# The Stickiness Curves of Dairy Powder

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# ABSTRACT

Powder stickiness problems encountered during spray drying are important to the dairy industry. Instantaneous stickiness is a surface phenomena that is caused by exceeding the glass transition temperature of the amorphous sugar in the powder, usually lactose in dairy powders. Instantaneous stickiness occurs at a certain temperature above the $T_g$ of amorphous lactose and has been denoted as the critical "X" value. Whether powder particles are sticky or not depends on whether there is enough liquid flow on the surface between the particles. Two particles stick to each other when there is enough liquid flow to form a bridge between them after the contact. This project aimed to measure the instantaneous sticky point conditions for various dairy powders and to relate these to the operating conditions to give a commerical outcome for the dairy industry.

The particle-gun rig was developed to simulate the conditions in the spray drier and the ducting pipe and cyclone. The stickiness of powder particles occurs after a short resident time in the particle-gun. Thus, stickiness is a surface phenomenon and the point of adhesion is the instantaneous sticky point. The amount of deposit on the plate was measured at a temperature, with increasing relative humidity. At a particular temperature and relative humidity, the powder stuck to the stainless steel plate instantaneously. This was observed by a sudden change in % deposition on a % deposition verse RH plot. The $T-T_g$ plot and stickiness curve profile were developed to determine the critical "X" value for the dairy powders.

The critical 'X' value is the temperature which exceeds the $T_g$ of amorphous lactose when instantaneous stickiness occurs. The critical "X" values for various dairy powders including WMP, SMP, MPC, whey protein, buttermilk, white cheese powder and GUMP powder were found to be 33-49°C, 37-42°C, 42-51°C, 50°C, 37-39°C, 28.5°C, and 40.7°C respectively. In addition, the slope of the trend line in the $T-T_g$ plot, indicates how quickly the particular powder becomes sticky once the instantaneous sticky point has been exceeded. The particle-gun rig demonstrated that powders with greater than 30% amorphous lactose are more likely to cause blockage than powders with less than 30%.

Both the critical 'X' value and the slope are unique to the powder. The stickiness curve was used to relate the powder surface stickiness condition with the drier outlet temperature and relative humidity. It was recommended to operate at conditions below the stickiness curve for a powder to avoid any chamber or cyclone blockages caused by stickiness. The slope enables a decision to be made about how close to the critical point a plant should be run for a particular powder. The inlet air temperature or concentrate feeding rate can be used to move the operating conditions towards or away from the stickiness curve, according to the operating situations.

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## 1.1 BACKGROUND

The stickiness of dairy powder particles and adhesion of the particulate mass to chamber walls and ducting surfaces are common severe problems in drying operations. Such problems include chamber, cyclone blockages and frequent downtime for cleaning; hence it has a significant economic impact in the dairy industry. It is estimated that the overall product loss due to the stickiness problem would be $4 million per year over all Fonterra operations. Coping with stickiness in spray driers has been a matter of trial-and-error experimentation to find conditions which avoid or control the sticky characteristic of a given composition. Therefore, it is desirable to be able to predict the stickiness conditions and then control the problem during processing.

## 1.2 PROPOSED SOLUTION

The two main stickiness mechanisms identified by Foster (2002) are (1) Powders that contain more than 42% total fat (greater than 1.95g/m$^2$ surface fat content), when exposed to a temperature above 40°C where the fat becomes completely molten and form liquid bridges between the adjacent powder particles, and (2) The glass transition temperature of the amorphous sugar present in the powder is exceeded sufficiently to make the amorphous sugar behave as a viscous liquid and form liquid bridges when particles come into contact. Hence, it is important to be able to identify this critical temperature condition which exceeds the $T_g$ of amorphous sugar to an amount, that allows the viscous liquid to be sufficiently liquid to enable liquid bridges to form when two particles come together or a particle impacts on the wall of a duct.

Preliminary work carried out by Chatterjee (2003) shows promising results in using a particle-gun rig to mimic the air conditions in ducting and constructing the 'stickiness curve' to relate the measurements to the industry process conditions. This work used the same rig with some modification to generate stickiness curves in the industry process temperature range. Some preliminary work was done in order to implement the stickiness curve in the plant more constructively.

## 1.3 PROJECT OBJECTIVES

The specific objectives of this research were:

1) To identify conditions under which dairy powders become instantaneously sticky using a particle-gun rig. The knowledge gained from the understanding of the stickiness mechanism helps to appreciate the causes of adherence in powder particles.

2) To relate these sticky conditions to plant operating conditions, to give a commercial outcome for the dairy industry.

3) To recommend the best way to control powder stickiness during the drying process in terms of its composition. To recommend changes in the operating conditions for the spray drier.

## 1.4 THESIS STRUCTURE

A literature review helped this research work stay in focus and it only included the topics that relate to this project such as the stickiness mechanisms and glass transition temperature of amorphous materials. Understanding these fundamental facts provides a good grounding for the following chapters. Chapter three discusses the materials and methods used and explains the dairy powder samples selected and experimental work carried out using the particle-gun rig. Instantaneous stickiness occurs at a certain temperature above the $T_g$ of amorphous lactose and has been denoted as the critical "X" value. Chapters four and five concentrate on the identification of the critical "X" value for powder instantaneous stickiness and use this information to construct a stickiness curve for various powders selected. A preliminary work with the aim to implement the stickiness curve in a plant environment is discussed in chapter six, with a case study on skim milk powder (SMP). Chapter seven summarises the project in a nut shell and provides the recommendations for this research.