Enhanced Report: Advancing Seafood Freshness Preservation with King Son IFP Chilling Technology

Executive Summary

King Son Instrument Tech. Co., Ltd.'s Constancy Initial Freezing Point (IFP) Chilling Technology represents a significant advancement in seafood preservation. Operating in the temperature range between 0°C and the initial freezing point (IFP) of seafood (typically -0.5°C to -2.8°C), this technology extends shelf life, maintains organoleptic quality, and minimizes microbial and enzymatic degradation without freezing. This report evaluates the impact of King Son IFP Chilling on seafood freshness, drawing on its mechanisms, benefits, and comparative advantages over traditional chilling and freezing methods. The technology's ability to inhibit microbial growth, reduce respiration, and preserve cellular integrity positions it as a transformative solution for the seafood industry, offering economic and environmental benefits by reducing waste and energy use.

1. Introduction

Seafood is highly perishable due to its high-water content, nutrient richness, and neutral pH, which fosters rapid microbial and enzymatic spoilage. Traditional preservation methods, such as refrigerative (0°C to 4°C) and freezing (below -18°C), have limitations: refrigerative offers limited shelf life (2-10 days), while freezing can compromise texture and flavor due to ice crystal formation. King Son IFP Chilling operates in a precise temperature range just above the seafood's initial freezing point, avoiding ice formation while maximizing freshness. This report assesses the IFP Chilling technology's impact on seafood quality, shelf life, and industry applications, supported by scientific principles and industry insights.

2. King Son Constancy IFP Chilling Technology: Mechanisms and Principles

King Son IFP Chilling leverages the concept of the initial freezing point (IFP), the temperature at which crystallization begins in food tissues, typically between -0.5°C and -2.8°C for seafood. Unlike freezing, which forms ice crystals that damage cellular structures, IFP Chilling maintains seafood in a non-frozen state, preserving tissue integrity. Key mechanisms include:

- **Temperature Control**: The technology maintains a stable temperature (e.g., -0.8°C) using precision refrigeration systems like the King Son Convertible IFP Sub Chiller, with fluctuations as low as ±0.3°C. This ensures seafood remains above its IFP, preventing freeze denaturation.

- **Inhibition of Microbial Growth**: Low temperatures significantly reduce the growth rate of spoilage bacteria (e.g., pseudomonads), extending shelf life. Studies indicate microbial activity is 30-60% lower at -0.8°C compared to 0°C.
- **Suppression of Enzymatic Activity**: IFP Chilling inhibits enzymes responsible for autolytic degradation, such as those breaking down adenosine triphosphate (ATP) into hypoxanthine (Hx), a key indicator of fish spoilage (K-value). Lower K-values correlate with higher freshness.
- **Reduced Respiration and Metabolic Rate**: For live or freshly harvested seafood, IFP Chilling lowers cellular respiration, reducing CO_2 exhalation by 30-60% compared to standard refrigerative temperature storage, preserving nutrients and flavor compounds.
- **Cellular Protection**: The presence of natural antifreeze compounds (e.g., glucose, amino acids) in seafood cells, combined with the King Son Constancy IFP Chilling technology's precise temperature control, prevents ice formation, maintaining cell membrane integrity and reducing drip loss.

These mechanisms collectively extend shelf life while preserving sensory attributes (taste, texture, appearance) and nutritional value.

3.Postmortem Quality Changes in Aquatic Products

Post-mortem quality degradation in aquatic products occurs in four stages:

1. **Rigor Mortis**: Post-death glycolysis produces lactic acid, and ATP and creatine phosphate decompose, causing muscle contraction and loss of elasticity.
2. **Rigor Off**: Endogenous proteases degrade proteins, relaxing and softening muscles.
3. **Autolysis**: Proteins break down into peptides and amino acids, enhancing flavor but facilitating bacterial growth.
4. **Putrefaction**: Microbial proliferation leads to off-odors, color changes, and spoilage.

These stages are accelerated by temperature, making low-temperature preservation critical.

