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WHITE PAPER
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FREEZING TECHNOLOGIES

PRODUCE PREMIUM IQF SHRIMP AT A TENTH OF THE COST. WHAT'S THE CATCH?

Cryogenic vs. Mechanical IQF freezing: A head-to-head comparison of operational costs.

Prepared by Svetlana Plotean
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www.octofrost.com

INTRODUCTION

As the seafood industry continues to evolve, the selection of the right freezing technology becomes paramount for efficiency and economic viability. This white paper dives into the comparative analysis of cryogenic and mechanical IQF freezing methods for shrimp, with a specific focus on operational costs.

Through a realistic case model, we aim to provide valuable insights into the cost implications associated with these two freezing technologies, aiding industry stakeholders in making informed decisions for their shrimp processing operations.

PROBLEM STATEMENT

In the face of intensifying competition within the shrimp industry and the rising costs associated with liquid nitrogen, there is a crucial need to identify economically efficient methods for freezing high-quality individually quick frozen (IQF) shrimp.

This paper aims to assist shrimp processors utilizing cryogenic freezing by introducing alternative solutions capable of achieving equivalent or superior freezing results while reducing freezing costs by a factor of 10.

Moreover, this analysis can prove valuable for processors exploring various technologies as they establish a shrimp freezing business, offering insights into cost-effective alternatives that can enhance overall operational efficiency.

A COMPETITIVE LANDSCAPE THAT DRIVES OPTIMIZATION

A significant growth of the shrimp industry has been witnessed over the last decade with a 5.8% CAGR from 2010 to 2022. Although facing challenges leading to a slight decline in production in 2023, the global shrimp market is anticipated to rebound in 2024 and reach an estimated value of US $69.35 billion by 2028 - making shrimp one of the most traded species of seafood worldwide.[1]

Compiled by Rabobank seafood analysts, the latest "What to Expect in the Aquaculture Industry in 2024", report predicts a 4.8% rebound growth in shrimp production in 2024, surpassing the record 7.4% CAGR peak recorded in 2022.[2]

The global production landscape is still largely dominated by the Pacific white shrimp, maintaining a strong presence.

Simultaneously, the production of black tiger shrimp is on the rise, contributing an estimated 550,000 metric tons in 2023 and is expected to grow further, reaching close to 600,000 metric tons in 2024.[3]

Despite the optimistic trends, the shrimp industry is confronted by several challenging factors such as the volatile shrimp prices, unstable demand, rising feed and production costs and emergence of new competitive sourcing countries. It has never been more relevant to discuss opportunities for more cost-efficient processing methods.

[1]Report Linker "Global Shrimp Market is expected to be US$ 69.35 Billion by 2028." *GlobeNewsWire*, April 25, 2023. https://www.globenewswire.com/news-release/2023/04/25/2654161/0/en/Global-Shrimp-Market-is-expected-to-be-US-69-35-Billion-by-2028.html

[2]Holland, Jason." Rabobank: Farmed fish, shrimp production to bounce back in 2024." *Seafood Source*, December 4, 2023. https://www.seafoodsource.com/news/premium/supply-trade/rabobank-farmed-fish-shrimp-production-to-bounce-back-in-2024

[3]DARRYL JORY, PH.D. "Annual farmed shrimp production survey: A slight decrease in production reduction in 2023 with hopes for renewed growth in 2024". Global Seafood Alliance, October 9, 2023. https://www.globalseafood.org/advocate/annual-farmed-shrimp-production-survey-a-slight-decrease-in-production-reduction-in-2023-with-hopes-for-renewed-growth-in-2024/

MAIN TECHNOLOGIES FOR FREEZING IQF SHRIMP

When it comes to high-quality shrimp freezing - Individually Quick Freezing (IQF) is the most common method.

The IQF method is designed to prevent the formation of large ice crystals within food products' cells due to the short freezing time. By individually freezing each piece, this technique avoids the cohesion of food pieces, ensuring that the final product does not freeze into a solid block.[4]

The two main IQF methods that are used by most shrimp processors around the world are Cryogenic freezing and IQF mechanical freezing.

Cryogenic Freezing

Cryogenic freezing is a rapid freezing technique that entails spraying or immersing the food product directly with either liquid nitrogen or carbon dioxide. The instantaneous freezing occurs as the product comes into contact with the refrigerant, despite the drawback of the refrigerant being released into the atmosphere.[5]

While cryogenic freezing equipment typically involves lower initial capital investment compared to mechanical freezing equipment with similar capacities, ongoing costs for producers are considerably higher due to the substantial volumes of refrigerant required.[6]

It is important to note that due to cryogenic vapours being both colourless and odourless, it requires careful attention to ventilation to prevent oxygen displacement, ensuring the safety of workers.

