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The compaction properties of polyethylene glycols

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The mechanical properties of polyethylene glycol (PEG) powders of different average molecular weights have been characterized in terms of their yield pressure, determined from the densification of compacts by the method of Heckel. The yield pressure was found to be proportional to the molecular weight of the PEG. The densification which occurred during compaction was greater the lower the molecular weight. In terms of compact tensile strength, PEG 10 000 produced the greatest strength for a given pressure. This arises from its ability to deform plastically to form a compact and be of sufficient intrinsic strength to resist fracture during the diametral compression test. Higher molecular weights PEGs do not allow sufficient plastic flow during consolidation for their inherent higher strength to be used.

The mechanical properties of powders determine how they respond to pressure in the process of tablet formation. Those materials which are soft and can deform plastically will allow the particles to flow, be reshaped and move into void space while harder powders are more likely to fill the voids only after fragmentation. Heckel (1961a, b) suggested that a value of the yield pressure of a material could be determined from a study of the consolidation which occurred when a powder compact was formed. Several authors (e.g. Hersey & Rees 1971; Fell & Newton 1971; York 1978; Paronen & Juslin 1983) have used this approach to compare the compaction of different chemical entities of physically-different samples, e.g. in terms of particle size. Comparison of different materials by this technique appears to be limited, probably due to the complexity of the compaction process, but this approach may be of more benefit if it is applied to a single material with mechanical properties that can be varied. Such a material is polyethylene glycol (PEG) which can be obtained in a range of molecular weights, and whose mechanical properties vary from a soft plastic material at lower molecular weights, to a harder brittle material at higher values.

MATERIALS AND METHODS

Materials

Samples of PEG with average molecular weights of 2000, 3000, 4000, 6000, 10 000, 20 000 and 35 000 g were supplied by Hoechst Laboratories in the form of flakes. These were reduced in a small grinder (IKA Analytical M11 A10) and separated into size fractions by sieving. It was possible to obtain significant quantities of a −500 +355 μm size fraction of each molecular weight.

Methods

A weighed quantity of the PEG sample was filled into a 10 mm diameter die of a single-punch tablet machine (Model F3, Manesty Machines Limited) instrumented with load washers as described by Kennerley (1980). Each sample was subjected to a single motor-driven compression cycle, starting from a point which gave the maximum distance of punch travel to the surface of the powder. Ten replicate tablets were prepared at a range of compaction pressures. The dimensions of the tablets produced were measured (±0·01 mm) using a micrometer and weighed (±0·0001 g). After storage of the compacts for 7 days in air-tight jars, their diametral breaking strength was determined using a CT40 tablet strength tester (Engineering Systems, Nottingham), and the tensile fracture stress calculated (Fell & Newton 1970).

RESULTS AND DISCUSSION

The degree of consolidation compaction was clearly related to the molecular weight of the glycol (Fig. 1) and the relation established by estimation of the tablet porosity, at given compaction pressure, is shown in Fig. 2. The lower molecular weight materials form compacts of lower porosity. This supports the hypothesis that the lower molecular weight materials can deform more readily to fill inter-particulate voids.

The results for changes in the volume of tablets with the applied pressure as described by Heckel

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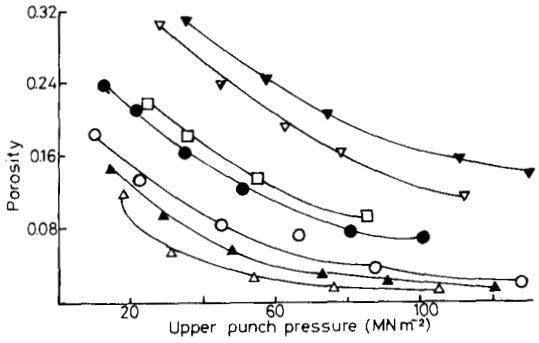

FIG. 1. The variation of tablet porosity with compaction pressure for −500 +355 μm size fractions of PEG (a) △ 2000, (b) ▲ 3000, (c) ○ 4000, (d) ● 6000 □ 10 000, (e) ▽ 20 000 and (f) ▼ 35 000.

