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Adsorption kinetics of lysozyme on multi-walled carbon nanotubes and amino functionalized multi-walled carbon nanotubes from aqueous solution

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ABSTRACT

In this work, adsorption capacity of egg whites lysozyme on multi-walled carbon nanotubes (MWCNTs) and amino group functionalized multi-walled carbon nanotubes (MWCNT-NH_2) was examined. The different parameters affecting the adsorption process for protein were optimized such as initial protein concentration, contact time, initial pH levels, and temperature. Results revealed that optimum time for adsorption process onto the surface of both studied adsorbents was 12 min while the best pH values and temperature were found at 6 and 298 K, respectably. Different kinetic models were assessed such as the intra particle diffusion, the pseudo-first-order, and the pseudo-second-order models. Adsorption of lysozyme onto MWCNT and MWCNT-NH_2 surfaces were found to be well fitted by the pseudo-second order kinetic model because of its high correlation coefficients (R^2) and the low chi-square statistic (X^2) values.

1. Introduction

Lately protein adsorption on solid surfaces has received increased attention due to its applications in biotechnology, medicine, food technology, and diagnostics [1–5]. Some of techniques that have been used for these studies include fluorescent tagging, radio labeling, adsorption, surface characterization methods, and spectroscopic methods [1]. Adsorption phenomenon has received the most attention in this regard [4].

About the 129 amino acids formed is the lysozyme which includes 12 anionic residues and 18 cationic residues [6]. Lysozyme is the protein present in egg white of hens which is considered in this study because at the molecular level the characteristics structural of this macromolecule are well-known [7]. One of the commercially important enzymes is lysozyme that can be found in wide range of sources of biological origin. Lysozyme has been found in egg white of goose and chicken, tissues of animal, tear fluid, human saliva, in reptiles, and insect's plants [6, 7].

Adsorption process has received a wider attention for the treatment of waste effluents mainly because of its high efficiency, lower cost, simple operation and also for its resistance towards harmful substances. Thus, the adsorption process was selected for the approach applied for the treatment of protein from wastewater [8–10].

In a number of disciplines such as: nanotechnology, biotechnology, biochemical, biomedicine and environment science, the nature of interaction between proteins and the sorbent surface is a fundamental phenomenon. Various modeling and experimental studies have been undertaken to understand the interaction on the surface of proteins [10]. Various types of interactions that are known to exist between the surface of the protein and that on the adsorbent include van der Waals bonding, H bonding, electrostatic, hydrophobic forces as well as physical and chemical interactions [11]. The adsorption of proteins is affected by various factors like protein concentration, shape and size of the protein, chemistry of the solid surface, hydrophilic or hydrophobic properties, amino acid composition, surface charge, pH, temperature, protein solution composition, and ionic strength of solution [11–15].

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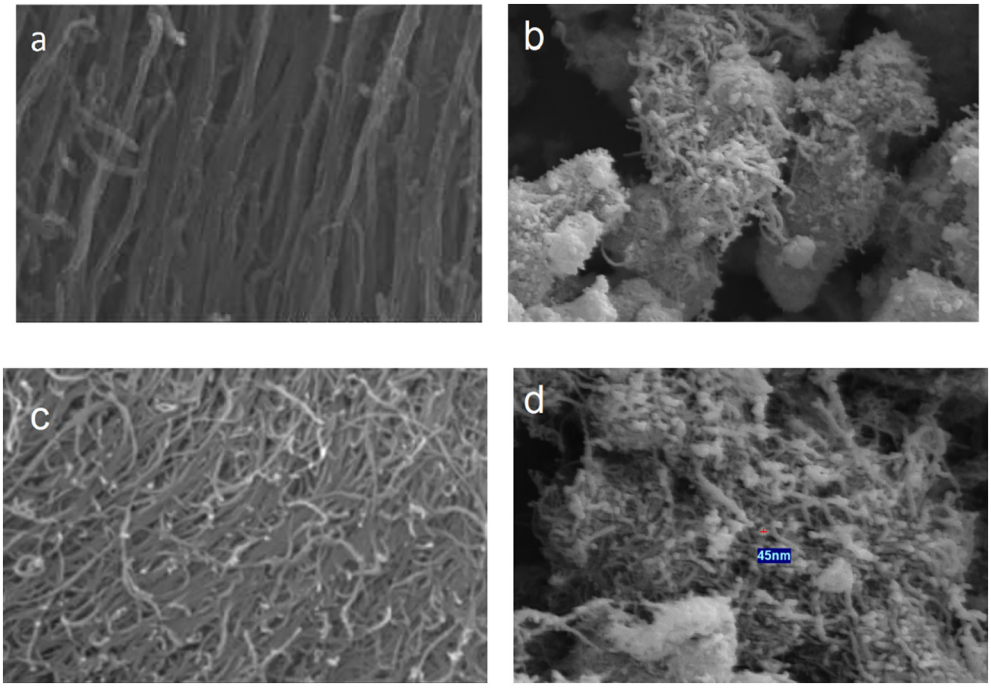

Fig. 1. SEM images (a). MWCNT before adsorption 20000× (b). MWCNT after protein adsorption 20000× (c). Amino-MWCNT before adsorption 25000× (d). Amino-MWCNT after protein adsorption 40000×.

