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Note

The mechanical and moisture permeability properties of aqueous-based hydroxypropyl methylcellulose coating systems plasticized with polyethylene glycol

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Abstract

The effects of polyethylene glycols (PEG 400, 1500 and 4000) used as plasticizer on the moisture permeability and mechanical properties of aqueous hydroxypropyl methylcellulose (HPMC) films were evaluated with free films. The free films were prepared by using a pneumatic spraying technique similar to that used in fluidized-bed coaters. There was a clear relationship between some physical film properties and the molecular weights and concentrations of the PEGs used as plasticizer. Over the range of concentrations tested, the moisture permeability of the films decreased slightly as compared to unplasticized control films with increasing molecular weight of the plasticizer. The mechanical strength of the films was shown to be more dependent on the concentration than on the molecular weight of the PEGs, while the ductility of the films was mainly dependent on the molecular weight of the PEG. The addition of PEG at a concentration of 10% resulted in relatively hard and strong films with a moderate elongation (ductility), especially when lower molecular weight plasticizers (PEG 400 or 1500) were used. As regards permeability to moisture and mechanical properties, the addition of PEG at a concentration in the range of 10–20% of the polymer weight seems to be beneficial for aqueous-based HPMC film coats.

Keywords: Hydroxypropyl methylcellulose; Plasticizer; Molecular weight; Moisture permeability; Mechanical properties; Free film

The major advantages of incorporation of a plasticizer in film coating systems include enhancement in film formation, reduction in film brittleness, better adhesion to the tablet surface, and reduction in logo bridging (Banker, 1966). According to the literature, aqueous-based coating systems of HPMC are most effectively plasticized with polyethylene glycols (PEG), especially a high molecular weight type (Nagai, 1989). The major disadvantage, however, associated with the use of these readily water-soluble PEGs is that the moisture resistance of the HPMC coat can be

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markedly decreased and this, in turn, may result in diminished stability of moisture-sensitive drugs.

Some early reports on free films and films applied to dosage forms provide evidence that plasticizers can also have a marked effect on the mechanical properties of aqueous-based HPMC films. Aulton and Abdul-Razzak (1981) and Okhamafe and York (1983) reported that the hardness and the tensile strength at film break were generally decreased by the inclusion of PEGs, and this was probably due to a decrease in the intermolecular forces along the plasticized polymer chains. These changes can result in poorer physical protection of a tablet core and reduced mechanical strength and resistance to high-speed packaging and handling by patients.

The present study was designed to investigate the effects of a molecular weight of polyethylene glycols (PEG 400, 1500 and 4000) on the moisture permeation and mechanical properties of hydroxypropyl methylcellulose (HPMC) films prepared from aqueous-based solutions.

Hydroxypropyl methylcellulose (Methocel E5) was obtained from Dow Chemical (U.S.A). Three types of polyethylene glycols, Macrogol 400, 1500 and 4000 (Hoechst, Germany), 10, 20 and 30% (w/w) of the polymer weight, were used as plasticizers. Distilled water was used as a solvent.

A spraying equipment used for preparation of polymeric films was mainly constructed by using the elements of a fluidized-bed coater (Aeromatic Strea-1, Aeromatic AG, Switzerland). The system is described in detail in Fig. 1. The coating solution was continuously fed into a spraying nozzle by a peristaltic pump (Watson-Marlow, U.K.) at a flow rate of 6 ml/min. The atomizing air pressure was 1.0 bar and drying air temperature was 55 ± 5°C. The spraying distance and rotating speed of the cylinder were 20 cm and 10 rpm, respectively.

Free films were dried at room temperature (21°C) for 24 h and were allowed to stabilize in a desiccator (21°C, 40% R.H.) for at least another 24 h before testing. The dry thickness of the films was measured by a Sony digital micrometer (Sony, Japan).

The permeability of the films (50–75 μm) to moisture was determined using glass vials containing 2 g of $CaCl_2 \cdot 2H_2O$ (Ph. Eur.). The vials were sealed with a piece of the film, and closed tightly with a rubber ring and an aluminium hole cap. The effective area of transmission was 1.767 cm^2. The preweighed vials were placed in a desiccator containing saturated sodium chloride solution (25°C, 75% R.H.). After an equilibration period of 24 h the vials were weighed periodically over the test period of 5 days.

