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Research paper

The adsorption of cellulose ethers in aqueous suspensions of pyrantel pamoate: effects on zeta potential and stability

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Abstract

This work examined the physico-chemical phenomena induced in aqueous suspensions of pyrantel pamoate by two varieties of hydroxypropylmethylcellulose (HPMC) and sodium carboxymethylcellulose (NaCMC) of different molecular weights, and the effects of these phenomena on the physical stability of the suspension. The mechanism of the interfacial adsorption of the polymer was investigated by constructing adsorption isotherms: for the two HPMC varieties, the isotherms were of type L and were fitted with the Langmuir model; of the NaCMCs, only the variety with higher molecular weight was adsorbed, its adsorption isotherm being of type S (sigmoidal). The resulting monolayer films were characterized viscosimetrically, determining their thickness and the number of polymer molecules adsorbed per unit area. The nonionic polymers formed thinner, more continuous monolayers than the NaCMC. Only the nonionic polymers significantly altered the zeta potential of the systems. In the range of conditions studied, all the polymers stabilized the initially flocculated systems, decreasing sedimentation volume and increasing the time necessary to redisperse them (the redispersabilily value). This stabilization occurred either by the steric mechanism (HPMCs and the high-molecular-weight NaCMC) or by depletion mechanisms (low-molecular-weight NaCMC). Owing to the complexity of these mechanisms, sedimentation volume was not found to be a useful index of the consistency of the sediments obtained from the suspensions. © 1998 Elsevier Science B.V.

Keywords: Aqueous suspensions; Physical stability; Hydroxypropylmethylcellulose; Sodium carboxymethylcellulose; Pyrantel pamoate; Interfacial adsorption; Zeta potential

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1. Introduction

The stabilization of pharmaceutical suspensions by hydrophilic polymers has traditionally been explained by the efficient thickening action of these macromolecules [1]. This stabilizing capacity is also conditioned by the extent to which the polymer adsorbs to the particles forming the internal phase [2], which, in its turn, depends on the polymer's chemical structure, the nature of its interactions with the solvent, and its solubility and tendency to deposit at the particle surface. A further polymer characteristic affecting adsorption is chain length, which, within a given homologous series, is closely related to molecular weight [3]. Of course, adsorption also depends on the nature of the adsorbent, especially that of its functional groups, which determine the surface electrical charge and can thus condition particle–polymer interactions [4]. The effects of the adsorption of polymers on the surface electrical charge of suspended particles have been examined in several recent papers [5,6], as have the stabilizing effects of hydrophilic polymers on particle suspensions [7,8].

Cellulose ethers are among the hydrophilic polymers most widely used in pharmaceutical suspensions. Although

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numerous studies have examined their stabilizing effects on suspensions [7,9,10], there has been little research into the physico-chemical phenomena responsible for this stabilization. Moreover, the few studies available have mainly dealt with model systems with characteristics appreciably different from the pharmaceutical suspensions in common use [11]. To redress this, in the present work we examined the effects of hydroxypropylmethylcellulose (HPMC) and sodium carboxymethylcellulose (NaCMC) (two varieties of each, differing as regards molecular weight) on suspensions of pyrantel pamoate, a widely used anthelmintic agent [12,13] with physico-chemical properties lending themselves to its oral administration in aqueous suspension [13]. This work had three principal aims: (1) quantitative characterization of the adsorption processes occurring and identification of their mechanisms; (2) evaluation of the effects of adsorption on the electrical properties of each system through determination of the zeta potential; and (3) evaluation of the stabilizing effects of the polymers on the suspensions.

2. Materials and methods

2.1. Drug and excipients

The drug used was pyrantel pamoate USP (batch 48F0042; Sigma Química). The excipients were hydroxypropylmethylcelluloses with nominal viscosities 15 000 cps (HPMC K15M) and 4000 cps (HPMC K4M) (batches 89760708 and 88760708, respectively; Colorcon), and sodium carboxymethylcelluloses with nominal viscosities 400–800 cps (hereinafter, NaCMC I) (batch 71H0397; Sigma Química) and 1000 cps (hereinafter, NaCMC II) (batch 012; J. Escuder). All suspensions and reagents were prepared using water of resistivity 18.2 MΩ·cm obtained from a Millipore Milli-Q® reverse osmosis system (Millipore).

