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# COMMUNICATIONS

## The effect of moisture content on the compression properties of maltodextrins

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**Abstract**—The effect of moisture content on the compression properties of maltodextrin powders obtained by different degrees of hydrolysis (depolymerization) of corn starch has been studied using the yield pressure determined from the Heckel plot and the compact tensile strength measured by the diametrical compression method. An increase in the moisture content of the powder reduced the yield pressure and improved the densification for all five maltodextrins evaluated. At the same moisture level, the extent of densification which occurred during compaction was greater for maltodextrins with a lower degree of polymerization. Compacts produced by maltodextrins with a lower degree of polymerization also exhibited a greater tensile strength for a given pressure at a moisture content below 8·0%. However, further increase in moisture content resulted in a decrease in compact tensile strength for maltodextrins having a lower degree of polymerization. Despite the significant difference in compression behaviour, the five maltodextrins did not show noticeable differences in crystallinity as revealed by their x-ray powder diffraction pattern.

Maltodextrins are carbohydrate ingredients prepared by controlled hydrolysis (depolymerization) of corn starch with acid and/or enzyme. A maltodextrin product has recently been evaluated as a directly compressible tablet excipient (Parrott 1989). It was shown that maltodextrin exhibits comparable compressibility to that of other excipients commonly used for direct tablet compression. The physical properties of a maltodextrin are mainly determined by the degree of starch hydrolysis which is represented by the dextrose equivalent value (D.E.) of the product. The D.E. value is defined as the amount of reducing sugars present and expressed as percentage of dextrose in the dry substance. A high D.E. value indicates a low average degree of polymerization of the maltodextrin which consists of a high percentage of low molecular weight saccharides. The purpose of the present study is to examine the relationship between the degree of polymerization and the compression properties of maltodextrins. The role of moisture content in the compression of maltodextrins has also been investigated.

### Materials and methods

*Materials.* Maltodextrin powders with varying degrees of polymerization were supplied by the Grain Processing Corporation, USA, under the trade name Maltrin. Based on the D.E. value of the product, the five powders used in this study are coded as M040 (D.E. = 5), M100 (D.E. = 10), M150 (D.E. = 15), M180 (D.E. = 18) and M200 (D.E. = 20). A-125 + 74 μm size fraction of each powder was used in this study.

*Determination of equilibrium moisture content.* Samples of powder were dried at 105°C under vacuum for 24 h and subsequently exposed to five different relative humidities (11–52%) in desiccators containing different saturated salt solutions at 22°C. The weight of the sample was determined at 2-day intervals until constant weight was obtained. The equilibrium moisture content of the powder was calculated as the percent weight increase.

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*Comparison of the powder crystallinity.* The x-ray powder diffraction patterns were obtained using an x-ray diffractometer (General Electric Co.) equipped with a copper x-ray source in rotating encasement. The change in powder crystallinity of the samples was studied by comparing their diffraction pattern.

*Powder compression and compact tensile strength.* Maltodextrin powders with various moisture contents were obtained by exposing the powders to different relative humidities at 22°C until equillibrium was reached. A weighed quantity of maltodextrin powder was compressed using the Carver Press (Model C) equipped with flat ½″ punches and die which were prelubricated with a 5% magnesium stearate suspension in chloroform. The duration for compression at a specific pressure was 5 s. Five replicate compacts were prepared at a range of compression pressures. The weight of the compacts was determined (±0·0001 g) and the dimensions of the compacts were measured (±0·01 mm) using a hand micrometer 24 h after compression. The apparent density of the compacts was subsequently computed and the relative density was given by the ratio between the apparent density of the compact and the particle density of the powder which was measured using an air comparison pycnometer (Beckman Model 930). The calculated relative density was plotted against the compression pressure according to the Heckel equation (Heckel 1961a,b). The slope of the linear portion of the plot was determined using the least square linear regression method. The reciprocal of the slope is referred to as the mean yield pressure of the powder. The force which caused the tensile failure of the compact under diametrical compression was measured using a stress-strain analyzer (McCurdy 1985). The tensile strength of the compact was subsequently calculated (Fell & Newton 1970).