The mechanical and stress-strain properties of free films were determined using a Lloyd LRX materials testing machine (Lloyd Instruments Ltd, U.K.) under environmental conditions of 22 ± 1°C and 40 ± 5% R.H. For testing, the thickness of each film was measured at least at five different points, and the films of thickness of 75 ± 5 μm were cut into 8×1.5 cm strips. The strips were fixed into the grips of an apparatus, and measurements were performed using a 50 N load cell, initial gauge length of 6.0 cm and a crosshead speed of 5 mm/min. For each sample, tensile strength, elongation (strain) at break, modulus of elasticity (Young's modulus) and work done were calculated from the stress-strain curve.

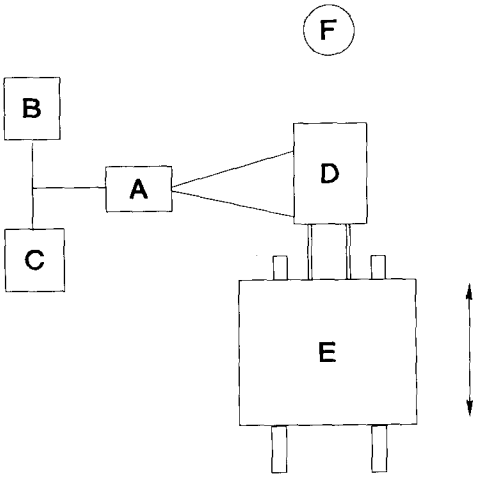

Fig. 1. Schematic diagram of the spraying equipment used for the preparation of aqueous-based hydroxypropyl methylcellulose free films. (A) Pneumatic spraying nozzle, (B) polymer solution, (C) atomizing air, (D) rotating cylinder covered with polytetrafluoroethylene (Teflon®) foil, (E) machine for rotating cylinder placed on the table and run on rails, (F) drying air.

Fig. 2 illustrates the relationship between time and moisture permeability (mg) of free films containing 0–30% w/w polyethylene glycol (PEG 400, 1500, 4000) as a plasticizer. All HPMC film formulations tested formed a relatively intact barrier to moisture with respect to the results ob-

