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The effect of humidity and temperature on the cohesion of powders

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The cohesion of wheat, maize and potato starch, acacia, tragacanth, alginic acid, lactose, dextrose and sucrose powders has been determined at different relative humidities and temperatures. For maize, wheat and potato starches, cohesion was a maximum at an intermediate moisture content, whilst for acacia, tragacanth and alginic acid it was independent of the moisture content over the range considered. Lactose, dextrose and sucrose remained free flowing except at high relative humidities.

THE cohesion of a powder is affected by the particle shape, size and size distribution. Smooth, spherical particles flow more easily than other shapes and monodisperse powders are usually free flowing and have low cohesion.

Craik & Miller (1958) obtained high angles of repose for powders which form large aggregates and which flow with difficulty, whilst low angles are obtained for powders in which the particles are smooth and flow easily. They also found that a high moisture content reduces the ease of flow of some powders, an effect very pronounced with soluble crystalline powders.

Dawes (1952) obtained a value for cohesion in a powder by measuring the force per square centimetre required to break a powder deposit and he concluded that cohesion in a powder is controlled by the particle shape, size and size range.

Eisner, Fogg & Taylor (1960) measured the cohesion of ground limestone, untreated and water-proofed. The method and apparatus were similar to those used by Dawes and the results showed a variation in the cohesion of both powders with the humidity of the air, that of the water-proofed powder being about three-quarters that of the untreated powder. The cohesion of both powders rose slightly between 15 and 31% relative humidity and thereafter remained constant until 84% when it rose steeply with increasing humidity.

Experimental

Apparatus. The cohesion apparatus used was similar to that used by Eisner & others (1960), but modified by using a complete disc fitted behind the tilting plate for the measurement of the angle of separation of the movable slide. Using suitable gearing, the disc traversed an angle four times that of the tilting plate and this improved the reading of the angle.

Materials. The materials used were wheat, maize and potato starch, acacia, tragacanth, lactose, dextrose and sucrose of the British Pharmacopoeia. Alginic acid was of food grade.

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Method. The cohesion apparatus was put inside the humidity cabinet (Shotton & Harb, 1965), and the powders brought into moisture equilibrium at each humidity. The air circulation in the cabinet was stopped during measurement of cohesion to avoid spreading of the particles or affecting the movement of the tilting plate. The table was tilted so that the graduated disc moved through 30° in 25 sec. Every 24 hr the powder was well mixed and then sprinkled uniformly from a height of 4 cm above the tilting table, onto the glass plate, using a small 16-mesh sieve so that a deposit was formed approximately 0·5 cm thick and 4 cm wide. The table was tilted until the movable slide separated. The blank angle was measured and deducted from the reading to give the actual angle of separation.

The cohesion of the powder was measured by observing the angle to the horizontal (θ) at which the powder broke in two. The cross-sectional area (A) of the broken face of the deposit was measured in cm^2. If W is the weight in grams of the broken away portion of the powder and slide, then the cohesion, C, is calculated according to the equation:

$$C = \frac{W \sin \theta}{A} \text{ g/cm}^2$$

The mean of three determinations was taken as a measure of cohesion. The equilibrium moisture content of the powders has been reported in a previous paper (Shotton & Harb, 1965). The results are in Table 1.

TABLE 1. COHESION OF THE POWDERS AT DIFFERENT HUMIDITIES AND TEMPERATURES (g/cm^2)

