Encapsulation of Astaxanthin with ß-Cyclodextrin by Utilizing Supercritical Antisolvent (SAS) Process

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1. Introduction

Astaxanthin is a type of carotenoids, which has high antioxidant activity, anti-inflammation effect, anti-diabetic activity, cardiovascular disease prevention, anticancer activity, and immune-system defense preservation[1]. Astaxanthin has low stability and water solubility, which makes it difficult to be used in pharmaceutical and food industries. Encapsulation is one of the strategies to increase the stability and the bioavailability of astaxanthin[2]. ß-cyclodextrin is chosen as an encapsulation material because its high structural stability and bioavailability. The cavity of ß-cyclodextrin enables other substances to enter and form inclusion complex. ß-cyclodextrin is highly soluble in water.

Supercritical antisolvent (SAS) process utilizes supercritical carbon dioxide ($scCO_2$) as an antisolvent to precipitate desirable chemicals and to form micron-sized particles. SAS allows the precipitation of encapsulated astaxanthin without additional step to remove the solvent.

In this study, astaxanthin is encapsulated in ß-cyclodextrin by using the SAS process. Dimethyl sulfoxide (DMSO) is used as the solvent in the preparation of the inclusion complex of astaxanthin and ß-cyclodextrin. The effect of pressure, temperature, initial feed solution concentration, and solution flow rate on the resulting precipitated particle are presented.

2. Materials and Methods

Inclusion complex solution is prepared by mixing astaxanthin and ß-cyclodextrin in DMSO. The inclusion complex solution is then feed into the SAS equipment. The schematic diagram of SAS equipment is shown in the Fig. 1.

Temperature, pressure, initial concentration of feed solution and solution flow are varied. As a comparison, physical mixture is prepared by grinding and mixing astaxanthin and ß-cyclodextrin. Analysis and characterization of the encapsulated astaxanthin including the encapsulation efficiency, particle morphology and size analysis, thermal analysis, and antioxidant content analysis were conducted.

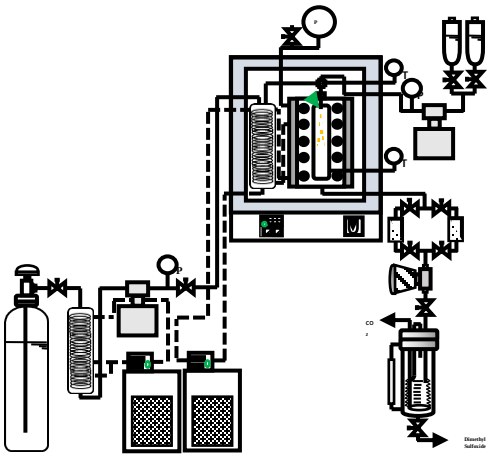

Figure 1. Schematic diagram of supercritical antisolvent (SAS) equipment.

3. Results and discussion

Values of dispersions solubility parameter (δ_D), polarity solubility parameter (δ_P), and hydrogen-bonding solubility parameter (δ_H) of astaxanthin were estimated to be 22.16 $MPa^{1/2}$, 4.55 $MPa^{1/2}$, and 8.88 $MPa^{1/2}$, respectively. Binding energy of the astaxanthin encapsulated in the ß-cyclodextrin is lower than that of free

astaxanthin and ß-cyclodextrin, which indicates that astaxanthin and ß-cyclodextrin will tend to form inclusion complex in DMSO.

The precipitated powder produced by the SAS process exhibited white-to-pinkish color, as shown in Fig. 2. As shown in the FE-SEM images of the encapsulated astaxanthin powder (Fig. 3), spherical shape particles were produced. The highest encapsulation efficiency of 67.2% was achieved at 15 MPa, 40 °C, initial β-cyclodextrin concentration of 50 mg/mL, and solution flow rate of 1 mg/mL. The uniform particle size distribution was achieved at 15 MPa, 40 °C, initial β-cyclodextrin concentration of 30 mg/mL and solution flow rate of 1.2 mg/mL. The decomposition temperature of encapsulated astaxanthin is higher than that of the free astaxanthin, as measured by TGA.

Figure 2. Encapsulated astaxanthin after the SAS process

4. Conclusions

Encapsulated astaxanthin in ß-cyclodextrin powder was produced by utilizing SAS process. The particle size can be controlled by adjusting the pressure, temperature, initial solution concentration and solution flow rate of the SAS process.

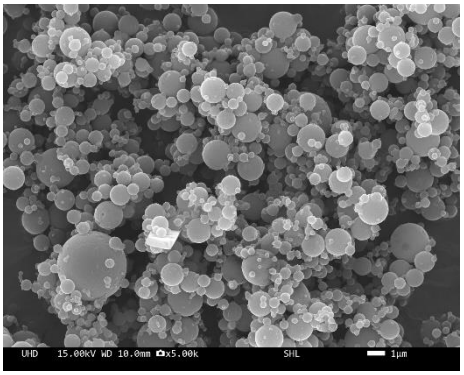

Figure 3. FE-SEM images of encapsulated astaxanthin.

References

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