4. Effects of King Son Constancy IFP Chilling Technology

4.1 Inhibition of Microbial Growth

Microbial activity is a primary cause of spoilage, particularly during autolysis and putrefaction. IFP Chilling reduces microbial metabolic rates by approximately twofold for every 10°C temperature decrease. At IFP Chilling temperatures, structured water molecules limit free water, significantly inhibiting microbial growth.

- **Study on White leg shrimp (Penaeus vannamei)**: Study found that after 2 days, IFP Chilling significantly reduced total bacterial colonies compared to refrigeration. By day 4, refrigerated shrimp exceeded second-grade freshness standards, while IFP Chilled shrimp remained within first-grade standards until day 8.

- **Cold-Tolerant Bacteria**: IFP Chilling inhibits cold-tolerant bacteria that spoil aquatic products under refrigeration and halts the growth of mesophilic bacteria like *Bacillus mutans*, *Vibrio parahaemolyticus*, and *Salmonella*.

4.2 Preservation of Freshness

IFP Chilling delays the production of volatile nitrogen-containing compounds associated with spoilage, enhancing freshness.

- **Fish Preservation**: The research showed that IFP Chilling reduced putrefactive volatile substances in fish, improving quality.
- **Flounder Study**: The research reported that flounder under refrigeration exceeded shelf life by day 4, while IFP Chilling stored the flounder maintained second-grade freshness until day 18, extending shelf life by 14 days.

4.3 Reduction of Chemical Reactions

Chemical reactions such as lipid oxidation and non-enzymatic browning are temperature dependent. IFP Chilling, operating at lower temperature just above initial freezing point lower than refrigeration, slows these reactions by 1.4-2 times.

- **Anchovy Study**: The study demonstrated that anchovies stored at -1.0°C in IFP Chilling conditions with ozone water showed reduced lipid oxidation compared to 3°C refrigeration.

4.4 Dehydration Applications

IFP Chilling is used for dehydration at -1.5°C to 0°C, preserving freshness while reducing drying waste.

- **Sardine Dehydration**: The study showed that sardine fillets dehydrated at -1.5°C had a K value (freshness indicator) of 40-50% after 19 days, compared to 60-70% after 3 days at 20°C cold air drying.

4.5 Microbiological Safety

King Son IFP Chilling at -1.7°C inhibits microbial growth, particularly cold-tolerant bacteria and pathogens like *Vibrio parahaemolyticus* and *Salmonella*. The technology maintains first-grade freshness for shrimp up to 8 days, compared to 4 days under refrigeration. At 0°C, microbial growth is slower than at 4°C, likely ensuring safety through 21-28 days with proper handling, reducing spoilage risks and enhancing consumer trust.

- **SGS Microbiological Tests**:
    - **Day 0**: Total Viable Count (TVC) of 6.4×10^3 CFU/g.
    - **Day 28**: TVC of 7.5×10^5 CFU/g, indicating acceptable microbial levels for extended storage.

5. Impact on Seafood Freshness

5.1 Shelf-Life Extension

King Son Constancy IFP Chilling Technology significantly extends the shelf life of seafood compared to traditional chilling. Research on super-chilling (a related concept) shows that fish stored at -1°C, -2°C, and -3°C can last 17, 22, and 29 days, respectively, compared to 14 days at 0°C. While specific data for King Son Constancy IFP Chilling varies by species, the technology's ability to maintain temperatures just above IFP (e.g., -0.8°C) suggests comparable or superior results. For example:

- **Finfish (e.g., salmon, cod)**: Shelf life extends from 7-10 days (ice chilling) to 14-21 days with IFP Chilling, based on reduced microbial growth and enzymatic activity.
- **Shellfish (e.g., shrimp, scallops)**: Shelf life increases from 2-3 days (refrigeration) to 7-14 days, with minimal texture degradation.

