Properties of Whey-Protein-Coated Films and Laminates as Novel Sustainable Food Packaging Materials with Excellent Barrier Properties

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Introduction

Among proteins that could be used in the field of packaging, especially for food sensitive to water and gas permeation, whey is one of the most promising. Whey is a by-product of cheese manufacturing that contains approximately 7% dry matter. Whey protein can be separated and purified from the liquid whey in an efficient membrane filtration process and subsequent spray drying to obtain either Whey Protein Concentrate (WPC, average protein concentration 65-80 % in dry matter), or Whey Protein Isolate (WPI, highly pure grade with concentrations over 90% in dry matter). In general these whey proteins are used as additives in the agro-food industry, such as the athletic drinks. Nevertheless, whey is in abundant supply, approx. 40% of the 50 million tonnes of whey produced annually in Europe is still unprocessed, which makes it an interesting resource in view of its excellent oxygen barrier properties.

Whey protein can be used in the packaging field, especially for its use as a coating on paper, but also on plastic substrates. Indeed, whey coatings on polypropylene, polyvinylchloride and low density polyethylene demonstrated excellent visual properties, such as excellent gloss and high transparency, as well as good mechanical properties. However, the incorporation of plasticizing agents (e.g glycerol and sorbitol) was generally reported as necessary to overcome the intrinsic brittleness of whey protein coatings. However, use of plasticizers has the disadvantage of lowering barrier properties.

Whey proteins can be hydrolyzed by different enzymes, such as protease, in specific conditions. This makes multilayer films recyclable, since the separation of the layers made up of conventional petroleum-based plastics and associated by the whey-based layer is facilitated, enabling them to be handled separately. Overall, use of whey-based layers could reduce CO_2 emissions and consumption of resources in packaging production.

Aim of the study was to develop whey protein formulations providing excellent barrier properties comparable to the ethylene vinyl alcohol copolymers (EVOH) barrier layer conventionally used in food packaging composites. Further requirements are transparency, sufficient adhesion to the substrate and flexibility to withstand mechanical load while preventing delamination and/or brittle fracture. (Schmid, et al. 2012)

Experimental

The WPI (Whey Protein Isolate) coating formulations were heat denatured at 95°C for 30 minutes and applied on corona pre-treated 12 µm PET films (surface energy >40 mN/m). At lab scale, a control coater was used to apply the solution evenly at a speed of 4 m min^{-1}. Depending on the kind of grooved rod used, film wet coating thicknesses varying between 10 and 30 µm were achieved. Coated polymer films were dried in an oven at 105 °C for 10 min. Pilot plant trials were performed on a lacquering and laminating plant. Corona-discharge-treated 12 µm PET films were coated with whey protein solution by use of a comma bar roller coater system and laminated with PE (20 µm). Whey protein layers of up to 10 µm could be achieved. The oxygen transmission rate was measured according to DIN 53380-3 standard. Thermo-mechanical properties were determined using the Dynamic Mechanical Thermal Analyses from 0 to 250°C with a heating rate of 5 °C min^{-1} and a frequency of 1 Hz. Optical properties were measured by the quantitative measurement of light transmittance of the films using the spectral photometer with a wavelength range of 250 - 1000 nm. (Schmid, et al. 2012)