2.2. Characterization of the drug

2.2.1. Particle size analysis

Particle size analysis was performed in a Coulter® Multisizer II instrument on samples obtained using a Quantachrome Rotary Microriffler. The dispersant medium was the electrolyte solution Isoton II (Coulter® Electronics), and the analyses were of 60 s duration. The particle volume diameter distributions obtained were fitted by log-normal probability-size distribution functions, from which the geometric mean of the distribution and the corresponding standard deviation were estimated.

2.2.2. Determination of specific surface area

Pyrantel pamoate samples were degassed at ambient temperature and 10^{-3} mmHg for 24 h, and were then subjected to nitrogen adsorption experiments in a Micromeritics ASAP 2000 instrument at 77 K and relative pressures (P/P_0) of 0.06–0.99. Specific surface areas were estimated using the expression:

$$S_{\mathrm{BET}}\ (\mathrm{m^2\ g^{-1}}) = 4.37 \cdot V_{\mathrm{m}}\ (\mathrm{cm^3\ g^{-1}}) \quad (1)$$

where V_{m} is the volume of nitrogen forming a monolayer, and was estimated from the adsorption isotherm by means of the BET equation [14].

2.3. Characterization of the polymers

2.3.1. Viscosimetric determination of molecular weights

Molecular weights were estimated from the intrinsic viscosities of the polymers. Stock 2-g dl^{-1} polymer dispersions were obtained by the procedure outlined in USP 23 and diluted with purified water (HPMC K4M and K15M) or 0.1 M NaCl (NaCMC I and II) to afford series of dilute dispersions. The kinematic viscosities of these dispersions were measured in sextuplicate at 20 (HPMCs) or 25°C (NaCMCs) in a Canon–Fenske viscosimeter (ref. 5354/2, Afora), these data were fitted with the model of Martin [15] in order to obtain intrinsic viscosities ($[\eta]$). Mean molecular weights were then estimated from these $[\eta]$ using the Mark–Houwink equation [16] with constants K and a set to 3.39×10^{-4} and 0.88 for the HPMCs [10], and to 1.23×10^{-5} and 0.91 for the NaCMCs [17].

2.3.2. Determination of the hydration enthalpy

The enthalpy of hydration of the two NaCMCs was determined at 25°C by immersion calorimetry in a Tronac calorimeter (model 458) comprised of a 50 ml reaction vessel immersed reaction vessel immersed in a thermostatted, insulated water bath. The test sample (0.09–0.11 g) was sealed in a thin-walled glass ampoule and mounted on a rotating support. After thermal equilibration, the ampoule was broken by means of a spring-loaded hammer mounted below it. The rise in the temperature of the system was monitored using a thermistor, and later reproduced using a heating coil in the reaction vessel. The hydration enthalpy was calculated from the applied current and voltage and the heating time.

2.3.3. Evaluation of the molecular dimensions

Characterization of the conformation adopted by each polymer in aqueous solution at 25°C used Simha's equation [18]

$$[\eta] = 0.207(l/d)^{1.732} \quad (2)$$

and Kräemer's equation [19]

$$1 = \left(\frac{6l^2 M\bar{v}}{d^2 N_a}\right)^{1/3} \quad (3)$$

which relate the lengths of the major (l) and minor (d) axes of the ellipsoid of revolution described by polymer molecules of mean molecular weight M and specific partial volume $\bar{v}$, to the corresponding intrinsic viscosity $[\eta]$. For the HPMCs, $[\eta]$ under these conditions was estimated from kinematic viscosities as described above, while for the NaCMCs $[\eta]$ were obtained for each polymer in 5×10^{-2} to 5×10^{-4} M NaCl solutions, and these were fitted with a fourth-degree polynomial by non-linear regression and extrapolated to infinite dilution. The value of $\bar{v}$ was estimated from the slope of the straight line with equation:

$$\rho = \rho_0 + (1 - \bar{v}\rho_o)c \tag{4}$$

where ρ_0 and ρ are the densities of the solvent and the polymer dispersion of concentration c, respectively [20].

