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Effect of Ultrafine Bubbles on Enrichment of Amino Acid in Aqueous Solution by Ultrasonic Atomization
超音波霧化による水溶液中のアミノ酸濃縮に及ぼすウルトラファインバブルの影響

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1. Introduction

When ethanol aqueous solution is atomized by ultrasound, ethanol is enriched in the mist. Ethanol enrichment is attributed to the hydrophobic interaction of ethanol molecules in water.[1)] The advantages of ultrasonic atomization separation are that it is simple to operate, usable with heat-sensitive materials, and requires no maintenance. Recently, Kozuka et al. reported that the use of a horn increased the amount of mist generated by ultrasonic atomization.[2)]

Small bubbles of less than 1 μm in diameter are called ultrafine bubbles.[3)] Ultrafine bubbles are able to stay in water for more than a few months because their rise velocity due to buoyancy is negligibly small. They also have very large specific surface area, are biologically active, and are electrically charged at the surface. Ultrafine bubbles water is attracting attention in many fields such as cleaning, medicine, surface treatment. L-Phenylalanine is a typical essential amino acid that has a phenyl group on its side chain and is used in foods and medicines.

In this study, ultrasonic atomization separation was conducted to L-phenylalanine aqueous solution using atomizer with a horn. By changing flow rate of carrier gas, pH and concentration of sample, and the presence of ultrafine bubbles, L-phenylalanine enrichment characteristics were investigated.

2. Experiment

Fig. 1 shows a photograph of ultrasonic atomizer. The cylindrical vessel was made from transparent acryl resin. The inside diameter and height of vessel were 80 and 250 mm, respectively. The transducer with a horn (Honda Electronics, HMC-2400) was attached at middle of vessel bottom. Ultrasonic frequency was 2.4 MHz. Sample was L-phenylalanine aqueous solution. Initial volume and height of sample was 200 mL and 40 mm, respectively. As carrier gas, dry nitrogen was used and flowed into the center of the vessel from a gas inlet. Mist generated by ultrasonic atomization accompanied by the carrier gas, exited the vessel

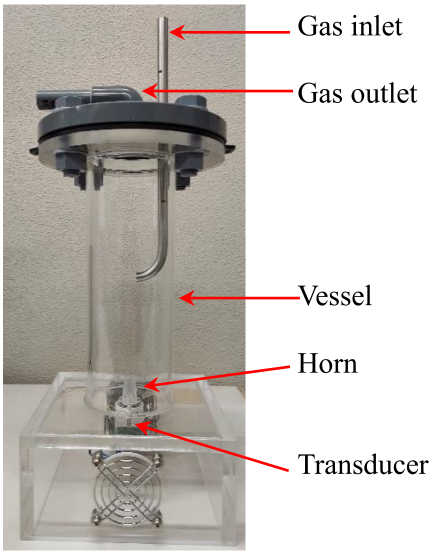

Fig. 1 Photograph of ultrasonic atomizer

from the gas outlet and was collected in a graduated cylinder immersed in liquid nitrogen. The phenylalanine concentration in the collected solution was measured by a UV-visible spectrophotometer (UV-1900, Shimadzu). Mass change of sample during ultrasonic atomization was measured by an electric balance to determine the mass of mist generation.

Sample with ultrafine bubbles was prepared from water with ultrafine bubbles which was generated form ultrapure water (Milli-Q Reference & Elix Essential UV5, Merck) and air by pressurized dissolution method (ultrafineGaLF, IDEC). The number density and mean diameter of ultrafine bubbles in sample measured by nanoparticle tracking method (NanoSight, Malvern) were about 5×10^9 /mL and 100 nm, respectively. The sample pH was changed using sodium hydroxide.

3. Results and discussion

Fig. 2 shows effect of carrier gas flow rate on collection mass and collection ratio of mist. The phenylalanine concertation in solution was 0.2

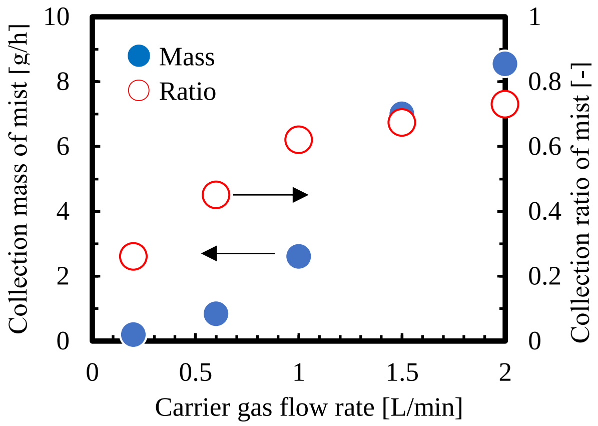

Fig. 2 Effect of carrier gas flow rate on collection mass and collection ratio of mist.

