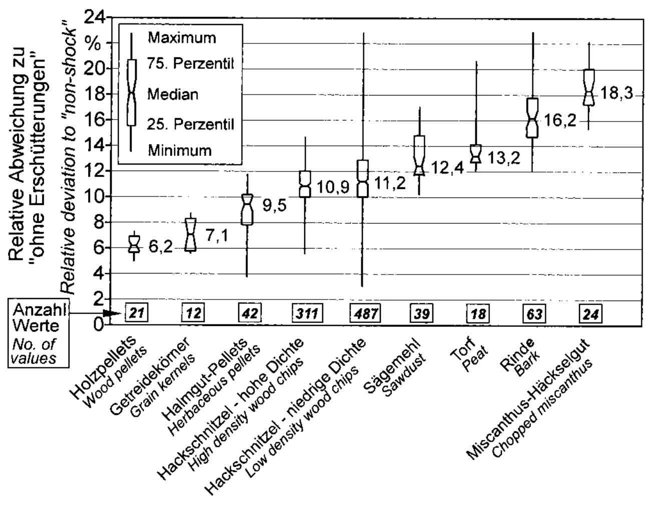

Fig. 2: Effect of shock impact compared to non-shock application (zero line) for the 50-l-cylinder

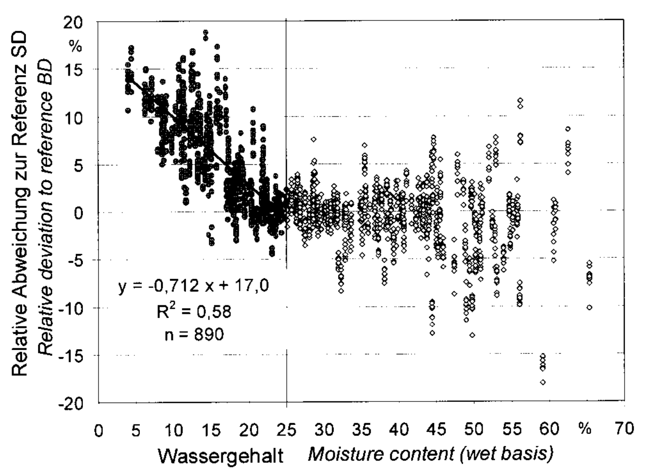

Fig. 3: Correction function for bulk density measurements of wood chips (dry base) as a function for the actual moisture content as received