### Results and discussion

The equilibrium moisture contents for the five maltodextrin powders achieved at various relative humidities are shown in Fig. 1. The highest water uptake was exhibited by Maltrin M040. There was no significant difference for the moisture content attained by the four other powders at a specific relative humidity. All five powders remained free flowing at the moisture content levels studied.

Fig. 2 shows the influence of the moisture content on the relative density of the maltodextrin compacts formed under two different compression pressures. It is apparent that an increase in moisture content facilitates powder consolidation for the maltodextrin powders under compression. This is thought to be due to the moisture acting as an internal lubricant and thus facilitating

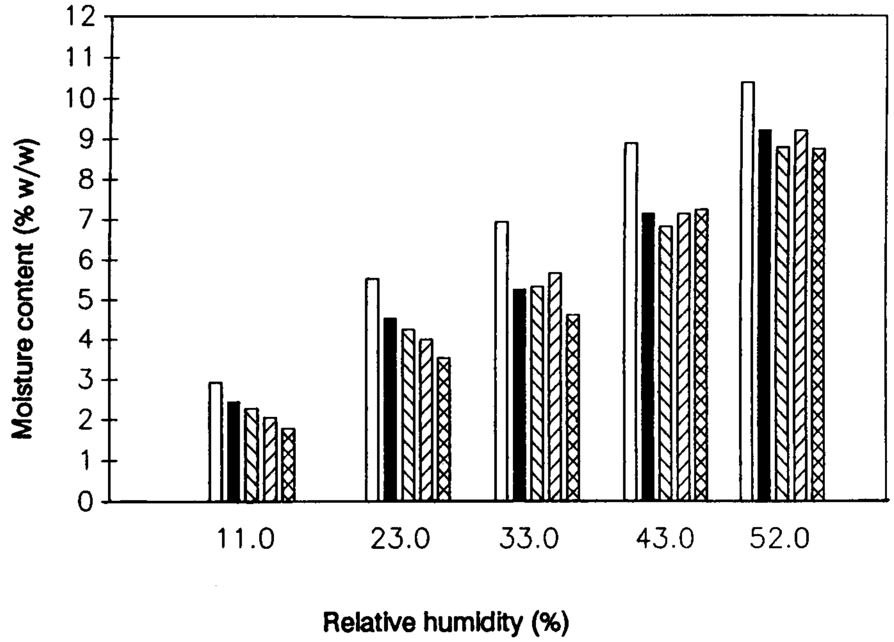


FIG. 1. The equilibrium moisture content of maltodextrins at various relative humidities. (□) M040; (■) M100; (▧) M150; (■) M180; and (⊠) M200.