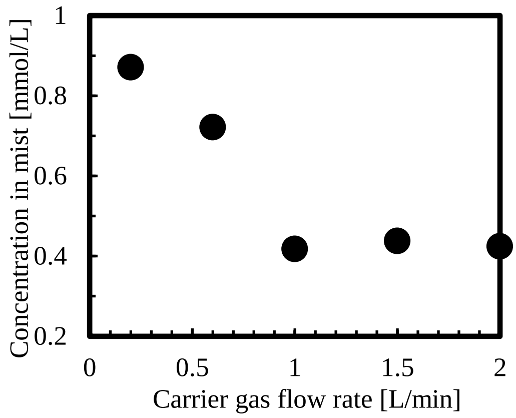

Fig. 3 Effect of carrier gas flow rate on concertation in collected mist.

mmoL/L. The sample pH was 7. As carrier gas flow rate become higher, collection mass of mist increases because large sized droplets also accompany by carrier gas at high flow rate. Since inertial force of droplets is large at high flow rate, collection ratio of mist increases.

Fig. 3 shows effect of carrier gas flow rate on concentration in collected mist. Since phenylalanine concentration is higher than 0.2 mmol/L, that is sample concentration, it is clear that phenylalanine is enriched by ultrasonic atomization. The concentration in mist increases with decreasing carrier gas flow rate. From this result, it is found that concentration in droplets becomes higher as droplet size becomes smaller. Since phenylalanine has hydrophobic group, they attach to droplet surface and enrich in droplets. Smaller droplets have higher phenylalanine concentrations due to the larger ratio of surface area to volume of droplets.

Fig. 4 shows effect of sample pH on concentration in collected mist. Carrier gas flow rate was 1 L/min. The concentration increases with pH. The phenylalanine has amphoteric ion. It is thought that hydrophobic property of phenylalanine becomes stronger as pH increases.

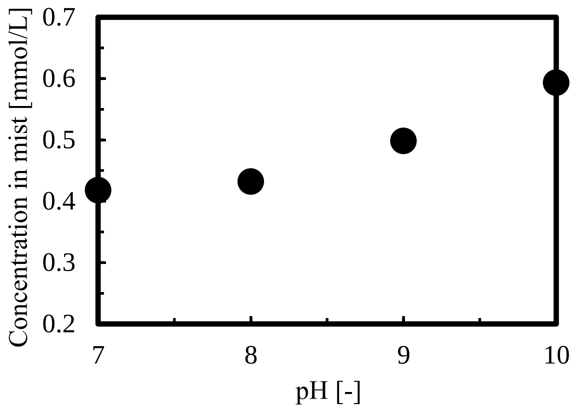

Fig. 4 Effect of sample pH on concertation in collected mist.

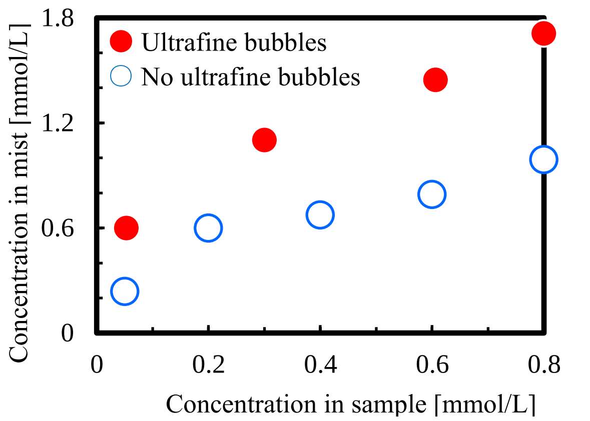

Fig. 5 Effect of concertation in sample on concertation in collected mist with and without ultrafine bubbles.

Fig. 5 shows effect of concentration in sample on concentration in mist with and without ultrafine bubbles. The sample pH was 10. Regardless of concentration in sample, phenylalanine is enriched by ultrasonic atomization. The concentration in mist with ultrafine bubbles is higher than that without ultrafine bubbles. It is thought that ethanol attaches on the surface of ultrafine bubbles, ultrafine bubbles aggregate or coalesce by secondary Bjerknes force, ultrafine bubbles move to liquid surface by radiation force and concentration in droplets increases.

Acknowledgment

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