

Water vapour transmission properties of applied polymer films

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The rates of moisture uptake by film-coated tablet matrices containing calcium chloride have been determined as a function of polymer coat formulation, film coat thickness and calcium chloride content of the matrix. The more hydrophilic polymer film formulations were less effective in reducing the rate of moisture uptake by the tablet matrices. A linear relation was observed between rate of moisture uptake and film thickness, in contrast to the log-log relationship obtained in previous work using the same systems cast as free films. Decreasing the calcium chloride content of the matrix caused an overall lowering of the moisture uptake rate. The results indicate that the water vapour transmission characteristics of these polymer film systems are not the same when assessed using the rate of moisture uptake of tablets coated with these films as when using the rate of water vapour transmission through the free films. It is suggested that films should not be accepted or rejected solely on the basis of transmission rates across free films but that due consideration should be given to the more meaningful moisture uptake rates of the film-coated dosage form.

THERE are several reports about the permeability of free polymer films with potential as film coating materials (see Banker, Gore & Swarbrick, 1966). No report dealing with the permeability properties of such films when applied to hygroscopic solid matrices appears to have been made nor any attempt to correlate the water vapour transmission properties of free and applied polymer films.

Banker & others (1966) reported the water vapour transmission properties of a hydrophilic, a lipophilic and a mixed hydrophilic-lipophilic polymeric film-forming system cast as free films. Preliminary investigations on these same systems when applied to tablet matrices of varying hygroscopicity are now reported.

Experimental

PREPARATION OF TABLET MATRICES

Table 1 summarises the various tablet matrices prepared and the compositions of the film coatings applied. Matrix A was prepared by dry slugging. It was necessary to granulate the microcrystalline cellulose used in matrices B and C with 10% w/v polyvinylpyrrolidone in isopropanol. The dicalcium phosphate dihydrate used in matrices D and E was granulated with a warm aqueous solution of gelatin (12% w/v) and acacia (4% w/v). Magnesium stearate (2% w/w) was used as a lubricant throughout. A Stokes rotary tablet press (model 512-1) fitted with standard 7/16 inch concave punches was used to prepare the tablets which had an average weight of 650 ± 12 mg and a hardness of 8 ± 1 kg when measured

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with a Pfizer tablet hardness tester. The tablets were stored in tightly closed glass containers at room temperature in the presence of silica gel until required.

TABLE 1. FILM COATED SYSTEMS STUDIED

Matrix	Composition of Matrix (% w/w)		Film coats applied
A	Microcrystalline cellulose ¹	50	HPC ² ; MHPC:EC ³ ; BMA ⁴
	Calcium chloride	50	
B	Microcrystalline cellulose	70	HPC
	Calcium chloride	30	
C	Microcrystalline cellulose	80	HPC
	Calcium chloride	20	
D	Dicalcium phosphate dihydrate	95	HPC; MHPC:EC; BMA
	Calcium chloride	5	
E	Dicalcium phosphate dihydrate	100	MHPC:EC

¹ Avicel, FMC Corporation, American Viscose Division, Newark, Delaware, U.S.A.

² Hydroxypropyl cellulose plus 20% propylene glycol, used as a 5% w/v polymer solution.

³ Methylhydroxypropyl cellulose:ethyl cellulose (3:1) plus 50% propylene glycol, used as a 3% w/v polymer solution.

⁴ n-Butyl methacrylate plus 5% diethyl phthalate, used as a 10% w/v polymer solution.

FILM COATING OF TABLETS

A Binks airless spray coating system operating at a pressure of 50 psi was used. The spray nozzle had an opening of 0.011 in and a spraying angle of 40°. One thousand tablets were placed in a coating pan (diameter 7.5 in) rotating at 65 rpm. The tablets were warmed with a hot air blower and an exhaust hose was used to remove solvent vapours. The temperature within the pan was maintained at 45–50° and the humidity within the coating room at 20–25% relative humidity. The tablets were sprayed with from 1 to 5 sec bursts of the film coat solution, sufficient time being allowed between each spray to permit evaporation of solvent and formation of the film. The total number of sprays given any one batch varied depending on the concentration of the polymer-plasticiser combination in the spraying solution, which in turn depended on the viscosity of the polymer in solution. Tablets were removed at regular intervals and stored in tightly closed glass containers at room temperature in the presence of silica gel. Measurements of film coat thickness were made with a micrometer on the peeled film coat as well as on the coated and uncoated tablets.

