Characterization of Moisture-Protective Polymer Coatings Using Differential Scanning Calorimetry and Dynamic Vapor Sorption

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ABSTRACT: The aim of this study was to evaluate the moisture-protective ability of different polymeric coatings. Free films and film-coated tablets (with cores containing freeze-dried garlic powder) were prepared using aqueous solutions/dispersions of hydroxypropyl methylcellulose (HPMC), Opadry® AMB [a poly(vinylalcohol)-based formulation] and Eudragit® E PO [a poly(methacrylate–methylmethacrylate)]. The water content of the systems upon open storage at 75% relative humidity (RH) and 22°C (room temperature) was followed gravimetrically. Furthermore, polymer powders, free films and coated tablets were analyzed by differential scanning calorimetry (DSC) and dynamic vapor sorption (DVS). The type of polymer strongly affected the resulting water uptake kinetics of the free films and coated tablets. DSC analysis revealed whether or not significant physical changes occurred in the coatings during storage, and whether the water vapor permeability was water concentration dependent. Using DVS analysis the critical glass transition RH of Opadry® AMB powder and Opadry® AMB-coated tablets at 25°C could be determined: 44.0% and 72.9% RH. Storage below these threshold values significantly reduces water penetration. Thus, DVS and DSC measurements can provide valuable information on the nature of polymers used for moisture protection.
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INTRODUCTION

The coating of solid pharmaceutical dosage forms with thin films is an established procedure to improve product aesthetics, packaging efficiency, patient compliance, swallow ability, and drug stability. Many drugs are sensitive to UV light, moisture and oxygen (oxidation). Surrounding the dosage forms with appropriate coatings can allow an efficient protection of the drug. In particular, atmospheric moisture can be critical, because hydrolysis is one of the main reasons for drug degradation. This is especially true for many herbal drugs.

Generally, polymeric film formers are used for moisture-protective coatings, including hydroxymethylcellulose, hydroxypropyl methylcellulose, poly(vinylalcohol), ethylcellulose, shellac and poly-

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(methacrylate–methylmethacrylates).[1–7] Depending on their physicochemical properties, they provide a more or less efficient barrier against humidity. For poly(vinylalcohol)-based coatings, a highly moisture-dependent water vapor permeability has been reported.[8] This could be explained by structural changes within the polymeric matrices upon water penetration (glassy-to-rubbery state transitions). When polymeric materials are exposed to high humidity, water first forms a monomolecular layer on the substances (characterized by strong interactions with polar groups of the polymer backbone) (type III water).[9,10] A multilayer system is subsequently created via hydrogen bonds between the water molecules, when the water vapor pressure is high enough (type II water).[11] Additional water that is taken up is “bulk” or “solvent like” water (type I water).[12] While bonded water (types II–III) shows only low reactivity, solvent like water (type I) can change the physical and chemical properties of the polymeric coating, for example, their glass transition temperature and water vapor permeability. Type I water can even change the properties of the entire formulation.[13–15] A thorough characterization of the water that is present in the system is, thus, necessary to identify the best storage conditions for the respective solid dosage forms.

Phase transitions in the solid state in pharmaceutical products can be of fundamental importance because they can lead to significant changes in the physical properties of the formulations.[16] For example, the transition of an amorphous polymer from the glassy to the rubbery state can result in drastic alterations and be induced by the presence of water. Water that has been taken up may be thought of as dissolving into the amorphous structure and acting as a plasticizer.[17] To avoid undesired glassy-to-rubbery phase transitions, amorphous materials with different glass transition temperatures (T_gs) can be blended. This approach can for example be used to increase the storage stability of the system.[18] The glass transition temperature of amorphous blends can be calculated using the Fox–Flory equation, taking into account the weight fraction of the respective substances and their T_gs.[19]

An in-depth understanding of the role of water acting as a plasticizer in polymeric systems is of major importance for the assurance of stable physical properties of solid dosage forms. It has for example been shown that a moisture-induced reduction of the T_g to a level near or below the operating temperature is sufficient to induce recrystallization of lower molecular weight substances through pharmaceutical processing.[20] Obviously, the T_g in polymers intended for moisture-protective coatings is of major importance, as glassy-to-rubbery state transitions can result in drastically increasing water vapor diffusivities through the thin films. The effects of the addition of various types of external plasticizers to polymeric coating formulations on the resulting permeability for water has been studied by different research groups.[21–23] Generally, moisture permeates more rapidly through films containing hydrophilic plasticizers,[24] whereas the addition of hydrophobic plasticizers exerts no significant effects on the water vapor permeability.[25]

The aim of this study was to use dynamic scanning calorimetry (DSC) and dynamic vapor sorption (DVS) analysis to better understand the impact of the water uptake of polymeric films on their moisture-protective abilities. Freeze-dried garlic powder was used as a model moisture-sensitive drug and compressed into tablets. The latter were coated with different types of polymers. The resulting water uptake kinetics of the coated tablets as well as of free polymeric films and polymer powder were studied.

MATERIALS AND METHODS

Materials

The following materials were used as received: tablets containing 100 mg freeze-dried garlic powder (diameter = 8 mm, weight = 250 mg; Lichtwer-Pharma, Berlin, Germany); partially hydrolyzed poly(vinylalcohol) (Opadry® AMB white, Colorcon, Orpington, UK); hydroxypropyl methylcellulose (Methocel® E5, Colorcon); poly(methacrylate–methylmethacrylate) copolymer (Eudragit® E PO, Degussa, Darmstadt, Germany); triethyl citrate (TEC, Morflex, Greensboro, USA).

Tablet Coating

Tablets were coated in a pan coater (15 rpm, air flow rate: 130 m^3/h, nozzle diameter = 1.2 mm, spraying pressure = 1.3 bar; Glatt® GC-300, Glatt, Binzen, Germany). Aqueous solutions or dispersions of the investigated polymers were sprayed onto tablets (which were preheated for 10 min) under the specific conditions recommended by the respective manufacturers