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The Stickiness Curves of Dairy Powder

A thesis presented in partial fulfillment of the requirements for the degree of
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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 commercial 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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TABLE OF CONTENTS

ABSTRACT.....	II
ACKNOWLEDGMENTS.....	IV
TABLE OF CONTENTS	V
LIST OF FIGURES	VIII
LIST OF TABLES	X
Chapter 1	
PROJECT OVERVIEW	1-1
1.1 BACKGROUND	1-1
1.2 PROPOSED SOLUTION	1-1
1.3 PROJECT OBJECTIVES	1-2
1.4 THESIS STRUCTURE	1-2
Chapter 2	
LITERATURE REVIEW	2-1
2.1 INTRODUCTION	2-1
2.2 STICKINESS MECHANISMS	2-1
2.2.1 Viscosity.....	2-2
2.2.2 Liquid Bridging	2-5
2.3 GLASS TRANSITION	2-12
2.3.1 Determination of Glass Transition Temperature	2-14
2.3.2 Prediction of Glass Transition Temperature	2-16
2.3.3 The 'T-Tg' Factor.....	2-18
2.4 DEVICES TO MEASURE POWDER STICKINESS PHENOMENA	2-20
2.4.1 Shear Cell Method.....	2-20
2.4.2 Blow Test.....	2-20
2.4.3 Sticky-point Temperature Test.....	2-21
2.4.4 Fluidised-bed Rig	2-22
2.4.5 Cyclone Stickiness Testing Device	2-23
2.4.6 Particle-gun Rig.....	2-24
2.5 STICKY POINT CURVE.....	2-25
2.6 PROJECT PLAN	2-30
Chapter 3	
MATERIALS AND METHODS	3-1
3.1 INTRODUCTION	3-1
3.2 MATERIALS.....	3-2
3.3 METHODS	3-3
3.3.1 The Particle-Gun Rig	3-3

Chapter 4	
MEASUREMENT AND PREDICTION OF THE CRITICAL “X”, STICKINESS TEMPERATURE FOR DAIRY POWDERS.....	4-1
4.1 INTRODUCTION.....	4-1
4.2 AN INSTANT SKIM MILK POWDER.....	4-3
4.3 CRITICAL ‘X’ VALUE OF POWDERS.....	4-10
4.3.1 Skim Milk Powders (SMP).....	4-10
4.3.2 Whole Milk Powders (WMP).....	4-10
4.3.3 Milk Protein Concentrate (MPC) and Whey Protein Powder.....	4-12
4.3.4 Specialty Powders.....	4-12
4.4 AMORPHOUS LACTOSE.....	4-13
4.5 PREDICTION OF THE CRITICAL “X”.....	4-14
4.6 COMPARISON OF STICKINESS CURVE USING CRITICAL ‘X’ APPROACH.....	4-16
4.7 CLOSURE.....	4-19
Chapter 5	
STICKINESS DUE TO FAT.....	5-1
5.1 INTRODUCTION.....	5-1
5.2 WHITE CHEESE POWDER (42.05 %TS fat).....	5-1
5.3 LOW FAT CREAM POWDER (55.84 %TS fat).....	5-4
5.4 HIGH FAT CREAM POWDER (71.79 %TS fat).....	5-8
5.5 STICKINESS DUE TO FAT-MELTING MECHANISM.....	5-10
5.6 CLOSURE.....	5-14
Chapter 6	
IMPLEMENTATION OF STICKINESS CURVE IN A PLANT - PRELIMINARY WORK.....	6-1
6.1 INTRODUCTION.....	6-1
6.2 CASE STUDY.....	6-2
6.2.1 Determination of critical “X”.....	6-2
6.2.2 Constructing stickiness curve and mapping plant conditions.....	6-4
6.3 SPRAY DRYING PROCESS OPTIMISATION.....	6-6
6.3.1 Effect on X via different inlet temperature and production rate.....	6-8
6.3.2 Effect on X and outlet temperature via different production rate.....	6-9
6.4 CLOSURE.....	6-12
Chapter 7	
CONCLUSIONS AND RECOMMENDATIONS.....	7-1

REFERENCES	8-1
NOMENCLATURE	9-1
Appendix A1	10-1
Appendix A2	10-2
SMP	10-2
WMP	10-8
MPC AND WHEY PROTEIN	10-18
SPECIALITY	10-28