2.4. Adsorption of the polymers on the drug particles

2.4.1. Construction of adsorption isotherms

Adsorption isotherms were obtained for series of suspensions of 4% (w/v) of pyrantel pamoate in a dispersion of between 10 and 700 mg dl^{-1} of polymer. Each suspension was equilibrated by stirring it at 25°C for 48 h, whereupon it was centrifuged at 85 × 1000 × g for 15 min, the supernatant was decanted and filtered through a 0.45 μm pore-diameter nylon membrane (ref. NY501300; Lida), and the unadsorbed polymer in the supernatant was determined by Mildwisky’s method [21]. To avoid any bias in the results due to adsorption of the polymer on the filter, the standards used to construct the calibration line were treated identically to the supernatant derived from the samples. The resulting adsorption data for suspensions containing up to 120 mg dl^{-1} of the nonionic HMPCs were fitted with the Langmuir equation [22]:

$$\Gamma = \Gamma_{\max} \cdot \frac{c}{c + (1/A)} \tag{5}$$

where Γ is the amount of polymer adsorbed per g of drug, $\Gamma_{\max}$ the amount of polymer per g of drug forming a monolayer, c the equilibrium concentration of polymer in the dispersion, and A the adsorption activity, which is a measure of the rate of formation of a single monolayer of the polymer, and is derived from the slope of the initial segment of the adsorption isotherm.

2.4.2. Estimation of the number of molecules adsorbed and the area occupied per molecule

For a single monolayer, the number of polymer molecules adsorbed per g of drug was obtained by dividing the amount of polymer adsorbed ($\Gamma_{\max}$) by the mean molecular weight (M). The number of molecules per unit area of the drug was then obtained by dividing this value by the specific surface area (S_{BET}).

2.4.3. Estimation of the thickness of the adsorbed monolayer

Series of suspensions were prepared containing between 0.002 and 0.018% (w/v) of pyrantel pamoate and sufficient polymer to form a monolayer (in all cases 100 mg dl^{-1}). The relative viscosities (η_r) of these suspensions were calculated as the ratio of the viscosity of the drug suspension to the viscosity of the solution obtained after the suspension was centrifuged at 85 × 1000 × g for 15 min and the supernatant was decanted and filtered through a 0.45-μm pore-diameter nylon membrane (ref. NY501300; Lida). Viscosities were measured in Canon–Fenske viscosimeters (refs. 5354/2 and 5354/2B; Afora) selected bearing in mind the viscosimetric characteristics of the suspensions. The thickness of the adsorbed monolayer of polymer molecules (b) was estimated from the slope of the straight-line plot of η_r versus V, in accordance with the equation proposed by Einstein [10]:

$$\eta_r = 1 + 2.5 \cdot V \cdot [(r + b)/r]^3 \tag{6}$$

where V is the mass fraction of the drug in the suspension, and r is the mean radius of the drug particles, as determined by particle size analysis.

2.5. Determination of the zeta potential

The zeta potentials for the suspensions were calculated from their electrophoretic mobilities by means of the Helmholtz–Smoluchowski equation [23]. Electrophoretic mobilities were measured in triplicate by laser doppler anemometry (LDA) in a Zetasizer III apparatus (Malvern Instruments) equipped with an AZ4 4 mm diameter capillary cell. Optimal particle concentrations were obtained by diluting the suspensions with 1 mM KCl solution. The electrode compartments of the measuring cell were filled with 2 mM KCl [24]. The applied field strength was 150 mV.

2.6. Stability studies

2.6.1. Determination of the redispersability

Twenty ml of suspension were sealed in a 25 ml glass tube of diameter 15 mm and stored at 25°C for 15 days. Redispersability (R), the time (measured in blocks of 30 s) needed to completely redisperse the sediment forming during storage, was determined with a rotary mixer (model 34526; Breda Scientific), spinning the tubes end over end at 40 rpm.