Temperature °C	Relative humidity	Maize starch	Wheat starch	Potato starch	Tragacanth	Acacia	Alginic acid	Lactose	Dextrose	Sucrose
25	34	0·27	0·03	0·18	0·13	f.f.*	0·03	f.f.	f.f.	f.f.
	55	0·33	0·03	0·42	0·1	0·12	0·08	f.f.	f.f.	f.f.
	66	0·33	0·30	0·75	0·09	0·05	0·05	f.f.	f.f.	f.f.
	87	0·28	0·28	0·67	0·11	Paste	0·05	0·179	0·14	0·06
	100	0·09	0·07	0·13	0·03	Paste	0·05	0·266	Solution	Solution
30	33	0·31	0·26	0·31	0·11	0·06	0·03	f.f.	f.f.	f.f.
	44	0·37	0·29	0·33	0·08	0·05	0·06	f.f.	f.f.	f.f.
	65	0·34	0·35	0·79	0·15	0·15	0·04	f.f.	f.f.	f.f.
	80	0·3	0·3	0·79	0·12	Caked	0·08	0·16	0·13	0·06
	86	0·25	0·16	0·52	0·07	Caked	0·05	0·15	0·10	0·06
	92·5	0·08	0·04	0·13	0·04	Gel	0·01	0·21	Solution	Solution
	100	0·05	0·04	0·04	Caked	Solution	0·03	0·29	Solution	Solution
40	32	0·25	0·27	0·37	0·10	0·06	0·04	f.f.	f.f.	f.f.
	50	0·3	0·23	0·47	0·11	0·14	0·04	f.f.	f.f.	f.f.
	63	0·25	0·23	0·7	0·11	0·13	0·07	f.f.	f.f.	f.f.
	75·5	0·22	0·21	0·54	0·11	· Paste	0·05	0·16	0·13	f.f.
	89·5	0·20	0·15	0·41	0·09	· Paste	0·06	0·19	Solution	Cake
	100	0·05	0·05	Caked	Caked	Solution	0·05	0·19	Solution	Solution
50	32	0·32	0·28	0·6	0·05	0·05	0·05	f.f.	f.f.	f.f.
	47	0·24	0·25	0·61	0·08	0·07	0·04	f.f.	f.f.	f.f.
	67	0·27	0·24	0·64	0·1	0·1	0·04	f.f.	f.f.	f.f.
	76	0·14	0·14	0·50	0·09	Paste	0·07	f.f.	0·11	f.f.
	87	0·2	0·21	0·35	0·08	Paste	0·06	0·21	Solution	Solution
	100	0·09	0·07	Caked	Caked	Solution	0·05	0·22	Solution	Solution

* Free flowing powder.

Discussion

The relationship between equilibrium moisture content (Shotton & Harb, 1965) and cohesion shows that starches followed the same pattern at each of the temperatures used. Potato starch had the highest measurable cohesion of all the powders. The cohesion of maize starch was slightly higher than that of wheat starch and both were lower than that of potato starch (Fig. 1).

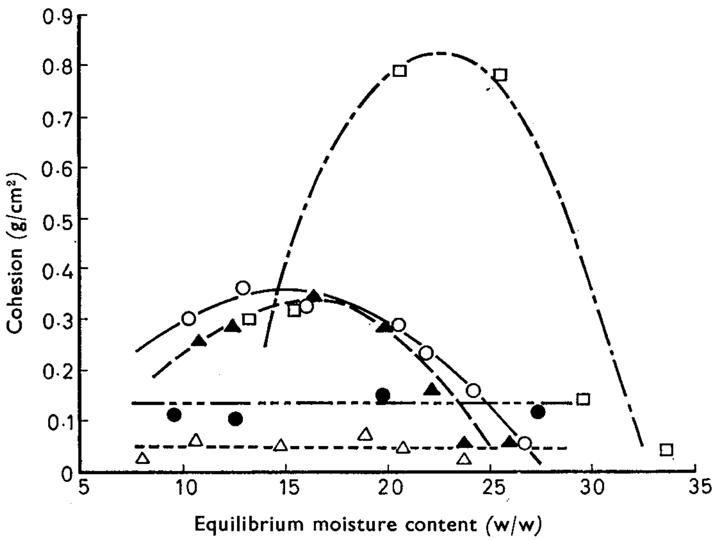

FIG. 1. Relationship between equilibrium moisture content and cohesion at 30° C. —○— Maize starch. – – ▲ – – wheat starch. – — - □ - — - - Potato starch. - - - △ - - - Alginic acid. — - - - - —● — - - - - — Tragacanth.

At low moisture content the less angular potato and wheat starches have lower cohesion than maize starch. With increasing moisture content the starches showed increasing adhesion up to a maximum at each temperature and this may be attributed to the capillary effect of surface moisture. This is also in agreement with Eisner & others (1960), who stated that cohesion in a dry atmosphere is due to van der Waals' forces and that cohesion rises when the asperities between most of the contacts are covered by a moisture film. The cohesion of all the starches falls at higher moisture contents, due to aggregation of the starch into granules.

The cohesion of powdered tragacanth, alginic acid and acacia were approximately the same at the different humidities and temperatures until tragacanth and acacia powders lost their powdery form, due to absorption of moisture, to form a cake which aggregated into lumps of different sizes on stirring. At saturation the cohesion could not be measured due to deliquescence.

Dextrose and sucrose were free flowing whilst free of moisture and it was impossible to measure the area of the broken surface, but when they contained traces of moisture, measurement could be made (Table 1) until deliquescence occurred.

The maximum cohesion of maize, wheat starch, tragacanth, acacia and alginic acid was not affected by a change of temperature but that of potato starch showed a slight decrease with increase of temperature.

References

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