[4] *Joseph J. Jen*, "Processing of vegetables". *Britanica* https://www.britannica.com/technology/vegetable-processing/Canning#ref501602

[5] Peterson, Randy "Cryogenic vs. Mechanical Freezers: The Best Uses for Each Method", *Stellar Food For Thought*. February 18, 2016. https://stellarfoodforthought.net/cryogenic-vs-mechanical-freezers-the-best-uses-for-each-method/

[6] Food Research Institute, Canada Department of Agriculture. "The Present Status of Liquid Nitrogen Freezing of Foods". *Science Direct*, 17 September 2014. https://www.sciencedirect.com/science/article/abs/pii/S0008386068744433

IQF Mechanical Freezing

Mechanical IQF Freezers, also called (air) blast freezers, employ a conventional mechanical freezing process, utilizing widely used refrigerants such as ammonia or carbon dioxide. In this method, the food's temperature is lowered through exposure to cold air flowing at a relatively high speed.

Air blast IQF freezers are systems that circulate cold air over the product, using powerful fans that propel the air through the evaporator, causing it to cool down before swiftly passing through the frozen product. Operating at temperatures between -22°F to -40°F (-30°C to -40°C), with an air velocity ranging from 4 to 6 m/s, this method can be categorized into tunnel freezing, belt freezing, and fluidized bed freezing based on the interaction between the air and the product.[7]

Mechanical IQF freezing systems generally entail higher upfront capital costs compared to cryogenic systems due to the need for supporting refrigeration infrastructure. However, they often prove to be more efficient and cost-effective in the long run, making them a favourable choice over time.[8]

Traders are inclined to pay a premium of 30% for more appealing appearance of frozen products.

AN APPEALING IQF PRODUCT SELLS BETTER

Frozen food manufacturers state that traders are inclined to pay 30% higher price for products with a more appealing appearance – and this inclination extends to end-consumers as well. When it comes to frozen food, an appealing appearance is characterized by:

- Absence of lumps (high IQF degree);
- A surface free of snow or ice crystals;
- Well-preserved shape, with no broken legs or antennas (in the case of HOSO shrimp);
- Vibrant, natural colour that closely resembles its fresh counterpart.

[7] Gökoğlu, Nalan. "Shellfish Processing and Preservation". *Google Books*, January 4, 2021, page 43. https://www.google.se/books/edition/Shellfish_Processing_and_Preservation/oh8SEAAAQBAJ?hl=en&gbpv=1&dq=air+temperature+igf+freezer+types&pg=PA43&printsec=frontcover

[8] Peterson, Randy "Cryogenic vs. Mechanical Freezers: The Best Uses for Each Method", *Stellar Food For Thought*. February 18, 2016. https://stellarfoodforthought.net/cryogenic-vs-mechanical-freezers-the-best-uses-for-each-method/

In terms of end-product appearance, processors assert that advanced mechanical IQF technologies typically excel in producing visually appealing products. The gentle separation facilitated by the upstream airflow addresses a common concern in cryogenic technologies where products like shrimp may freeze together, requiring forceful measures to break them apart. This forceful separation can potentially lead to damage of the surface and compromise the overall quality of the product.

Another challenge lies in the layer of snow that envelops products treated with liquid nitrogen, which not only bleaches the natural colour of the products but also results in a frosty and unappealing appearance. In contrast, this problem is non-existent when employing mechanical Individual Quick Freezing (IQF) methods.

INNOVATION IN FOCUS

To ensure a fair comparison between two systems achieving similar IQF shrimp quality, our chosen model for this case is the OctoFrost IQF fluidized freezer.

Shrimp processors worldwide have affirmed that the OctoFrost technology is not only a viable but – in terms of product appearance – even a superior alternative to cryogenic solutions in both output and results. This validation is the basis for our consideration of this head-to-head comparison as fair and meaningful.

The OctoFrost IQF freezer features a perforated bedplate that is using asymmetrical back-and-forth movements to advance the product forward (in contrast to conventional conveyor belt freezers). A strong upward airstream circulates through the holes of the bedplates, fluidizing the product and gently freezing each individual piece of shrimp.[9]

This particular IQF technology, can achieve premium quality IQF shrimp while the design of the freezer prioritizes easy cleaning, promoting optimal food safety throughout the processing cycle.