2.6.2. Determination of the sedimentation volume

For samples treated identically to those described in Section 2.6.1, the sedimentation volume was calculated as the ratio of the volume of the resulting sediment (V_u) to the volume of the suspension (V_o) [8].

3. Results and discussion

Table 1 summarizes the results of the experiments to characterize the pyrantel pamoate, and Table 2 lists the intrinsic viscosities and molecular weights of the cellulose ethers. The molecular dimensions of the polymer molecules

Table 1

Properties determined for the pyrantel pamoate

Parameter	Mean (SD)
Specific surface area (m^2 g^{-1})	1.237 (0.003)
Volume equivalent diameter	
Mean (μm)	9.53 (0.65)
Geometric standard deviation (μm)	1.73 (0.03)

in aqueous medium at 25°C are listed in Table 3. For each type of polymer, the length of the major axis of the ellipsoid of revolution increased in consonance with molecular weight. For the HPMCs, these increases were in keeping with those reported by Law and Kayes [10] for varieties of this polymer with lower molecular weight. The major axis was longer for the ionic NaCMCs than for the nonionic HPMCs, than for the nonionic HPMCs, indicating that the former were more expanded in solution than the latter owing to the strong interaction between their carboxylic acid groups and the solvent [25]. In keeping with this, decreasing solvation of these carboxyl groups by increasing the concentration of NaCl electrolyte in the medium led to a decrease in the intrinsic viscosities of the NaCMCs.

The mechanism of polymer adsorption at the surface of pyrantel pamoate particles was examined by constructing adsorption isotherms for suspensions containing polymer concentrations up to that necessary for monolayer formation (Fig. 1). For the HPMCs, type L isotherms [26] were obtained, indicating that these polymers linked to the pyrantel pamoate particles through nonspecific interactions, probably of a hydrophobic nature, given the natures of these polymers and the drug [3]. Fitting these data with the Langmuir model (Eq. (5)), showed that the low-molecular-weight HPMC K4M had the greatest adsorption activity (Table 4), accounting for the fact that they attained equilibrium (the plateau region in Fig. 1) at lower polymer concentrations, and with the adsorption of smaller amounts of polymer, than suspensions with HPMC K15M. According to the model of Perkell and Ullmann [27], the isotherms and adsorption activities obtained for the HPMCs suggest that they adsorb through only a few points along the polymer chain, the number of these points being similar for the two varieties. The differences observed in $\Gamma_{\max}$ for the two polymers (Table 4) are thus probably due to differences in the lengths of the loops and tails of polymer chain lying between these points and extending into the liquid medium [2]. Support for this hypothesis comes from the fact that, for both HPMCs, viscosimetry indicated the adsorbed monolayer to have thickness (Table 4) intermediate between the lengths of the minor and major axes of the corresponding ellipsoid of revolution. Monolayers of the HPMCs studied are slightly thicker than reported by Law and Kayes for other varieties of HPMC [10], which is attributable to differences in molecular weights and molecular dimensions.

Table 2

Intrinsic viscosities obtained by adjusting Martin's model to kinematic viscosities for series of dispersions of the four polymers studied in water at 20°C (HPMCs), or in 0.1 M NaCl at 25°C (NaCMCs), together with molecular weights derived from them

Polymer	Intrinsic viscosity (dl g^{-1})	Martin's constant	Mean molecular weight
HPMC K4M	7.9 ± 0.3	0.220	92358 ± 2064
HPMC K15M	11.5 ± 0.1	0.154	140980 ± 626
NaCMC I	5.35 ± 0.07	0.457	124940 ± 1740
NaCMC II	6.83 ± 0.06	0.316	163699 ± 1275

Table 3

Molecular properties of the polymers (dimensions of their ellipsoids of revolution) in aqueous solution at 25°C

Polymer	Intrinsic viscosity (ml g^{-1})	Partial specific volume (ml g^{-1})	Major axis (nm)	Minor axis (nm)
HPMC K4M	720	1.0006	225	2.03
HPMC K15M	955	1.0001	288	2.22
NaCMC I[a]	3772[a]	0.9984	470	1.63
NaCMC II[a]	4100[a]	0.9985	530	1.76

[a] Estimated by extrapolation to infinite.

