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The effect of starch type, concentration and distribution on the penetration and disruption of tablets by water

D. R. FRASER AND D. GANDERTON*

*Department of Pharmaceutical Technology, University of Strathclyde, Glasgow C.*1, *U.K.*

The effect of starch type, and its concentration and distribution, on the pore structure of tablets of aspirin and magnesium carbonate has been measured using air permeability and liquid penetration techniques. The addition of starch had no significant effect on the pore structure of the dry tablet but caused disruption and alteration of this structure when penetrated by water. When each starch was incorporated into the granules in wet massing the rate of disruption decreased in the order potato, maranta, wheat, corn, waxy corn and rice; but a more complicated pattern was produced when the starch was added to the granules as a pre-dried powder. Maximum break-up efficiency of magnesium carbonate tablets was produced when 10% potato starch was incorporated internally and the tablet compacted to a porosity of 28%.

The physical and chemical properties of starch, its components and derivatives, have been extensively studied (Hellman, Boesch & Melvin, 1952; Hofstee, 1953; Samec, 1953; Nemitz, 1962; Schierbaum & Taeufel, 1963; Montgomery, Sexson & others, 1964; Goudah & Guth, 1965; Shotton & Harb, 1965). The unique characteristics of these materials have led to their use in tabletting as binders, glidants, lubricants and distintegrants, although their most important role is that of tablet disintegrants.

Starch may be incorporated as a granulating agent (binder) either in the form of a paste or as a dry binder in direct compression (Kwan & Milosovich, 1966). It can be added to granules as a pre-dried powder (Higuchi, Elowe & Busse, 1954) and this will be referred to as "external" starch. Added thus its distribution in the final tablet is uneven and is controlled by the configuration of the granules during packing and compression. The incorporation of starch powder into the granules during the wet massing process—"internal" starch—is the most common method and presents an even distribution of starch throughout the tablet. However, in some tablet formulations a percentage of starch, added as disintegrant, is incorporated before massing and the remainder added after granulation. Nair & Bhatia (1957) have suggested that the external starch would break the compressed tablets, on disintegration, into granules and the internal starch would reduce these into particles with a size distribution similar to that of the original powder blend. Added concentrations of starch may vary from 5–20%, and, from disintegration studies, several authors agree that there is an optimum concentration of starch that can be added to a formulation to make disintegration efficient (Fakouhi, Billups & Sager, 1963; Bergman & Bandelin, 1965; Commons, Bergen & Walker, 1968; Nogami, Nagai & others, 1969). This optimum concentration is dependent on the physical properties of the

* Present address: I.C.I. Pharmaceuticals Division, Alderley Park, Cheshire.

tablet constituents. It therefore appears that distribution and concentration are essential criteria when stating the efficiency of starch as a tablet disintegrant.

Starches from different botanical sources have been used as disintegrants and because of its availability and cost, the most popular is corn (maize) starch. Properties such as vapour sorption and swelling have been studied, although these cannot be related to disintegrating efficiency (Billups & Cooper, 1964). Some starches such as potato, wheat, rice, yam, cassava and moriyo have been examined along with ultra amylopectin, amylose and gelatinized starch (Horsch, Martin & Roppert, 1958; Patel & Chikhlia, 1963; Saber, Rahman & others, 1963; Krebs, 1959; Patel & Paucholi, 1964; Mital & Ocran, 1968). In these comparative studies variations in disintegrating efficiency have variously been ascribed to amylose-amylopectin ratio, grain size, moisture absorption properties and to differences in fat content.

Although many starches have been examined as disintegrants, no conclusive agreement has been reached on their mechanism of action. Some authors (Fakouhi, Billups & Sager, 1963; Billups & Cooper, 1964; Patel & Hopponen, 1966) consider that swell'ng of the starch grains disrupts the tablet. Others (Curlin, 1955; Manudhane, Contractor & others 1969; Borzunov & Shevchenko, 1967; Ingram & Lowenthal, 1968) attribute the effect to improved capillarity of the starch-containing powder matrix. This inconclusive situation is partly due to the lack of control of the powder system as the starch type, concentration and distribution were varied. In this paper, these variables are allowed to affect powder aggregates prepared under closely controlled conditions.

MATERIALS AND METHODS

Materials and granulation

The starches chosen were potato, rice, wheat, maranta (arrowroot), corn (maize) and waxy corn. Some properties of these starches are given in Table 1. Their grain size ranges were measured microscopically (mean of n grains).

