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Regular Article

Evaluation of nonionic surfactant modified montmorillonite as mycotoxins adsorbent for aflatoxin B_1 and zearalenone

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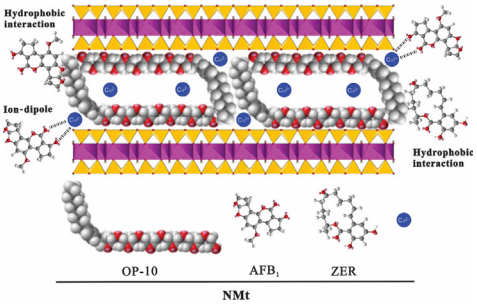
GRAPHICAL ABSTRACT

Polar mycotoxin AFB_1 can be captured by the exchangeable cations through ion-dipole interactions and the organic carbon chains through hydrophobic interaction. Low polar, hydrophobic mycotoxin ZER was mainly adsorbed through hydrophobic interaction.



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ABSTRACT

This work aims at exploring the potential of nonionic surfactant octylphenol polyoxyethylene ether (OP-10) modified montmorillonites (NMts) as mycotoxins adsorbent. The resulting NMts has different structural configurations, organic carbon contents, surface hydrophobicity and textural properties at different surfactant loadings. The prepared NMts were used for adsorption of polar aflatoxin B_1 (AFB_1) and weak polar zearalenone (ZER) in both single and binary-contaminate systems by simulating conditions of gastrointestinal tract. The adsorption capacities of NMts to AFB_1 and ZER increased up to 2.78 and 8.54 mg/g respectively from 0.51 and 0.00 mg/g of raw montmorillonite (Mt). High adsorption capacities of NMts to AFB_1 and ZER could be reached at low surfactant loadings. There was little decrease from pH of 3.5 to 6.5 but became negligible with increasing the surfactant loadings. In binary-contaminate adsorption system, the adsorption of ZER was obviously affected by the existence of AFB_1, while ZER had little effect on the adsorption process of AFB_1 due to different adsorption mechanism. This study demonstrates that NMts could be a promising adsorbent for simultaneous detoxification of polar and non-polar mycotoxins.

1. Introduction

The worldwide contamination of animal feeds, cereal grains and foods intended for human consumption with mycotoxins has been a long-lasting significant problem [1]. It has been estimated that

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almost 25% of food crops over the world are contaminated with mycotoxins each year [2–4]. Mycotoxins are a large group of secondary metabolic products from fungi, or molds, which pose huge health threat to animals and humans due to their mutagenicity and carcinogenicity [5,6]. Moreover, mycotoxins bring enormous economic losses in food industry and animal husbandry annually. Thus, strategies to eliminate or inactivate mycotoxins in foods and feeds which are highly toxic to human and animals remain a research priority.

Several techniques including biological degradation, extrusion cooking, ammoniation and ozonation have been developed for the treatment of mycotoxins [7,8]. However, they have some limitations such as low efficacy, long time treatment, losses in the nutritional value and the palatability of feeds, as well as the expensive equipment required to implement these techniques. Using mycotoxins adsorbents to bind mycotoxins in gastrointestinal tract of animals and then decrease their bioavailability and toxicities has been regarded as the most promising and economical approach to detoxifying mycotoxins contaminated animal feedstuffs [9,10]. Recent studies applying zeolite [11], montmorillonite [12,13], halloysite [14], talc and diatomite [15] for detoxification of mycotoxins suggest the potential of natural minerals as mycotoxins adsorbents. Of particular note in the regard is montmorillonite (Mt), an aluminum silicate possessing a permanent negatively charged surface and exchangeable cations in the interlayer space. Reports show that Mt has excellent effectiveness in binding polar aflatoxins and reducing their toxicity [16–21]. However, the hydrophilic negatively charged surface of Mt is less effective in binding low polar, hydrophobic mycotoxins such as zearalenone and ochratoxin [7,11].

Organic modification of clay minerals with cationic surfactant is another strategy to improve the affinity of adsorbents to non-polar or weak polar mycotoxins. Unfortunately, few studies can be founded for the detoxification of polar aflatoxins using organic clay to the best of our knowledge. Simultaneous detoxification of mycotoxins with different polarities remains a critical unmet challenge.