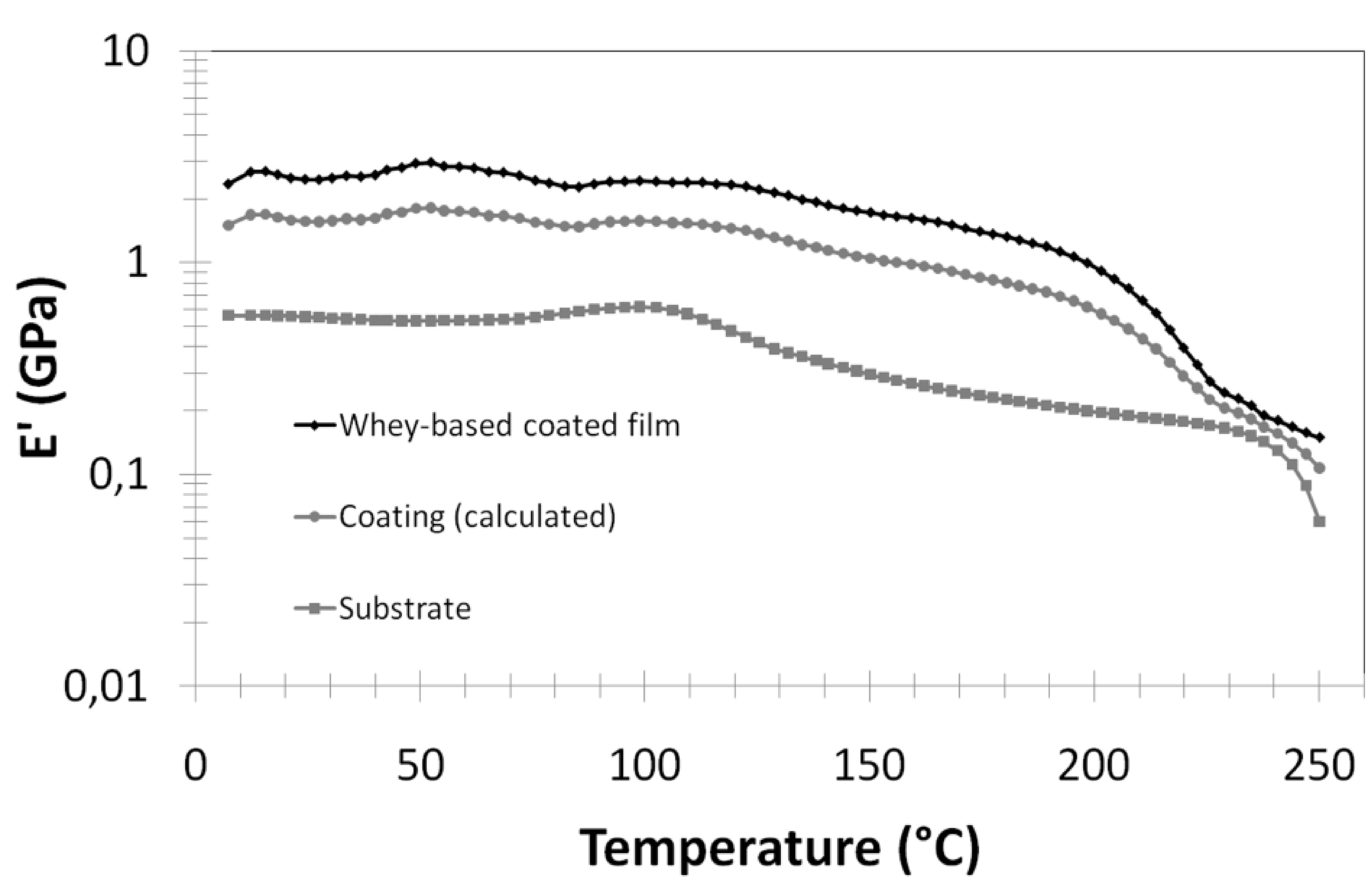

Figure 1: Comparison of the evolution of Young's modulus versus temperature of whey-based coated films, coating (determined applying the theory of composite materials in "isodeformation conditions" and PET substrate

