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Bactericidal and ammonia removal activity of silver ion-exchanged zeolite

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ABSTRACT

The antimicrobial activity of silver-zeolite against *Escherichia coli*, *Vibrio harveyi*, *Vibrio cholerae* and *Vibrio parahaemolyticus* was examined in liquid medium and agar well diffusion assays. The minimum inhibitory concentration for silver ion-exchanged zeolite against *E. coli* and *V. harveyi* was 40 μg/ml, and 50–60 μg/ml for *V. cholerae* and *V. parahaemolyticus*. The diameter of the inhibition zones for *E. coli*, *V. harveyi*, *V. cholerae* and *V. parahaemolyticus*, respectively, increased from 0.5 to 2.3 cm, 0.6 to 2.4 cm, 0.3 to 1.65 cm and 0.3 to 1.7 cm with increasing concentrations of silver ion-exchanged zeolite from 10 to 400 μg. Silver-zeolite removed 20–37% ammonia from aqueous solutions. This study suggests that silver ion-exchanged zeolite could impact disease and environmental management in shrimp aquaculture.

1. Introduction

Although *Vibrio* species such as *Vibrio harveyi, Vibrio parahaemolyticus, Vibrio vulnificus* and *Vibrio cholerae* are considered to be mostly opportunistic pathogens in aquatic environments (Lightner, 1996; Karunasagar et al., 1994), vibriosis has caused mass mortality of the shrimp *Penaeus monodon* reared in hatcheries and grow-out farms (dela Pena et al., 1993; Haldar et al., 2010). The presence of *V. parahaemolyticus* and *V. cholerae* in shrimp is a human health concern since these bacteria can cause acute gastroenteritis (Spite et al., 1978). Chemical control of *Vibrio* contamination is difficult (Baticados et al., 1990) and there is a need to find new types of safe and cost-effective materials for eliminating and controlling the spread of such pathogens in foods or food processing environments.

Nanomaterials have increasingly been used in water treatment because of economical and environmental viability and wider availability (Zhang et al., 2011; Ali et al., 2010; Cheung, 2009; Watlington, 2005). Antibacterial materials can be prepared by combining silver with organic or inorganic matrixes by adsorption, grafting or other methods (Rivero et al., 2011; Park et al., 2003; Rivera-Garza et al., 2000). Silver nanoparticles have emerged with diverse medical applications (Marini et al., 2007; Rai et al., 2009) such as silver based dressings, silver-coated medicinal devices and nanogels and nanolotions with broad antibacterial spectrum. Inorganic composites were developed by loading silver onto various carriers such as zeolites, SiO_2, carbon fibres and montmorillonite (Beving et al., 2008).

Zeolites are three-dimensional, microporous and crystalline solids, which have increasingly been used in water treatment because of their ion exchange properties and thermal stability (Auerbach et al., 2003). In addition, modifications of the surface and pores of zeolites make them attractive candidates for various applications. For example, clinoptilolite has been studied for the selective removal of ammonium ions (Jama and Yücel, 1989; Langella et al., 2000; Wang et al., 2011). There are several studies concerned with the use of synthetic and natural zeolites: A, X, Y, Z, and clinoptilolite supporting metal ions as bactericides for water disinfection. Ayben and Ulku (2004) have investigated silver, zinc and copper exchange properties of the sodium form of clinoptilolite and proposed silver-zeolite as low cost antibacterial material. Shameli et al. (2011), Kawahara et al. (2000) and Kwakye-Awuah (2008) also evaluated antibacterial activity of silver-zeolite against Gram positive and Gram negative bacteria. The antimicrobial property of silver is related to the amount and rate of silver released. Silver in its metallic state is inert but ionized silver is highly reactive as it binds to tissue proteins, nuclear membranes, and bacterial cell walls, leading to cell distortion and death. The commercial product, Zeomic, which is known as silver-exchanged synthetic zeolite A, has been used as a sterilizing and antibacterial agent in such items as paper, plastic, paint, and ceramics (Mumpton, 2000). The Mexican silver clinoptilolite-heulandite mineral was reported to eliminate *Escherichia coli* and *Streptococcus faecalis* from water, suggesting further studies in this field (Rivera-Garza et al., 2000). However, reports on the bactericidal activity against shrimp pathogenic bacteria and ammonia removal capability of silver ion-exchanged zeolite for aquaculture use are not available. In the present study, the antimicrobial effects of silver ion-exchanged

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