RELCO®
A Kovalus Company

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How to Prevent Caking in the Dairy Processing Industry

By exploring effective prevention strategies and innovative technologies, we aim to equip dairy processors with actionable insights to enhance product stability and improve handling processes, ultimately ensuring superior quality for consumers.

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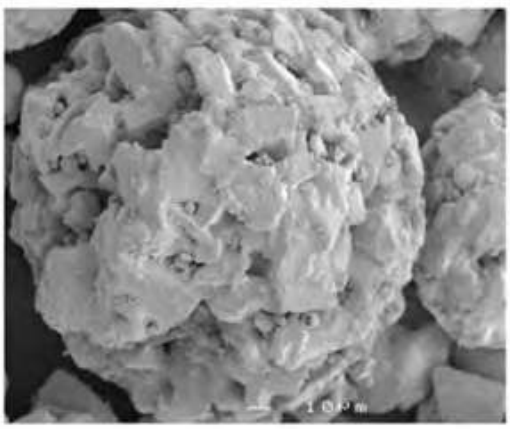
Taking a Closer Look at Lactose

Lactose, the key ingredient in dairy products, exists in two major forms:

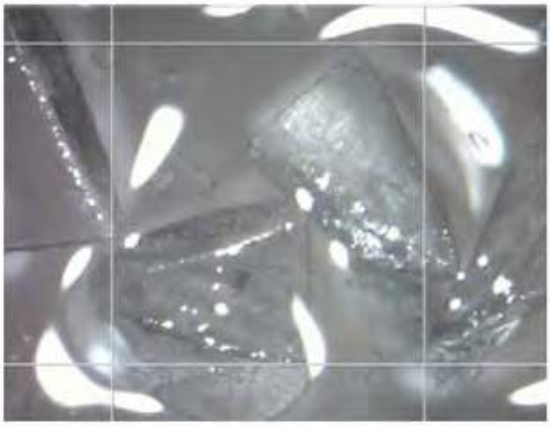
- Amorphous
- Crystallized

Amorphous lactose has no defined form, is very sticky, and hygroscopic (attracts water). Crystallized alpha monohydrate lactose or crystallized lactose for short, is not sticky, compared to amorphous lactose. Crystallized lactose is also not hygroscopic.

Figure 1 below compares the morphology of amorphous lactose (left) against crystallized lactose (right). On the left, you can see the random and indistinct nature of the lactose, whereas on the right, distinct crystals of lactose are visible, in the typical Tomahawk from.



Amorphous lactose



Crystallized Lactose, typical Tomahawk form

In the dairy processing industry, crystallized lactose is preferred to avoid caking. Whey/permeate powder can clump together becoming caking powder, if exposed to high ambient temperatures or large swings in humidity. In contrast non-caking powder is very loose and does not clump together.