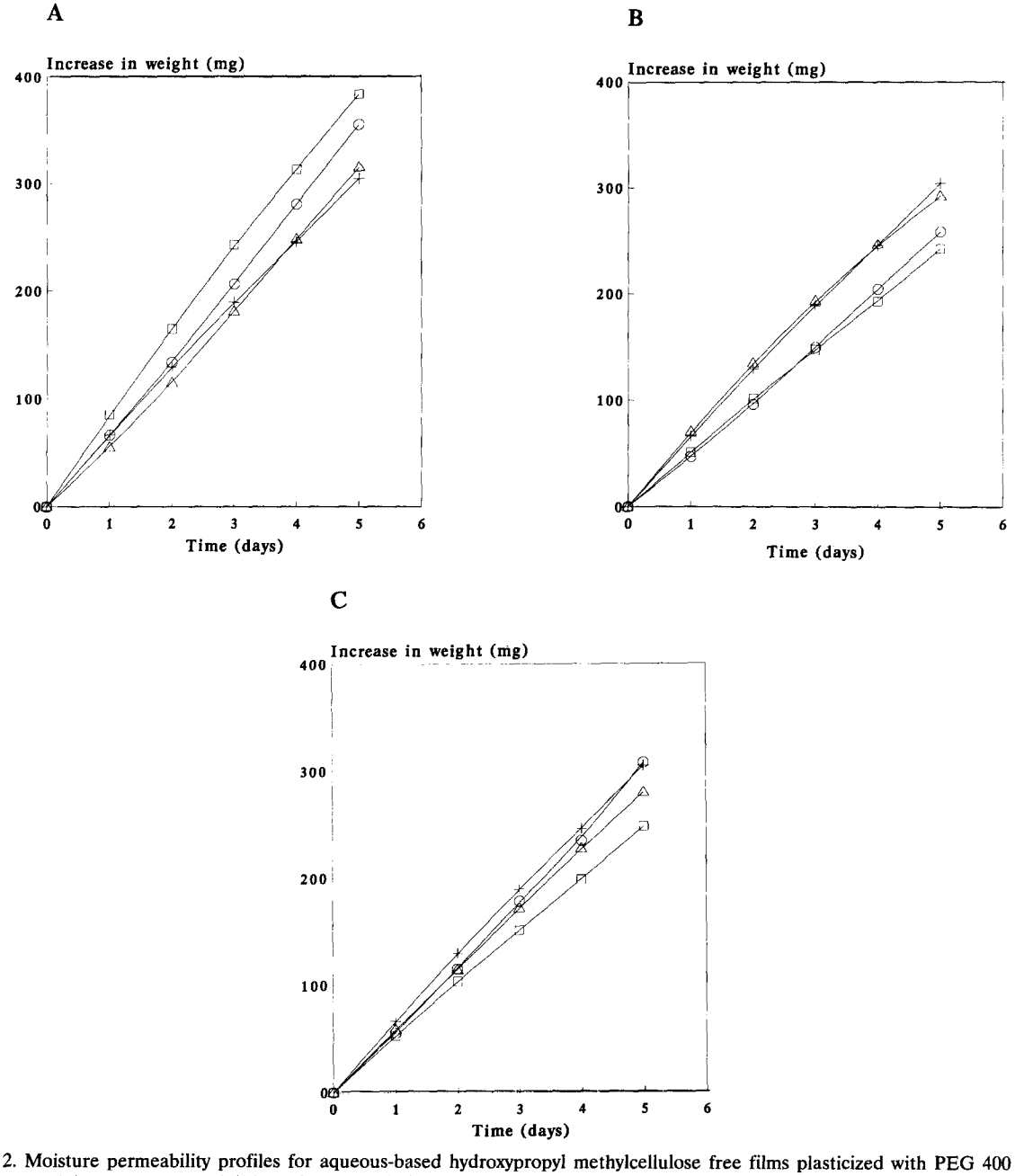

Fig. 2. Moisture permeability profiles for aqueous-based hydroxypropyl methylcellulose free films plasticized with PEG 400 (A), PEG 1500 (B) and PEG 4000 (C) ($n = 6$). HPMC (+), with PEG 10% (○), with PEG 20% (△), with PEG 30% (□).

tained with open control vials. The moisture permeability of HPMC films was found to be dependent on both the amount and molecular weight of PEG added; over the range of molecular weights of PEG tested, the moisture permeability of the films decreased with increasing

