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ORIGINAL ARTICLE

Optically active: microwave-assisted synthesis and characterization of L-lysine-derived poly (amide-imide)s

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Abstract L-lysine hydrochloride was transformed to ethyl L-lysine dihydrochloride. This salt was reacted with trimellitic anhydride to yield the corresponding diacid (**1**). Microwave-assisted polycondensation results a series of novel Poly (amide-imide)s ($\mathbf{PAI_{a-i}}$). These polymers have inherent viscosities in the range of 0.23–0.66 dl g^{-1}, display optical activity from +8.02 to +15.11 (as there is no obvious regioselectivity between alpha and epsilon amino groups of the chiral diacid during the polymerization step then random orientation of diacid moieties along the polymer backbone can be predicted and the concept of "tacticity" cannot be addressed in this research), and are readily soluble in polar aprotic solvents. They start to decompose ($T_{10\%}$) above 362°C and display glass-transition temperatures at 119–153°C. All of the above polymers were fully characterized by UV, FT-IR and ^1H NMR spectroscopy, elemental analysis, thermogravimetric analyses, DSC, inherent viscosity measurement and specific rotation.

Keywords Thermal properties · Optically active · L-lysine · Poly (amide-imide) · Microwave-assisted polymerization

Introduction

The interest for developing new biodegradable and/or biocompatible polymers, especially polyesters and polyamides, has largely encouraged the use of monomers based on naturally occurring products (Gonsalves and Mungara 1996; Steinbuchel 2002). Both carbohydrate- (Thiem and Bachmann 1994; Varela and Orgueira 1999) and amino acid- (Gonsalves and Mungara 1996) derived monomers are being currently used as building blocks to generate novel polymeric structures with enhanced biodegradability.

L-Lysine in particular has been repeatedly used for making polyamides with potential as biomaterials (Gachard et al. 1997; Saotome and Schultz 1967; Crescenzi et al. 1968; Katsarawa et al. 1985; Espartero et al. 1993). For instance, L-lysine with good functionalities has been used to prepare some polytartaramides (Majo et al. 2004).

Optically active polymers are one of the most important classes of high performance engineering materials which are suitable candidates for use as the chiral stationary phases in high performance liquid chromatography (HPLC) (Nakano 2001; Cirilli et al. 2003; Coa et al. 2007; Mallakpour and Kowsari 2005; Yuan et al. 2005) as well as asymmetric catalysis applications (Itsuno 2005; Hu et al. 2001, 2002; HB et al. 2000; Canali et al. 1999). The synthesis and application of these polymers is a considerable topic, which has been paid more attention recently (Hajipour et al. 2005). Most of the natural polymers are optically active and have special chemical activities, such as catalytic properties that exist in genes, proteins and enzymes. Some other applications are construction of chiral media for asymmetric synthesis, chiral stationary phases for resolution of enantiomers in chromatographic techniques (Akelah and Sherrington 1981), chiral liquid crystals in ferroelectrics and nonlinear optical devices

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due to anthropogenic activities and from natural sources [2]. Copper and zinc are some of the metals that are necessary for living organisms, but they become toxic at higher concentrations. Therefore, remediation of contaminated aquatic resources is important for healthy living. In this work we used fine powder of *Typha latifolia* L. root as an alternative low-cost sorbent for removal of heavy-metal ions such as Cu(II) and Zn(II) ions from aqueous solutions. *T. latifolia* L. plant, commonly known as cattails or bulrush, can grow in a mixture of mature sewage sludge compost, commercial compost, and perlite (2:1:1 by volume) [3]. Previous studies by other researchers have shown that various parts of this biomass have a capacity for taking heavy metals from liquid environments without serious physiologic damage to their tissues. It has been reported that the uptake of metal ions by this plant is highest in the root section [4, 5]. Recently, some scientists have used cheaper substances such as algae, peat, moss, *Carex*, fern, and fungi rather than activated carbon as adsorbents for removal of heavy-metal ions and dyes from polluted water [6–8]. Moreover, adsorption is nowadays one of the most efficient methods among various techniques to take heavy metals from effluents [9]. On the other hand, expensive techniques such as electroplating, evaporation, ion exchange, chemical precipitation, membrane filtration, oxidation/reduction, and electrolysis may generate hazardous byproducts [10, 11]. A survey of the literature shows that several biologic species have been investigated for sorption of different heavy-metal ions, but that no work has been done on the kinetics and isotherms of sorption of heavy-metal ions by *T. latifolia* L. biomass. Therefore, we were interested in researching this topic. Up to now, all relevant studies aimed to determine the high capacity of *T. latifolia* to take metal ions from contaminated solids and water. In all cases the results have indicated that cattails have considerable ability to adsorb and tolerate pollution from the environment [12–16]. Thus, the aim of this study is to characterize the effects of pH, contact time, initial concentration of metal ion, and ammonium acetate buffer on the adsorption of Cu^{2+} and Zn^{2+} ions by *T. latifolia* L. root. We also evaluated the parameters in relation to the adsorption kinetics and isotherms in two separate series of experiments, performed in the presence and absence of ammonium acetate buffer respectively. The results showed that ammonium acetate buffer has a strong effect on the kinetics and isotherm parameters.

Materials and methods

Biomass preparation

The biomass sampling site is located at Baliqly Chay River sediments, in Ardabil City, Iran, being one of the main river channels of Khazar Lake in the north of Iran. This biomass is one of the aquatic plants that grows widely along this river. The plant samples were collected, and the root section was separated from other tissues (leaf, stalk, and rhizome). The root samples were thoroughly washed with tap water to remove dirty materials from their surfaces, followed by distilled water. Then, a certain amount of washed biomass was soaked in 2 L of 0.01 M H_2SO_4 solution to