DETERMINATION OF MOISTURE UPTAKE

The moisture uptake cell consisted of a cylindrical screw capped bottle, capacity approximately 23 ml, containing 5 ml of a saturated sodium tartrate solution which maintained a vapour pressure of 29.0 mm Hg at 30° (Lowry & Morgan, 1924). The tablet was suspended within the cell by a wire loop which pierced the cap liner. The moisture uptake of both coated and uncoated tablets was determined by removing and weighing the cap plus tablet at intervals over 12 hr. It had been determined previously that the cap and wax liner did not change weight under the conditions of the experiment.

To assess the moisture uptake of the film coat, blank tablets of dicalcium phosphate dihydrate containing no calcium chloride (matrix E) were film

WATER VAPOUR TRANSMISSION ACROSS POLYMER FILMS

coated with the mixed polymer formulation along with tablets of matrix D. The tablets of matrix E contained amaranth dye (1 : 1500 parts by weight) to permit their ready separation following film coating from those containing calcium chloride. Moisture uptake of the uncoated blank tablets of matrix E was also measured.

Results and discussion

The change in weight of the uncoated tablet matrices A, B and C increased linearly with time over the period studied. With the uncoated

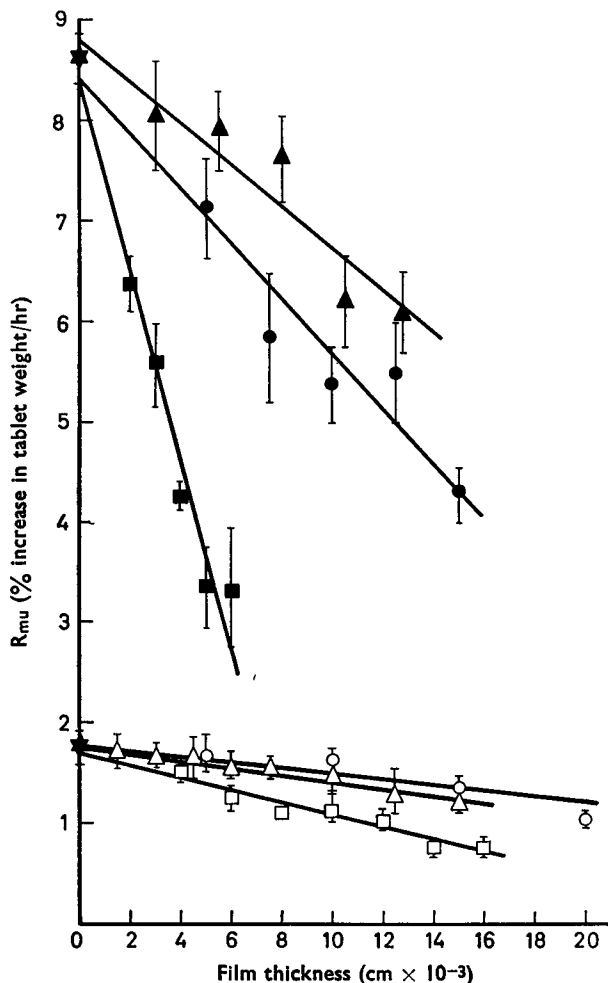


FIG. 1. Effect of film coat thickness on the rate of moisture uptake of tablet matrices containing 5 and 50% calcium chloride at 30°. Uncoated tablets, ★; n-butyl-methacrylate: matrix A, ■; matrix D, □; hydroxypropyl cellulose: matrix A, ●; matrix D, ○; methylhydroxypropyl cellulose: ethyl cellulose: matrix A, ▲; matrix D, △.

matrix D the rate became linear after 2-3 hr. The moisture uptake by the tablets film-coated with n-butyl methacrylate was linear with time and no macroscopic changes in the film coat were apparent even though matrix A, containing 50% calcium chloride, did swell noticeably. The possible effect of the resultant stretching of the film upon its permeability was therefore held to be insignificant. Initial uptake of moisture by the