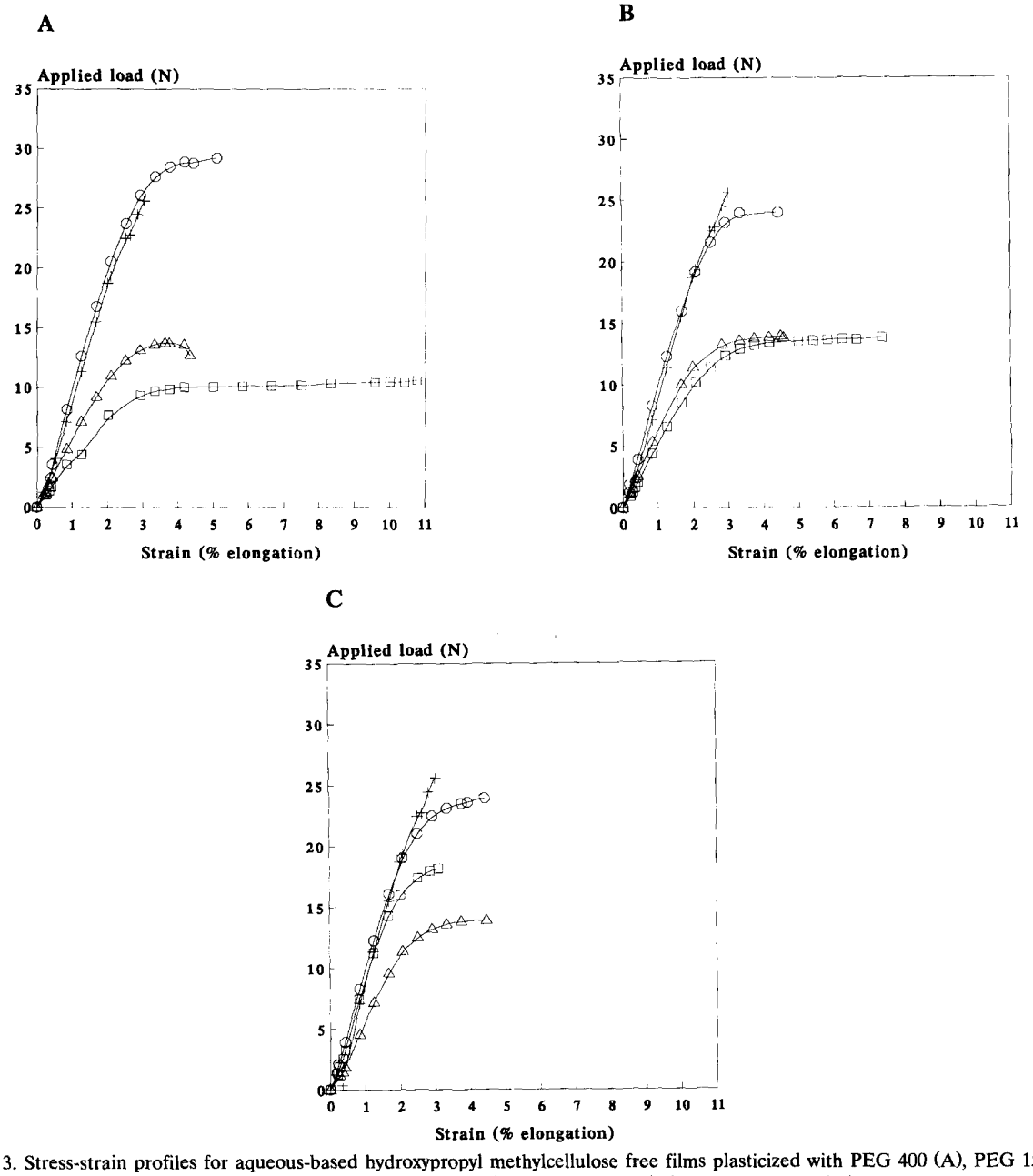

Fig. 3. Stress-strain profiles for aqueous-based hydroxypropyl methylcellulose free films plasticized with PEG 400 (A), PEG 1500 (B) and PEG 4000 (C) ($n = 6$). HPMC (+), with PEG 10% (○), with PEG 20% (△), with PEG 30% (□).

Table 1
Values of Young's modulus for hydroxypropyl methylcellulose free films plasticized with polyethylene glycols ($n = 6$)

Film composition		Young's modulus (N/mm^2)
HPMC		953
Plasticized with PEG 400	10%	994
	20%	502
	30%	387
Plasticized with PEG 1500	10%	904
	20%	577
	30%	453
Plasticized with PEG 40000	10%	873
	20%	557
	30%	775

molecular weight as compared to that obtained with unplasticized control films. This could be explained by a less enhanced chain mobility and, consequently, the smaller diffusion pathways of the higher molecular weight plasticizers, resulting in a lower diffusion rate in the film matrix (Banker, 1966; Okhamafe and York, 1983).

Stress-strain data may be used in defining mechanical film properties and in comparing the films as a function of formulation factors such as plasticizers (Banker, 1966). Stress-strain profiles for plasticized HPMC free films and the values of Young's modulus are shown in Fig. 3 and Table 1, respectively. The stress-strain properties of the films were shown to be dependent on both the concentration and molecular weight of the plasticizers. The mechanical strength of plasticized HPMC films was generally clearly lower than that of unplasticized control films, and the values for applied force decreased as the concentration of the plasticizer increased. For all plasticized film samples, elongation at break was higher than that of unplasticized films, and the elongation of the film samples appears to be indirectly related to the molecular weight of the plasticizer at their higher concentrations (30% or more with respect to polymer).

According to the literature, a desirable pharmaceutical film coat is hard and tough without being brittle, and it is characterized by a high tensile strength, a moderate elongation at break and a high Young's modulus (Lever and Rhys, 1968; Aulton, 1982). According to the classification of Lever and Rhys (1968), the unplasticized aqueous HPMC films evaluated here can be regarded as brittle and hard films (see Fig. 3 and Table 1). The addition of plasticizer at the lowest concentration of 10% resulted in relatively hard and strong films with a moderate elongation (ductility), especially when lower molecular weight plasticizers (PEG 400 or 1500) were used. The addition of plasticizers at a concentration of 20% resulted in clearly softer and weaker films, with virtually no enhancement in film elongation compared to that obtained with the plasticizer level of 10%. The inclusion of lower molecular weight PEGs at the highest concentration of 30% resulted in extremely soft and tough films, while inclusion of higher molecular weight PEG (PEG 4000) resulted in harder and stronger films. The present results are in accordance with those obtained by Aulton and Abdul-Razzak (1981), and suggest that the use of PEGs as plasticizers in aqueous HPMC films is beneficial at concentrations of 10–20% with respect to polymer weight.

In summary, it can be concluded that sprayed free films can be used in preliminary testing and in comparing aqueous-based film samples as a function of basic formulation factor. There are clear relationships between some physical film properties (moisture permeability, ductility) and molecular weight and concentration of PEGs used as plasticizer. As regards moisture permeability and mechanical properties, inclusion of PEGs at a concentration within the range of 10–20% seems to be the most beneficial.

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