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Note

Effect of the Pore Size of Microfilters in Supercritical CO_2 Bubbling on the Dissolved CO_2 Concentration

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The effect of the pore size of microfilters installed in a supercritical (SC-) CO_2 bubbling device on the concentration of CO_2 dissolved in the solution was investigated. Dissolved CO_2 concentration in the solution treated with a microfilter was approximately 27% higher than that without a microfilter for lower CO_2/sample flow ratio, whereas there was no difference in the dissolved CO_2 concentration between treatments with and without a microfilter at a higher flow ratio. Additionally, at 25 MPa, the dissolved CO_2 concentration reached a maximum with a 10 μm pore size microfilter. However, at 10 MPa, the highest concentration of dissolved CO_2 was achieved with a 1 μm pore size microfilter, and this concentration was the same as at 25 MPa. Therefore, it was found that the same concentration of dissolved CO_2 could be maintained by minimizing the microfilter pore size and lowering the pressure from 25 to 10 MPa.

Keywords: supercritical CO_2 bubbling, the concentration of dissolved CO_2, pore size of microfilters

Introduction

Chlorine and activated carbon are generally used for the sterilization and deodorization of tap water in Japan. However, there is a risk that carcinogenic organochlorine compounds, such as trihalomethanes, would be produced by a reaction between the chlorine and organic compounds (Graham *et al.*, 1989). Furthermore, activated carbon, which is used for deodorization, must be disposed as industrial waste. Previously, we found that supercritical CO_2 bubbling (the SC-CO_2 treatment), which has been investigated as a non-thermal technology for the inactivation of bacteria in food, could be substituted for both chlorine inactivation and deodorization with activated carbon (Kobayashi *et al.*, 2006, 2007). The concentration of dissolved CO_2 in the solution can be increased using microfilters, and the effect of microbial inactivation by the SC-CO_2 treatment is dependant on the concentration of dissolved CO_2 (Shimoda *et al.*, 2001a, 2002; Kobayashi *et al.*, 2007). However, the device was so expensive as to be impractical, as it had to be operated at high pressure. Therefore, it was desired that the concentration of dissolved CO_2 be increased to a level where effective inactivation could be performed at a lower pressure.

At a high-pressure condition of 25 MPa, SC-CO_2 has previous been microbubbled with 10 μm pore size microfilters in order to increase the concentration of dissolved CO_2 in the solution (Ishikawa *et al.*, 1995; Shimoda and Osajima, 2001). However, the effect of microfilters on the concentration of dissolved CO_2 has not yet been reported at a pressure below 25 MPa. Therefore, the aim of this study was to clarify the effect of pressure and the pore size of microfilters installed in the SC-CO_2 device on the concentration of dissolved CO_2 in the solution.

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Materials and Methods

Continuous flow treatment with SC-CO_2 microbubbles The device used in this experiment for continuous flow treatment with SC-CO_2 microbubbles was the same as that described in a previous paper (Kobayashi *et al.*, 2006). SC-CO_2 treatment conditions were as follows: temperature was 35℃; pressures were 10, 20 and 25 MPa; exposure time was 13.3 min; and the CO_2/sample flow rates were 27-71%. The microfilter pore sizes were 1, 5, 10, 100 and 200 μm.

Measurements of the concentration of dissolved CO_2 The concentration of CO_2 dissolved in distilled water was measured as described in a previous paper (Kobayashi *et al.*, 2007) and expressed as Kuenen gas absorption coefficient (γ value), which is defined as the gas volume dissolved in one gram of water under standard conditions (Shimoda *et al.*, 2001a). The coefficient at 35℃ was calculated using the following equation:

$$\gamma = 273\ V_{CO2,\ 35℃}(760 - P_{water,\ 35℃})\ [(273+35)V_{water,\ 35℃}\ 760\ d_{water,\ 35℃}]^{-1}$$

where, $V_{CO2,\ 35℃}$ is the volume of CO_2 dissolved in water at

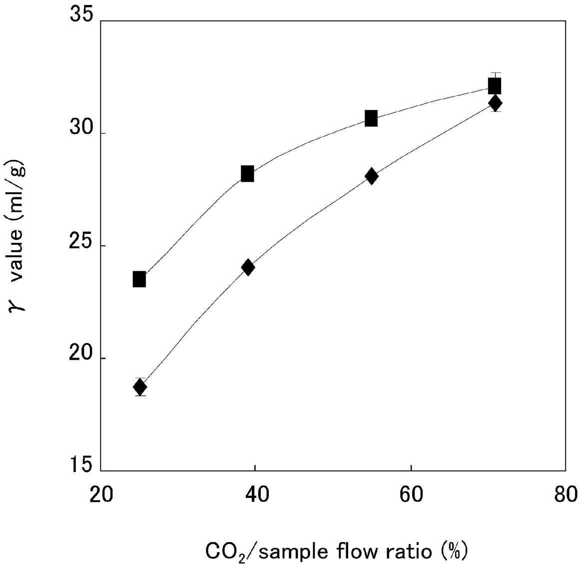

Fig. 1. Effect of microfilter on the concentration of dissolved CO_2 during SC-CO_2 treatment. Temperature, 35℃; pressure, 10 MPa; exposure time, 13.3 min; CO_2/sample flow rate, 27–71%; ■, SC-CO_2 treatment with 10 μm microfilter pore size; ◆, SC-CO_2 treatment without microfilter.