In comparison with the HPMCs, the ionic polymers had much lower affinity for pyrantel pamoate particles. Indeed, no appreciable adsorption of NaCMC I was detected in the adsorption experiments (Fig. 1), and viscosimetric characterization of the suspensions confirmed that no adsorption layer had been formed. This low affinity was undoubtedly due to the high hydrosolubility of these polymers [28]. The hydrosolubility is known to depend on the molecular weight and degree of substitution of the NaCMC, and is also influenced by how uniformly the carboxylic acid groups are distributed along its chain. Of the two varieties studied, NaCMC II (with the higher molecular weight) appears to have these acid groups least uniformly distributed, judging by the slightly less transparent appearance of aqueous solutions [25] and lower hydration enthalpy of this variety compared to those of NaCMC I. Indeed, the large discrepancy between these enthalpies (127.7 J g^{-1} for NaCMC I, as against 107.9 J g^{-1} for NaCMC II) suggests that there is a marked difference between the hydrophilicities of the two NaCMCs. The adsorption isotherm for NaCMC II (Fig. 2) was of type S (sigmoidal), in contrast to the L-type isotherms obtained by Kellaway and Najib [29] for other NaCMC varieties in suspensions of polystyrene latex. According to Denoyel and Rouquerol [30], who obtained sigmoidal isotherms for the adsorption of alkylbenzene-polyoxyethylene surfactants on various adsorbents, such isotherms indicate a complex adsorption mechanism. In the case of NaCMC II, this mechanism most probably involves electrostatic repulsion and hydrophobic attraction between the polymer and the particle surface and, at low concentrations, between the polymer in solution and the adsorbed polymer. As regards the orientation of the adsorbed polymer, the fact that NaCMC II formed a monolayer almost as thick as the length of the major axis of its

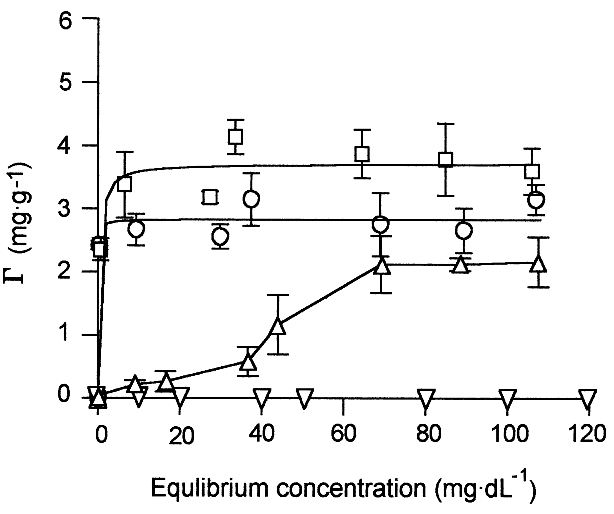

Fig. 1. Adsorption isotherms at 25°C for dilute dispersions of HPMC K4M (○), HPMC K15M (□), NaCMC I (▽) and NaCMC II (△) containing suspended pyrantel pamoate particles.

ellipsoid of revolution (Tables 3 and 4) suggests that it adsorbs to the particles through one end of its chain, while the remaining portion extends into the dispersant medium. This orientation may have been favoured by the relative rigidity of the NaCMC chain, which is due to repulsive interactions between the charged, highly hydrated carboxylic acid groups [25]. It is noteworthy that fewer NaCMC II than HPMC molecules were adsorbed per unit area of the particle surface, indicating that NaCMC II produces a less continuous polymer layer than the HMPCs. Viscosimetric characterization of the monolayers brought to light the tendency of the cellulose ethers to form very thick adsorbed layers. In this regard, Dalgleish [31] has reported the formation of considerably thinner films for casein adsorbed in latex suspensions, attributing small differences in thickness among the various proteins studied to differences in their hydrophilicities, a property with an apparently profound effect on the structure of the monolayer. The thinness of these protein films compared to the films formed by the cellulose ether studied here can likewise be attributed to the marked hydrophilicity of the protein adsorbate, and also to differences in the composition of the medium (Dalgleish used a buffer, we used purified water).

