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Utilization of simulated flue gas for cultivation of *Scenedesmus dimorphus*

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HIGHLIGHTS

- ► *Scenedesmus dimorphus* showed excellent tolerance to high CO_2 (2–20%) and NO concentrations (150–500 ppm).
- ► The maximum SO_2 concentration *S. dimorphus* could tolerant was 100 ppm.
- ► The extremely low pH as well as the accumulation of bisulfite caused by SO_2 inhibited algae growth.
- ► By neutralization with $CaCO_3$, *S. dimorphus* could grow well on flue gas.
- ► The toxicity of flue gas could be overcome by intermittent sparging and CO_2 utilization efficiency was enhanced.

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ABSTRACT

Effects of flue gas components on growth of *Scenedesmus dimorphus* were investigated and two methods were carried out to eliminate the inhibitory effects of flue gas on microalgae. *S. dimorphus* could tolerate CO_2 concentrations of 10–20% and NO concentrations of 100–500 ppm, while the maximum SO_2 concentration tolerated by *S. dimorphus* was 100 ppm. Addition of $CaCO_3$ during sparging with simulated flue gas (15% CO_2, 400 ppm SO_2, 300 ppm NO, balance N_2) maintained the pH at about 7.0 and the algal cells grew well (3.20 g L^{-1}). By intermittent sparging with flue gas controlled by pH feedback, the maximum biomass concentration and highest CO_2 utilization efficiency were 3.63 g L^{-1} and 75.61%, respectively. These results indicated that *S. dimorphus* could tolerate high concentrations of CO_2 and NO, and the methods of $CaCO_3$ addition and intermittent sparging have great potential to overcome the inhibition of flue gas on microalgae.

1. Introduction

CO_2 fixation by microalgae is seen as an economically feasible and environmentally sustainable way to mitigate CO_2 emissions and to generate biomass for the productions of biofuels and other chemicals. At least 1.83 tons of CO_2 are needed for obtaining 1 ton of algal biomass (Ho et al., 2010a). Consequently, coupling the cultivation of microalgae with bio-fixation of the CO_2 in flue gas from combustion sources has the potential not only to reduce the cost of microalgae production on an industrial scale but also to offset carbon emissions (de Morais and Costa, 2007a; Hughes and Benemann, 1997). Typical flue gas emitted from combustion sources contains 10–15% CO_2, and 100–300 ppm NO_X and SO_X (Lee et al., 2002). Some species of microalgae showed little growth inhibition at the typical CO_2 percentages in flue gas (Hanagata et al., 1992; Ho et al., 2010b; Tang et al., 2010), but some other studies showed that growth of microalgae was inhibited at CO_2 concentrations above 5% (Chiu et al., 2008; de Morais and Costa, 2007a,b). In contrast, the SO_X and NO_X in flue gas, especially from coal-fired power plants, impose more serious inhibition on microalgae (Lee et al., 2002; Negoro et al., 1991). When sparged with a gas mixture containing 300 ppm NO, the growth of *Chlorella* KR-1 was suppressed (Lee et al., 2002), and *Nannochloris* sp. (NANNO02) showed some growth only after a considerable lag time (Negoro et al., 1991). Sulfur oxides, particularly SO_2, cause a dramatic decline in pH of the culture medium (Lee et al., 2002; Meada et al., 1995). When the SO_2 concentration reaches 400 ppm, the medium pH decreases to below 4 within 24 h, significantly reducing the growth rate of microalgae (Matsumoto et al., 1997). Growth of *Nannochloris* sp. (NANNO02) was strictly inhibited within 20 h at SO_2 concentration of 300 ppm (Negoro et al., 1991).

Several attempts have been made to overcome the toxic effects, more specifically, the acidification of the medium when using flue gas for microalgae cultivation. Some researchers tried to screen NO_X- and SO_X-tolerant microalgae or acidophilic algae, but such algae grew consistently only at concentrations of 50 ppm SO_2 or below (Hauck et al., 1996; Kurano et al., 1995). Some researchers

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