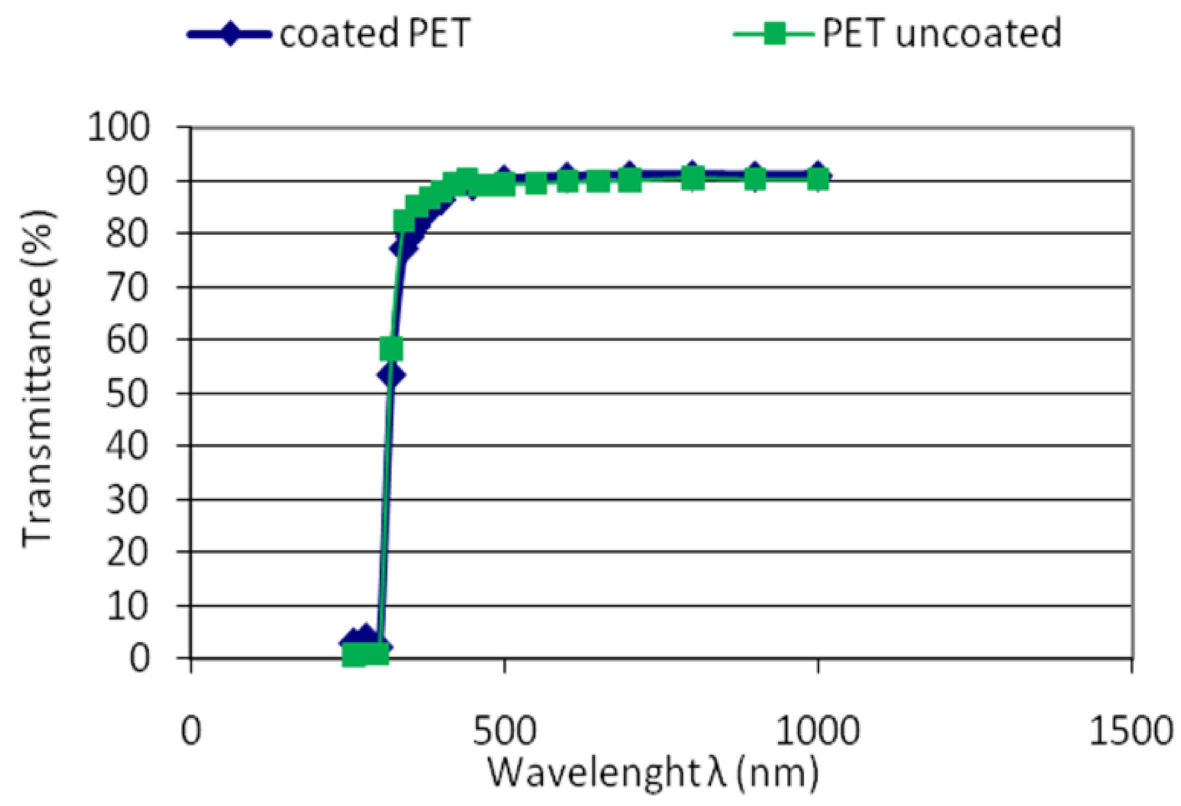

Figure 2: Transmittance spectrum of uncoated and whey-coated PET

Results and Discussion

Thermo-mechanical properties: Isolating the value of the elastic modulus of PET and considering its contribution to the modulus of the total structure made it possible to calculate the Young's Modulus of the coating applying the theory of composite materials in "isodeformation conditions". The tests showed that the whey-based layer is much stiffer than the substrate used and it is possible to observe that it contributes to increasing the rigidity of the coated film. The high stiffness of the whey-based layer could be related to the high crosslinking density of the structure formed by the proteins (Fig. 1).

Optical Properties: The transmittance spectrum was recorded over the whole wavelength range. As shown in Fig. 2, no difference in light transmittance was observed between pure PET and coated PET and appeared transparent.

Barrier Properties: The developed whey protein formulations had excellent barrier properties almost comparable to the ethylene vinyl alcohol copolymers (EVOH) barrier layer conventionally used in food packaging composites, with an oxygen barrier (OTR) of < 2 cm^3(STP) $m^{-2}d^{-1}$ bar^{-1} when normalized to a thickness of 100 µm (Fig. 3). Further requirements of the barrier layer are good adhesion to the substrate and sufficient flexibility to withstand mechanical load while preventing delamination and/or brittle fracture. Whey-protein-based coatings have successfully met these functional requirements. (Schmid, et al. 2012)