More recently some groups have explored amphiphilic surfactants such as nonionic and zwitterionic surfactants for simultaneous adsorption of hydrophilic heavy metal ions and hydrophobic organics [22–25]. These pioneering studies give us new inspiration of utilizing amphiphilic surfactants to modify Mt for simultaneous adsorption of mycotoxins with different polarities. Despite the popularity of amphiphilic surfactant modified Mts used in environmental recommendation, no studies have yet successfully applied amphiphilic surfactant modified Mts as mycotoxins adsorbents for the simultaneous detoxification of different kind of mycotoxins.

Here we use the nonionic surfactant octylphenol polyoxyethylene ether with 10 CH_2CH_2O radicals (OP-10) as a modifier to develop a novel Mt-based mycotoxins adsorbent (NMt). The structure configurations and organic contents of NMts were detected with XRD and TG techniques. The surface hydrophobicity was deduced from moisture adsorption capacity. And the porous nature of NMts was measured from N_2 adsorption–desorption isotherms. The potential of NMt as mycotoxins adsorbent was examined with the adsorption properties of polar aflatoxin B_1 (AFB_1) and weak polar zearalenone (ZER). The molecular structures of AFB_1 and ZER are displayed in Fig. 1, the dipole moment of which is 9.5 and 2.2 D, respectively.

2. Materials and methods

2.1. Materials

The montmorillonite (Mt) with a cation exchange capacity (CEC) of 68.29 meq/100 g used in this study is supported by Baifubang Mining Fertilizer Co. Ltd. from Neimenggu province, China. It was ground into powder to pass through 200 mesh after being received. It contains very little quartz but no organic matter. And no excess hazardous heavy metals and dioxin are detected too in raw Mt, which meets the requirements of feed additives. The nonionic surfactant used in this study is octylphenol polyoxyethylene ether (OP-10) obtained from Usolf Chem. Co., China with a purity of 99%. Mycotoxins aflatoxins B_1 (AFB_1) and zearalenone (ZER) were purchased from Fermentek Co. Ltd, whose purity is above 99.5% analyzed by HPLC method. Other chemical reagents such as phosphoric acid, sodium phosphate monobasic, disodium phosphate, acetonitrile and methyl alcohol were all purchased from Beijing Reagent Co. (Beijing, China). Acetonitrile and methyl alcohol are chromatographic grade, and other reagents are analytical grade. All reagents are used as obtained without further purification.

2.2. Preparation of NMts

The NMts were prepared using an ultrasonic bath method. Firstly, 4 g of Mt was dispersed in 300 mL of deionized water and stirred 0.5 h to form a homogeneous clay dispersion at room temperature. A stoichiometric amount of surfactants were firstly dissolved in 100 mL of deionized water and then slowly introduced to the clay suspension using a peristaltic pump. The mixtures were treated for 0.5 h at 60 °C on a Geneng G-020 ultrasonic bath with ultrasonic power of 120 W and frequency of 40 kHz, and then stirred for another 24 h at room temperature with a Kexi magnetic

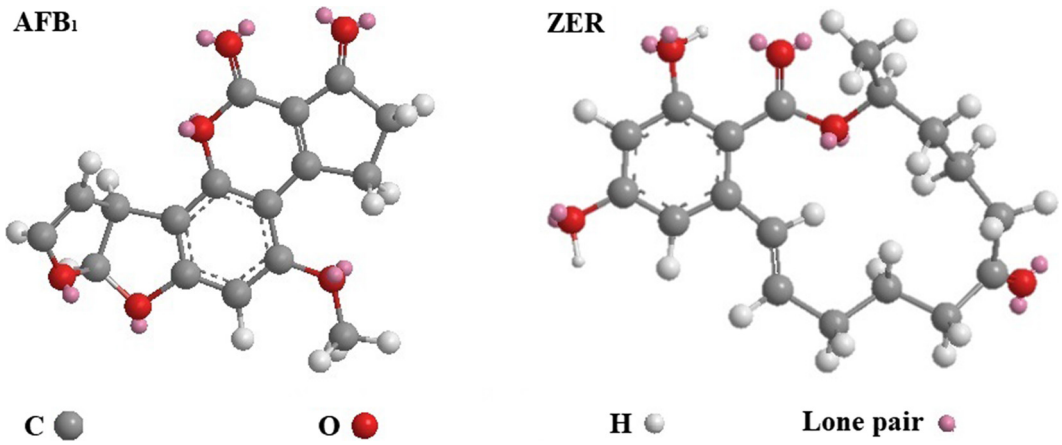

Fig. 1. Molecular structural information of AFB_1 (polar mycotoxin, dipole moment: 9.5 D) and ZER (weak polar mycotoxin, dipole moment: 2.2 D).