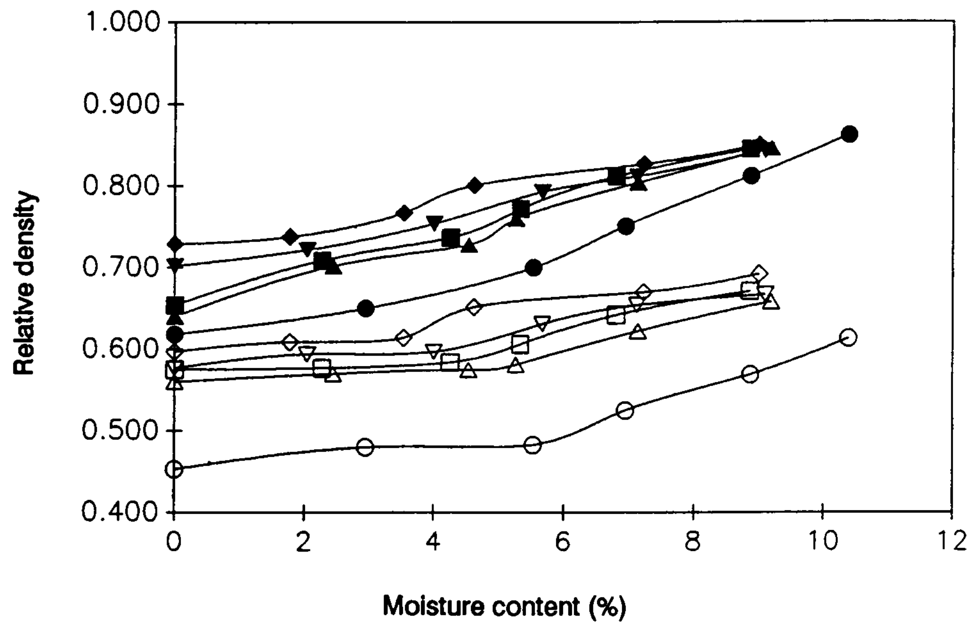


FIG. 2. The effect of moisture content on the relative density of maltodextrin compacts prepared at 20 MPa, (open symbols) and 50 MPa, (closed symbols), respectively. (○) M040; (△) M100; (□) M150; (▽) M180; and (◇) M200.

powder consolidation (Khan et al 1981). The degree of consolidation was also related to the degree of polymerization of the maltodextrin (Fig. 2). For a given pressure the maltodextrins with a lower degree of polymerization (a higher D.E. value) formed compacts with greater relative density. This supports the hypothesis that maltodextrins with a low degree of polymerization can deform more readily to fill inter-particulate voids in a compact. Considering the lack of compressibility of corn starch, the enhanced compressibility seen in maltodextrins with decreasing degree of polymerization is probably due to the presence of a larger amount of compressible low molecular weight saccharides.

The effect of moisture content on the yield pressure of maltodextrin powders is shown in Fig. 3. An increase in the moisture content resulted in a marked reduction in the yield pressure of the maltodextrin powders. This indicates that the moisture greatly enhanced the plastic deformation of the powder under compression. For a given moisture content below 6 percent, maltodextrins with a lower degree of polymerization exhibited a lower yield pressure. The effect of degree of polymerization on the yield pressure of maltodextrin is apparently associated with the amount of low molecular weight saccharides in the powder. A high level of low molecular weight saccharides was found to facilitate the plastic deformation of the

