Fruit powders as a natural emulsifying agent: The importance of powder-added phase

果実由来の粉末乳化剤：添加相の影響

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Plant-based nutrition is promoted worldwide for sustainability, health promotion, and animal welfare. However, the intake of agricultural products, especially fruits, has been decreasing yearly in developed countries, including Japan, according to the FAO official data. Currently, fruits are consumed in fresh, dried, canned, juice and jam form. To enhance consumption of fruits, one solution is to broaden fruit eating styles such as utilization of fruit powders. Powder form of fruits has potential usages in several types of food products such as suspension (e.g., smoothie and juice), dough (e.g., cake and bread), foam (e.g., meringue and beverage), and emulsion (e.g., dressing, mayonnaise, ice cream, sauce, and beverage). Even though those oil-in-water emulsions are massively used in the food industry to give palatability to food, application of fruit powders in food emulsions was not explored yet because of the lack of fundamental knowledge on colloidal and interfacial properties of fruit powders.

Typical food emulsion products such as milk beverage, ice cream, and mayonnaise are essentially prepared with animal-based milk proteins and egg yolk, sometimes with the support of synthetic small molecule surfactants, but high and long-term stability are not achieved sometimes. In recent years, emulsions stabilized by solid particles (known as Pickering emulsions) have attracted much attention because of their remarkable stability against coalescence.

In this context, the first objective of this study is to clarify the possibility that whole fruit powders function as an emulsifying agent. Considering the chemical composition of fruit powders containing hydrophilic and lipophilic compounds, fruit powders may be more water wettable or more oil wettable according to the ratio of hydrophilic/lipophilic. In typical emulsions, hydrophilic and lipophilic emulsifiers are dispersed in water and oil phases, respectively, prior to emulsification. As an analogy of this methodology, the added phase of fruit powders should be selected to produce high quality emulsions, depending on the hydrophilic and lipophilic characteristics of powders. Therefore, the second objective is to investigate the effects of powder-added phase on interfacial and emulsifying properties of fruit powders in order to develop their applications and understand the governing factors in emulsification.

Chapter 1 Utilization of dried Japanese apricot and avocado fruit powders as an emulsifying agent: The importance of the powder-dispersed phase in emulsification

In this chapter, effects of powder-added phase on emulsifying properties of fruit powders containing more hydrophilic and more lipophilic compounds were investigated. Japanese apricot [JA] (rich in sugar and fiber) and avocado [Avo] (rich in neutral and polar lipids) powders were selected as a representative of hydrophilic and lipophilic fruit powders, respectively. The powders were added and dispersed in deionized water or in soybean oil to make powder-in-water (p/w) and powder-in-oil (p/o) dispersions. For the emulsification, the p/w and p/o dispersions were homogenized with oil and water phases, respectively, to produce p/w and p/o emulsions (final powder concentration fixed at 2 wt%). The emulsifying capacity (the maximum oil amount that can be emulsified), oil droplet size, microstructure, and emulsion stability were analyzed. Emulsifying capacity of JA powders showed no difference between the p/w and p/o emulsions (60 wt% of oil), while for Avo, the p/o method emulsified more oil (70 wt%) than the p/w ones (60 wt%). Avo powders could produce smaller oil droplets compared to JA powders. For JA emulsions, smaller oil droplets were obtained when adding powders into the water phase, whereas for Avo emulsions, smaller oil droplets were observed when adding powders in the oil phase, suggesting that JA and Avo powders show high affinity to water and oil, respectively. Microscopic images of JA and Avo emulsions prepared with both p/w and p/o methods demonstrated that fibers surrounded the oil droplets for stabilization. The resultant emulsions were stable against coalescence by properly choosing the powder-added phase.

Chapter 2 Effects of powder-added phase on emulsifying properties of avocado powders under acidified and salted conditions

Results in chapter 1 showed that Avo powders exhibited the higher emulsifying properties than JA ones, suggesting a great potential of Avo powders for the application to real food emulsion products. Generally, various emulsion-based food products are designed over a wide range of pH and ionic conditions to achieve attractive sensory properties but these adjustments consequently influence emulsifying properties of the applied emulsifiers. In this context, the effects of acidification (pH 4.0, 5.5, and 7.0) and salting (0 and 1 wt%) on the emulsifying properties of avocado powders were studied in this chapter. Adjustments of pH and salt induced flocculation of the p/w emulsions immediately after preparation, suggesting that electrostatic interaction or repulsion play a dominant role in the association of oil droplets covered with charged components, leading to flocculation. On the other hand, the p/o emulsions showed no flocculation under acidified and salted conditions, probably because the powders in the oil phase were hardly hydrated/charged and therefore less influenced by pH and salt adjustments even after their adsorption onto the oil-water interfaces. For emulsion stability during storage, the p/o emulsions were more stable against flocculation and coalescence, especially under acidified conditions, than the p/w emulsions.

Chapter 3 Interfacial stabilization scheme of avocado powders: Contribution of soluble and insoluble components

In chapter 1 and 2, Avo powders demonstrated high emulsifying properties especially when dispersed in an oil phase, but the reasons for the advantage of dispersions in an oil phase are unknown. When Avo powders are dispersed in water or in oil phase, a part of components may be solubilized in each phase, possibly affecting the interfacial and emulsifying properties. In this chapter, the contribution of soluble and insoluble components on stabilization behavior was studied. The p/w and p/o dispersions were centrifuged to separate them into water soluble/insoluble and oil soluble/insoluble parts, respectively, and their interfacial and emulsifying properties were compared with non-separated p/w and p/o dispersions. Interfacial tension experiments for non-separated samples suggested that the p/o dispersions decreased interfacial tension quicker and lower than the p/w ones. However, after centrifugation separation, the water soluble components of the p/w dispersions became more effective to reduce interfacial tension than oil soluble ones, suggesting that solubilized components in the oil phase did not contribute to interfacial tension reduction. On the other hand, the oil insoluble particles were shown to reduce interfacial tension effectively, suggesting the particle adsorption. To confirm this hypothesis, emulsions were prepared by respectively homogenizing the oil soluble components and oil insoluble particles with aqueous buffer solutions. It turned out that only oil insoluble particles could emulsify oil, meaning that Pickering stabilization importantly contributes to emulsion formation when dispersed Avo powders in an oil phase.