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Novel method for improving the water dispersibility and flowability of fine green tea powder using a fluidized bed granulator

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ABSTRACT

To develop new green tea beverages and dietary supplements in powder form, the surface of green tea powder (GTP) was modified by spraying a hydrophilic polymer Soluplus® (Sol) solution using a top-spray fluidized bed granulator. This enhanced the water dispersibility and powder flowability of the GTP. Spraying with levels of 0.5%–9% Sol polymers improved the flow properties but significant agglomeration occurred in products coated with 3%–9% Sol, but not in those coated with 0.5% and 1% Sol. This suggested that low levels of coating solution inhibited agglomeration. The highest level of water dispersibility and improved flowability with no agglomeration were exhibited by GTP with 1% Sol coating. Overall, surface modification with hydrophilic polymer can improve the flow properties, dispersibility and other properties of GTP. This method might also be useful for developing other novel food ingredient powders.

1. Introduction

Green tea is one of the most widely consumed beverages in the world (Sinija et al., 2007), especially in Asian countries such as China and Japan. Green tea leaves contain several hydrophilic active ingredients: polyphenolic compounds such as catechins and amino acids such as theanine, which exhibit anti-oxidative, anti-inflammatory, and anti-carcinogenic properties (Moore et al., 2009; Ojo et al., 2007; Sadzuka et al., 1996, 2000). These hydrophilic active ingredients can be easily extracted and diffused in water from the surface of the tea leaves, providing beverages with certain health benefits for consumers (Koo and Cho, 2004). However, other hydrophobic active ingredients, located inside the tea leaves, are less easy to extract and can easily be precipitated in water because of their low water solubility. This means that, at present, green tea beverages cannot provide the full advantage of these active ingredients. Therefore, if beverages can be developed where the green tea powder (GTP) is dispersed well, they would provide several types of active compounds simultaneously compared with those containing only extracts from the tea leaves.

Particle size is a key parameter influencing the efficacy of extracting and diffusing active ingredients from GTP and the dispersibility of GTP in water. The appropriate grinding method can reduce the particle size of food ingredients to between 1 and 100 μm. These superfine particles of tea leaf have been reported to increase the extraction efficacy and dispersibility in water because of the increase in particle surface area and the breakdown of the cell walls of the leaf (Hu et al., 2012; Park et al., 2001). When GTP with a smaller particle size is dispersed in water, oral discomfort is also reduced and the rate of sedimentation inhibited. However, for smaller particles, the adhesive forces such as electrostatic and van der Waal's forces increase, while the gravitational or inertial forces decrease, leading to undesirable changes in dispersibility in water and flow properties (Ehlers et al., 2008; Heim et al., 1999). Therefore, during the manufacturing process, it is essential to keep the particle sizes of GTP small without reducing their dispersibility in water and flow properties.

Some methods for producing tea powder, such as freeze-drying tea leaves after wet grinding (Saito and Shobu, 1997), or milling tea leaves with saccharides (Park et al., 2001), have been developed to solve these problems. However, freeze-drying improved dispersibility but not the flow properties because of the non-spherical and porous forms of tea powder produced. Direct milling with

Abbreviations: GTP, green tea powder; Sol, Soluplus; d_{50}, the volume-based mean particle size; R_w, relative particle size distributions width.

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saccharides improved dispersibility, but was not suitable for practical use because of the high quantity of additives needed. Recently, Xiao et al. (2017) have reported the successful development of superfine black tea powders with high levels of infusion and dispersibility through using a water-dispersible stabilizer, but the procedure required a large quantity of additives.

Generally, the surface conditions of powders greatly affect the physical properties of powders such as flowability and dispersibility, which can determine their storage and handling properties as well as their subsequent processing or application (Gaiani et al., 2006, 2011; Kim et al., 2002; Murrieta-Pazos et al., 2012; Nijdam and Langrish, 2006; Shrestha et al., 2007; Szulc and Lenart, 2013). Surface modification has been widely used in the pharmaceutical field to improve the flow properties and solubility of drugs (Ehlers et al., 2008; Miyadai et al., 2010). However, studies on modifying the surface of food ingredient powders such as GTP have not yet been reported.

In the present study, we aim to modify the surface properties of GTP by spraying a dilute solution of Soluplus® (5%, *w*/*w*, BASF Japan Co. Ltd., Tokyo, Japan) using a top-spray fluidized bed granulator to enhance its dispersibility, flowability, and other properties. Fluidized bed coating is selected because this methodology is widely used in the pharmaceutical and food industries to modify powders to enhance their processability, to mask any unpleasant taste or appearance and to enhance or create functional features such as delayed release or increased stability of the active ingredients (Ehlers et al., 2008; Tenou and Poncelet, 2003; Turton, 2008; Werner et al., 2007). As preliminary experiments, only just GTP did not flow in and adhered to the wall of fluidized bed chamber because of strong electrostatic and van der Waal's forces of GTP, 1% (*w*/*w*) fumed silica was added to GTP as a flowing and glidant agent. In addition, surfactants have been reported to decrease the interfacial tension between particles and the dispersion media, leading to enhanced levels of dispersibility (Martin et al., 1993). Polyvinyl caprolactam-polyvinyl acetate-polyethylene glycol graft copolymer Soluplus® (Sol), a synthesized amphiphilic polymer with a surfactant action, has recently been developed as a safe polymer for use in the hot-melt extrusion technique for pharmaceutical sciences (Ashour et al., 2016; Thiry et al., 2016). We will use a dilute Sol solution to spray onto GTP at levels up to 9% by weight of the coating and thereby modify its surface characteristics. We will then investigate the effect of Sol on the physical properties, particle size distribution, flow properties, wettability, dispersibility, and dispersion stability of GTP, and its application in developing beverages containing dispersed fine GTP.