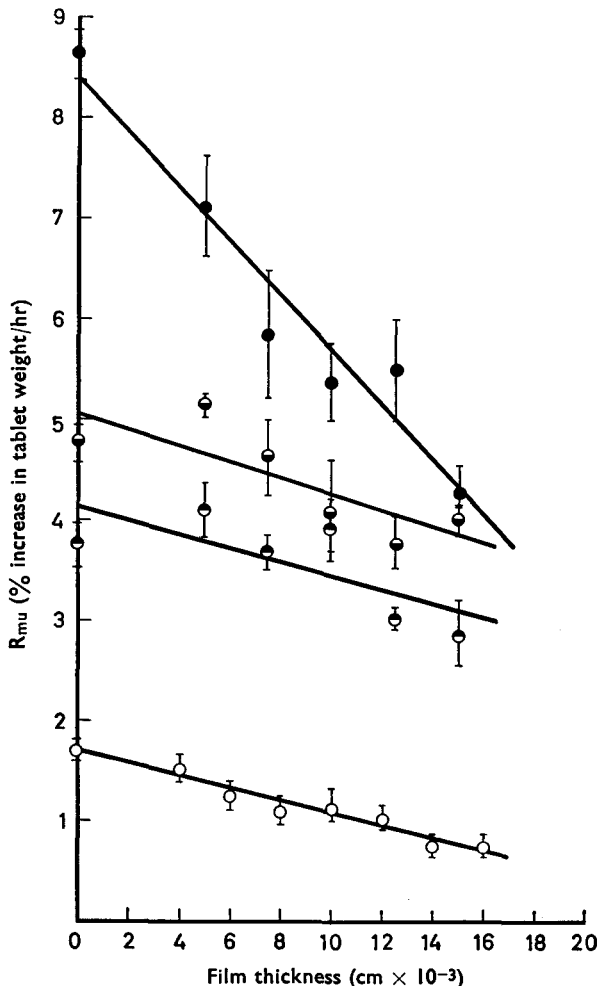


FIG. 2. Effect of film coat thickness on the rate of moisture uptake of tablet matrices containing 5, 20, 30 and 50% calcium chloride at 30°. Hydroxypropyl cellulose: matrix A, ●; matrix B, ◐; matrix C, ○; matrix D, ○.

hydroxypropyl cellulose film-coated tablets was also linear with time using matrices A, B and C. However, the swelling of the core caused the coat to break after approximately 6 hr, whereupon moisture uptake was accelerated. With matrix D the rate was constant from 2 to 5 hr and no

WATER VAPOUR TRANSMISSION ACROSS POLYMER FILMS

rupturing of the film was observed. With the mixed polymer coat applied to matrix A, the films became noticeably mucilaginous and thickened after 4 hr in the moisture uptake cell, due presumably to partial solution of the methylcellulose. The films did not rupture and the rate of moisture uptake decreased after this point. This phenomenon was not observed with film-coated tablets of matrix D. It is worth noting that the various films did not exhibit these changes when used as free films in permeability studies (Banker & others, 1966). This demonstrates the need to observe the performance of polymer films under conditions which closely simulate their actual use.

The total moisture uptake of both the coated and uncoated tablets of matrix E lay within the range 0.9–1.1% of the original tablet weight and was complete within 2–3 hr. The amount of moisture absorbed by the film coat was therefore negligible compared to that absorbed by the matrices containing calcium chloride, a result not unexpected in view of the volume of film coat applied (Banker & others, 1966). Since the moisture uptake of the blank matrix was complete within 3 hr, and in the light of the previous discussion concerned with changes in the integrity of the film after 4 or more hours, the rate of moisture uptake at 3 hr was chosen in all instances.

Fig. 1 shows the rate of moisture uptake by matrices A and D uncoated and also when film coated with the three polymer-plasticiser formulations. The effect of calcium chloride content upon the moisture uptake rate for hydroxypropyl cellulose coated tablets is shown in Fig. 2. In both figures each point represents the mean of at least 2 determinations; the vertical lines represent the range of values obtained. The rate is expressed as the percentage increase in weight with respect to the average uncoated tablet weight.

The relation between the rate of moisture uptake and film thickness, illustrated in Figs 1 and 2, may be expressed as follows:

$$R_{mu} = mt + C \quad \dots \quad (1)$$

where R_{mu} is the percentage increase in the original average tablet weight per hr, t the film thickness in cm, m the slope of the line and C the ordinate intercept. The statistical constants for these plots are presented in Table 2. In view of the number of possible sources of error in the manufacture and film coating of the tablet matrices, the correlation is held to be good.

TABLE 2. STATISTICAL PARAMETERS FOR MOISTURE UPTAKE OF FORMULATIONS STUDIED

Film system	Matrix	Correlation coefficient	Slope of line m	Ordinate intercept C
n-Butylmethacrylate + 5% diethyl phthalate	D	0.97	-609	1.69
	A	0.98	-936	8.37
Hydroxypropyl cellulose + 20% propylene glycol	D	0.96	-32.1	1.83
	C	0.72	-68.1	4.12
	B	0.83	-78.8	5.05
	A	0.97	-275	8.42
Methylhydroxypropyl cellulose: ethyl cellulose (3:1) + 50% propylene glycol	D	0.97	-35.1	1.76
	A	0.94	-209	8.82

The effect of film formulation on moisture uptake is only qualitatively similar to that observed in water vapour transmission studies on the free films. Thus tablets containing 50% calcium chloride and coated with the hydroxypropyl cellulose and mixed polymer film formulations show a higher rate of moisture uptake than those coated with the same thickness of the n-butyl methacrylate film. Similar results were observed with tablets containing 5% calcium chloride. The decrease in R_{mu} per unit increase in film thickness is again greatest in those tablet matrices coated with the lipophilic n-butyl methacrylate film.