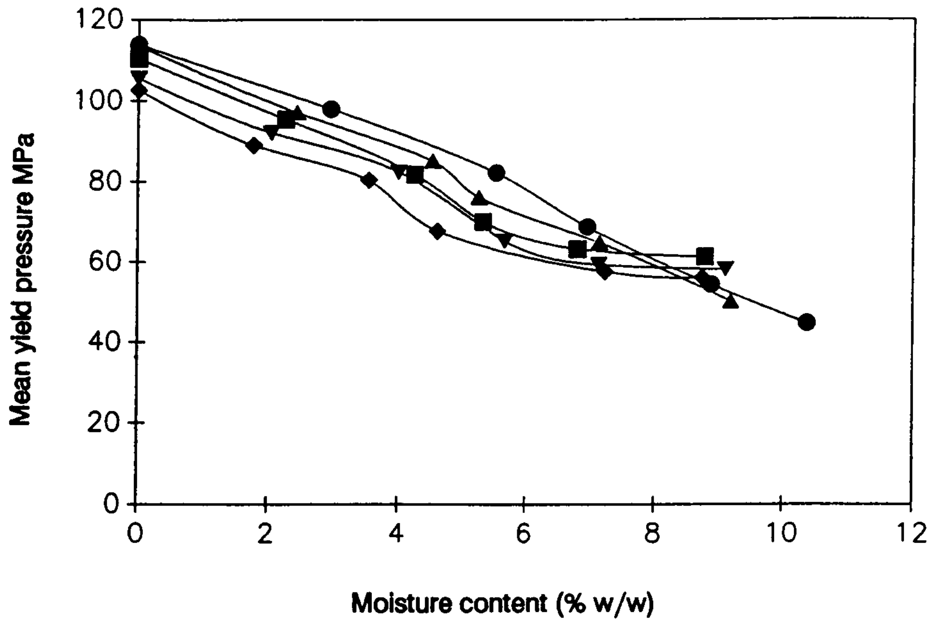


FIG. 3. The relationship between the moisture content and mean yield pressure for various maltodextrins. (●) M040; (▲) M100; (■) M150; (▼) M180; and (◆) M200.

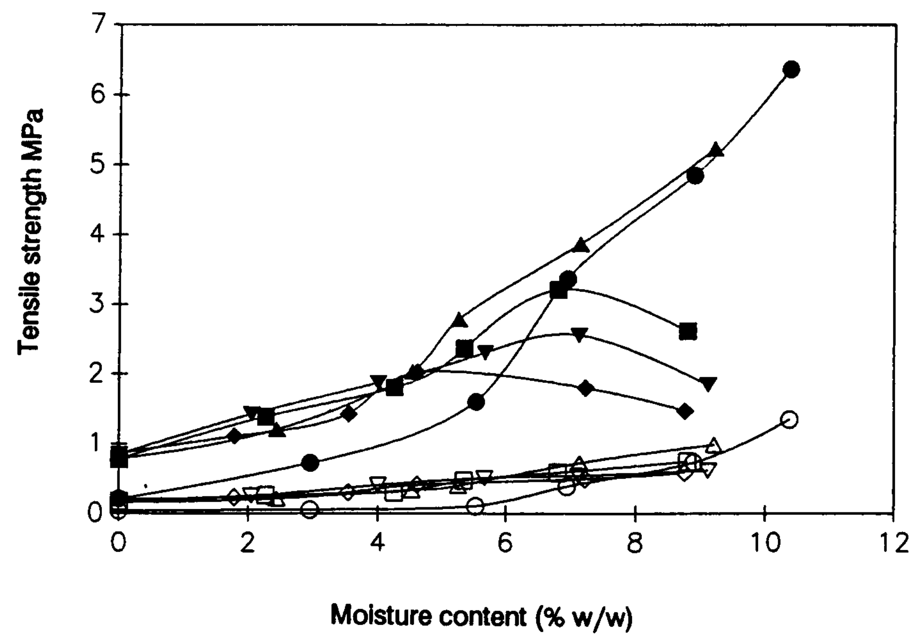


FIG. 4. The effect of moisture content on the tensile strength of maltodextrin compacts prepared at 20 MPa, (open symbols) and 50 MPa, (closed symbols), respectively. (○) M040; (△) M100; (□) M150; (▽) M180; and (◇) M200.

powder. A further reduction in the yield pressure at a moisture content beyond 6 percent was observed for the maltodextrins with a low D.E. value (5 and 10); however, the yield pressure for maltodextrins having a higher D.E. value tended to level off.

The tensile strength of maltodextrin compacts was influenced by the compression pressure applied, the degree of polymerization and moisture content of the powders (Fig. 4). At a compression pressure of 20 MPa, maltodextrin powders with a higher D.E. value gave rise to compacts with greater tensile strength at higher moisture contents. At a moisture content above 6 percent, a more drastic increase in compact tensile strength was shown by the two maltodextrin powders with a D.E. value of 5 and 10, respectively. As the compression pressure was increased to 50 MPa, the compact tensile strength for maltodextrins with a higher D.E. value increased with the moisture content of the powder; however, a decrease in the compact tensile strength was seen as the moisture content was above 8 percent. On the contrary, an increase in the moisture content of maltodextrins with D.E. value of 5 and 10 consistently resulted in compacts with greater tensile strength. The marked increase in tensile strength of maltodextrin compacts with increasing moisture content is believed to be due to the lubrication effect of water which improves force transmission from the upper to lower punch and results in greater consolidation at a given pressure (Armstrong et al 1986). The reduction in compact tensile strength observed at a moisture content above 8