2. Materials and methods

2.1. Materials

Green tea leaves were provided by Arahataen Co., Ltd. (Shizuoka, Japan). Fumed silica (Aerosil® 200, Nippon Aerosil Co. Ltd., Tokyo, Japan) was used as a flowing and glidant agent. Soluplus® (Sol) was provided by BASF Japan Co. Ltd. as a coating material.

2.2. Preparation of finely green tea powders modified by coating materials

To produce GTP, green tea leaves were milled using a Bisaiki® powder mill (Terada Seisakusho Ltd., Shizuoka, Japan) with running water to prevent denaturation and the loss of tea flavor. The GTP was dried for 24 h at 50 °C in an oven. Then 1.5 g fumed silica was added to 150 g of the bulk powder and resultant powders were manually pre-mixed by shaking in a polyethylene bag for 5 min. In the present study, the coating experiments were performed using a top-spray fluidized bed coater (Flow Coater® FL-Mini, Freund Corp., Tokyo, Japan) (Fig. 1A). The chamber of the coater was preheated to 35 °C then 150 g of the GTP/fumed silica mixture was put into the chamber and mixed at 30 °C. The coating solution was then sprayed into the chamber, and the flow rate and spray air pressure were adjusted to 1.0 g min^{-1} and 0.15 MPa, respectively. The composition of the solutions is shown in Table 1. After all the coating solution was added to the GTP, a stream of air at 35 °C was passed over the particles to dry them completely.

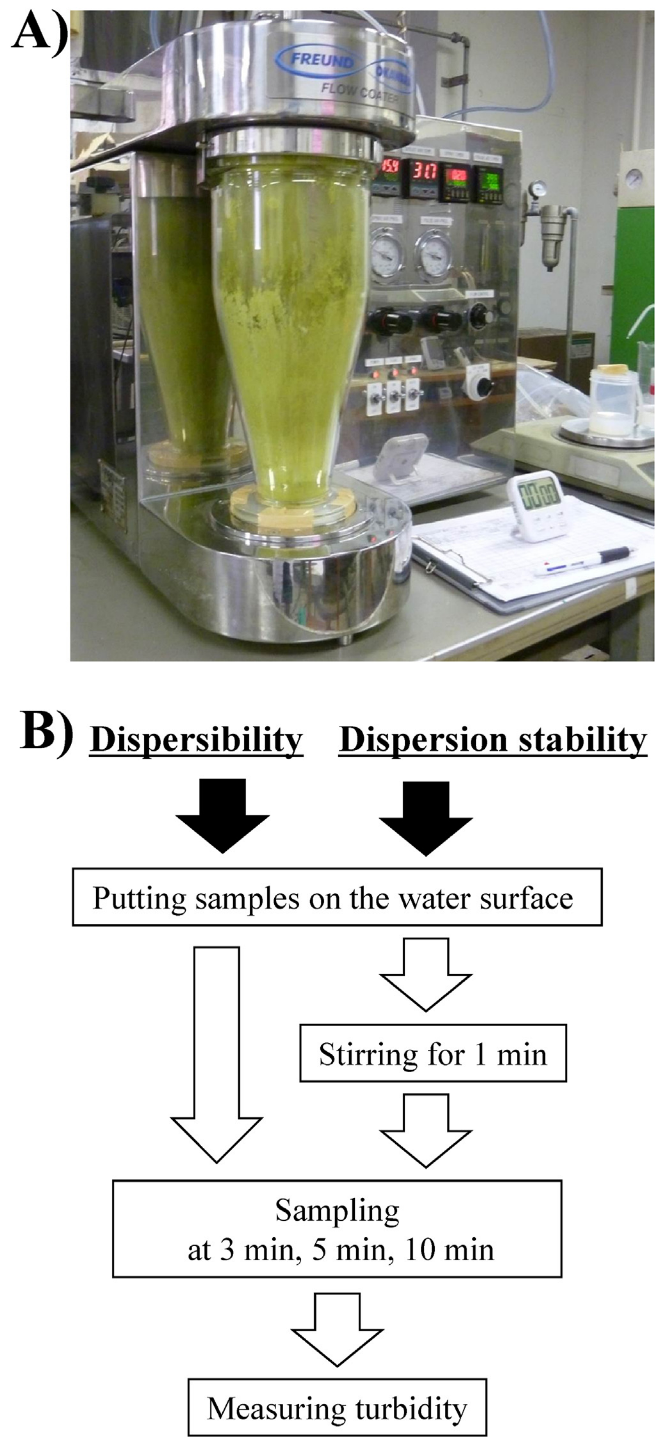

Fig. 1. The top-spray fluidized bed coater (A) and the procedure for evaluating the dispersibility and dispersion stability of GTP products.