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Assessment of measurement characteristics for rehydration of milk protein based powders

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ABSTRACT

Rehydration is an important powder property and is regarded as a critical issue by the dairy industry. Traditional powder rehydration measurements are relatively empirical with poor reproducibility. Thus, more reliable techniques tailored for dairy powders should be developed based on varied rehydration behaviours and applications. In this paper, a critical assessment to identify the measurement characteristics of milk protein powder rehydration is presented. Milk protein based powders were used as model systems. Four different wettability measurements (Immersion, Capillary rise, Condensation and Spreading) and four different dispersibility measurements (Dispersibility Index, Light scattering of particles in suspension, Light transmission and Conductivity of suspension) are compared and analysed. The results show that the method based on immersional wetting procedure is only appropriate for skimmed milk powder while the method for capillary rise wetting is more useful for the agglomerated milk protein powders with porous structures. Contact angle changes in the spreading wetting approach is found to be a straightforward technique to show the hydrophobicity or hydrophilicity of milk protein powders. If compared with traditional dispersibility measurements, light transmission of suspension is suitable to reflect optical properties of slow dispersion process. Light scattering methods can also be used to measure the dynamic size change of particles during the dispersion process. Furthermore, the conductivity of suspensions is a useful indicator to quantify the dispersibility indirectly by the release of minerals during rehydration. In summary, it is necessary to understand the specialities and applications of dairy powders before choosing the appropriate rehydration measurement methods.

1. Introduction

Rehydration properties are considered as an important benchmark to determine the overall quality of powder products. In the dairy industry, powder rehydration is regarded as a critical issue as some powders exhibit poor wettability with the materials floating on the surface of solution and others dispersing very slowly accompanied by lump formation, which is especially the case for high-protein-containing powders (Anema, Pinder, Hunter, & Hemar, 2006; Havea, 2006). Traditional dairy powder rehydration measurements, which were often designed for the analysis of instant skimmed milk powder or whole milk powder, are thus relatively crude with poor reproducibility for other specialty milk protein products (i.e., micellar casein, whey protein or milk protein isolate powders). Therefore, more analytical approaches have been developed to observe each dynamic step and to find the methods to quantify the kinetics of powder rehydration process (Crowley et al., 2015; Fang, Selomulya, & Chen, 2010; Forny, Marabi, & Palzer, 2011; Freudig, Hogekamp, & Schubert, 1999; Gaiani, Scher, Schuck, Desobry, & Banon, 2009; Marabi et al., 2008; Mimouni, Deeth, Whittaker, Gidley, & Bhandari, 2009). However, it is a challenge to find a universal method to measure the rehydration abilities of varied dairy powders, as they present significantly different behaviours during the rehydration process. Recent studies have shown that whey protein isolate powder has poor wettability and that the wetting stage is the main limiting factor for whey protein rehydration. In comparison, the slow dispersion of micellar casein is responsible for its extended rehydration time. Whereas for milk protein isolate, both wetting and dispersing processes are rate-limiting steps (Gaiani, Schuck, Scher, Desobry, & Banon, 2007;

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Schuck et al., 2007). Consequently, it is necessary to examine the feasibility of the existing techniques for determination of the rehydration of milk protein powders and to validate the every typical powder and technique case by case in order to find the most appropriate one.