The present work deals with assessing the capacity of adsorption of lysozyme protein onto MWCNT and amino functionalized MWCNT adsorbents. The effect of contact time and the concentration of the adsorbate on the adsorption process were studied. Different kinetic models were tested on the adsorption process viz. the intra particle diffusion, the pseudo-first-order, and the pseudo-second-order kinetic models. Lysozyme adsorption onto both studied adsorbents was found to be well fitted and was in good agreement with the pseudo-second order kinetic model.

2. Experimental

2.1. Materials

MWCNTs had a purity of >95%. Its dimension revealed an outer diameter of 8–15 nm, inner diameter of 3–5 nm, length of 50 μm, and a special surface area > 223 m^2/g. It had a tap density of 0.15 g/cm^3,true density of 2.1 g/cm^3, and conductivity of electric >100 s/cm. MWCNT-NH_2 had a NH_2 content of 0.45 wt% with a purity >95%. Dimensional analysis revealed an outer diameter of 8–15 nm, inner diameter of 3–5 nm, 50 μm of length, and a special surface area > 223 m^2/g. Both adsorbents were purchased from the Neutrino Company and were manufactured in China using the catalytic chemical vapor deposition (CVD) method. Egg whites lysozyme (L7651) was procured from Sigma (Germany) and was studied as adsorbate in the present study. Deionized water was used for the preparation of solution. Phosphate buffers with pHs of 4, 7, and 10 were used to investigate desorption.

2.2. Methods

Different protein amounts were dissolved in deionized water to prepare varying adsorbate concentrations (10 to 50 mg/L). 0.02 g of two adsorbents (MWCNT-NH_2 and MWCNTs) was suspended in 20 mL of the prepared protein solution. Kinetics of adsorption was studied at fixed pH 6 and temperature of 293 K by mixing 20 mL of lysozyme solution with 20 mg of different adsorbents at different time intervals (3–18 min). For subsequent protein concentration analysis the samples of protein solution were centrifuged at 4000 rpm and the supernatant was filtered in 0.2 μm filter paper. The remaining concentration of protein in aqueous suspension was determined by UV–vis

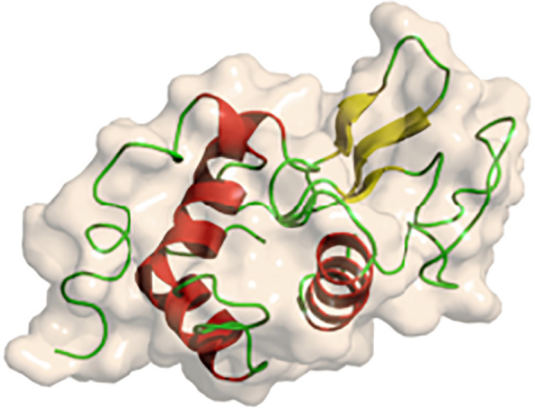

Fig. 2. Available structure of lysozyme.

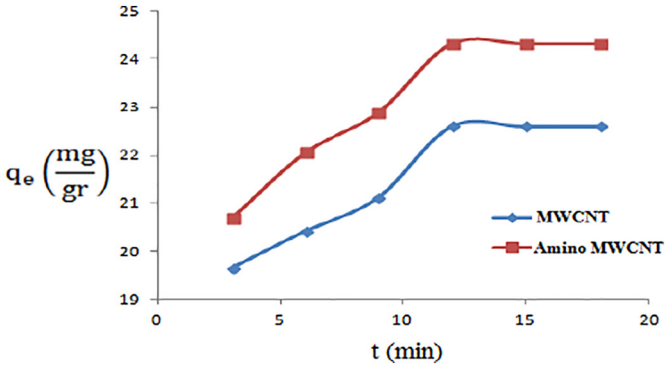

Fig. 3. Effect of contact time on adsorption of lysozyme on MWCNTs and MWCNT-NH2 surfaces. Adsorbents dosage = 20 mg, initial pH 6, initial concentration of lysozyme = 30 mg/L and T = 293 K.