The main point of difference between the moisture permeability of the free and applied films is in the relation between film thickness and the rate of permeation or uptake. With the free films, the rate decreased linearly with thickness only when these parameters were expressed on a log-log basis. With the applied films the rate of moisture uptake was a direct function of the film thickness. One possible explanation is that the affinity of the tablet matrix for moisture is such that Fickian, or near-Fickian, diffusion through the film is supplanted by the chemical affinity of the substrate for moisture immediately adjacent to the distal surface of the film. Work is currently in progress to establish whether or not this phenomenon is common to all hygroscopic film coated matrices.

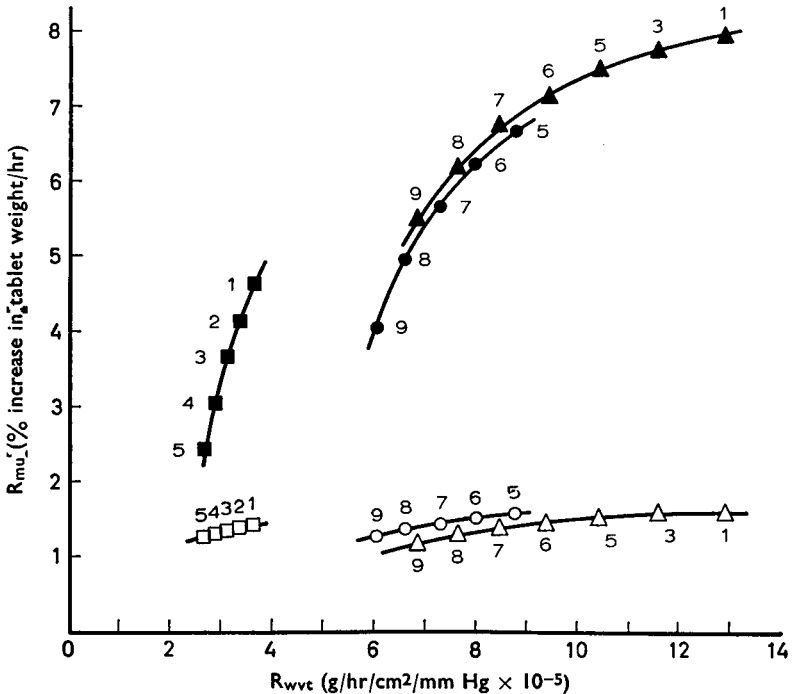


FIG. 3. Relationship between rate of moisture uptake of film coated tablet matrices and water vapour transmission rate of free polymer films at 30°. Key. Polymer systems as in Fig. 1; film coat thickness (cm $\times 10^{-3}$); 1, 4.0; 2, 4.5; 3, 5.0; 4, 5.6; 5, 6.3; 6, 8.0; 7, 10.0; 8, 12.6; 9, 15.9.

WATER VAPOUR TRANSMISSION ACROSS POLYMER FILMS

The results of this preliminary study establish the existence of a “*within film system*” correlation between the water vapour transmission properties of polymers when cast as free and applied films. Thus, we have plotted the water vapour transmission rates (R_{wvt}) presented previously (Banker & others, 1966) against the moisture uptake rates of the various film coated systems at equivalent film thicknesses (Fig. 3). It is apparent, however, that the various film systems which show identical R_{wvt} values do not confer identical R_{mu} values upon the coated dosage form. Furthermore, as shown in Table 3, the ratio of R_{mu} to R_{wvt} at a particular film

TABLE 3. RATIO OF THE PERCENTAGE INCREASE IN THE ORIGINAL AVERAGE TABLET WEIGHT PER HOUR R_{mu} TO R_{wvt} , THE WATER VAPOUR TRANSMISSION RATE, FOR FREE FILMS, $6.30 \text{ cm} \times 10^{-3}$ THICK AT 30°

Film system	$(R_{mu}/R_{wvt}) \times 10^4$	
	Matrix A	Matrix D
n-Butyl methacrylate	0.92	0.48
Hydroxypropyl cellulose	0.76	0.18
Methylhydroxypropyl cellulose:ethyl cellulose (3:1)	0.72	0.15

thickness for a polymer-matrix system is not a constant between films and the same matrix. The effect of reducing the calcium chloride content of the matrix is also not constant between the polymer systems investigated. Consequently, it would appear a worthwhile practice at this time not to accept or reject a film coat formulation solely on the results obtained using water vapour transmission across the free film but to evaluate the performance of the film when applied to the particular dosage form in question.

References

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