THE MODELLING OF CAKING IN BULK LACTOSE

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ABSTRACT

Caking during storage is a serious problem for manufacturers of bulk lactose. This study was carried out to investigate the causes of caking and identify solutions as to how such problems can be eliminated.

The mechanisms for caking in crystalline lactose powders were identified. Liquid bridging between adjacent particles was shown to occur in high relative humidity environments (>80% RH) These liquid bridges could form crystalline solid bridges if the material was subsequently dried out. The potential mechanism of amorphous lactose flow and bridging in conditions where the glass transition temperature is exceeded was shown to be insignificant in predominantly crystalline lactose powders (<5% amorphous lactose) The presence of amorphous lactose is still important as the amorphous matrix acts as a sink of moisture, which can be released upon crystallisation. This increases the moisture available in the system which can contribute to caking by the liquid bridging mechanism. Both of these mechanisms involve changes in the local temperature and moisture conditions within the bulk powder. Such changes were known to be caused by moisture migration under the influence of a temperature gradient.

A model which describes the transport of moisture in one dimension as a result of temperature gradients was developed and validated. The microscopic scale processes of liquid bridging and amorphous lactose moisture relations were included into this model. The model predictions agreed well with experimental trials for completely crystalline lactose powders. Comparison of model predictions for the case where amorphous lactose was present on the surface of the particles showed some inadequacies exist in the model. These were the rate of amorphous lactose crystallisation and the assumption of instantaneous equilibrium between the crystallising amorphous matrix and the air present in the interstices of the bulk lactose.

Using the model it was shown that for expected storage conditions, the product should be stored with a water activity below 0.57 a_w if no amorphous lactose is present and below 0.25 a_w if it is present. If these prescribed limits are met then the goal of producing caking free lactose powders can be achieved.

ACKNOWLEDGEMENTS

I always used wonder why research into industrial problems satisfies the requirements for a Doctorate in Philosophy.

Then I found a definition for Philosophy;

> *Philosophy, is like a blind man, in a dark room, looking for a black cat that isn't there.*

Then I realised that this was the ideal qualification for this kind of research.

When it comes to lactose caking, I have been that blind man in the dark room. This is not to say that I didn't get any help during my search for the alleged black cat. Indeed there have been many people who have helped and encouraged me along the way.

Tony Paterson, my principal supervisor, has spent many hours over the last few years helping me ponder the riddles of what is lactose. My other supervisors, Dr Richard Archer, Dr Dong Chen and Professor Ray Winger were also of great help, particularly at the two ends of the whole exercise. Dr Jim Hargreaves's initial work into lactose has also been invaluable to this work. Also thanks to Aaron O'Donnell for all his work in searching for the same lactose cat.

John Alger, Bruce Collins and Don McLean have aided me in the design and manufacture of many cat searching devices. Thank you all very much.

I would like to thank Ma and Pa Bronlund, my family and friends who have listened and encouraged me to complete this thesis. This was mostly in the form of questions like "Is your thesis finished yet John?".The people responsible for asking such questions know who they are and many will be hearing similar questions from me in the near future. Special thanks to Jules, Kath, Dave, Kim, Lynley, Stacey, Mike, Clint, Ross, Silvia and Inge.

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At the end of this work there was still no sign of the Black Cat, but I did find a small hard deposit of a white powdery substance in one corner.

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