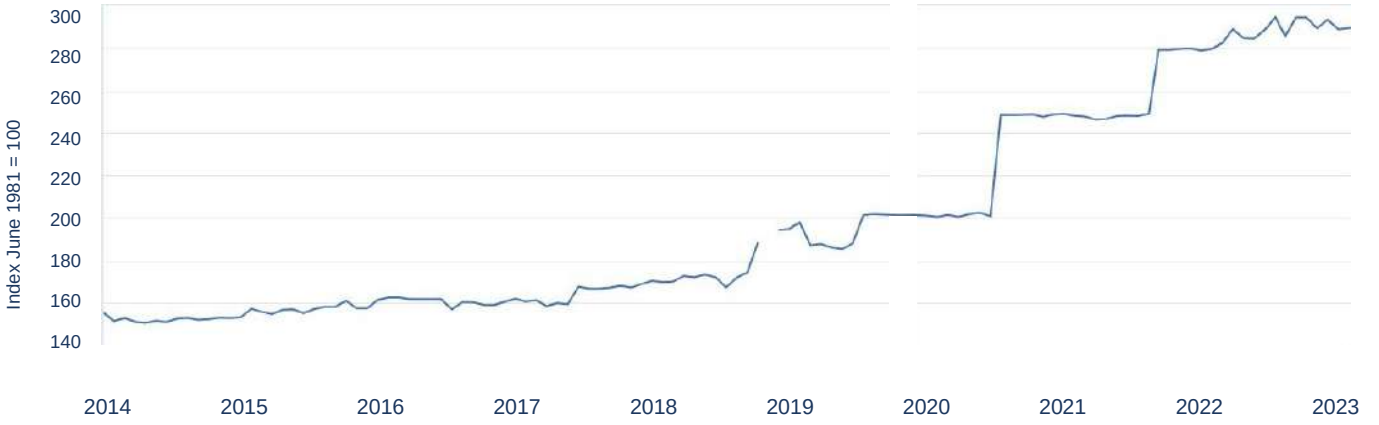
[9] Frozen Food Europe, "Energy Efficiency in IQF Freezers?" *Frozen Food Europe*, December 7, 2017. https://www.frozenfoodeurope.com/energy-efficiency-iqf-freezers/

The perforated OctoFrost bedplates have a smooth surface that prevent any marks or damage to frozen shrimp during the freezing process. Furthermore, this IQF tunnel allows for adjustable airflow, ensuring rapid crust-freezing in the initial freezing zone. This prevents lump formation, promotes gentle shrimp separation, and enhances energy efficiency.[10]

LIQUID NITROGEN COST OF OPERATION

One important element of our analysis is the cost of handling and using liquid nitrogen (LN2). The prices of liquid nitrogen (LN2) have demonstrated a consistent upward trend over the past two decades, experiencing notable spikes, particularly within the last 10 years (refer to Table 1).

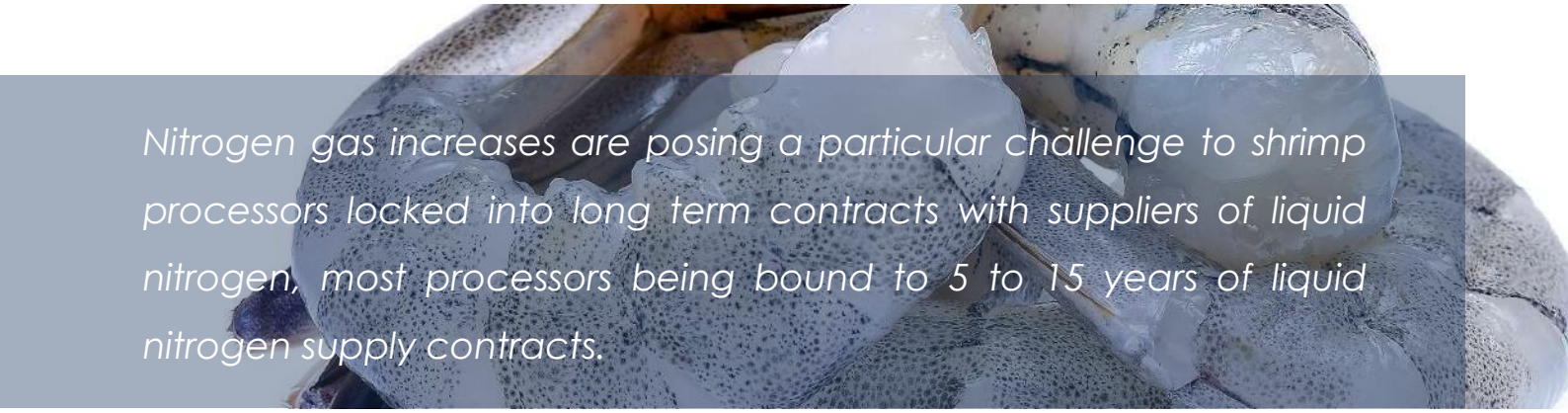
TABLE 1. FRED Producer Price Index by Industry: Industrial Gas Manufacturing Nitrogen



Shaded areas indicate U.S. recessions.