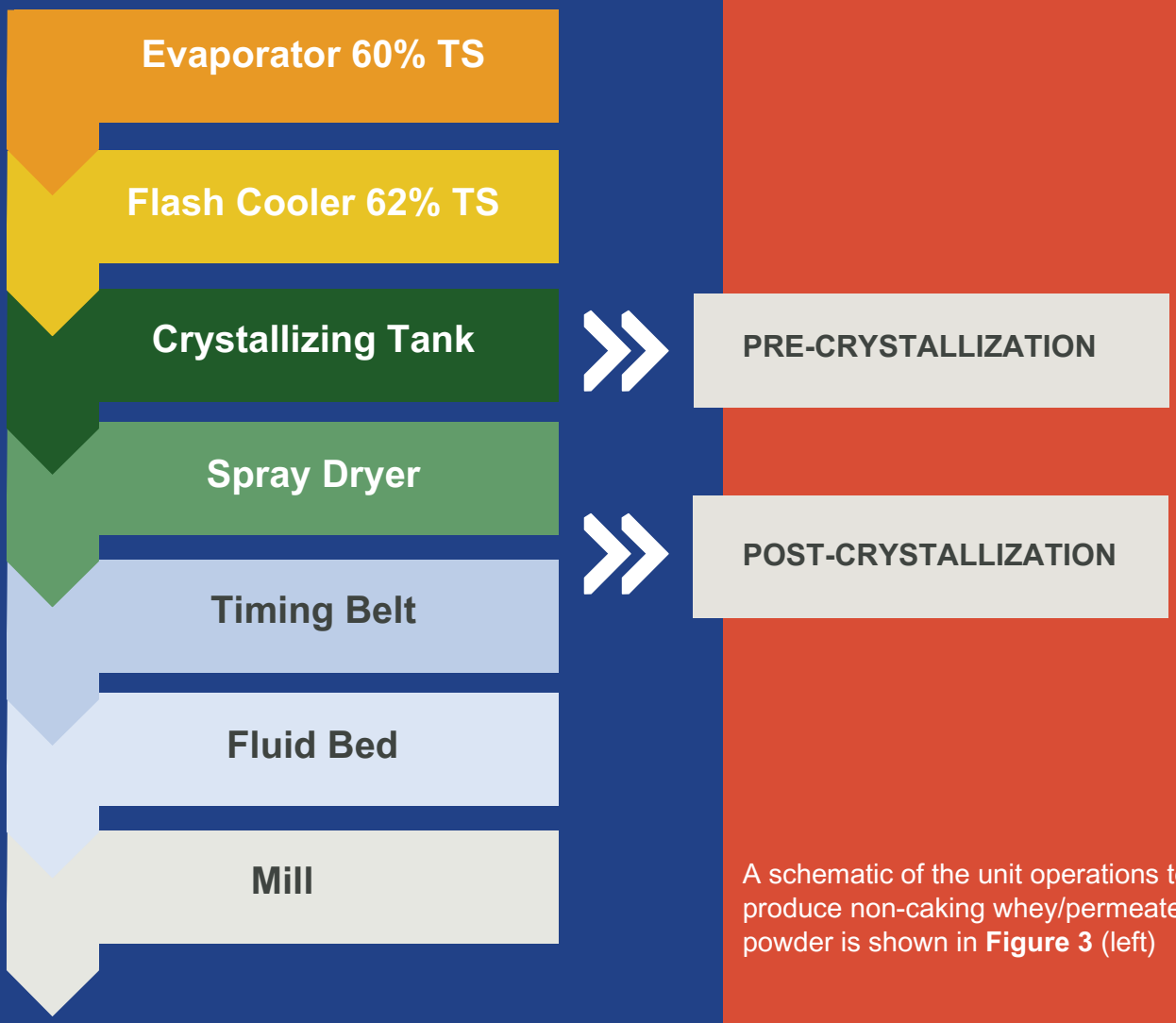
Figure 2 below shows what happens when lactose-containing powder is exposed to high temperatures and high humidity. Caking, compact powder forms when lactose-containing powder is exposed to high temperatures and high humidity (left). Non-caking, loose powder forms when manufacturing and ambient conditions are optimized for lactose crystallization (right).

Figure 2: Caking, compact powder versus non-caking, loose powder (right).

To make non-caking whey/permeate powder, the bulk of the amorphous lactose must be converted to crystallized lactose. This is done in two phases:

- Pre-crystallization
- Post-crystallization

Unit Operations: Non-Caking Whey/Permeate Powder



A schematic of the unit operations to produce non-caking whey/permeate powder is shown in **Figure 3** (left)

Pre-Crystallization

Evaporator

The liquid concentrate is sent to the evaporator, where the total solids is increased to ~60%.

Flash Cooler

The liquid concentrate needs to be rapidly cooled to prevent caking during the drying process.

Flash cooling is needed to:

- Increase total solids percent (TS %)
- Initiate nuclei crystallization of lactose

Rapid cooling occurs in the flash cooler (vessel), increasing the total solids of the liquid concentrate to ~62% before being sent to the crystallizer tank.

Crystallizing Tank

In the crystallizer tank, the liquid concentrate continues to be rapidly cooled down. This rapid cool down process initiates the formation of small lactose crystals (nuclei). Seed powder, which is milled lactose powder, is added to the crystallizer tank to speed up the crystallization process. This helps to start the nuclei crystallization process. Typically, one or two 25 kg bags of milled lactose is sufficient to initiate the pre-crystallization process.

To obtain small lactose crystals (**Figure 4**) with a target size of 80 um, it is essential to cool down the liquid concentrate rapidly. Rapid cooling leads to the forming of the small crystals without further growth of the crystals. Small crystals dry faster and more efficiently during the drying process.

