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The compression characteristics of microcrystalline cellulose powders

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Microcrystalline cellulose is thought to undergo stress relief deformation by several mechanisms. At low compressive forces stress relief is dominated by a highly elastic phase (Aulton et al 1974) followed at higher forces by either little further deformation (Huettenrauch & Jacob 1970) or permanent deformation by non-specific plastic flow (Reier et al 1966). Microcrystalline cellulose was also shown to exhibit plastic flow by Travers et al (1978) who found after removal of the compressive force that a time-dependent stress relief occurred within the die. In an attempt to further elucidate the compaction mechanism, microcrystalline cellulose compacts have been prepared and their physical characteristics studied over a wide range of compaction pressures.

The compacts were prepared from four commercially available forms of microcrystalline cellulose, namely Avicel PH 101, PH 102, PH 103 and PH 105. These powders were as received from the manufacturers and conditioned at 30–40% relative humidity and 18–20 °C for several days before compression.

The tablets were prepared on an instrumented single station tablet machine (Manesty E2) (Marshall 1970). For each tablet the die was hand filled with powder to ensure uniformity of weight. All tablets were produced at a standard speed and the instrumentation responses recorded on a direct recording u.v. oscillograph (Southern Instruments, Mitcham).

Difficulties were encountered in measuring the radial force produced because of relative movement between the die and radial force sensor which was in contact with the die through the die table. To enable compation profiles (Leigh et al 1967) to be generated, compacts of a similar h/d ratio to those produced by the tablet machine were made in an instrumented punch and die set (Sixsmith 1975). After placing the punch and die set between the plattens of an Instron compression testing machine compacts were prepared by hand filling the die with powder and compressing this by lowering, at a standardized speed, the cross head of the Instron until a maximum force had been recorded. Immediately this occurred the direction of motion was reversed, thus mimicking a single station tablet machine, whilst recording the axial and transmitted forces, and the tablet vertical thickness throughout.

Ten tablets from each sample were subjected to diametrical crushing using a Heberlein tablet hardness tester (Schleuniger & Co, Zurich), and the mean value of ten determinations taken. The disintegration time for each sample of tablets was determined using the disintegration test described in the British Pharmacopoeia, Appendix XIIA, p A113–A114.

The compaction profiles for the Avicels, shown in Fig. 1, suggest that on application of stress the powders undergo elastic deformation throughout the range of compaction pressures studied using the compaction apparatus, showing the elastic limit to be above 50 MPa. This is in agreement with previous findings for Avicel PH 101 which, when compacted to a maximum pressure of 50 MPa, was found to exhibit a high degree of elastic recovery (Aulton et al 1974).

The break in the decompression phase of the cycle at around 40 MPa can be explained by reference to Fig. 2. For all the Avicels during the decompression stage at below 40 MPa the rate of decay of axial consolidating pressure and lower punch pressure are equal. This phenomenon is only possible if the die and compact move relative to the lower punch so that the lower punch supports the die, compact and upper punch. This is in fact the case with the compaction apparatus as the die merely sits within the apparatus and is not rigidly locked into place. This movement of the die will allow the compacts to expand axially in both directions increasing the area of contact with the die wall which will lead to an apparent increase in radial pressure.

The relationships between the measured physical properties of the tablets and compressional force suggest that the elastic limit for the Avicels is reached when the particles are subjected to a compressive force of 60–80 MPa.

A linear relationship exists between porosity and log compaction force. There is however, an increase in slope in the range 60–80 MPa suggesting that some change takes place in the response of the particles to the compaction pressure enabling a greater degree of consolidation to occur. This change is also seen in the relationship between

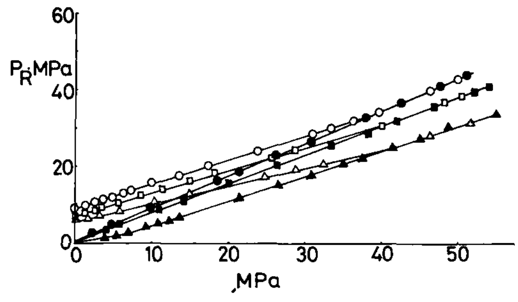

FIG. 1. Compaction profiles for Avicel powders: squares PH 101/PH 103, triangles PH 102, circles PH 105. Solid symbols—compression; open symbols—decompression. X-axis—compaction pressure (MPa). y-axis—radial pressure (P_R.MPa).

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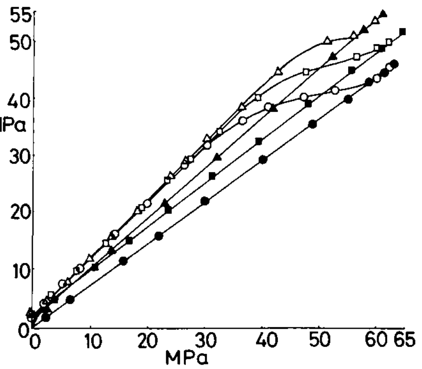

FIG. 2. P_A–P_L profiles for Avicel powders. Symbols as for Fig. 1: x-axis compaction pressure (MPa). y-axis pressure transmitted to the lower punch (P_L.MPa).

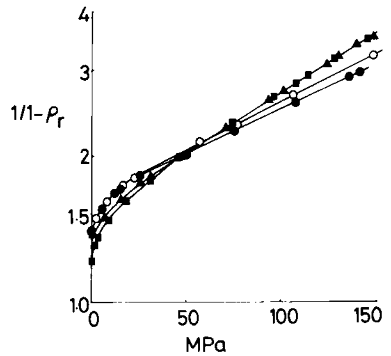

FIG. 3. Heckel plots for all grades of Avicel: ■ PH 101/PH 103; ▲ PH 102; ● PH 105; ○ Milled PH 101. X-axis axial compaction pressure (MPa) y-axis a function of relative density: $1/(1 - \rho_r)$

diametrical crushing strength and log compaction pressure. Again there is an increase in the slope between 70–80 MPa which indicates a change in the characteristics contributing to mechanical strength. The disintegration times also show a marked increase as the compaction pressure exceeds 70 MPa. This effect is not noticeable in tablets prepared from Avicel PH 105 as the disintegration times are very much greater than for the other three grades, tablets prepared at pressures in excess of 20 MPa requiring up to 24 h in which to disintegrate.

Size reduction of Avicel PH 101, to a particle size distribution comparable to that of Avicel PH 105, causes an increase in distintegration time of the tablets prepared from it, from 9 to 1800 s, but it is still not comparable with tablets prepared from Avicel PH 105 under identical conditions. This suggests that the difference in disintegration of Avicel PH 105 tablets is not caused solely by the smaller particle size of the original powder.

The use of a Heckel plot (Heckel 1961), which follows the relationship between compaction pressure and a function of relative density, enables the type of deformation undergone by particles subjected to compaction to be determined. Application of this to the Avicel results in Fig. 3 shows that initially Avicels PH 101/ PH 103 and PH 102 have different bulk densities, but as the pressure increases their bulk densities become identical. For this to occur after the elastic limit is reached the particles must consolidate predominantly by brittle fracture.

Avicel PH 105, however, gives an entirely different plot neither coincident nor parallel with that for the other three grades. Compaction of a milled sample of grade PH 101, with a size distribution, as determined by sedimentation, similar to that of Avicel PH 105, gave a line intermediate between PH 105 and the other three grades. This seems to indicate that the cause of this difference is not only the particle size but also the change in particle shape between grade PH 105 and the other pharmaceutical grades (Marshall & Sixsmith 1974).

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