Table 4

Properties determined for the polymers adsorbed onto particles of pyrantel pamoate in aqueous suspension

Polymer	Γ_{max} (mg g^{-1})	Adsorption activity (dl mg^{-1})	Molecules adsorbed/m^2	Monolayer thickness (nm)
HPMC K4M	2.82 ± 0.06	19.1 ± 9.1	1.49×10^{16}	133.6
HPMC K15M	3.70 ± 0.08	2.68 ± 0.6	1.27×10^{16}	153.0
NaCMC II	2.18 ± 0.07	–	6.48×10^{15}	469.7

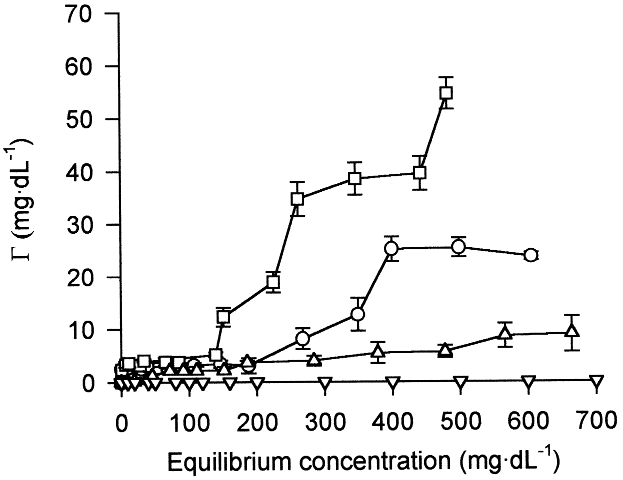

Fig. 2. Adsorption isotherms at 25°C for dispersions of HPMC K4M (○), HPMC K15M (□), NaCMC I (▽) and NaCMC II (△) containing suspended pyrantel pamoate particles.

Adsorption isotherms for suspensions containing polymer concentrations up to those habitually used in pharmaceutical suspensions are shown in Fig. 2. Above the concentration necessary for monolayer formation, the amount of polymer adsorbed increased considerably, especially for the nonionic polymers. Similar increases have been observed by Law and Kayes [10] for hydroxypropylcellulose or other varieties of HPMC in suspensions of polystyrene latex and ibuprofen, and are attributable to the formation of successive layers of adsorbed polymer, probably by an aggregation mechanism involving polymer–polymer interactions, as polymer concentration increases.

The effects of the polymers on the surface electrical charge of the suspended drug particles were characterized by determining the zeta potential (Fig. 3). Without polymer, the particles had a zeta potential of around –60 mV, its negative sign being due to the presence in the pyrantel pamoate of a carboxylic acid group and two easily ionized phenolic hydroxyl groups. Inclusion of either of the HPMCs in the system drastically decreased the magnitude of zeta, which is attributable to polymer adsorption onto the parti-

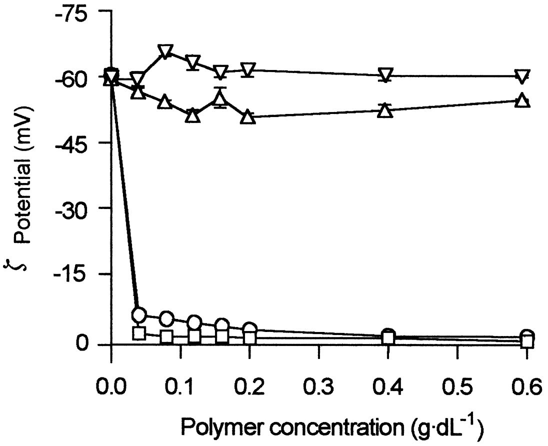

Fig. 3. Effects of HPMC K4M (○), HPMC K15M (□), NaCMC I (▽) and NaCMC II (△) on the zeta potential of suspended pyrantel pamoate particles.

