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Using a particle-gun to measure initiation of stickiness of dairy powders

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Abstract

A novel particle-gun technique has been developed for measuring the stickiness of dairy powders. Particles are impacted against a stainless steel plate using air at different temperatures and relative humidities (RH). The percentage deposition on the plate is used as a measure of the stickiness of the powders. Flow conditions similar to those existing in the ducts of commercial spray dryers are used in the test, making the results directly applicable to industry. The points where skim milk powders become sticky enough to form significant deposits at a given temperature, as measured by the particle-gun, occurred at significantly higher RH values than those measured by the other techniques with different flow conditions, such as stirring devices and fluidized beds.

Keywords: Sticking point temperature; Caking; Blockages; Dairy powders; Skim milk powder

1. Introduction

Undesired particle agglomeration and particle deposition on the wall and ducting surfaces are common problems in spray drying operations. With dairy powders containing sugars, the property of powder stickiness is strongly dependent on both particle temperature and moisture content. At certain conditions the particle behaves in an adhesive and cohesive way, whereas at lower temperature and moisture contents, the particles in non-sticky state are free flowing. The sticky state is caused by the formation of liquid bridges between the individual particles and/or the walls when they touch.

Researchers have developed various techniques to measure powder cohesion and adhesion phenomena over the last 50 years, but most of these measure the stickiness of the powder when the particles are stationary or moving only very slowly, such as the shear cell (Jenicke, 1964), the blow tester (Brooks, 2000; Burr, 1999; Paterson, Bronlund, & Brooks, 2001; Foster, 2002; Paterson, Brooks, Foster, & Bronlund, 2005), or the stickiness-point temperature test (Lazar, Brown, Smith, Wong, & Lindquist, 1956; Downton, Flores-Luna, & King, 1982; Wallack & King, 1988; Chuy & Labuza, 1994; Hennigs, Kockel, & Langrish, 2001) or the fluidized bed (Chatterjee, 2003).

This paper introduces a new device, the particle-gun, that mimics the conditions the particles experience during spray drying and transport and compares the stickiness curves found with the stickiness curves obtained in a fluidized bed test, and with literature data reported from other devices that have been used in characterizing the stickiness of dairy powders.

2. Materials and methods

2.1. Fluidized bed equipment and method

The experimental equipment is shown schematically in Fig. 1. This equipment was designed and built by K.I.M. Toy of Fonterra Research Centre, Palmerston North in 2000 based on the work of Andrew Dixon in 1999 at Monash University in Australia. Chatterjee (2003) modified the rig into its current configuration and used it to measure the stickiness points of dairy powders by increasing the RH of the air at a constant temperature until fluidization was observed to stop. The combination of temperature and RH where this occurred was taken as the stickiness point. The powders used in this work were commercially produced powders from Fonterra

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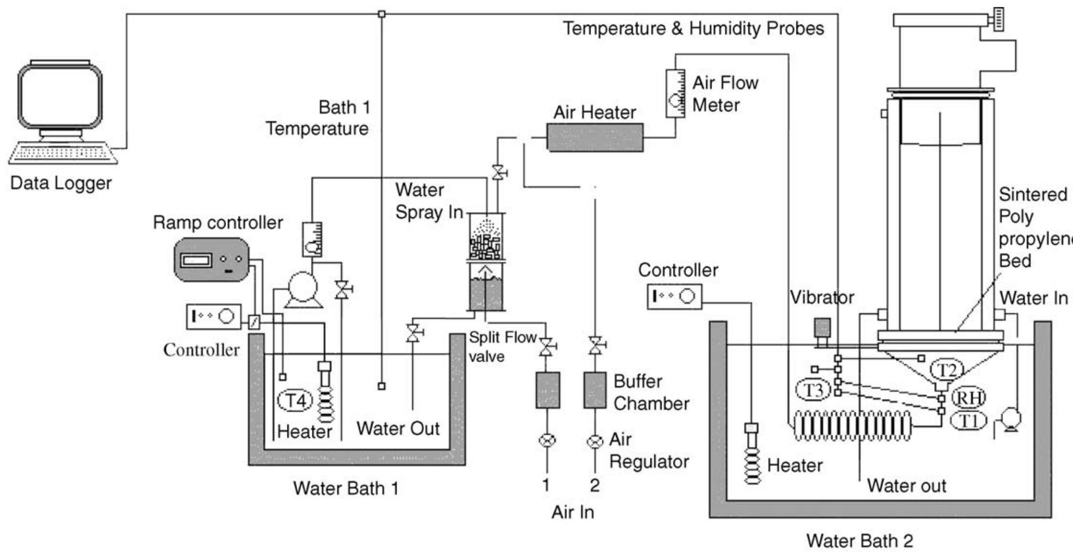

