（第３号様式）(Form No. 3)

学 位 論 文 要 旨
Dissertation Abstract

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学位論文題目：
Title of Dissertation

Microencapsulation of Flavors in *Saccharomyces cerevisiae* by Spray Drying and Characterization of Their Release Behavior
(噴霧乾燥法による酵母へのフレーバー包括粉末化と酵母粉末からのフレーバー徐放特性)

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Flavor compounds in food products hugely influence consumers' satisfaction, taste and other sensorial perceptions. However, they are very prone to occur losses and degradation during processing and storage phase due to their high volatility, and poor stability properties. Microencapsulation overcomes these problems by entrapping flavor compounds within secondary substances and provide the benefits of delivering those flavors at right time with right amount. Compared to other secondary substances (carbohydrate, protein or liposome), *Saccharomyces cerevisiae* cells provide some additional benefits in nutritional perspective and prolong the release or shelf-life of encapsulated flavor. Among the other techniques of flavor encapsulation such as molecular encapsulation, coacervation, fluidized-bed, and extrusion, spray drying is the mostly used efficient technique due to the production of high-quality powder within very short time. Therefore, encapsulation of flavors in *Saccharomyces cerevisiae* cells by spray drying was investigated in this study. The yeast cells used as the encapsulants were by products in the production of β-glucans. *d*-Limonene (log P=4.8) and ethyl hexanoate (log P=2.8) were used as model flavor compounds based on the octanol-water partition coefficient (log P).

The formation of flavor encapsulated yeast cells was prepared by the mixing of yeast, flavor and water in a slurry. Effects of incubation time, temperature, and spray drying conditions on the encapsulated flavor content after spray drying were investigated. The encapsulation rate constant was 0.69 h^{-1} for *d*-limonene and ethyl hexanoate. High contents of both flavors were obtained at an incubation temperature of 40°C for 4 h and an inlet air temperature of 200°C for spray drying (mini spray dryer B-290). Inlet air temperature did not significantly affect encapsulation of flavor content for ethyl hexanoate. Flavor content obtained was 37 wt% for *d*-limonene and 49 wt% for ethyl hexanoate, respectively, at an inlet air temperature 200°C. The

morphology of yeast cells was observed as bubble shaped aggregated structure.

Flavor release kinetics from the yeast were also investigated at 40, 60, 80, and 105°C with different moisture content (0, 50, 100, and 200% of powder). Considering the commercial application, a lab scale pilot spray-dryer was used to encapsulate flavor for this experiment setting the inlet air temperature 160°C. Flavor encapsulated in maltodextrin (MD) (DE=19) were used to compare the release behavior at the same conditions. Water affected flavor release from the yeast cells. The release rate constants were correlated using Gaussian distribution of the activation energy of the release rate constants. The release of *d*-limonene from the spray-dried MD powder showed a different trend than that of yeast cells at various temperatures. The activation energies of the release rate constant for ethyl hexanoate and *d*-limonene from yeast were 55 and 49 kJ/mol, respectively, under a wet condition. The formation rates of limonene oxide and carvone were slower in yeast than that of MD powder at 30°C after 2 months.

Apparent glass transition temperature (T_g), which influences the release of encapsulated flavor, was measured by measuring the flavor release using aroma sensor. The rapid increment in flavor release from the encapsulated powders was monitored using a ramping method (linear programmed temperature gradient). To confirm the apparent T_g of the flavor-encapsulated yeast powders, *d*-limonene and ethyl hexanoate were extracted from yeast cells under ramping temperature conditions (at 1°C/min) and analyzed by GC-FID. The obtained intercepts point from both methods were very similar to the apparent T_g value above 160°C found using the aroma sensor.

Finally, release profiles of encapsulated flavors were investigated under a stepwise humidity changed condition using a home-built dynamic vapor sorption (DVS) system. Relative humidity (RH) was stepped from 20 to 50, 60, 70, and 80% at individual incubation temperature of 30, 40, 50, and 60°C. The maximum release flux was obtained at 60°C with 80% RH condition. The Weibull distribution function was well fitted with the experimental data to analyze release kinetics. The release mechanism parameter was greater than 1.0, which indicates a controlled release with initial induction time.

Thus, *Saccharomyces cerevisiae* cells are successful and useful encapsulants to encapsulate flavorings, which provide better stability of actives in dried powder. Furthermore, the controlled flavor release by moisture absorption might prolong the flavor perception in mouth during mastication of food products which consist of flavor encapsulated yeast cells.