5.2 Organoleptic Quality

IFP Chilling preserves sensory attributes critical to consumer acceptance:

- **Texture**: By avoiding ice crystal formation, IFP Chilling prevents cellular damage, maintaining firmness and juiciness. For sashimi-grade fish, dry aging in IFP conditions enhances flavor without compromising texture.
- **Flavor**: Reduced enzymatic breakdown of ATP preserves umami compounds (e.g., inosine monophosphate). The IFP Chilling technology's low temperature minimizes off-flavors from microbial metabolites.
- **Appearance**: Seafood retains vibrant color and sheen, with no discoloration or drying around edges, unlike refrigerated storage at 0-4°C.

Organoleptic assessments of super-chilled cod and salmon show shelf-life extensions of 5-7 days beyond standard refrigerative storage, with retained palatability. IFP Chilling likely achieves similar results due to its precise temperature control.

5.3 Nutritional Integrity

IFP Chilling minimizes nutrient loss by slowing bacteriological degradation and oxidative processes. Unlike freezing, which can disrupt protein and fat structures, IFP Chilling preserves essential fatty acids (e.g., omega-3s in fatty fish) and water-soluble vitamins. The technology's ability to maintain a "living state" in cells ensures nutrient retention, comparable to fresh-caught seafood.

5.4 Microbial Safety

By inhibiting psychrotrophic pathogens and spoilage organisms, IFP Chilling enhances food safety. The IFP Chilling technology reduces the growth rate of specific spoilage organisms (e.g., Shewanella, Pseudomonas), which produce off-odors and flavors. This is critical for raw consumption (e.g., sushi-grade fish), where microbial safety is paramount.

6. Comparative Analysis

6.1 IFP Chilling vs. Traditional Chilling (0°C to 4°C)

- **Shelf Life**: Traditional chilling (e.g., ice storage) limits shelf life to 7-10 days for finfish and 2-3 days for shellfish. IFP Chilling doubles or triples this duration.
- **Quality**: Ice chilling can lead to dehydration and weight loss, while IFP Chilling retains moisture and texture.
- **Energy Use**: IFP Chilling requires precise refrigeration but uses less energy than maintaining ice production and storage.

6.2 IFP Chilling vs. Freezing

- **Quality**: Freezing forms large ice crystals, causing drip loss and texture degradation. IFP Chilling avoids these issues, offering “fresh-like” quality.
- **Consumer Perception**: Consumers associate “never frozen” with higher quality, giving IFP-chilled seafood a market advantage.
- **Flexibility**: Freezing requires thawing, which can degrade quality if done improperly. IFP-chilled seafood is ready for immediate use.

6.3 IFP Chilling vs. Superchilling

King Son Constancy IFP Chilling Technology and King Son Constancy Superchilling Technology are advanced food preservation methods that operate at low temperatures to extend shelf life while maintaining quality, but they differ in their temperature ranges and effects on food. Below is a concise comparison based on their definitions, processes, and outcomes:

IFP Chilling

- **Definition**: Involves storing food at temperatures between 0°C (32°F) and just above the food’s **initial freezing point (IFP)**, typically -0.5°C to -2.8°C (31.1°F to 26.96°F) for most foods. The IFP is the temperature where ice begins to form.
- **Process**: Food is kept in a non-frozen state, avoiding ice formation. This is achieved using precise refrigeration systems like the King Son Convertible IFP Chiller, which maintains temperatures with minimal fluctuation (±0.3°C) and high humidity (85–95%) to prevent drying.
- **Effects**:
  - **Shelf Life**: Extends shelf life by 2–3 weeks compared to traditional refrigeration (0–6°C).
  - **Quality**: Preserves freshness, flavor, and texture by inhibiting enzyme activity and microbial growth without freezing, avoiding tissue damage from ice crystals.

- **Applications**: Used for fresh meat, fish, and produce. No thawing is required before consumption, making it ideal for cooked or ready-to-eat foods.
- **Benefits**: Maintains cell integrity, reduces drip loss, and retains nutritional value. Energy-efficient compared to freezing.

- **Example**: Storing poultry at 0°C to -1°C to keep it fresh without freezing, compliant with regulations like the EC's fresh poultry definition (-2°C to +4°C).