It is commonly believed that wetting is the critical step in powder rehydration process, as powder materials with poor wettability have limited access to contact with water which then causes the formation of non-hydration regions. In general, wetting behaviour can be assessed through different procedures including immersional wetting, capillary wetting, condensational wetting and spreading wetting in Fig. 1, which was modified and developed from the other researches (Israelachvili, 2011; Lazghab, Saleh, Pezron, Guigon, & Komunjer, 2005). The immersional wetting process uses the time required for a given mass of powder to submerge fully below the liquid surface as a measure of wettability. But it is mainly of practical use for dairy powders that are easy to wet whereas milk protein based powders tend to float on the surface of the liquid and so wetting time is no longer a useful measure. Thus, it is interesting to assess which kind of dairy powders will be suitable for characterisation by this traditional immersional wetting process. Secondly, capillary rise wetting is a process whereby the liquid penetrates into the solid porous structure by capillary force. For this case, the Washburn method is mostly used, which can be quantified by the mass of adsorbed liquid as a function of time (Ji, Cronin, Fitzpatrick, Fenelon, & Miao, 2015; Thakker, Karde, Shah, Shukla, & Ghoroi, 2013; Washburn, 1921). However, the feasibility of this approach for dairy powders is still not validated, as some researches have shown that spontaneous liquid penetration only occurs if the contact angle between the liquid and solid is lower than 90° (Yuan & Lee, 2013). Also the wetting behaviour by capillary rise is not only influenced by the actual wettability but also by the porous architectures of solids (Buckton & Newton, 1986). Thirdly, the condensational wetting process concerns the adsorption of moisture vapour on a solid surface and faster wetting usually corresponds to higher rates of vapour sorption (Israelachvili, 2011). The method uses different salts solution in desiccators to provide varied relative humidity environment for powder adsorption (Schuck, Jeantet, & Dolivet, 2012). Hence uptake of water vapour may represent totally different wetting behaviours for milk protein powders compared to wetting by liquid water where surface tension effects need to be considered. Finally, the spreading wetting process focuses on the contact angle when a given amount of a liquid spreads over a solid substrate (Israelachvili, 2011; Rouquerol, Rouquerol, Llewellyn, Maurin, & Sing, 2013). The method examines a single liquid drop penetrating into solids and thus evaluates the wettability by monitoring the changes in contact angles over time. In summary, all four methods corresponding to different wetting procedures have been widely used in pharmaceutical research, however few applied in dairy powder research. Therefore, it is important to identify whether the analytical methods based on these four wetting procedures are suitable for the typical milk protein powders.

Dispersibility is also believed to be an important step in the rehydration process, as it is necessary for particles to be dispersed into the liquid before dissolving (Galet, Vu, Oulahna, & Fages, 2004; Goalard, Samimi, Galet, Dodds, & Ghadiri, 2006). The dispersion process is accompanied by the transfer of particle mass, particle size and particle energy, which can be used as the indicators to quantify the process (Forny et al., 2011). The use of the dispersibility index is the traditional standard method to measure the amount of dry matter combining simple mixing in a liquid followed by sieving.

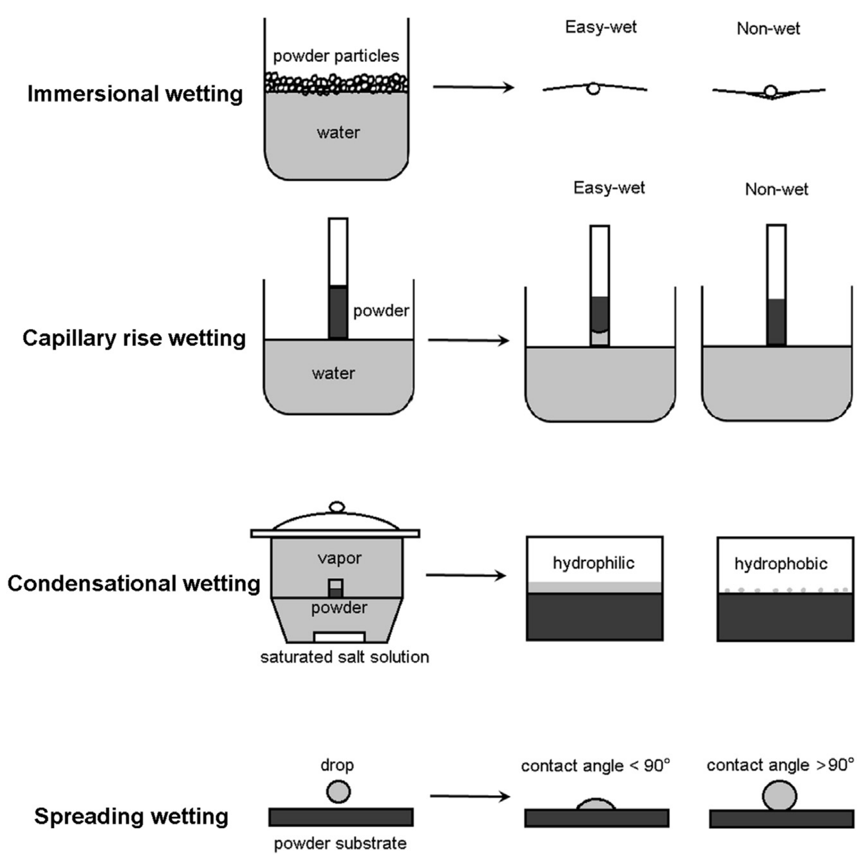

Fig. 1. Different wetting procedures.