Effect of Moisture Content on Compression Properties of Two Dextrose-Based Directly Compressible Diluents

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Moisture sorption characteristics and the effect of moisture content on the compression properties of two dextrose-based directly compressible diluents, namely, Emdex (diluent A) and Sweetrex (diluent B) were studied. Both diluents sorbed moisture rapidly at relative humidities greater than 60%. For both the diluents, pressures required to compress tablets to the same relative density decreased with increasing moisture content. Yield pressures calculated from linear Heckel plots obtained from the compression data of both diluents reflected decreasing values with increasing moisture content. Three-way surface profile graphs of moisture content versus tablet parameters such as crushing force, relative density, and compression pressure give a unique overall picture of the compression properties of a diluent and offer the tablet formulator a useful tool for diluent comparison.

KEY WORDS: moisture content; compression properties; dextrose-based directly compressible diluents.

INTRODUCTION

The presence of moisture in granules can affect physical properties such as blending, flow characteristics, binding, and compact behavior (1–9). However, current literature has little to say about the effect of moisture content on compression properties of sugar-based direct compression diluents (10–13). The purpose of this investigation was to compare the moisture sorption characteristics and to study the effect of moisture on compression properties of two directly compressible dextrose based diluents.

MATERIALS AND METHODS

The materials were used as received from the suppliers except as noted to adjust the moisture content. They were Emdex or diluent A (Edward Mendell Co. Inc., Carmel, N.Y.) containing 100% dextrates including 95% dextrose, Sweetrex or diluent B (Edward Mendell Co. Inc., Carmel, N.Y.) containing 70% dextrates and 30% fructose, magnesium stearate (Amend Drug and Chemical Co., Inc., New York), Karl Fisher reagent, and formamide (Fisher Scientific Co., Fairlawn, N.J.).

Moisture Content Determination

Moisture content determination of the diluents was carried out by the Karl Fisher method. Formamide was used as the solvent instead of methanol for the Karl Fisher titrations because of greater solubility of the sugar diluents in the solvent.

Moisture Adjustment of the Powders

Once the initial moisture content of the diluent was determined, the diluents were dried in the oven at 50°C for an appropriate time in order to attain moisture contents below the initial concentrations. The dried samples were stored in dry glass bottles with tight-sealing screw caps and equilibrated for at least 24 hr before determining the exact moisture content of the powders by the Karl Fisher method.

Moisture Sorption by the Diluents

Three grams of dried diluents with the lowest moisture contents were placed in tared 5-cm-diameter petri dishes and exposed to five different relative humidity chambers, *viz.*, 10, 30, 55, 80, and 92%, prepared with saturated salt solutions. The petri dishes containing the powders were periodically taken out of the humidity chambers at specified intervals and accurately weighed to determine any changes in weights of the diluents. The moisture content of the diluents was calculated on a dry-weight basis established by Karl Fisher titration. The temperature was maintained at 23 ± 2°C throughout the investigation. Equilibrium moisture contents of the diluents were also determined by exposing the powders to controlled humidity chambers for more than 2 weeks.

Density Determination

The density of the diluents was determined with an air comparison pycnometer (Beckman Model 930, Beckman Instruments Inc., Scientific and Process Instrument Division, Fullerton, Calif.). The density of the sample was calculated from a mean of four readings.

Tablet Compression

Diluents with the desired moisture content (obtained by oven drying and equilibration) ranging from 0.36 to 10.6% for diluent A and 0.59 to 8.32% for diluent B were blended with 0.75% magnesium stearate (lubricant) in a twin-shell blender for 4 min just prior to tableting. Tablets were compressed on

Table I. Equilibrium Moisture Contents of the Diluents at Different Relative Humidities

Relative humidity (%)	Equilibrium moisture content (%)	
	Diluent A	Diluent B
10	0.30	0.16
30	0.53	0.65
55	1.49	6.87
80	12.16	34.45
92	26.79	88.20

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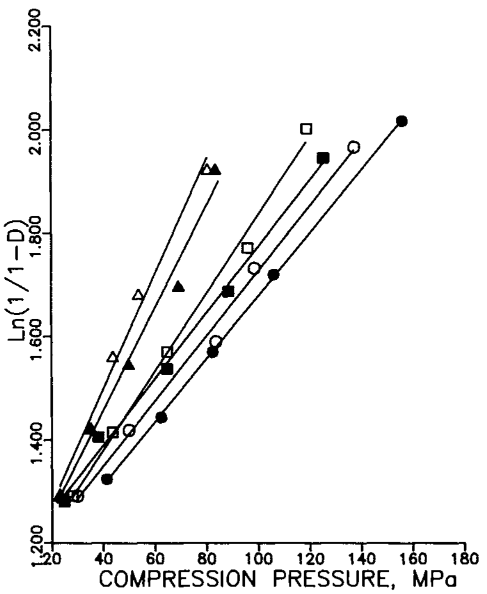

Fig. 1. Heckel plots for diluent A at different moisture contents. (●) 0.36%; (○) 1.93%; (■) 3.60%; (□) 6.06%; (▲) 8.08%; (△) 10.59%.