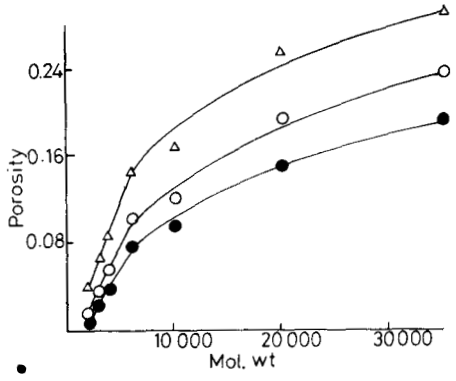

FIG. 2. The influence of molecular weight of PEG on estimated porosity of compacted −500 +355 μm size fraction of PEG at compaction pressures of △, 40; ○, 60 and ● 80 MN m^{-2}.

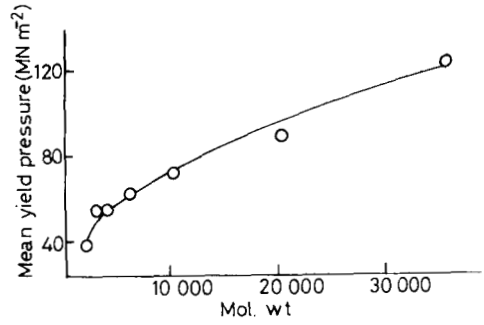

FIG. 3. Yield pressure of −500 +355 μm size fractions of PEG as a function of molecular weight.

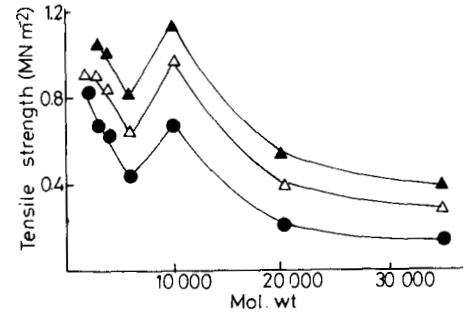

FIG. 4. The relation between tablet tensile strength and molecular weight for −500 + 355 μm PEG size fractions compacted at ● 40, △ 60 and ▲ 80 MN m^{-2}.

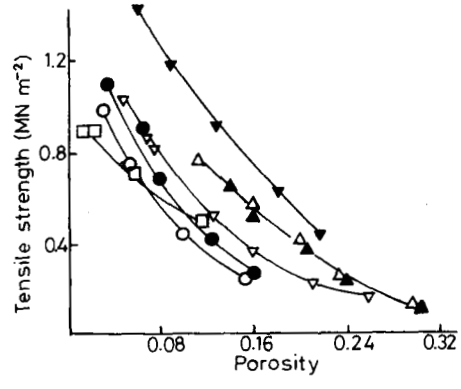

FIG. 5. The relation between the porosity and tensile strength of tablets of −500 +355 μm size fractions of PEG □, 2000; ○, 3000; ● 4000; ▽, 6000; ▼, 10 000; △, 20 000 and ▲ 35 000.

(1961a, b) provides a method whereby the yield pressure of the material may be obtained from the linear portion of the slope. The values of the yield pressure increase with an increase in the molecular weight of the PEG (see Fig. 3). Even the highest value of yield pressure, however, was much lower than that obtained for lactose (Fell & Newton 1971).

The mechanical properties of the tablets will be influenced by the compaction process and the mechanical properties of the material itself. Consolidation to a given voidage should give an indication of the strength of the material if the voidage approaches zero. Thus a graph of the tensile strength of the tablets formed at three compaction pressures was derived from a plot of the tensile strength as a function of upper compaction force (see Fig. 4). Dense, strong tablets were formed with the low molecular weight PEG, the strength decreasing with increase in molecular weight up to a value of 6000. There was then an increase at 10 000 followed by a decrease at 20 000 and 35 000. The high strength at low molecular weights could be an artifact of the

testing process whereby very soft materials can spread at the contact area between platen and tablet. This could cause an increase in the breaking load and hence tensile strength (Fell & Newton 1970). It appears that the PEG 10 000 possesses the optimum property in being soft enough to flow during compaction but strong enough to resist fracture when subjected to tensile testing. The higher molecular weight materials do not deform as readily during compaction and hence cannot form compacts of comparable strength. This effect is further illustrated by the finding that for an equivalent porosity, the PEG 10 000 provides the highest tensile strength (Fig. 5). Clearly, then, voidage reduction alone cannot characterize the strength produced by consolidation. The mechanism of the voidage reduction obviously has a significant effect on the mechanical strength of the compact produced.

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