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Biodegradation and detoxification of bisphenol A with one newly-isolated strain *Bacillus* sp. GZB: Kinetics, mechanism and estrogenic transition

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ABSTRACT

A facultative anaerobic bacterial strain, *Bacillus* sp. GZB, was isolated and identified to effectively degrade bisphenol A (BPA) under anaerobic and aerobic conditions. Under anaerobic condition, Fe^{3+} can be used as an electron acceptor for *Bacillus* sp. GZB, while 5 mg L^{-1} BPA can be fully removed and 51% was mineralized under optimal aerobic conditions. Additionally, seven metabolites were identified by GC–MS, four of which were doubly confirmed by authentic standards (two synthesized) and three of four initial degradation intermediates were also quantified during BPA aerobic degradation. The evolution of 1-(4-hydroxyphenyl)ethanone showed a similar tendency with estrogenic activity changing during BPA biodegradation course, indicating its potential estrogenicity. The estrogenicity temporary increase first and decline ultimately during BPA degradation revealing the GZB can effectively detoxify BPA as well as its estrogenic intermediates. This was the first study to report a facultative anaerobic strain can degrade BPA with or without of oxygen.

1. Introduction

Bisphenol A (BPA), one of the highest production volume chemicals (Burridge, 2003), is widely used as an intermediate in the synthesis of polycarbonate plastics, epoxy resins and flame retardants (Staples et al., 1998). As a frequently detected environment pollutant, BPA was not only found in the environmental samples, such as water, sludge and air (Khim et al., 2001; Zafra et al., 2003), but also in the biological samples as well as human tissues (Vandenberg et al., 2007). Unfortunately, more and more evidence revealed that BPA might cause reproductive toxicity because of its estrogenic activity (Hu et al., 2002). Although the affinity of BPA for estrogen receptors is five to six orders weaker than that of estradiol which was the most potent estrogen (Rehmann et al., 1999), it may still stimulate cellular responses and altered cell functions at very low concentration (Wetherill et al., 2007). Therefore, the study of BPA degradation and detoxification was essential to avoid the potential of reproductive disturbance.

Up until now, most BPA degradation studies were mainly focused on the oxidation reaction including photodegradation (Nomiyama et al., 2007; Ohko et al., 2001) and biodegradation (Kolvenbach et al., 2007; Yamanaka et al., 2007; Yim et al., 2003). The organisms such as fungi (Kabiersch et al., 2011), plant-cultured cells (Saiyood et al., 2010) as well as bacteria (Kang and Kondo, 2002a,b; Lobos et al., 1992; Yamanaka et al., 2007) can all be used as biocatalysts for BPA biodegradation. However, all the biodegradations above were carried out under aerobic condition, and no reference reported the capability of both aerobic and anaerobic degradation of BPA by one facultative anaerobe. As far as was known, BPA is an important degradation intermediate of tetrabromobisphenol-A (TBBPA) from the reductive debromination (An et al., 2011a), and the possibility of BPA anaerobic degradation may offer an alternative way for TBBPA biodegradation since it is difficult to biodegrade BPA during TBBPA anaerobic debromination process (Ronen and Abeliovich, 2000). Thus, the isolation of one facultative anaerobe will be of interest for the biodegradation of BPA as well as TBBPA in water environments.

Moreover, not only BPA, as an estrogen disrupter, but also its degradation intermediates exhibited estrogenic activity (Nomiyama et al., 2007). For example, BPA could be metabolized into 4-methyl-2,4-bis(*p*-hydroxyphenyl)-pent-1-ene (MBP) by rat liver S9 fraction (Yoshihara et al., 2004), which showed a strong estrogenic activity to Japanese medaka fish *in vivo* (Ishibashi et al., 2005). Therefore, some researchers assessed the transitions of estrogenic activity during BPA photodegradation course (Nomiyama et al., 2007; Ohko et al., 2001), and one report found that the intermediates produced by the photo-oxidation of BPA exhibited

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