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Effect of dextrose equivalent of maltodextrin on the stability of emulsified coconut-oil in spray-dried powder

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ABSTRACT

Effect of dextrose equivalent (DE) of maltodextrin (MD) on the reconstituted emulsion stability of emulsified hydrated coconut oil (HCO) in spray-dried powder was investigated. HCO-encapsulated powders were produced with MDs of DE 2, 10, and 25 as wall material and sugar stearic acid esters (SSE) as emulsifier. The reconstituted emulsion from MD of DE 10 was less stable than those from MDs of DE 2 and DE 25. The increase rates of average diameter of reconstituted oil-droplet could be correlated by the zero-order reaction model. By FT-IR and powder X-ray diffraction measurement, spectrum results suggest a stronger interaction between MD of DE 10 and SSE compared to the other two MDs. The interaction between the surfactant and MD is important to select the wall material to form spray-dried powder with a stable reconstituted emulsion.

1. Introduction

Coconut (*Cocos nucifera* L.) oil is a natural source of medium-chain triglycerides (MCTs) with approximately 60% of the total oil content being MCTs (Appaiah et al., 2014). MCTs have been reported to be beneficial to human health. MCTs are mainly utilized as a nutritional supplement for patients. Furthermore, coconut oil, especially hydrated coconut oil (HCO), is hardly affected by the oxidization, and is stable during long period preservation because the content of unsaturated fatty acid of coconut oil is lower than the other vegetable oils. Therefore, the coconut oil is useful as a raw material for healthy and delicious foods.

In the food industry, we could see many spray-dried powders with emulsified oils and/or fats such as flavor, milk fat, vegetable oil, fish oil and MCTs. (Furuta et al., 2011) Various oils and/or fats are powdered by spray drying to improve handling and stabilizing oils and fats through long period storage. To form a powder the oils is sprayed dried using ingredients as carrier matrix to encapsulate the oil and convert it into powdered form. In many cases, oils and fats are emulsified by emulsifiers which have surface activity before the powderization by spry drying, and emulsions are generally defined as oil-in-water emulsion droplets. Solid state emulsions, thin a solid-phase, were first described in the early 1960s, obtained by removal of the aqueous phase of a liquid emulsion by spray-drying (Roudaut et al., 2007).

Carrier matrix is selected by desirable powder property, for example: stability, yield, solubility, absorbency. Usually maltodextrin (MD), cyclodextrin, lactose, starch, and modified starch are used as carrier matrix. Physical stability of dry emulsions (solid emulsions) with various wall materials such as lactose or malotodextrin (MD) problems arise. Stability of dry emulsions containing lactose (Fäldt and Bergenståhl, 1996; Pedersen et al., 1998; Heinzelmann and Franke, 1999), maltodextrin (Myers and Shively, 1993; Pedersen et al., 1998; Corveleyn and Remon, 1999; Heinzelmann and Franke, 1999), mannitol (Lladser et al., 1968 and Molina and Cadorniga, 1995) were investigated since the amorphous carrier exhibits a strong tendency to form crystalline. Crystallization of amorphous lactose was not inhibited by adding maltodextrin (Pedersen et al., 1998).

Moreover, the interaction with MD was occurred not only oil and/or fat but also emulsifiers with aliphatic part, so it is important to investigate the interaction between emulsifiers and MD because it is influenced the stability and the property of the emulsified oils and fats powders. Myasoedova et al. (2001) reported on the effect of MD with variable DE on the surface behavior at the air–water interface: legumin and small-molecule surfactant (sodium caprate; citric acid ester of monoglyceride), and suggested some complex formation between the small-molecule surfactants and the MD.

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Table 1
Average powder particle size and oil droplet size of the reconstituted solutions of spray-dried powders, water contents and yield of hydrated coconut oil encapsulated powders from each DE of MD.

	Powder size (μm)	Oil droplet size (μm)	Water contents (% w/w)	Yield (% w/w)
DE = 25	38 ± 4	0.72 ± 0.05	2.0 ± 0.04	55 ± 3
DE = 10	38 ± 3	0.83 ± 0.04	1.7 ± 0.05	61 ± 4
DE = 2	42 ± 2	0.78 ± 0.05	1.8 ± 0.04	54 ± 3

Wangsakan et al. (2001, 2003, 2004a,b) studied interactions between MD dextrose equivalent (DE) 10 and sodium dodecyl sulfate (SDS) in a buffer solution. They indicated, on average, one SDS monomer bound per 24 glucose units of MD at saturation, and there was a critical surfactant concentration (0.05 mM SDS) below which surfactant and MD did not interact and that the amount of surfactant bound to MD above this concentration increased with increasing MD concentration by surface tension measurements. They studied also interactions between SDS and MD with different DE in a buffer solution and reported the interaction between SDS and MD was exothermic, which was attributed to incorporation of the hydrocarbon tail of the surfactant into a helical coil formed by the MD molecules. In this paper, they proposed that SDS only binds to MD molecules that have a DE greater than 10 glucose units. Klinkesorn et al. (2004) studied the influence of MD concentration and DE on the stability and rheology of 5 wt% corn oil-in-water emulsions stabilized by TWEEN 80. They found that rapid creaming was observed when the concentration of MD exceeds a particular value, which was attributed to depletion flocculation caused by the non-adsorbed MD. Turchiuli et al. (2013) studied about emulsions and powders including sunflower oil, acacia gum as emulsifier, MD with DE 12 or 21, and reported MD DE 12, leading to more viscous aqueous phases, was found to be more efficient than MD DE 21 to produce fine emulsions.