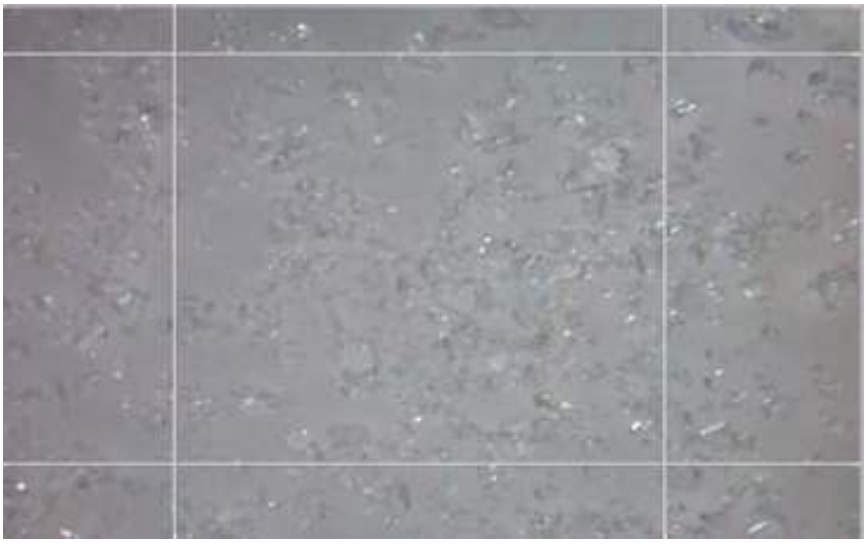


Figure 4: Small lactose crystals in they whey concentrate.

At optimum conditions ~65 – 75% of the lactose is converted to crystallized lactose. The higher the total solids content, and the colder the end concentrate, the more lactose that is crystallized.

In **Figure 5** below, whey temperature is plotted against whey total solids concentration to give the solubility curve of lactose. The blue arrows indicate the Labile Zone of Spontaneous Nucleation. This zone reflects the point at which whey temperatures and total solids concentration are optimized for crystallization to occur.

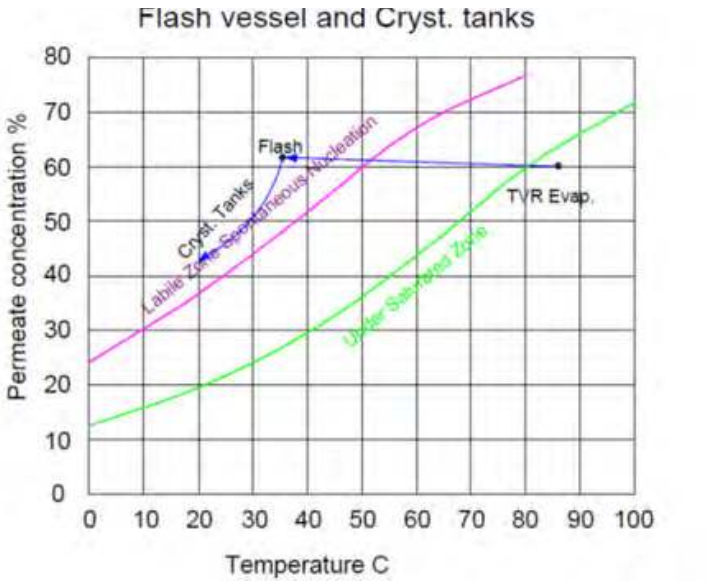


Figure 5: Solubility curve of lactose: whey temperature (°C) vs whey concentration (% total solids).

Not only is it important to rapidly cool the liquid concentrate, but it's also important to continuously stir it. A special agitator in the tank prevents crystals building up on the tank wall. Stirring helps keep the contents homogeneous with a consistent ratio of liquid to solids throughout. This is important as differences in the liquid-solid ratio will lead to caking in the drying process.

The pre-crystallized product is still very hygroscopic and sticky at this point of the process. More of the lactose needs to be crystallized to make the end powder non-caking. This is achieved in the post crystallization process.

The Art of Post Crystallization

Spray Dryer: 1st stage of post crystallization

In the spray dryer chamber, the wet and sticky powder builds-up on the wall. The high moisture (mobile water) and high air humidity inside the spray dryer chambers leads to more lactose being crystallized. The powder gets less sticky as it crystallizes, and eventually falls off the wall on to the timing belt.

The exhaust air from the spray dryer chamber is very humid and contains fine, high moisture powder that is very sticky. To prevent the fines from sticking to and building up on the duct walls, cyclone or baghouse, and leading to issues with rotary valves, hot dry conditioning air is introduced into the spray dryer to lower the humidity. This air dries the fines and prevents powder build up.

The spray dryer chamber exhaust temperature is a very important parameter to control the correct moisture of the powder. However, powder build up on the temperature probe can lead to slow response times or false values. RELCO has designed a unique system that automatically cleans the temperature probe as shown in **Figure 6**.

Figure 6: Self-cleaning temperature probe.

RELCO uses online relative humidity sensors to monitor that sufficient conditioning air is being supplied, and that the fines stay below the “sticky line”. These relative humidity sensors are very sensitive and should be strategically placed downstream of the baghouse. Proper maintenance and calibration of these relative humidity sensors ensure the accuracy of the drying process.

Timing Belt: 2nd stage post crystallization

The powder from the spray dryer chamber falls onto a slow-moving belt, known as the timing belt (**Figure 7**). On the timing belt, the high moisture powder is given sufficient time to finally crystallize on its own.