Source: U.S. Bureau of Labor Statistics

Another concern is that many suppliers only factor in the price of liquid nitrogen (LN2) before delivery. This means that expenses related to storage, delivery, and other miscellaneous costs are not initially included. Bulk purchasing of LN2 often involves hidden costs that businesses may overlook due to a lack of available information. There are unpredictable but nearly unavoidable expenses associated with nitrogen handling, including the cost of storage. [11]



Nitrogen gas increases are posing a particular challenge to shrimp processors locked into long term contracts with suppliers of liquid nitrogen, most processors being bound to 5 to 15 years of liquid nitrogen supply contracts.

[10] Peters, Nick. "IQF Freezing berries: The challenges of dehydration". Freshplaza, April 29, 2022. https://www.freshplaza.com/north-america/article/9423198/iqf-freezing-berries-the-challenges-of-dehydration/

[11] Ruther Ford Titan. "The Price of Liquid Nitrogen In The United States". *Ruther Ford Titan*. https://www.rutherfordtitan.com/liquid-nitrogen-generators/liquid-nitrogen-price-usa/?v=7516fd43adaa

CASE MODEL

This model is derived from a real case involving a U.S. shrimp processor seeking to replace a cryogenic freezer with a mechanical IQF freezer.

The IQF Freezer employed in this case model is the OctoFrost IQF Freezer, chosen to align with the desired capacity requirements.

PRODUCT TYPE: HOSO/PUD Shrimp

COUNT: 20 – 30 pc/lb

PRODUCTION CAPACITY: 4,000 LBS/h

PRODUCTION HOURS PER YEAR: 1680

YEARLY PRODUCTION: 6 720 000 LBS

CURRENCY USED: USD

ELECTRICITY AND REFRIGERATION per year	Cryogenic Freezer	OctoFrost IQF
Refrigeration need, TR	0	132
Need for electricity refrigeration based on TR, COP	0	383
Electricity need freezer, kW	5	105
Gas need, LBS LIN/LBS product (Industry average - 1,5 LIN/LBS Product)	10,080,000	0
OPERATIONAL COSTS		
Electricity cost + refrigeration cost, USD/kWh (Industry average - 0,10 USD/kWh)	840	82,040
Gas per LBS cost + tank cost + service cost, USD/LBS (Industry average - 0,08 USD/LBS)	**806,400**	**0**
TOTAL	**807,240**	**82,040**
RESULTS OPERATIONAL COSTS		
Freezing cost, USD/LBS	0,12	0,012
Freezing cost per year, USD/year	807,240	82,040
OPERATIONAL COST SAVINGS **With IQF OctoFrost vs. Cryogenic Freezer**		**725,200 USD/year**
OPERATIONAL COSTS DECREASE **OctoFrost vs. Cryogenic Freezer**		**9,8 times lower**

LESS THAN 2 YEARS FOR CAPEX INVESTMENT PAYBACK

The initial investment in the IQF freezer and refrigeration plant is of course variable based on capacity and equipment chosen. However, even when considering the investment for a new, advanced IQF freezer and a refrigeration plant – the substantial reduction in operation costs will result in a payback time of less than 2 years.

CONCLUSIONS

The current landscape of volatile shrimp prices, unpredictable demand, increasing feed and production costs, and the emergence of competitive sourcing countries requires a thorough exploration of cost-efficient processing methods. In the realm of industrial-scale IQF freezing, two primary technologies dominate the practices of IQF shrimp processors worldwide: Cryogenic freezing and IQF mechanical freezing.

While cryogenic freezing equipment demands lower upfront capital investment, operational costs for producers are markedly high due to the substantial volumes of refrigerant required. The increasing costs of nitrogen gas along with the associated logistical expenses, pose a specific challenge for shrimp processors committed to long-term contracts with liquid nitrogen suppliers.

On the other hand, IQF mechanical freezing systems generally entail higher initial capital costs due to the need for supporting refrigeration infrastructure. However, their efficiency and cost-effectiveness over the long term make them a favourable choice.

Innovative IQF mechanical freezing technologies can match or even surpass the quality of IQF shrimp produced with cryogenic freezing. The technological advancements in mechanical IQF freezing can reduce freezing costs per pound of product by tenfold, making shrimp processors less vulnerable to market price volatility and significantly improving business profitability. As the industry navigates these challenges, embracing advanced mechanical freezing methods emerges as a strategic move for sustainable and resilient shrimp processing operations.

MODEL ADAPTATION

*Try this **Online Calculator** for quickly adapting the model to your shrimp processing business and calculate your yearly savings in operational costs when transitioning from cryogenic to an IQF Freezer. For more information visit www.octofrost.com.*