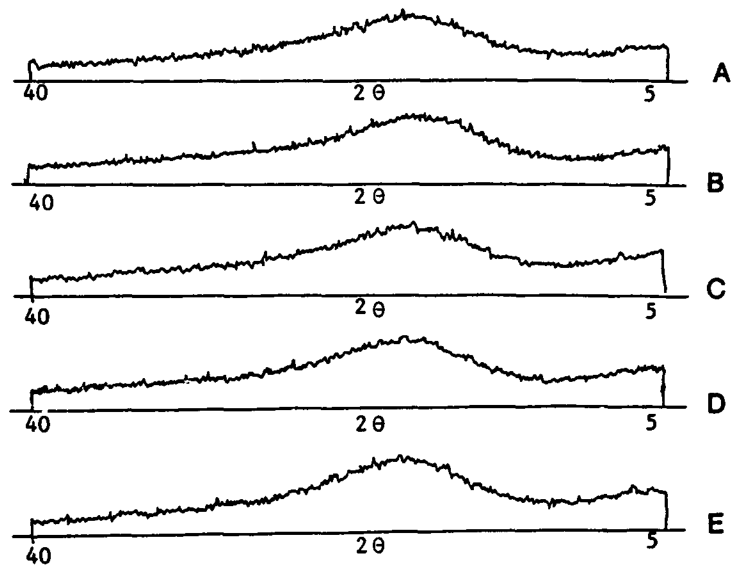


FIG. 5. The x-ray powder diffraction patterns for various maltodextrins. (A) M040; (B) M100; (C) M150, (D) M180; and (E) M200.

percent for maltodextrins with a high D.E. value may be caused by the water associated with the low molecular weight saccharides. The water may form surface films on the particles acting as a physical barrier for interparticulate bonding (Rees & Hersey 1972). The hydrostatic resistance to consolidation may also play a role in reducing compact strength (Shotton & Rees 1966).

Fig. 5 shows the x-ray powder diffraction patterns for the five maltodextrins evaluated in the present study. In spite of the difference in degree of polymerization and compressional behaviour, there was no difference in crystallinity for these powders as revealed by their x-ray diffraction pattern. Furthermore, the amorphous nature of these powders is indicated by the diffused x-ray patterns.

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## References


Armstrong, N. A., Patel, A., Jones, T. M. (1986) The compression properties of dextrose monohydrate and anhydrous dextrose of varying water contents. Drug Dev. Ind. Pharm. 12: 1885–1901

Fell, J. T., Newton, J. M. (1970) Determination of tablet strength by the diametral-compression test. J. Pharm. Sci. 59: 688–691

Heckel, R. W. (1961a) An analysis of powder compaction phenomena. Trans. Metall. Soc. A.I.M.E. 221: 671–675

Heckel, R. W. (1961b) Density-pressure relationships in powder compaction. Ibid. 221: 1001–1008

Khan, K. A., Musikabhumma, P., Warr, J. P. (1981) The effect of moisture contents of microcrystalline cellulose on the compressional properties of some formulations. Drug Dev. Ind. Pharm. 7: 525–538

McCurdy, V. E. (1985) The effect of microcrystalline cellulose in a sugar coating suspension on the coating process and on the physical properties of the coated tablets, PhD Thesis, Purdue University, West Lafayette, Indiana, USA

Parrot, E. L. (1989) Comparative evaluation of a new direct compression excipient, Soludex™ 15. Drug Dev. Ind. Pharm. 15: 561–583

Rees, J. E., Hersey, J. A. (1972) The strength of compact containing moisture. Pharm. Acta Helv. 47: 235–243

Shotton, E., Rees, J. E. (1966) The compaction properties of sodium chloride in the presence of moisture. J. Pharm. Pharmacol. 18: 160S–167S