Table 1. *Some properties of various starches.*

Starch	Amylose content (%)	Grain size range (μm)	Grain shape
Potato	20	15–100	Egg-shaped
Rice	16	3–8	Polygonal
Maranta	20	25–50	Egg-shaped
Corn	24	5–25	Round
Wheat	22	2–35	Elliptical
Waxy corn	0	5–25	Round

Heavy magnesium carbonate and aspirin were used as granules and these were prepared by wet massing with 10% acacia solution and absolute ethanol respectively. Heavy magnesium carbonate granulations were prepared with 2, 5, 10 and 20% potato starch internally and 5% internally + 5% externally. It was also used in formulations to which each of the starches (10%) was added internally and in others to which the starches were added externally. Aspirin granulations were prepared with each of the starches (10%) internally.

All granular material was screened and the fraction passing a 1000 μm (16 mesh) sieve but retained on a 710 μm (22 mesh) sieve was selected for study.

Characterization of tablets

The compressibility, permeability and water penetration of the tablets were measured according to Ganderton & Selkirk (1970) and Ganderton & Fraser (1970). The time of disintegration was measured by the method of the British Pharmacopoeia 1968 using individual tablets.

RESULTS AND DISCUSSION

The physical properties of starches

Of the various samples studied, potato starch had the largest grain size and rice the smallest. The compressibility of the starch powders did not differ *greatly* with source although potato and waxy corn starches were most compressible giving compacts with a porosity of 11–12% when compressed at 100 MNm^{-2}. Other starches compacted to 15–17% porosity under these conditions. Fig. 1 shows that increasing grain size gave compacts of more open structure and higher permeability.

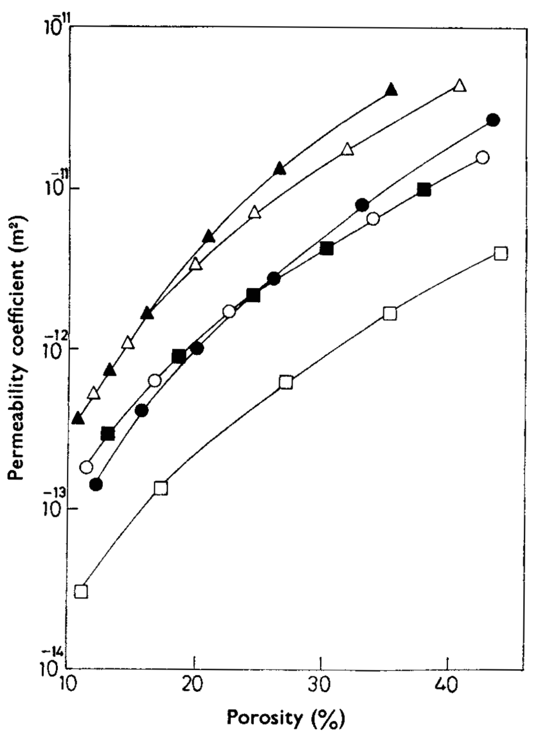

FIG. 1. The effect of starch type on the permeability of starch tablets. ▲ Potato. △ Maranta. ● Wheat. ○ Corn. ■ Waxy corn. □ Rice.

The porosity and permeability of tablets containing starch

Table 2 shows that the effect of starch on the porosity and permeability of tablets, though small, is largely additive. When 10% starch is added to fine, incompressible

Table 2. *The effect of starch type and distribution on the permeabilities and porosities of tablets compressed to* 100·0 MNm^{-2}.

Material	Mode of incorporation and starch type (10% added)	Porosity (%)	Permeability Coefficient (m^2)
Magnesium carbonate		36·4	$1·9 \times 10^{-13}$
Magnesium carbonate:	with internal potato	33·4	$2·6 \times 10^{-13}$
	" external "	33·8	$2·4 \times 10^{-13}$
	" internal wheat	34·8	$3·6 \times 10^{-13}$
	" external "	34·4	$2·5 \times 10^{-13}$
	" internal rice	34·8	$2·2 \times 10^{-13}$
	" external "	33·8	$2·0 \times 10^{-13}$
	" internal corn	35·6	$2·2 \times 10^{-13}$
	" external "	34·3	$2·3 \times 10^{-13}$
	" internal waxy corn	34·4	$2·6 \times 10^{-13}$
	" external " "	34·6	$2·8 \times 10^{-13}$
	" internal maranta	35·4	$2·3 \times 10^{-13}$
	" external "	35·3	$5·0 \times 10^{-13}$
Aspirin		6·0	$6·6 \times 10^{-15}$
Aspirin:	with internal potato	6·6	$1·1 \times 10^{-14}$
	" " wheat	6·0	$9·7 \times 10^{-15}$
	" " rice	6·4	$1·3 \times 10^{-14}$
	" " corn	6·0	$1·5 \times 10^{-14}$
	" " waxy corn	5·7	$9·5 \times 10^{-16}$
	" " maranta	5·2	$9·5 \times 10^{-16}$

