



## Cryogen Injection to Enhance Meat Mixing Operations



Innovation, continuous improvement, and a focus on yield, costs, and quality have been the foundation of Linde's technology development efforts.

### Temperature Control Methods in Meat Mixing and Processing

Temperature control in meat processing and mixing is important for flavor, texture and appearance. With the modernization of large scale processing plants and the potential cost of bacterial outbreaks, product recalls, and diminished consumer experience, temperature control is even more critical than ever before. While early food processing plants relied on water ice and a sharp eye, today's food processors benefit from automated, cutting edge technology. While the transformation hasn't been overnight - the industry generally moved from water ice, tested glycol based chilling, and then selected dry ice pellets. Each approach brought some benefits albeit with some lingering limitations.



Today's meat processor has pushed past those limitations using a highly efficient automated CO<sub>2</sub> snow system for temperature control during mixing. By metering a fine dust of cold "snow" particles (-109°F) temperature control became easy and precise. When this approach became limited due to industry wide CO<sub>2</sub> shortages (and hence cost), engineers continued to innovate, using readily available liquid nitrogen (-320°F) to achieve efficiency and performance on par with CO<sub>2</sub> snow systems. Now, processing plants have options to achieve the highest food safety, product conformity and quality standards while minimizing operational costs.

Both fresh and raw-cooked meat products benefit from temperature control in processing. If uniform cooling is not achieved during the mixing and forming process, fresh meat products such as sausage are susceptible to degradation including fat smearing and bacterial growth. Raw-cooked meat products (i.e. products that are processed raw by grinding and mixing and then subsequently cooked) have an additional concern of negatively impacting water holding capacity with uncontrolled processing temperatures. Additionally, processors who are forming product after the mixing process often require lower average product temperatures and lower temperature variability to ensure product shape reproducibility and consistency.

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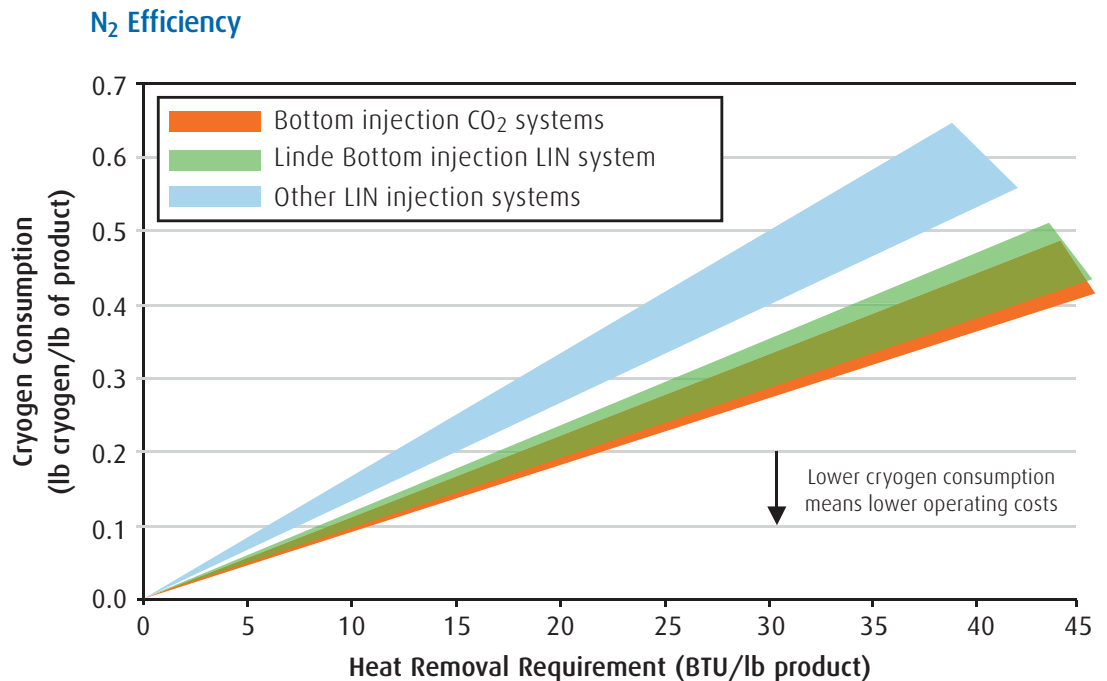
Today's meat processor is under mounting pressure to produce high quality, consistent product at minimal costs while avoiding unscheduled downtime, waste and spoilage. As successful brands are nationalized, there is additional expectation that product made in one plant will have a consistent shape, texture, flavor and color as the product made in a sister plant hundreds of miles away.

### Traditional Carbon Dioxide Uses

There are two main CO<sub>2</sub> applications for temperature control in the meat mixing process. The first approach is the use of CO<sub>2</sub> dry ice pellets that are mixed into the batch during the mixing process. This approach – a potential vector for bacterial contamination – typically requires significant manual labor to shovel the ice, and may result in batch inconsistency (i.e. cold spots) and batch to batch temperature variations.

The second approach is a more modern, automated approach that involves the injection of CO<sub>2</sub> snow into a mixer to achieve optimal performance and temperature control. These CO<sub>2</sub> snow systems are relatively straight forward relying on a liquid CO<sub>2</sub> supply tank, a distribution system (hose) and delivery manifolds installed inside the meat mixer. As liquid CO<sub>2</sub> transitions through highly engineered delivery nozzles into the mixer, it experiences a drop in pressure and is turned into a fine CO<sub>2</sub> snow. This snow has direct contact with the meat mixture. As heat transfers from the meat mixture to the CO<sub>2</sub> snow, the snow sublimates (i.e. turns from solid to gas) efficiently removing process heat. Plants appreciate the operational ease and finished product consistency afforded with CO<sub>2</sub> meat mixing.