Thus, there are some researches about the influence of the wall material in a powder state and the influence of MD in a solution or emulsion state. However, there were few investigations in the effect of wall materials of encapsulated emulsified oil in spray-dried powder on the stability of reconstituted emulsion solution. In this study, effect of dextrose equivalent (DE) of MD on the stability of reconstituted emulsion for encapsulated emulsified HCO with sugar stearic acid esters (SSE) was investigated.

2. Materials and methods

2.1. Materials

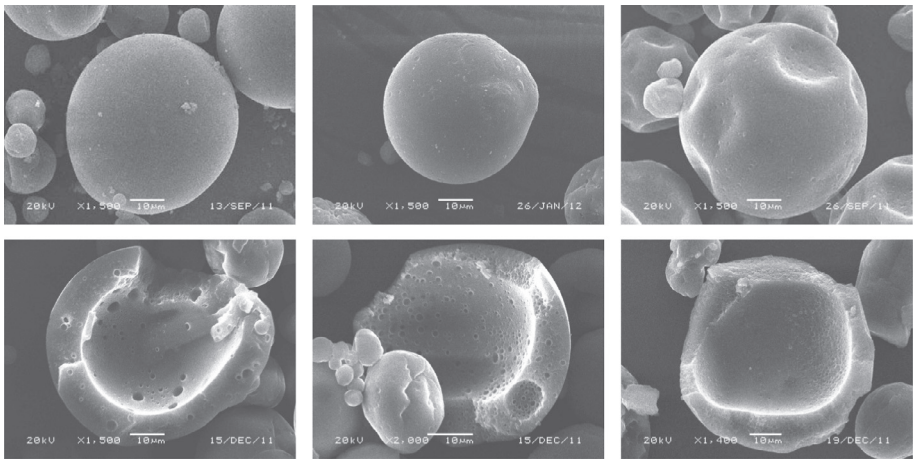
DE 2 (PAIN-DEX #100, DE: 2–5, waxy corn starch origin), DE10 (PAIN-DEX #2, DE: 10–12, corn starch origin), DE25 (PAIN-DEX #3, DE: 24–26, corn starch origin) of MDs were obtained from Matsutani Chemical Industry Co., Ltd. (Hyogo, Japan). SSE (S-570, ester composition: mono-ester was about 30%, di-, tri-, poly-ester were about 70%) and HCO (melting point: 30–35 °C) was gifted from Mitsubishi-Kagaku Foods Co., Ltd. (Tokyo, Japan). Other chemical reagents were from Wako Pure Chemical Industries, Ltd. (Osaka, Japan) without further purification.

2.2. Formation of spray-dried powder

2.5% w/w of SSE and 27.5% w/w of MD (DE = 2, 10, 25) added to 50% w/w of distillated water and stirred at 50 °C. 20% w/w of HCO melted at 50 °C previously was added gradually to SSE and MD solution with stirring. This solution was homogenized by a Polytron homogenizer (Kinematica GA, Littau, Swiss) at 10,000 rpm for 3 min and a high-pressure homogenizer (APV Lab-2000, SMT Co., Ltd., Tokyo, Japan) at 60 MPa and 10 MPa for 4 min as 2-pass homogenization. This feed liquid emulsion was spray dried by Okawara-L8 spray dryer (OKAWARA MFG. CO., LTD., Shizuoka, Japan) with a centrifugal atomizer under the operational condition of the spray-drying as follows; inlet temperature of air: 150 °C, outlet temperature of air: 95–104 °C, rotational speed of atomizer: 30,000 rpm, feed rate: 30 mL/min, air flow rate: 110 kg/h, and feed-liquid temperature: 50 °C. Powder formations for single species were done in triplicate and more times.

2.3. Measurement of oil-droplet diameter distribution and powder diameter

Oil-droplet diameter distribution of the feed-liquid emulsions and the reconstituted solutions of spray-dried powders, which were prepared to dissolve HCO-encapsulated powders to distillated water by supersonic treatment, were analyzed using a laser scattering particle size analyzer (SALD-7100, SHIMADZU Co., Kyoto, Japan). Powder particle size distribution of the HCO-encapsulated powders, which was dispersed in 2-methyl-1-propanol by



(a) DE = 25 (b) DE = 10 (c) DE = 2

Fig. 1. SEM photograms of the hydrated coconut oil encapsulated powders with different DE of MD. Upper: Surface structure (a) 1500 magnification ratio, (b) 1500, (c) 1500. Bottom: Cross-sectional structure (a) 1500 magnification ratio, (b) 2000, (c) 1400.