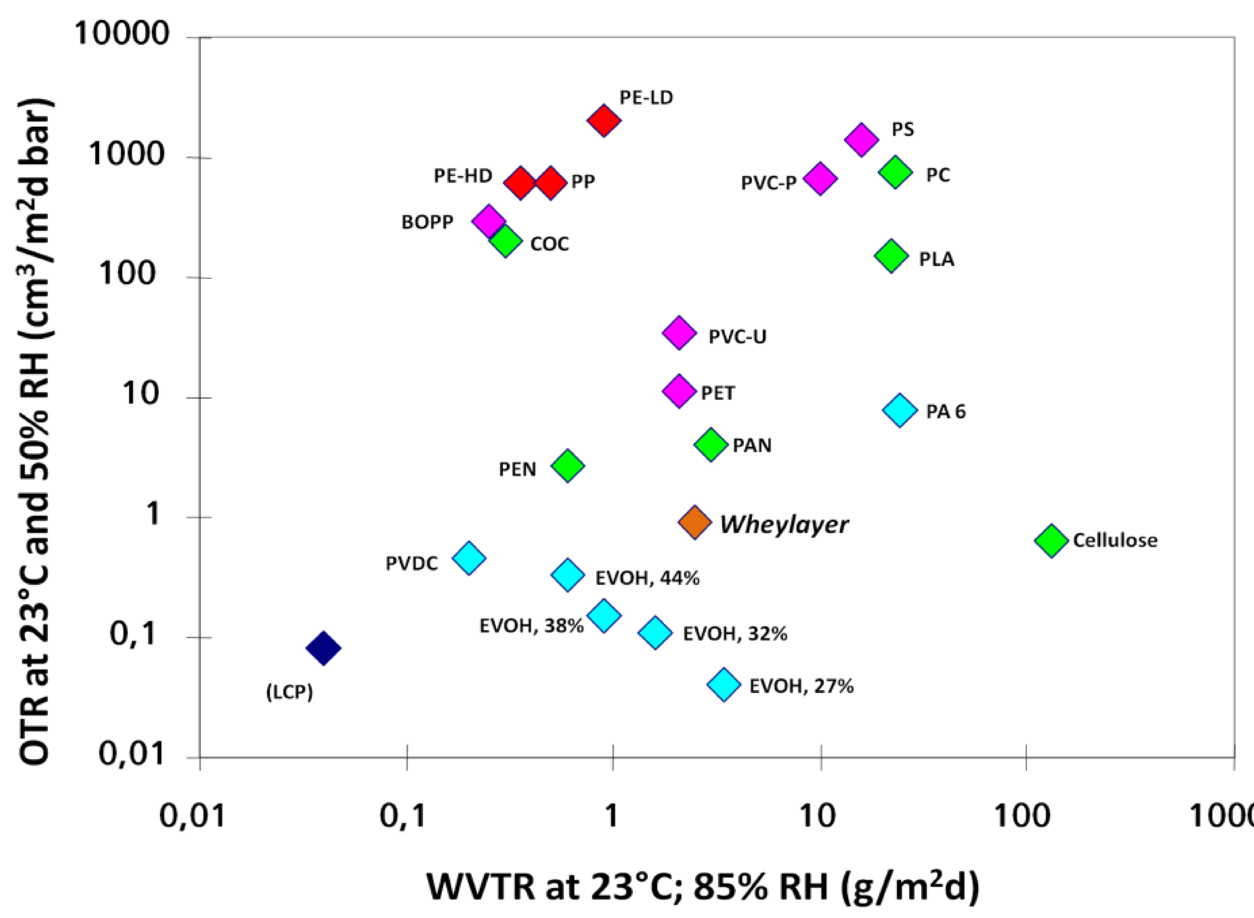

Figure 3: Barrier properties of whey-based layer versus other plastics commonly used in the packaging industry

Reference and Acknowledgement

Markus Schmid, Kerstin Dallmann, Elodie Bugnicourt, et al., "Properties of Whey-Protein-Coated Films and Laminates as Novel Recyclable Food Packaging Materials with Excellent Barrier Properties," International Journal of Polymer Science, vol. 2012, Article ID 562381, 7 pages, 2012. doi:10.1155/2012/562381

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