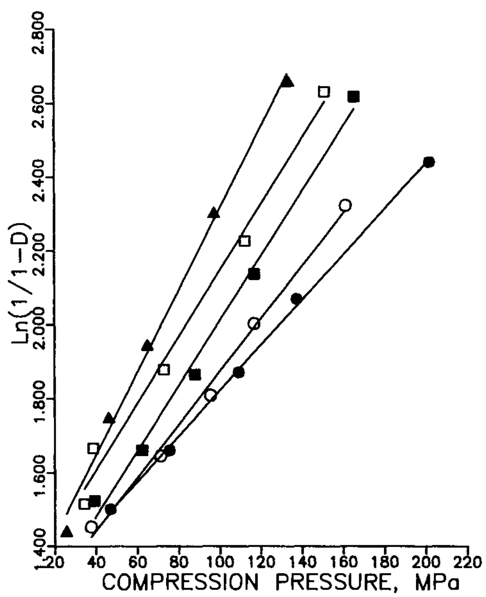

Fig. 2. Heckel plots for diluent B at different moisture contents. (●) 0.58%; (○) 2.12%; (■) 4.29%; (□) 6.60%; (▲) 8.32%.

a single-punch machine (Stokes Model F, F. J. Stokes Machine Co., Philadelphia, Pa.) on which compression pressure was measured with calibrated strain gauges on the upper punch and read out with an oscilloscope.

Since the temperature and the relative humidity of the room varied between 23 and 25°C and 20 and 60%, respectively, minimal exposure of powders to the atmospheric air was allowed during the compression process. This was accomplished by adding small quantities of the diluent to the feed shoe and quickly covering it with aluminum foil. The compressed tablets were quickly transferred to tightly sealed dry containers. Weight of the tablets was constantly monitored during the compression period and at least 200 tablets were punched for each batch size. The moisture content analysis on the diluent remaining after the compression process was performed by the Karl Fisher method soon after compressing the desired number of tablets in order to ascertain the amount of moisture that may have been lost or sorbed from the atmosphere by the diluents during the compression process. Other physical tests such as weight variation, crushing force (Erweka Tester Type TBT, Erweka Apparatebau, Heusenstamm, West Germany), and thickness were carried out on a random sample of 20 tablets within 6 hr after compression. The relative density of the tablets was determined from the geometric parameters, the weights of the tablets, and the true density of the diluents.

RESULTS AND DISCUSSION

Moisture Sorption by the Diluents

Table I shows the equilibrium moisture content of the two diluents at five different relative humidities. Both the diluents sorbed little moisture at or below 55% relative humidity, whereas at 80% relative humidity and higher, the amount of moisture sorbed by both the diluents was considerably higher. Diluent B was more hygroscopic than diluent A at all relative humidities, and at 92% relative humidity, diluent B was completely deliquesced after being exposed for more than 2 weeks.

Moisture content analysis of the diluents before and after the compression process revealed no significant increase or decrease in the moisture content from the starting value in spite of the relative humidity ranging from 20 to 60%, since both the diluents sorbed little moisture under 55% relative humidity (Table I).

Table II. Calculated Data for Heckel Plots, Diluent A

	Moisture content (%)					
	0.36	1.93	3.60	6.06	8.08	10.60
Correlation coefficient	0.9997	0.997	0.997	0.998	0.992	0.994
Slope (K) × 10^3	6.04	6.30	6.43	7.49	10.00	10.95
Intercept (A)	1.074	1.097	1.134	1.082	1.056	1.059
Yield pressure (MPa)	166	159	156	134	100	91
D_0	0.405	0.405	0.405	0.405	0.405	0.405
D_a	0.658	0.666	0.678	0.666	0.652	0.653
D_b	0.254	0.262	0.274	0.257	0.248	0.249

