Investigation of stickiness of milk powder for the purpose of improved process control in milk powder manufacture

Key external stakeholders:
Dairy ingredient manufacturers; infant milk formula manufacturers.

Practical implications for stakeholders:
- Partial substitution of lactose with proteins or maltodextrin can reduce stickiness problems during drying, crystallisation and storage.
- New measurement techniques have been developed and are applicable to industry.

Understanding the effects of specific formulation components (type of sugar, type of protein) on stickiness is of immense practical benefit with regard to new product development. To this end the project has demonstrated the role of different powder constituents (proteins, maltodextrins and lactose) on stickiness and has developed measurement techniques that are in use in our laboratories.

Modelling was used to show how to deal with the constraints of drying sticky products (including infant formula and other high lactose formulations) and how to optimise process control to maximise production while avoiding plant blockage (and downtime) while air humidity varies.

Main results:
- Partial substitution of lactose with proteins (i.e. higher molecular weight components) is a means of reducing stickiness problems.
- Maltodextrin inclusion in skim milk powder decreases susceptibility to sticking during drying and crystallisation during subsequent storage.
- Modelling was used to show how to deal with the constraints of drying sticky products (including infant formula and other high lactose formulations).

Opportunity / Benefit:
Teagasc can assist interested parties in improving process efficiencies in the manufacture of dried products. The opportunity exists for further research in this area and expressions of interest from relevant companies are invited.

Collaborating Institutions:
University College Cork

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1. Project background:
It was known by experience that stickiness plays a critical role in the manufacture of milk powder, both in a positive sense, i.e. as a prerequisite to agglomeration, and in a negative sense in causing powder to adhere to contact surfaces. It was also known that the phenomenon is related to temperature, moisture content and composition. In particular, where sugars (such as lactose) are present, stickiness is related to glass transition.

The project was undertaken because in the dry ingredients industry (which is increasingly targeting the nutritional sector for added value), production is constrained by stickiness issues, especially in novel formulations where different carbohydrates are being added.

2. Questions addressed by the project:
- Does the recipe (carbohydrates, proteins, and fat) influence stickiness of dry dairy ingredients?
- Does protein type (e.g. casein, whey protein, hydrolysed whey protein) influence stickiness?
- Does carbohydrate type (e.g. lactose, sucrose, maltodextrin) influence stickiness?
- Is it possible to develop strategies for dealing with variation in environmental humidity and its effects on drying performance?

3. The experimental studies:
5 series of milk powders were produced in MTL, according to experimental designs
1. skim milk powder
2. a range of milk powders varying in protein: lactose ratio;
3. a range of milk powders with added low DE (dextrose equivalent) maltodextrin;
4. whey protein and
5. infant formula powders
A range of techniques were developed for measuring stickiness and glass transition temperatures of milk powders, together with complementary techniques for determination of related physical characteristics (Differential Scanning Calorimetry (DSC), dynamic mechanical analysis (DMA), dielectric analysis (DeA), vapour sorption analysis).

Modelling of process conditions during spray drying was used to determine optimum process settings when environmental humidity changes.

4. Main results:
- In experiments where the protein: lactose ratio was varied it was found that susceptibility to sticking, crystallisation and caking increased (decreasing temperature of sticking and glass transition) with increasing lactose content.
- XPS showed that the composition on the surface of spray dried powder particles differs from the bulk composition, with a preferential deposition of proteins and fat at the surface of powders probably reflects the rapid rearrangement of bulk constituents during drying. Such data provides valuable information on the influence of recipe.
- Partial substitution of lactose with higher molecular weight maltodextrins makes powders that are easier to dry (less sticky, higher glass transition temperature, less crystallisation).
- Partial substitution of sucrose for lactose were investigated. Stickiness of increased with increasing sucrose levels.
- Different types of protein, with the same level of lactose, influenced stickiness and crystallisation behaviour. Substitution of whey protein for intact casein gave powders that were less sticky.
- Hydrolysis of whey proteins resulted in increased susceptibility to sticking.
- Modelling of spray drying thermodynamics showed how variation in environmental humidity introduces additional constraints to the drying process, causing plant blockages. Strategies for
optimising process conditions were devised.

5. Opportunity/Benefit:
This project has delivered expertise and knowledge in an area that is critical to NPD in the ingredients area and which can benefit the ingredients and infant formula sectors in dealing with constraints to process efficiency.

6. Dissemination:
Dissemination has taken place through Relay workshops, direct presentations to industry, training courses for industry, journal publications, conference posters and presentations.

Main publications:


7. Compiled by: Dr. Donal O'Callaghan