magnesium carbonate, a tablet of higher permeability but lower porosity is produced. When the starch was added to compressible aspirin, the changes were even smaller. With neither material were statistically significant effects found that could be attributed to starch type or distribution. No structural changes which would greatly affect the penetration of a tablet by water are therefore apparent.

Aqueous penetration studies

The rate of uptake of water into compacts of pure starch was so fast that it could not be measured adequately. The effect of starch type on the pattern of water penetration into tablets containing starches of different botanical source is shown in Fig. 2. In the early stages of penetration, starch enhances penetration in all cases except rice, the intensity of this effect increasing with starch grain size. There follows a sudden increase in penetration rate that indicates severe disruption of the wetted portion of the tablet and the decline of the viscous resistance to entry. Since the uptake rate is the same for all materials, this phase of the destruction of the tablet is independent of starch type. However, the overall rate of disruption decreases in the sequence potato, maranta, wheat, corn (maize), waxy corn, rice, and this is also shown in the results of the disintegration test (Table 4).

The effect of starch distribution

The pattern of penetration of tablets containing external starch was similar to tablets containing internal starch. Table 3 shows, however, that although potato gave the fastest penetration and rice the slowest, the progressive effect of grain size is not followed: a similarly confused situation is found in the disintegration test (Table 4). Thus, simple comparison of the two methods of distribution is not

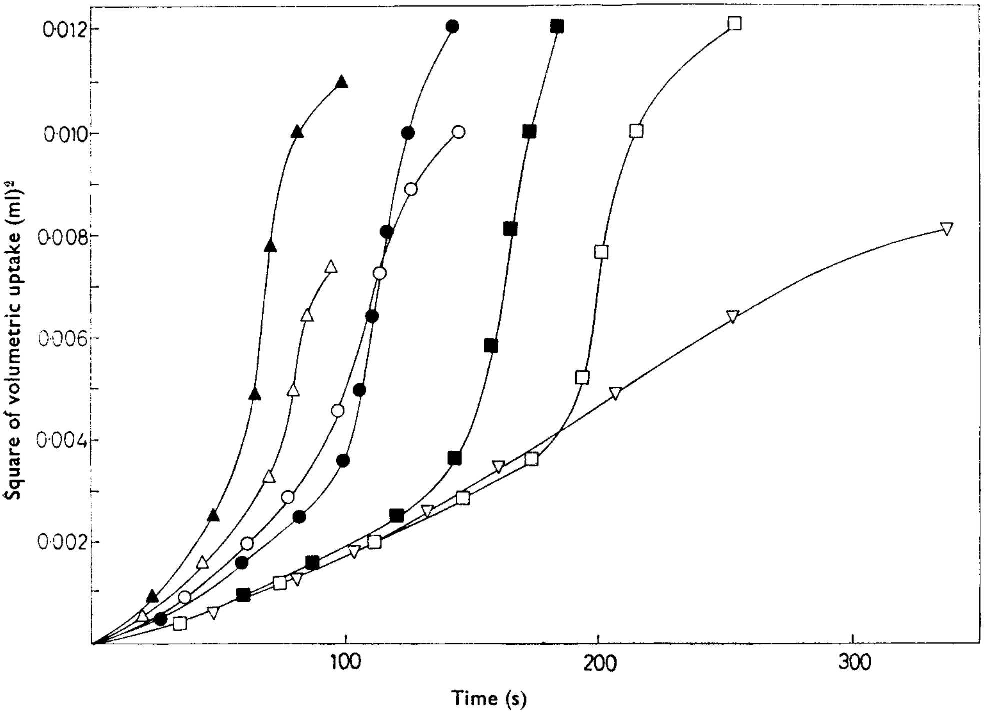

FIG. 2. The effect of starch type on the aqueous penetration of magnesium carbonate granules containing 10% internal starch compressed at 100 MNm^{-2}. ▲ Potato. △ Maranta. ● Wheat. ○ Corn. ■ Waxy corn. □ Rice. ▽ No starch.

