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Development of Lipid-based Food Materials with High Functionality

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Abstract

A research project supported by a Japanese governmental institution was introduced. The project that aims to develop novel lipid-based food materials with high functionality has been accomplshing in collaboration of food angineers with food acientists. Importance of the collaboration was emphasized for success in the project. Japan Society for Food Engineering, which was newly found in 2000, was briefly introduced.

Key words: lipid, functional food, food engineering

Introduction

A concept of functional food has well been established, and some goods have been commercialized in Japan. Knowledge not only on physiological, nutritional and food sciences but also on food engineering is required to develop a novel functional food. That is, collaboration of food scientists and engineers would be important in the development.

As an example of such collaboration, a research project will be introduced. The project was organized by Professor Matsuno, chair of our laboratory, to develop lipid-based food materials with high functionality under a support by the program for the Promotion of Basic Research Activities for Innovative Biosciences (PROBRAIN), Japan. Two professors are joining to the project; one is Prof. Nakanishi, Okayama University, who works on Enzyme Engineering and Food Engineering, and another is Prof. Mori, Kyoto University, who works on Food Chemistry and Properties. Furthermore, we will collaborate with specialists of other disciplines for physiological and nutritive assessment of the materials that will be produced in the project.

The Japan Society for Food Engineering was found in the last year. The society will briefly be introduced.

Background

Economic growth has brought about variety in lifestyle including diet. Diversification and westernization in eating habits seems to have caused two opposite problems, overeating and undereating, in developed countries. Overeating sometimes causes obesity and its related diseases. Undereating is the coinage that means intake of meals extremely poor in nutritive value and balance to over-worry the figure (slim body). It also causes some serious problems in health. Part of young women tends towards such habits.

Lipid would be a key component in modern eating habits. It plays a major role when many of us feel tasty for a high-fat meal such as steak. The good taste leads us to overeating of food rich in saturated fatty acids and to imbalance in intake between saturated and unsaturated fatty acids. Some of lipids possess physiological functions as well as tasty properties. For example, polyunsaturated fatty acids (PUFAs) have preventive effects against some diseases, e.g., reduction in the risk of coronary heart disease. However, PUFAs are prone to be easily oxidized. The oxidation of PUFAs causes sensory and nutritional deterioration, and oxidation products are,

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in some cases, harmful to health. Medium-chain fatty acids promote epithelial absorption of hydrophilic substances. This property would be usable to design food materials that facilitate the intestinal absorption of hydrophilic physiologically-bioactive compounds.

Lipid encapsulation technology

Liquid lipid is homogenized with a dense solution of saccharide or protein to produce O/W-type emulsion, and dehydration of the emulsion produces powdery material in which small oil droplets are covered with the dehydrated polymer matrix. Such a technology is called lipid-encapsulation.

Encapsulation of lipid into powdery matrix provides some functions to the lipid (Matsuno and Adachi, 1993) retardation of lipid oxidation, improvement in handling, controlled release of aromatic compounds, masking of bitter taste and carrier for bioactive compounds from the mouth to the intestine (Fig. 1). We investigate two topics on microencapsulation. One is retardation of lipid oxidation through microencapsulation. Another is a preparation of microcapsules that can enhance the intestinal absorption of hydrophilic or hydrophobic bioactive compounds without spoiling their bioactivity.

Suppression of lipid oxidation by encapsulation

Microcapsules of O/W-type emulsions were prepared by hot-air-drying or freeze- drying using a single droplet method (Charlesworth *et al.*, 1960) or by spray-drying. The dehydrated polymer layer of microcapsule would act as a barrier for diffusion of oxygen and retard the oxidation of encapsulated PUFA. To examine whether the diffusional limitation is a primary cause for the retardation, knowledge both on diffusivity of oxygen through the layer and on oxidation kinetics of PUFA is required. We reported the diffusivity (Adachi *et al.*, 1994) and the kinetic expression of autocatalytic type by which an entire oxidation process could be described (Adachi *et al.*, 1994; Adachi *et al.*, 1995). It was also shown that the enthalpy-entropy compensation held in autoxidation of PUFAs and their acylglycerols (Adachi *et al.*, 1995). A simulation of oxidation process of encapsulated PUFA based on the diffusivity and the kinetics revealed that not only the diffusional limitation but also an interaction between the core and wall materials played an important role in the retardation (Imagi, *et al.*, 1992; Adachi *et al.*, 2000). The oxidation process of encapsulated PUFA was affected by many factors such as drying method (Minemoto *et al.*, 1997) and ratio of core to wall materials (Minemoto *et al.*, 1999). The effect of the ratio on oxidation of encapsulated PUFA was analyzed based on the percolation theory (Minemoto *et al.*, 1999).

Enhancement of absorption of hydrophilic bioactive substances

Although hydrophilic substances are hard to be absorbed because cell membrane consists of hydrophobic lipid, it has been known that medium-chain fatty acids (MCFAs) can enhance the absorption of the sub-