LIST OF FIGURES

- Figure 2.1 Milk fat-melting mechanism (taken from Foster (2002)).
- Figure 2.2 The relationship between total fat content and surface fat content expressed in terms of the specific surface area (Foster (2002)).
- Figure 2.3 Comparison of sticky-point for skim milk powder measured by different techniques.
- Figure 2.4 Comparison of sticky-point obtained by fluidised-bed rig and particle-gun rig for amorphous lactose (adapted from Chatterjee (2003)).
- Figure 2.5 Comparison of sticky-point obtained by fluidised-bed rig (adapted from Chatterjee (2003) and particle-gun rig for whole milk powder.
- Figure 2.6 Stickiness curve for whey powder measured by the cyclone stickiness test (adapted from Boonyai (2004)) and Amorphous lactose powder measured by particle-gun rig (adapted from Chatterjee (2003)).
- Figure 3.1 Selected dairy powder compositions (2-D Matrix) for experimental work.
- Figure 3.2 The particle-gun rig.
- Figure 3.3 A schematic diagram of the particle-gun rig.
- Figure 3.4 This part of the particle-gun shows where powder feed from the glass funnel and firing on the stainless steel plate occur.
- Figure 4.1 The liquid-bridging mechanism caused by T_g amorphous lactose being exceeded.
- Figure 4.2 The % deposition of dry instant skim milk powder plotted against relative humidity at constant temperatures.
- Figure 4.3 The stickiness curve of the instant SMP from four experimental points fitted the curve above T_g of amorphous lactose.
- Figure 4.4 % deposition plotted against $T-T_g$ for four different temperature data sets.
- Figure 4.5 The slope of the trend line ($T-T_g$ plot) show how fast is the powder response to temperature and relative humidity change exceed the stickiness curve line.
- Figure 4.6 % deposition plotted against $T-T_g$ for four different temperature data sets of replicates.
- Figure 4.7 The stickiness curve of the instant SMP in comparison with the replicate.
- Figure 4.8 The stickiness curve of amorphous lactose with reference line T_g , including Chatterjee (2003)'s result.
- Figure 4.9 The correlation between the critical "X" value and % lactose of powder (total fat content less than 42%) tested.
- Figure 4.10 The interaction of slope as function of ($T-T_g$) and % lactose in bulk.
- Figure 4.11 Stickiness curve of whey powder measured using cyclone stickiness test (Boonyai *et al.* (2004)) and amorphous lactose and instant SMP measured by particle-gun rig.

- Figure 4.12 Stickiness curve of SMP measured by particle-gun rig (Chatterjee (2003)), fluidised-bed rig (Chatterjee (2003)), and stirrer test (Hennigs *et al.* (2001)).
- Figure 5.1 Deposition of the spray dried white cheese powder (42.05 %TS fat) tested on the particle-gun rig.
- Figure 5.2 The cheese powder (42.05 %TS fat) stickiness points at temperatures above T_g of amorphous lactose.
- Figure 5.3 The stickiness curve for cheese powder (42.05 %TS fat) including the fitted $T_g + X$ line from the Gordon-and-Taylor equation and fitted $T_g + X$ line from cubic equation.
- Figure 5.4 Deposition of the spray dried low fat cream powder (55.84 %TS fat) tested on the particle-gun rig.
- Figure 5.5 Close-up of the deposition of the low fat cream powder (55.84 %TS fat) tested on the particle-gun rig.
- Figure 5.6 The low fat cream powder (55.84 %TS fat) stickiness points at temperatures above T_g of amorphous lactose.
- Figure 5.7 The stickiness curve for low fat cheese powder (55.84 %TS fat) including the $T_g + X$ line.
- Figure 5.8 Deposition of the spray dried high fat cream powder (71.79 %TS fat) tested on the particle-gun rig.
- Figure 5.9 The stickiness of high fat cream powder (71.79 %TS fat) caused by molten fat and amorphous lactose.
- Figure 5.10 Deposition due to fat in low fat cream powder tested on the particle-gun rig with increasing air temperature and keeping RH low to avoid the amorphous lactose mechanism.
- Figure 5.11 Deposition due to fat in high fat cream powder (2001 sample and 2003 sample) tested on the particle-gun rig.
- Figure 5.12 2001 high fat cream powder sample was checked for crystalline lactose under a polarising microscope at 50X magnification.
- Figure 6.1 The $T - T_g$ plot of the SMP and the critical 'X', determined to be 38°C.
- Figure 6.2 The stickiness curve of the SMP is fitted line through experimental points.
- Figure 6.3 The stickiness curve constructed from the average critical "X" of SMP with ± 3 error bar.
- Figure 6.4 Effect of dry product throughput and inlet temperature on $T - T_g$.
- Figure 6.5 Effect on dry production rate and outlet temperature on $T - T_g$.
- Figure 6.6 Demonstration of the possible changes that could effect the drier outlet conditions.

LIST OF TABLES

- Table 2.1 The specific 'T-T_g' factor for instantaneous sticking.
- Table 4.1 A summary table of critical "X" value of SMP tested.
- Table 4.2 A summary of critical "X" value of WMP tested.
- Table 4.3 A summary of critical "X" value of MPC and the whey protein powders tested.
- Table 4.4 A summary of critical "X" value of cheese, buttermilk and GUMP powders tested.
- Table 6.1 The possible experimental matrix for variation in the solids production rate, inlet temperature and corresponding T-T_g.

CHAPTER 1

PROJECT OVERVIEW

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.