（様式２）

学位論文の概要及び要旨

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題　　目　Influences of feed liquid properties and spray drying conditions on microencapsulation characteristics of emulsified *d*-limonene
（カプセル化乳化リモネンの特質に与える供給液特性と乾燥操作条件の影響）

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The microencapsulation technology is defined as enclosing a labile material into different material and can release the included ingredient at controlled rates under specific conditions. Numerous methods have been developed for the manufacture of encapsulated flavor. Among them, spray drying is the most commonly used to produce flavor powders. However, the high temperature air is commonly used in spray drying which possible to affect the flavor loss during drying. The objective of this dissertation is to figure out the loss of flavor during spray drying associated with its morphologies in order to improve the efficiency of encapsulated flavors (*i.e.* flavor retention and surface oil).

The impact of emulsifiers on the microencapsulation of *d*-limonene was investigated for the wall materials gum arabic or maltodextrin and their blend. The emulsifiers used were sucrose ester, polyglycerol ester, and sugar beet pectin. The emulsion stability and emulsion size was also studied in order to correlate the *d*-limonene retention. It was found that the stable emulsion with relatively small average emulsion droplet size provided the high *d*-limonene retention with low surface oil. Even if the average emulsion droplet size was moderately small, very few *d*-limonene were retained in the powder for the unstable *d*-limonene emulsion stability.

The effects of high oil load and oil composition on the encapsulation efficiency were investigated on the mixture of medium-chain triglycerides and *d*-limonene. The MCT oil powder provides higher benefit of a rapid energy formation after consumption without accumulation in the body. The encapsulation efficiency was optimal at a specific oil load range while the retention of *d*-limonene decreased exponentially with increasing of the oil load. The increase of the oil load also predominately increased the surface oil amount of MCT and *d*-limonene due to the increasing of the emulsion droplet diameter of the infeed liquids.

The powder morphology and the distribution of spray-dried particles are important to the powder redispersibility and flowability. Therefore, the morphology of spray-dried powder was investigated by using scanning electron microscope (SEM) and confocal laser scanning microscope (CLSM). The external and internal structures (*i.e.* hollow particle) of spray-dried powder were evaluated. CLSM images indicated that

spray-dried powders at higher outlet temperatures include higher percentages of hollow particles. The addition of gelatin, decaglycerin monolaurate or ethanol to gum arabic/maltodextrin solution affected the increasing percentage of hollow particles in spray-dried powders.

Furthermore, the influence of feed liquid temperature was investigated on the particle morphology, peculiarly, on the vacuole size and the shell thickness of hollow particles. The increasing of feed liquid temperature slightly increased the percentage of the hollow particles, increased the shell thickness and decreased the vacuole diameter of the particle. This finding which is obtained with a confocal laser scanning microscope was qualitatively supported by scanning electron microscopy images of the fractured particles. These results indicated that the feed temperature influence the skin formation of the wall material during spray drying.