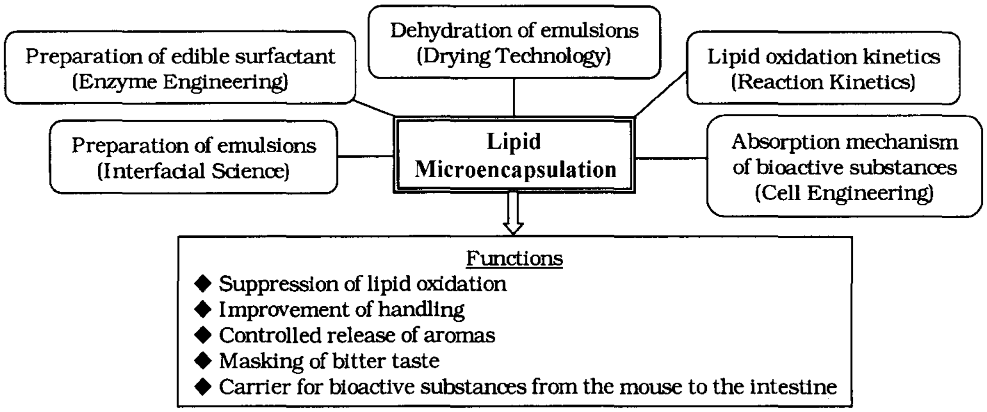

Fig. 1. Lipid microencapsulation: a multi-disciplinary subject

stances through the epithelium. We intended to utilize the property of MCFAs for preparing food materials with carrier function for hydrophilic bioactive compounds. However, the mechanism on absorption enhancement of MCFAs has not been elucidated. Therefore, we examined what types of MCFAs were effective for the enhancement using cultured human cells, Caco-2 (Shima *et al.*, 1997) and correlated the enhancement effect (Shima *et al.*, 1997), effective concentration (Kimura *et al.*, 1998) and cell viability (Shima, *et al.*, 1997) with physicochemical properties of MCFAs.

A hydrophilic bioactive compound will be loaded in the inner aqueous phase of W/O/W-type emulsions, the outer aqueous phase of which contains edible polymer at a high concentration. Dehydrated W/O/W emulsions (microcapsules of W/O/W-type emulsions) have been prepared using a single-droplet method.

Enzymatic synthesis of edible surfactants

Surfactant that consists of hydrophilic and hydrophobic moieties is usually used in preparation of emulsions. Food includes both hydrophilic and hydrophobic substances such as saccharides and fatty acids. Binding of them would produce edible surfactants. Enzymatic method is preferable to chemical one for food applications. Lipase-catalyzed synthesis of esters with saturated or unsaturated fatty acids with long-chains has been extensively investigated. However, enzymatic esterification of hydrophilic substances with MCFAs has scarcely reported. The esters with MCFAs are expected to exhibit surfactant properties different from those with long-chain fatty acids. Furthermore, MCFAs and their acylglycerols enhance absorption of hydrophilic substances in the intestine, as above-mentioned. We take interest in the absorbability of hydrophilic substances esterified with MCFAs. To examine surfactant properties and absorbability of the products, methods for preparing them should be established. In this context, the lipase-catalyzed condensation of erythritol (Adachi *et al.*, 1999), saccharides (Watanabe *et al.*, 2000) and ascorbic acid (Watanabe *et al.*, 1999), as examples, with MCFAs was studied.

L-Ascorbic acid (vitamin C) has a strong reducing ability. We expected that binding of ascorbic acid to PUFA could suppress the oxidation of the PUFA. As expected, eicosapentaenoic acid (EPA) bound with ascorbic acid was highly resistant against autoxidation (Watanabe *et al.*, 2000).

Table 1. Number of papers presented at the 1st JSFE annual meeting (August, 2000)

	Category	No.
A	Supply of Food Materials	0
B	Preservation & Transpoatation	4
C	Food Analysis	5
D	Physical Properties & Reology	24
E	Separation & Refining	12
F	Concentraion & Drying	8
G	Mixing & Emulsification	5
H	Thermal Processing	5
I	Mechanical Processing	0
J	Cooking	5
K	Fermentation & Enzyme Technology	13
L	Cleaning & Pasteurization	15
M	Sensor & Process Control	3
N	Packging	0
O	Food Distribution	0
P	Waste-water Treatment	0
Q	Environment & Recycling of Food Resources	6
R	HACCEP, ISO1400 etc	0
S	Food Processing under Unusual Conditions	2
T	Chaose & Food	3
U	"KANSEI" (Sensitivity) Engineering	3
V	Others	4
Z	Industrial Plaza	21

Japan Society for Food Engineering

Professor Chun, the president of Korean Society for Industrial Food Engineering (KSIFE), well introduced the status of food engineering in Korea (Chun, 2000). The history and present status of food engineering in Japan seems to be similar to those in Korea.

Food engineers in Japan (have) belonged to some societies such as chemical engineering, agricultural chemistry and agricultural engineering, and the number of food engineers in each society is not many. Because food engineering is an integrated discipline, it would be necessary that researchers and engineers of various fields collaborate each other to promote food engineering research.

After the constant activities for *ca.* 20 years, the members of food engineering group in the Society of Chemical Engineers, Japan founded the Japan Society for Food Engineering (JSFE) in August in 2000 together with members from some other disciplines. The current numbers of the regular, student, sustaining and associate members are 277, 30, 18 and 47, respectively.

The society published 2 issues of "Japan Journal of Food Engineering" in 2000. From this year, the society plans to publish 4 issues a year. Manuscripts written in Japanese or in English are acceptable. The society holds the annual meeting, spring and autumn seminars and irregular seminar(s) in each year. The first annual meeting was held in August in 2000 at Tokyo University of Fisheries with about 500 participants. 6 plenary and 13 invited lectures were made, and 117 papers excluding papers in "Industrial Plaza" were poster-presented. The Industrial Plaza is also a kind of poster presentation where sustaining and associate members can demonstrate their own new or unique goods or technologies using poster panel. 21 presentations were made in the Plaza. The second annual meeting will be held in Otsu, which is a city just adjacent to Kyoto and faces the Lake Biwa, the biggest lake in Japan, on August 4th and 5th in this summer.

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