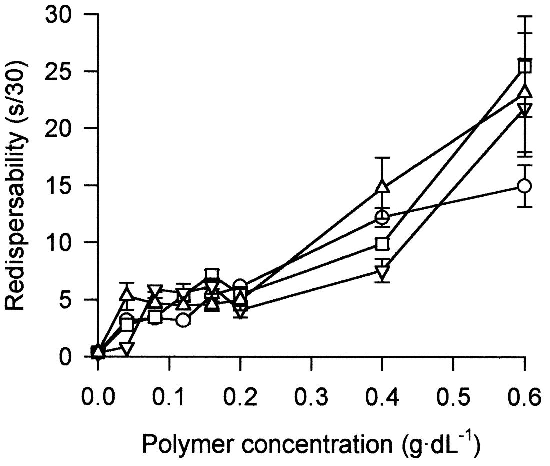

Fig. 4. Effects of HPMC K4M (○), HPMC K15M (□), NaCMC I (▽) and NaCMC II (△) on the redispersability of pyrantel pamoate suspensions.

cles having increased the distance between the particle surface and the shear plane [6,32]. By contrast, the ionic polymers only slightly modified the zeta potential of the drug particles, which can be explained by the absence of adsorption in the case of NaCMC I, and by the presence in the adsorbed polymer of carboxylic acid groups with negative charge similar in magnitude to the charge on the particles, in the case of NaCMC II. A further factor affecting the zeta potential may have been compression of the electrical double layer at the higher electrolyte concentration resulting upon addition of either of the NaCMCs to the suspension.

The stability of pyrantel pamoate suspensions was significantly modified by all four polymers studied. Thus the flocculated pyrantel pamoate–water system was transformed into a stable suspension by the addition of polymer, with the result that the sediment formed upon storing was more difficult to redisperse in the samples with polymer (Fig. 4). Stabilization of the suspensions by the nonionic polymers and NaCMC II could be due to their tendency to adsorb at the surface of the particles, in which case the steric mechanism would be chiefly responsible for the stabilization process [2,7]. This hypothesis is supported by the correlations observed between the redispersability of these suspensions and the amounts of polymer adsorbed by the particles (Fig. 5). Furthermore, the small magnitude and the direction of the changes induced in the zeta potential by the polymers suggest that electrical phenomena are not important in the stabilization process.

For suspensions containing polymer concentrations above that necessary for monolayer formation, redispersability decreased as the amount of polymer adsorbed increased. This was attributed to intertwining of polymer chains during adsorption of multiple polymer layers, and the consequent formation of a polymeric framework that bound the particles together in the sediment [33]. A further factor contributing to this decrease in redispersability may have been the increased viscosity of the dispersant medium at high polymer concentration, which would have slightly diminished the effects of the agitation applied during the redispersability experiments.

The observations that NaCMC I was not appreciably adsorbed by the particles and only minor changes induced, suggest that stabilization of the suspension by this polymer occurred chiefly by depletion mechanisms [2]. This is supported by the observation that the stabilizing effect of this polymer was manifest only above a critical concentration limit around 40 mg dl^{-1} (Fig. 4) [34,35].

The stabilizing effects of the polymers were manifest as changes in the sedimentation volumes of the suspensions (Fig. 6). The nonionic HPMCs decreased sedimentation volume with respect to aqueous suspensions of pyrantel pamoate. The effects of the ionic polymers were more complex and differed for the two varieties. In suspensions with <40 mg dl^{-1} of NaCMC I, in which there was no apparent stabilization, a flocculated sediment formed with a sedimentation volume slightly smaller than that obtained for pyrantel pamoate alone. Above this critical stabilizing concentration [36], however, NaCMC I caused the forma-