Table III. Calculated Data for Heckel Plots, Diluent B

	Moisture content (%)				
	0.59	2.12	4.29	6.60	8.32
Correlation coefficient	0.999	0.994	0.996	0.994	0.997
Slope (K) × 10^3	6.15	6.90	8.80	8.98	11.05
Intercept (A)	1.21	1.19	1.13	1.25	1.21
Yield pressure (MPa)	163	145	114	111	91
D_0	0.408	0.408	0.408	0.408	0.408
D_a	0.701	0.695	0.677	0.712	0.701
D_b	0.293	0.287	0.269	0.305	0.293

Compression Properties of the Diluents

Each data point in all the figures represents an average value obtained from physical tests performed on 20 tablets. Heckel plots (14,15) constructed from the compression data of diluent A and diluent B as shown in Figs. 1 and 2, respectively, were apparently linear. Tables I and II show the values of slope K (reciprocal of the yield pressure), the intercept A (related to the movement of the particles during the initial stages of compression), the relative apparent density D_o, the total densification due to the filling of the die and particle arrangement D_a, and the density contribution from individual particle movement and rearrangement D_b (14).

The value of yield pressure P_y depends on the nature of the material. Low values are characteristics of soft easily compressible materials. Conversely, high values are exhibited by hard, difficult to compress materials. It is evident from Table II that the yield pressure for diluent A decreases with increasing moisture. Thus, diluent A with 0.36% moisture is hard and less plastic and needs higher pressure (166 MPa) to deform, whereas at 10.6% moisture, the diluent is soft, more plastic, and easily compressible at lower pressure (91 MPa). The yield pressure for diluent B decreased from 163 to 91 MPa when the moisture content increased from 0.58 to 8.32% (Table III). The D_a values are greater than the D_b values for both diluents A and B, indicating that more densification is occurring by granule deformation than by rearrangement and granule movement (16).

Figure 3 shows that as moisture content of diluent A increased up to 10.6%, relative densities of the compressed tablets increased for given compression pressures. These results indicate that densification of the diluents becomes less difficult as moisture content increases (up to 10.6% moisture). Similar results were observed with diluent B.

Figure 4 depicts the tablet crushing force determined for diluent A tablets prepared at compression pressures ranging from 23 to 156 MPa and moisture contents ranging from 0.4 to 10.6%. For given compression pressures, harder tablets were formed as the moisture content of the diluent was increased up to 10.6%, indicating more or stronger bonding between particles. Since the relative density of the tablets also increased with moisture content (Fig. 3), at least part of the increased tablet strength can be said to be due to increased particle surface contact.

Results with diluent B (Fig. 5) were parallel up to about 6.6% moisture content, but the crushing force of the tablets then decreased at 8.3% moisture, thus indicating an optimum

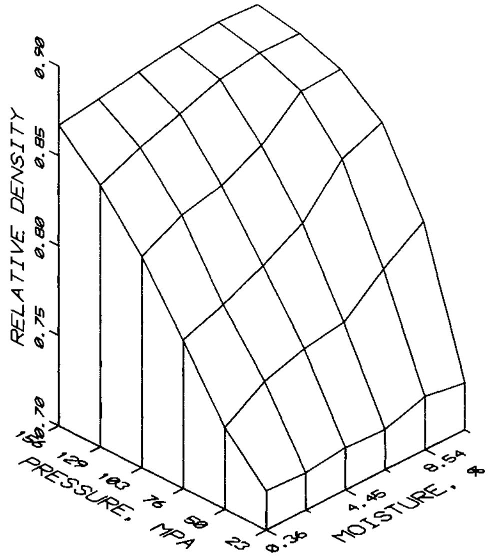

Fig. 3. Effect of moisture content on the relative densities of diluent A tablets compressed at different pressures.

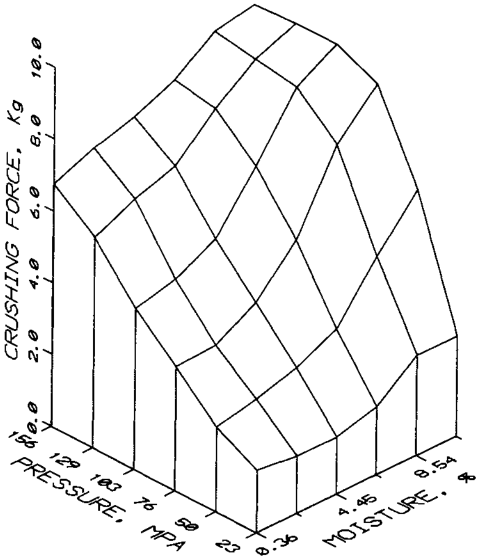

Fig. 4. Effect of moisture content on the crushing force of diluent A tablets compressed at different pressures.