Fig. 1. The fluidized bed rig used to measure sticky point curves for dairy powders. Abbreviations: RH, humidity measurement; T1, humidity sensor temperature; T2, fluid-bed temperature; T3, water bath 2 temperature; T4, water bath 1 temperature.

Table 1
Composition of milk powders[a]

Milk powder	Fat %TB[b]	Protein %TB	Lactose %TB
SMP A	0.62	34.27	57.84
SMP B	0.8	34.63	57.56
SMP C	0.62	34.27	57.84
SMP D	0.83	38.05	53.01
Amorphous lactose	0	0	100
WMP	27.9	24.6	42.4
WPI	0.52	96.34	1.05

[a]All the powders used in this work (apart from the amorphous lactose powder) were commercial dairy powders produced by Fonterra. The compositions are those supplied by Fonterra as measured by their quality control laboratories for the specific batches of powder produced.

[b]Abbreviations: TB, total basis; SMP, skim milk powder; WMP, whole milk powder; WPI, whey protein isolate.

Co-operative Group Ltd. (Fonterra). Their compositions as supplied by Fonterra are given in Table 1. The dry bulk temperature range was 40-80°C, and the RH of the fluidising air was varied by changing the temperature of water bath 1 in Fig. 1, between the ranges of 0°C to 80°C. By ramping this temperature up, at $12\,^{\circ}C\,h^{-1}$, the RH of the air was increased while the dry bulb temperature was maintained by the coil in water bath 2.

Powder weighing between 20 and 30 g was placed in the fluid bed and the air flow was turned on to fluidise the powder. Superficial velocities were in the range of 0.22 – $0.42\,m\,s^{-1}$. Velocities in excess of $0.42\,m\,s^{-1}$ typically led to a loss of fines, while lower velocities did not fluidise the powder. The end point of fluidisation during the test was taken to be the point where the bed was visually seen to stop moving This was categorised by a bed that could be re-fluidised temporarily by vigorous shaking but which would collapse very quickly (Chatterjee, 2003).

2.2. Particle-gun equipment

Research conducted by Moreyra and Peleg (1981) has shown that physical conditions such as ‘stickiness’ are mainly characteristic properties of the particle surface and can occur at much shorter times than those necessary to reach equilibrium with the interior of the particle. The occurrence of ‘‘instantaneous’’ agglomerate formation or incipient stickiness in food powders has been examined by Wallack and King (1988). The particle-gun rig has been developed to measure the onset of initiation of stickiness with particles travelling and hitting walls at velocities, temperatures and relative humidities similar to those encountered industrially.

The equipment was constructed in two parts: a constant humidity air supply system and the particle feeding system that enables the particle to be ‘‘fired’’ on the deposition plate at the desired velocity (Fig. 2).

O’Donnell, Bronlund, Brooks, and Paterson (2002) built an apparatus that produced air at controlled temperature and relative humidity, at a desired throughput by saturating the air at one pressure and then lowering the pressure through a pressure regulator. This principle was used to build a constant temperature and RH air supply apparatus. The schematic diagram of the particle-gun rig is shown in Fig. 3. It consists of a bubble column to saturate the air under pressure, an air heater and the particle-gun, which uses a glass funnel feeding into a venturi effect to feed powder into the tube which causes the powder particles to be impacted on the target/hitting plate.

A constant pressure air supply was ensured by passing compressed air through two pressure regulators, R1 and R2.