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# 学 位 論 文 要 旨
# Dissertation Abstract

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学位論文題目： Encapsulation of Functional Oils by Spray Drying and their Stability in Spray-Dried Powder
Title of Dissertation (噴霧乾燥による機能性油の粉末化と粉末内機能性油の安定性)

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The spray drying process is commonly technique for encapsulation of functional food ingredients such as flavorings, colorings, sweeteners and oils. The benefits of this technique include the controlled release of encapsulated ingredients, which affects the nutritional contents. The objective of this dissertation was to investigate the effect of oil-droplet diameter, wall materials such as maltodextrin (MD) with various dextrose equivalents (DE) and emulsifier on the stability of functional oil in spray-dried powder.

The stability of squalene oil (SQ) retention in spray-dried powder were investigated. SQ droplet diameter significantly affected the oxidation stability of the oil in spray-dried powders. The degradation behavior of SQ powders at 105 °C was correlated using the Avrami equation. This oxidation mechanism of SQ in spray-dried powder might be estimated the propagative transfer of radical oxidation between oil-droplet particles. SQ emulsified with 5 wt% PNC and small oil droplets had better oxidative stability when compared with 5 wt% NC.

The stability of SQ in the spray-dried powder was also investigated at three different temperatures, 50, 70, and 105 °C. Spray-dried powders of emulsified SQ were formed with 3, 5 and 8 wt% of NC to total solid powder and at three homogenization pressures. The reconstituted oil-droplet diameters were obtained about 0.69–0.77 μm, 0.47–0.61 μm and 0.19–0.27 μm at 20, 50 and 100 MPa high-pressure homogenization, respectively. SQ at 100 MPa was more stable at high temperature 105 °C and SQ at 20 MPa had lower degradation rate at 50 and 70 °C. The frequency factor of degradation

rate constant was also correlated to the activation energy as the chemical compensation relationship. These results suggest that oil-droplet diameter might be a major controlling factor of the degradation of SQ in spray-dried powder.

The surface oil ratio of encapsulated fish oil powders was measured with two types of oil-droplets diameter, nano and micro using the hexane washing method. A matrix composed of MD and NC was used as the wall material to encapsulate the fish oil, and Nile red was used to stain the oil. Fluorescence intensity using confocal laser scanning microscopy (CLSM) indicates good correlation between the oil content and fluorescence intensity.

The encapsulation efficiency is affected by several parameters such as oil-droplet diameter, solid and oil contents, and processing conditions in spray drying. Effect of DE values of MD on the stability of fish oil in spray-dried powder was investigated. NC (3 wt%), MD (DE = 8, 11, 19, 25, and 40) as wall material, and fish oil as core material were used to form spray-dried powders with 30, 40, 50 and 60 wt% of oil load to total solid content. Feed emulsions were prepared using a rotor-stator homogenizer and/or a high-pressure homogenizer at 20 or 100 MPa. The percentage of microcapsules with a vacuole was 73, 39, and 38%. Peroxide values (PVs) were measured for incubated the microcapsules at 60 ºC. The microcapsules prepared with MD of DE = 25 and 19 had lower PVs than those prepared with MD of DE = 11. The surface-oil ratio was remarkably increased when the ratio, $E = (d_e/d_p)$ of the average reconstituted oil-droplet diameter ($d_e$) to the average particle diameter ($d_p$) was higher than 0.01. The oil-droplet diameter might affect the stability of fish oil in spray-dried powder

The composition of material in feed emulsion is important for the oil encapsulation efficiency. The emulsification method is important to control the oil-droplet diameter of fish oil powder. The oil-droplet diameter affected significantly surface-oil ratio and stability of functional oil in spray-dried powder.