Table 3. *Effect of starch type and distribution on the time for penetration of* 0·08*ml water into tablets compressed at* 100·0 *MNm*$^{-2}$. (*Figures are the means of* 8 *results.*)

Material	Time (s) Internal starch	External starch
Magnesium carbonate with 10% potato starch	67·5[1]	82·0[2]
" " 10% maranta starch	85·0	121·0
" " 10% wheat starch	111·0	133·8
" " 10% corn starch	112·0	98·6
" " 10% waxy corn starch	159·0	120·6
" " 10% rice starch	197·5	157·3
Magnesium carbonate with no starch		445·0[4]
Magnesium carbonate with 5% internal and 5% external potato starch		108·9[3]

1. s.d. 2·13, coefficient of variance (%) 3·2.
2. " 30·8 " " 37·6.
3. " 22·5 " " 20·7.
4. " 37·5 " " 8·4.

possible although in most cases *internal* distribution gives tablets that are penetrated and disrupted more quickly.

A clear difference in the consistency of disruption was, however, found. Table 3 also gives the variation in the time required for the uptake of 0·08 ml of water. The coefficient of variance for tablets containing external starch was over ten times that of a tablet containing internal starch. Tablets in which half the starch was

Table 4. *The effect of starch type and distribution on the disintegration time of tablets compressed at* 100·0 MNm^{-2}. (*Figures are the means of* 8 *results.*)

Material			Disintegration time (s) Internal	External
Magnesium carbonate	with 10%	potato starch	13·9	31·5
,,	,,	maranta starch	17·2	36·6
,,	,,	wheat starch	24·6	40·9
,,	,,	corn starch	29·5	32·9
,,	,,	waxy corn starch	34·0	43·1
,,	,,	rice starch	47·6	40·4
Magnesium carbonate with no starch				63·2
Magnesium carbonate with 5% internal and 5% external potato starch				43·6

added before and half after granulation showed an intermediate variability. This effect must be ascribed to the difficulty of mixing starches effectively after granulation. Segregation and variation in starch content are thus unavoidable and variation in tablet break-up results.

The effect of starch concentration

The variation of starch concentration between 0 and 10% showed profound effects on break-up. Further addition up to 20% was almost without effect. Addition of starch to magnesium carbonate reduced the disintegration time from 63 s at 0% concentration to 48 s at 2%, 39 s at 5% and 14 s at 10%. A further addition of 10% caused a further reduction of only 1 s. The mechanism of disruption is therefore fully realized at a concentration of 10%. It has been shown earlier, however (Ganderton & Fraser, 1970), that a suitably close packing of starch and drug is also necessary for proper tablet break-up. This is shown in Fig. 3 where

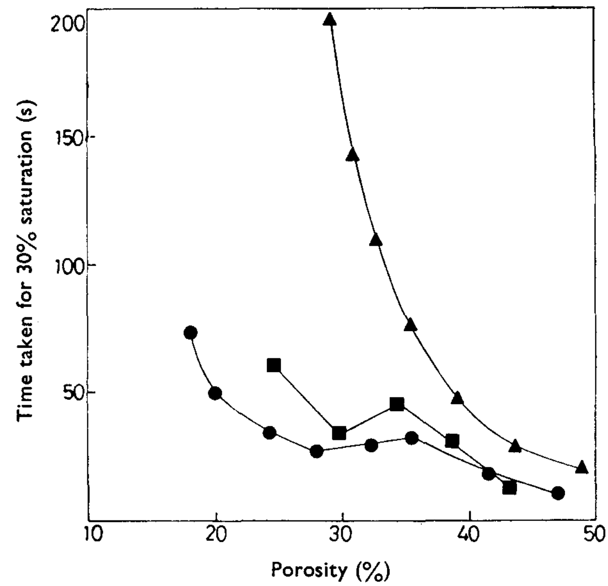

Fig. 3. The effect of starch distribution and tablet porosity on the aqueous penetration of magnesium carbonate tablets. ▲ Magnesium carbonate. ● Magnesium carbonate with 10% internal potato starch. ■ Magnesium carbonate with 10% external potato starch.

both internal and external starch show maximum penetration and break-up when tablets were compressed to a porosity of 28%. Here again, internal distribution was superior in producing disruption, and 10% starch added in this way and compressed to a porosity of 28% represents the optimum combination of variables for the efficient and reproducible break-up of magnesium carbonate tablets in water.

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