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ORIGINAL PAPER

Modeling of equilibrium and kinetics of human polyclonal immunoglobulin G adsorption on a tentacle cation exchanger

Katarzyna Wrzosek, Pavel Ačai, Michal Gramblička, Milan Polakovič*

Department of Chemical and Biochemical Engineering, Institute of Chemical and Environmental Engineering, Faculty of Chemical and Food Technology, Slovak University of Technology in Bratislava, Radlinského 9, 812 37 Bratislava, Slovakia

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Adsorption of human immunoglobulin G (IgG) on a commercial cation exchanger with a grafted polymer layer was investigated at pH 4.5 and in the NaCl concentration range of 0–150 mM. Adsorption equilibrium was determined in static batch experiments and verified in batch uptake experiments. Parameters of the Langmuir isotherm were estimated for each salt concentration separately. The batch uptake experiments provided also the estimates of effective pore diffusion coefficients of IgG for individual protein and salt concentrations. The values of the effective pore diffusion coefficient depended strongly on both factors. They increased by about 5–15 times with the NaCl concentration and decreased about three times with the protein concentration. The quality of the estimated parameters was confirmed by frontal experiments described by the general rate model of chromatography.

Keywords: cation-exchange chromatography, grafted tentacle layer, IgG adsorption, Langmuir isotherm, effective pore diffusion coefficient, general rate model

Introduction

Ion-exchange is a leading chromatographic technique used in protein purification. Due to the amphoteric nature of proteins, it is possible to find suitable binding conditions for a cation or anion exchanger. This type of chromatography is often employed in the production of pharmaceutical proteins. Nowadays, ion-exchange chromatography is frequently used in the production of monoclonal antibodies which form a significant section of pharmaceutical industry (Denton et al., 2001; Follman & Fahrner, 2004; Necina et al., 1998; Shukla et al., 2007).

In the industrial ion-exchange chromatography, there is a strong demand for adsorbents with high binding capacity as well as with fast mass transfer. In case of protein chromatography, the rate-limiting factor is typically pore diffusion (Melter et al., 2008; Yao & Lenhoff, 2006). The diffusion of large molecules inside the limited space of pores is restricted due to the steric hindrance and hydrodynamic drag. The exclusion effect can be enhanced since both the pore surface and the protein are charged and additional repulsion can occur. Antibodies are large proteins and their binding at the pore mouth may severely limit their transport inside the pores (Harinarayan et al., 2006; Ljunglöf et al., 2007; Wrzosek et al., 2009; Zydney et al., 2009). The knowledge of the mass transfer rate of antibodies is therefore of special importance.

The mass transfer kinetics of ion exchangers with a grafted polymer layer has been investigated intensively in recent period (Lenhoff, 2011). The exact transport mechanism and interpretation of uptake experiments are a subject of ongoing discussion. In these materials, charged groups are attached to flexible spacer arms called tentacles which ensure an increased binding surface and adsorption capacity. Such structure enables binding of a protein through multi-

*Corresponding author, e-mail: milan.polakovic@stuba.sk