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The compressive to tensile strength ratio of pharmaceutical compacts

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Summary

The tensile and compressive strength of cylindrical compacts of lactose and microcrystalline cellulose has been assessed by diametral compression and axial loading, respectively. The ratio of the compressive to the tensile strength of the specimens indicates that lactose is more brittle in character than microcystalline cellulose. Thus, the test procedure provides a method of characterising the mechanical properties of the powders.

Assessment of the mechanical properties of pharmaceutical powders is usually achieved by their compression to form compacts, followed by determination of the mechanical properties of the specimens formed. The most usual type of strength test takes the form of a tensile strength assessment either by diametral compression (Fell and Newton, 1970), axial pulling (Nystrom et al., 1978) or flexure (David and Augsburger, 1974). While strength values are readily measurable, they represent specimen rather than material properties and the inferences from the values in terms of ability of material to form tablets are not as yet clearly quantified. This is presumably because during the compaction process, although particles may be subjected to tensile stresses, they are also subjected to shear and compression stresses which may themselves result in deformation and failure. Alternative methods of characterising pharmaceutical powders are in terms of 'stiffness' by means of Young's modulus (Church and Kennerley, 1983; Kerridge and Newton, 1986; Roberts and Rowe, 1987b) and fracture mechanics (Mashadi and Newton, 1987). For brittle materials, the values of Young's modulus can differ when determined in tension and compression, whereas ductile materials have similar values. Kerridge and Newton (1986) have shown how it is possible to determine the value of Young's modulus in compression; for microcrystalline cellulose Avicel PH102, the value was about half of that determined in tension (Bassam et al., 1988).

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Most materials are weaker in tension than in compression. This is particularly true for brittle materials. Hence, they probably do fail predominantly in tension, even when subjected to compression forces; tensile tests are therefore of particular importance. Nevertheless there is merit in the evaluation of the compressive strength of materials, for the purpose of providing a more complete understanding of mechanical behaviour.

The determination of the compressive strength of a brittle material may present problems. The classical approach is to compress a cylinder between two platens using lubricated interfaces to prevent friction between the platens and the specimen. The fact that pharmaceutical powders can be compacted into cylinders with a length approximately equal to the diameter offers the possibility of using the same form of specimen for both compressive and tensile strength testing, the former by loading to fracture in unconfined compression parallel to the cylinder axis, the latter by loading to fracture in diametral compression. The use of the same specimen is advantageous in reducing systematic error; material isotropy is assumed.

Tablets were individually prepared from lactose (coarse powder grade Svenska Mjolkhscocher AB) and microcrystalline cellulose (Avicel PH101, FMC Corp., Philadelphia, U.S.A.) at a fixed compression setting by uniaxial compression on an instrumented single punch tablet machine (Korsch EKO, Germany), with 1.13 cm diameter punches and dies at a compaction speed of 30 tablets per min. The quantity of material added to the die, which had been pre-lubricated with a 1% dispersion of magnesium stearate in alcohol, was adjusted to ensure that at the compaction pressure used, the tablets were 1 cm in height. The formation pressure, weight (± 0.0001 g) and dimensions (± 0.001 mm) were recorded for each specimen. The mean formation pressures for Avicel and lactose were 150 and 50 MN m^{-2}, respectively. The tablets were stored for at least 48 h prior to strength testing.

The tensile strength was determined by loading the specimens at 1 mm/min across a diameter on a universal testing instrument (Lloyds) and the compression strength by loading at the same

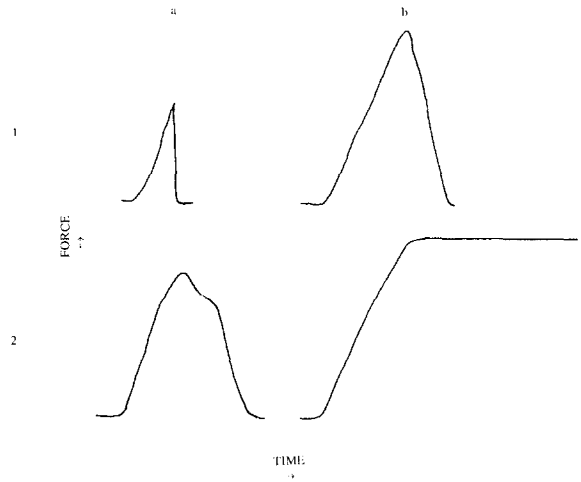

Fig. 1. Force time curves for fracture of tablets at (a) diametral compression and (b) compression. (1) Lactose and (2) microcrystalline cellulose.

rate parallel to the cylinder axis with the same system. It was found in a series of initial experiments that a piece of teflon sheet between the tablet and the platen did not significantly change the force-time curve recorded or the maximum load detected. Tests were therefore conducted without such sheets. The force-time curve was recorded; typical traces are shown in Fig. 1. The diametrical test provided clear failure points and the specimens fractured across the loaded diameter. In compression tests, a clear failure was observed in the trace for lactose and crumbling of the tablet could be observed. For the Avicel, a slightly rising plateau was reached with no clear evidence of failure within the tablet. The initial value of this plateau was taken as the force at failure.

To calculate strength values from these forces at failure, the standard equation was applied for diametral compression, namely, $\sigma_t = 2P/\pi\ dt$, where σ_t is the tensile strength, P denotes the load at failure, d is the diameter of the cylinder and t its length. For the compressive strength, σ_c, the force at failure was divided by the cross-sectional area of the specimen. The values for compressive and tensile strength (the mean of five values in each case) are recorded in Table 1, together with the ratio of the compressive to

TABLE 1

Compressive and tensile strength of cylindrical compacts of microcrystalline cellulose and lactose

Material	Tensile strength ($MN\ m^{-2}$) (σ_t)	Compressive strength ($MN\ m^{-2}$) (σ_c)	Ratio (σ_c/σ_t)
Microcrystalline cellulose	0.839	5.62	6.70
Lactose	0.383	4.30	11.27

tensile strength. As the two materials were not compacted at the same pressure, there is no point in comparing their strength values directly, but it is quite clear that the strength ratio for lactose is very much greater than that for microcrystalline cellulose. Hence, lactose can be classified as being more brittle than microcrystalline cellulose. This agrees with the findings based on a brittle propensity index (Roberts and Rowe, 1986) and fracture energy estimations (Roberts and Rowe, 1987b).

Thus, by testing cylindrical specimens of powders prepared by compaction, an indication of the type of mechanical strength behaviour of the material can be obtained.

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