Industrial demand for CO<sub>2</sub> continues to increase. Besides being used in food/beverage applications, CO<sub>2</sub> is used in oil and gas recovery, pharmaceutical production, and waste water treatment applications – to name a few. CO<sub>2</sub> is typically a by-product of an industrial process such as fermentation, refining, or chemical manufacturing. Industrial gas suppliers will further process the raw CO<sub>2</sub> stream to produce liquid CO<sub>2</sub> suitable for food/beverage applications. In contrast, liquid nitrogen is typically produced at an air separation plant with air being the primary raw material. Hence, liquid nitrogen supply tends to be less susceptible to supply disruptions. Many food processors have experienced disrupted CO<sub>2</sub> supply in the past few years. To cope, processors have had to rearrange production schedules, change product mix, or in some cases curtail operations.



### A New, Efficient, and Reliable Option

Liquid nitrogen (LIN) is an alternative cryogen used in the food processing (typically in food freezers). Historically, liquid nitrogen's use for meat mixing has been limited due to inferior efficiencies and excessive costs. Previously liquid nitrogen injection was 30% less efficient than CO<sub>2</sub> snow, or in other terms, a processor could expect to extract about 100 BTU/lb of liquid CO<sub>2</sub> (LCO<sub>2</sub>) but less than 70 BTU/lb of liquid nitrogen. The two major differences between use of LCO<sub>2</sub> and LIN for mixer cooling are:

- For LIN, a large portion of the refrigeration capacity is in the vapor phase (~50%), compared to LCO<sub>2</sub> for which the majority of the refrigeration capacity (~90%) is in the solid phase (CO<sub>2</sub> snow). In a mixer, where there is no means for recirculating the vapor phase, it is difficult to recover the vapor phase refrigeration capacity. Thus traditionally, LIN efficiency for mixer cooling has been significantly lower than LCO<sub>2</sub> efficiency.
- Heat transfer rates are much faster with LIN than with LCO<sub>2</sub>. This is because (i) temperature of LIN is much colder than that of dry ice and (ii) the vaporization of LIN into nitrogen gas is significantly faster than the sublimation of dry ice. Due to these two reasons LIN tends to cool the food product much faster than LCO<sub>2</sub>. Due to its lower heat transfer rates, even if a large amount of LCO<sub>2</sub> is injected into the mixer at once, there will be significant time to allow the mixer to uniformly distribute the resulting CO<sub>2</sub> snow evenly throughout the mixer before it all sublimates and cools the product. In other words, the characteristic time for dry ice sublimation in mixers is of the same order or slower than the characteristic time for mixing. This allows fairly uniform cooling with LCO<sub>2</sub> even if a large amount is injected through a smaller number of nozzles. However, due to the faster LIN vaporization rates, the characteristic time for LIN vaporization is significantly faster than the characteristic time for mixing. Thus, when a large amount of LIN is injected through a nozzle, the LIN tends to quickly freeze the product closest to the point of injection. In addition to being inefficient, early efforts to cool with LIN resulted in non-uniform cooling, nozzle plugging and overall unsatisfactory product quality.

Recent advancements in liquid nitrogen meat mixing technology now provide processors with an attractive, cost-efficient alternative to CO<sub>2</sub> snow. Linde has developed a proprietary liquid nitrogen injection technology that is on par with CO<sub>2</sub> meat mixing technology in every aspect including cryogen efficiency. Linde's ACCU-CHILL continuous or batch injection systems for meat mixing allows the use of liquid nitrogen in place of liquid carbon dioxide without an increase in operating costs. Engineers have also overcome ice plugging, non-uniform cooling, inferior product quality and other technical challenges previously associated with liquid nitrogen injection.

Meat processors conducting mixing at their plants now have more options. With a highly efficient nitrogen injection system on the market, processors facing supply disruptions with CO<sub>2</sub> can choose to add nitrogen supply to their mixing operations to avoid production downtime. Mixers with CO<sub>2</sub> injection systems can be retrofitted with a new LIN injection system. If processors have existing nitrogen supply at the plant, and prefer to use a single cryogen in their operations, liquid nitrogen injection is now an option.

While today's modern meat processor still faces operational challenges, temperature control for meat mixing is not one of them. Given advances in technology, either cryogenic CO<sub>2</sub> or liquid nitrogen offer attractive options for meat processing operations, product safety and enhanced consumer experience.

### Benefits of Temperature Control with Cryogen (CO<sub>2</sub> or LIN)

Criteria	Benefit
Fat Smearing	→ Melting/degradation of fat is avoided at lower temperature
Product Consistency	→ Precise temperature control from batch to batch → Improved product formability
Bacteria Inhibition	→ CO <sub>2</sub> or N <sub>2</sub> environment limit growth of aerobic bacteria → Sub-optimal temperature for some kinds of bacterial growth
Appearance	→ By mixing in CO <sub>2</sub> or N <sub>2</sub> environment, exposure to excessive oxygen is avoided → Oxidation of oxymyoglobin to metmyoglobin is reduced
Protein Extraction	→ Optimized at low temperature