Figure 7: Image of powder falling from the spray dryer chamber onto the timing belt.

It is essential that the sticky powder coming from the spray dryer chamber stays below the “collapse line”. Powder with too much moisture or too high of a temperature will collapse into a solid powder layer that sticks to the timing belt, as well as forms rocks inside the fluidized bed further downstream in the process.

The powder on the timing belt should be “fluffy” like snowflakes. At the end of the timing belt, 85 – 90% of the lactose has undergone crystallization. This crystallization process makes the powder non-sticky, non-hygroscopic, and non-caking.

Fluidized Beds: 3rd stage post crystallization

The powder from the belt is then transferred to fluidized (fluid) beds where it is dried to its end moisture and cooled down.

The cold air for cooling the powder should be dehumidified from a desiccating unit to prevent the end powder from absorbing moisture from the cooling air.

The powder coming from the end of the bed is mostly porous, brittle pebbles. The pebbles are milled into a powder in the hammer mill.

The end product of the milling process is non-caking whey/permeate powder.

No More Caking with RELCO®

There are many parameters at each stage of the drying process that need to be closely monitored to achieve a cake-free final product. By following these best practices, you can reduce the chances of caking occurring within your end product.

At RELCO, our proprietary program (**Figure 8**) monitors the operating conditions (temperature and relative humidity) of the following key parameters:

- Collapse line – Spray dryer chamber exhaust air before conditioning air is introduced
- Sticky line – Spray dryer chamber exhaust air after conditioning air is introduced

If the operating conditions exceed the Collapse line or the Sticky line, an alarm will sound. The operator can then take appropriate action to return the operating conditions back under the line.

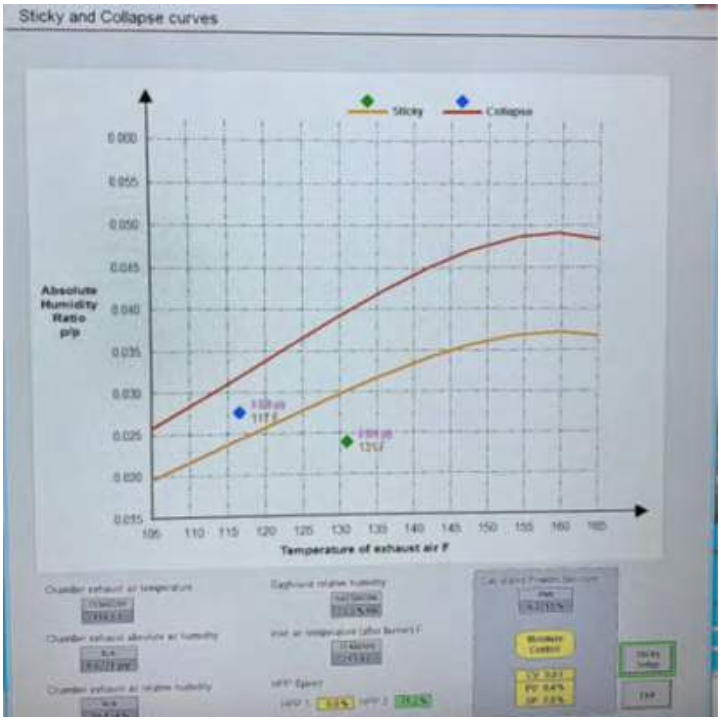


Figure 8: RELCO's proprietary program. The Sticky line is shown in yellow. The Collapse line is shown in red.

RELCO's proprietary program also predicts the moisture of the powder from the spray dryer chamber, and automatically adjusts the temperatures to keep the powder moisture on target. This automatic adjustment reduces the number and frequency of adjustments that the operator has to make.

RELCO makes it easy to keep a pulse on your entire drying operations to ensure caking does not occur. RELCO takes the trial and error out of maintaining and optimizing your drying process to eliminate caking.

We offer equipment solutions that optimize each of these critical parameters at every step of your drying process, taking the complexity of drying whey/permeate off your plate. By partnering with RELCO, caking can become a headache of the past.

ABOUT US

RELCO®, A Kovalus Company, is a specialized engineering and systems-building company dedicated to providing tailored solutions that streamline processes and elevate efficiency for dairy and food ingredient producers.

With a focus on transforming challenges into opportunities, RELCO offers a comprehensive range of technologies, including liquid processing, cheesemaking equipment, dairy filtration, drying systems, evaporators, and powder handling and packaging solutions.

RELCO is headquartered in Willmar, Minnesota, USA, with regional offices located in Brazil, New Zealand, and The Netherlands.

Visit us at www.RELCO.net to learn more about how we can help you exceed your production quotas with the right equipment for your unique needs.

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