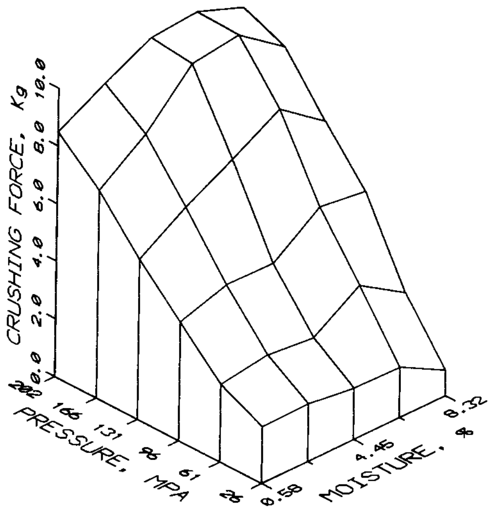

Fig. 5. Effect of moisture content on the crushing force of diluent B tablets compressed at different pressures.

moisture content of about 7% (from the standpoint of tablet strength and ease of compression).

Compressed tablets of diluent A showed a dramatic increase in crushing force with moisture content for a given tablet relative density (Fig. 6). The results indicate that increased moisture content improves bonding between particles of this diluent. At higher relative densities, similar results were observed for tablets prepared from diluent B up to about 6% moisture, after which the tablet crushing force declined (Fig. 7).

When compression pressure is plotted versus tablet crushing force and moisture content (not shown), pressure requirements for given tablet crushing force values generally decline as the moisture content of diluent A is increased up to 10.6%. Pressure requirements decline somewhat for diluent B to nearly 7% moisture content but then show an increase at higher moisture content (8.3%), indicating excess moisture which decreases tablet strength.

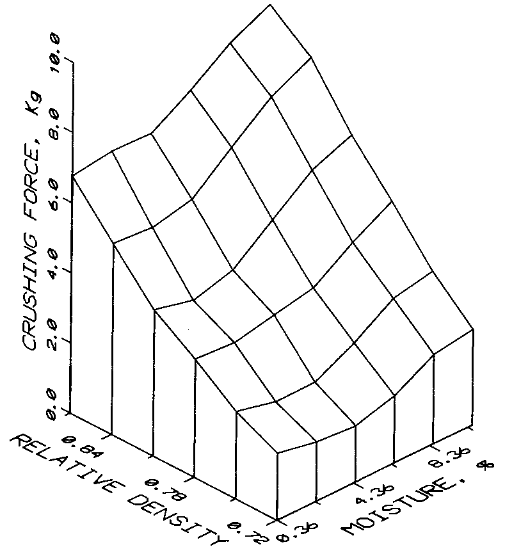

Fig. 6. Effect of moisture content on the crushing force of diluent A tablets at different relative densities.

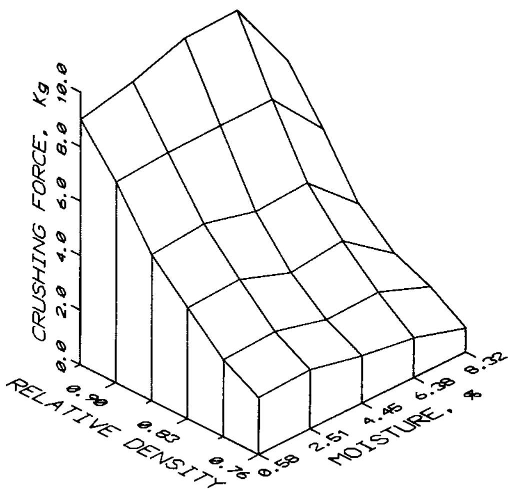

Fig. 7. Effect of moisture content on the crushing force of diluent B tablets at different relative densities.

The increase in tablet crushing force and tablet relative density with increasing moisture content of diluent A could be because of recrystallization from a supersaturated solution formed during the compression of the diluent (10). Movement of the solution may occur due to the presence of surface tension forces within the compact and recrystallization in areas of weaknesses (pores) will result in an increase in the relative density of the tablets with a corresponding increase in crushing force.

A similar explanation could be offered for the increase in tablet crushing force and tablet relative density with increasing moisture content up to about 7% for diluent B. However, decreased tablet crushing force and increased pressure requirements for the diluent with moisture content exceeding 6.6% could be because of hydrodynamic resistance to consolidation due to the presence of excess moisture (3,10). The excess moisture may act as a physical barrier to interparticle bonding, thus reducing the tablet strength and increasing the pressure requirement to compress tablets.

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