35℃; $P_{water,\,35℃}$ is the saturated water vapor pressure at 35 ℃ (42.180 mmHg); $V_{water,\,35℃}$ is the volume of the treated samples at 35℃; and $d_{water,\,35℃}$ is the water density at 35℃ (0.994 g cm^{-3}). Measurements of the concentration of dissolved CO_2 were done in triplicate. The data in each figure are presented as mean with standard error of the results of triplicate experiments.

Results and Discussion

The effect of microfilter installation on the concentration of dissolved CO_2 during SC-CO_2 treatment is shown in Fig. 1. A 10 μm pore size microfilter, which was reported to produce the highest concentration of dissolved CO_2 under a high pressure condition of 25 MPa (Ishikawa *et al.*, 1995; Shimoda and Osajima, 2001b), was used in this experiment. The concentration of dissolved CO_2 in the solution treated with this microfilter was approximately 27% higher than without a microfilter for a lower CO_2/sample flow ratio, and was achieved more rapidly to an almost saturated level (γ=30 ml/g), indicated by Shimoda *et al.* (2001a). These results indicated the effectiveness of microfilters at increasing the concentration of dissolved CO_2 in the solution, although there was no difference in the concentration of dissolved CO_2 between treatments with and without a microfilter, when there was a higher CO_2/sample flow ratio.

The effect of pressure and pore size of microfilters on the concentration of dissolved CO_2 during SC-CO_2 treatment is shown in Fig. 2. At 25 MPa, the concentration of dissolved CO_2 increased as the pore size of microfilters was lowered from 100 to 10 μm, and then decreased significantly for microfilters with a pore size smaller than 10 μm. This behavior concurs with the results of Shimoda *et al.* (2001b). In contrast, the concentration of dissolved

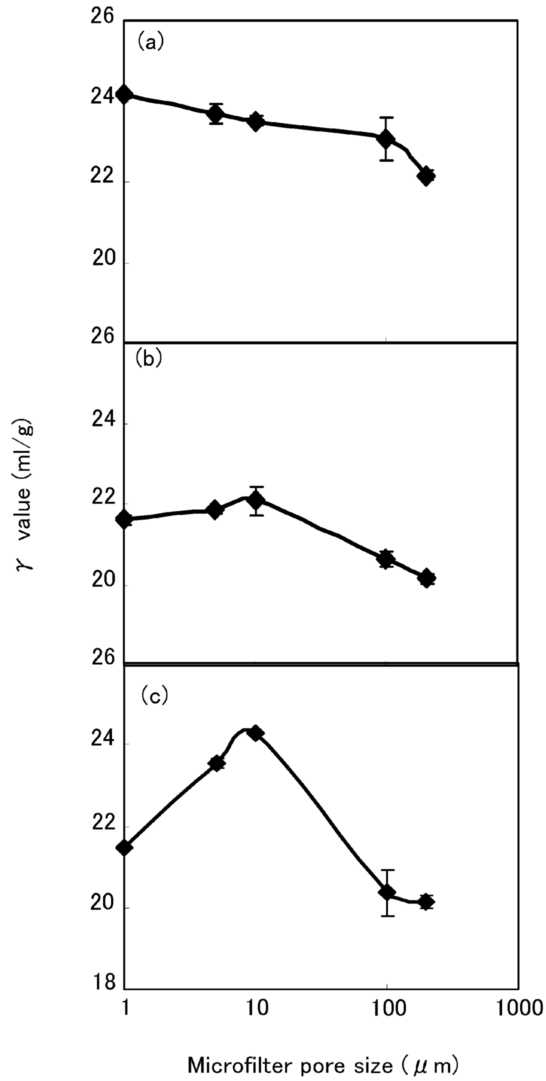

Fig. 2. Effect of pressure and pore size of microfilters on concentration of dissolved CO_2 during SC-CO_2 treatment. Temperature, 35℃; exposure time, 13.3 min; CO_2/sample flow rate, 27%; (a), 10 MPa; (b), 20 MPa; (c), 25 MPa.

CO_2 at 20 MPa was at a maximum for microfilters with a pore size in the 1 to 10 μm range, and at 10 MPa the maximum was at 1 μm, the smallest microfilter pore size. These results suggested that the concentration of dissolved CO_2 increased concomitant with the increasing contact area between SC-CO_2 and the solution, which expanded as the size of CO_2 bubbles became smaller with smaller microfilter pore size. It was found that when the pressure was lowered from 25 to 10 MPa, the concentration of dissolved CO_2 could be maintained by decreasing the microfilter pore size and the highest concentration of dissolved CO_2 at 10 MPa was the same as that at 25 MPa. The exact reason why the concentration of dissolved CO_2 at 10 MPa was higher than that at 20 and 25 MPa with a microfilter pore size of more than 10 μm was unclear. We presumed that the factor was related to the re-fusion of bubbles. We have already reported that the inactivation effect of the SC-CO_2 treatment depends on the concentration of dissolved CO_2 (Kobayashi *et al.,* 2007). Therefore, we suggest that it might be possible to develop a new sterilization system, with an equal effect on microbial inactivation to that of SC-CO_2 treatment at 25 MPa, by minimizing microfilter pore size at pressure of less than 10 MPa.

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