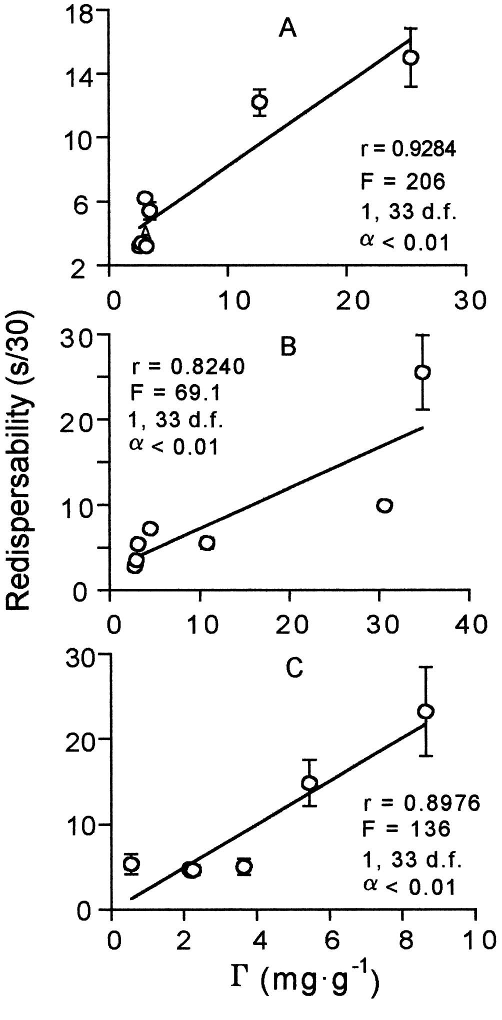

Fig. 5. Correlation of the redispersability of the suspension with the amount of (A) HPMC K4M, (B) HPMC K15M and (C) NaCMC II adsorbed per g of drug.

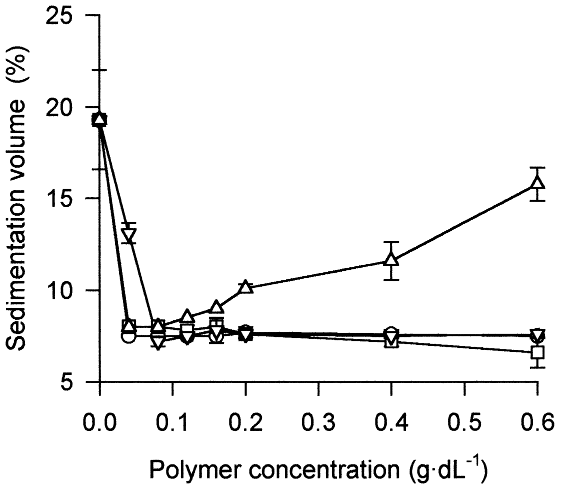

Fig. 6. Effects of HPMC K4M (○), HPMC K15M (□), NaCMC I (▽) and NaCMC II (△) on the sedimentation volume of suspensions of pyrantel pamoate.

tion of particulated sediments with volumes as small as those from suspensions with HPMCs. By contrast, addition of up to 100 mg dl^{-1} of NaCMC II decreased sedimentation volumes to levels approaching those obtained with equivalent concentrations of HPMCs, while at higher concentrations the sedimentation volume increased towards the value obtained for pyrantel pamoate alone. Given the poor redispersability of these suspensions, this behaviour cannot have been due to the formation of a flocculated sediment. Rather, bearing in mind the rigidity of NaCMCs in low ionic strength systems [25], this increase in sedimentation volume was attributed to adsorption of NaCMC II having increased the hydrodynamic volume of the particles, thereby impeding their flocculation.

Sedimentation volume is often used as a measure of sediment consistency and its tendency to redisperse [37]. In this work, however, there was no correlation between the sedimentation volumes of the systems studied and their redispersabilities, possibly due to the diversity of the stabilizing mechanisms acting and the complex structures of the resulting suspensions.

In conclusion, this work shows that the two varieties of HPMC and the high-molecular-weight NaCMC are adsorbed in significant amounts at the surface of pyrantel pamoate particles; that this adsorption process modifies the zeta potential of the drug particles and stabilizes their suspensions; and that, although the low-molecular-weight NaCMC was not adsorbed appreciably by the particles, it did stabilize their suspensions, possibly by depletion mechanisms.

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