IFP Superchilling

- **Definition**: Involves cooling food to 1–2°C **just slightly below its initial freezing point,** typically -1.5°C to -2°C (29.3°F to 28.4°F), where 10–30% of the water content forms small ice crystals, often in the outer layer (shell freezing).
- **Process**: Food is rapidly cooled using methods like blast chillers, mechanical freezers, or slurry ice to form a thin frozen layer, then stored at a stable superchilling temperature (e.g., -1.7°C for salmon) with precise control (±0.3°C, ±5% humidity) to minimize large ice crystal growth.
- **Effects**:
  - **Shelf Life**: Extends shelf life by 3–4 weeks, or 1.4–4 times longer than traditional refrigerative temperature storage, due to reduced bacterial and enzymatic activity. For example, superchilled salmon lasts 17–29 days vs. 14 days on ice.
  - **Quality**: The IFP (Initial Freezing Point) Superchilling process effectively maintains the glossy appearance and firmness of seafood and meat products. While small ice crystal formation may induce slight and limited texture changes, these are minimal compared to traditional freezing methods. Drip loss is significantly lower than freezing, though slightly higher than IFP chilling without surface ice formation. The use of vacuum packaging further enhances quality retention, minimizing oxidation, microbial growth, and moisture loss throughout storage.
  - **Applications**: Common for seafood (e.g., salmon, cod), poultry, and pork. Used in processing (e.g., filleting) and transport without ice, reducing costs.
  - **Benefits**: Longer shelf life, higher yields (e.g., in filleting), and energy savings compared to freezing. Thawing is faster than fully frozen products.
- **Example**: King Son Shell-Superchilling processed salmon at -1.7°C to form 10–30% ice, preserving it for 2–3 weeks with minimal weight loss compared to refrigeration.
- **Key Differences**

Aspect	King Son IFP Chilling	King Son IFP Superchilling
Temperature Range	0°C to just above IFP (-0.5°C to -2.8°C)	-1.5°C to -2°C (1–2°C just slightly below IFP)
Ice Formation	None; non-frozen state	10–30% water frozen, often in outer layer
Shelf Life	2–3 weeks	3–4 weeks (1.4–4x longer than chilling)
Quality Impact	No tissue damage; preserves original texture	Limited slight texture changes due to small ice crystals

Aspect	King Son IFP Chilling	King Son IFP Superchilling
Applications	Fresh produce, meat, cooked foods	Seafood, poultry, processing, transport
Thawing	Not required	Minimal thawing needed
Energy Use	Lower than freezing	Lower than freezing, slightly higher than IFP chilling

Critical Considerations

- **IFP Chilling** is better for foods requiring no freezing to maintain premium texture and freshness, especially for retail or culinary applications where thawing is undesirable. However, its shorter shelf-life limits long-term storage.
- **IFP Superchilling** offers longer preservation and is ideal for industrial processing and transport (e.g., fish without ice contained in the box), but precise temperature control is critical to avoid large ice crystals that could damage the texture.
- Regulatory nuances exist: in the US, poultry superchilled above -3.3°C (26°F) can be marketed as “fresh,” while EU regulations define fresh poultry as -2°C to +4°C, aligning more with King Son Constancy IFP chilling Technology.

Both methods outperform traditional refrigeration in shelf life and quality but cater to different needs. King Son Constancy IFP Chilling Technology prioritizes zero freezing for maximum freshness, while King Son Constancy IFP Superchilling Technology balances longer storage with minimal freezing. For specific foods like salmon, Shell Superchilling process and treatment has proven effective in experiments, reducing weight loss and maintaining appearance when vacuum-packed. Always verify the initial freezing point of the product and use standardized equipment to ensure consistent results.

7. Experimental Validation: Salmon Shell Superchilling

An experiment conducted from March 18 to April 15, 2024, tested King Son IFP Chilling on salmon fillets using an IRINOX Blast Chiller and King Son Convertible IFP Seafood Sub Chiller.

7.1 Methodology

- **Sample**: Fresh salmon fillets (imported from Norway to Taiwan).
- **Initial Freezing Point**: -2.2°C.
- **Processing**: Fillets were Shell-Superchilled process at -35°C for 5 minutes to form a surface ice content of less than 30%, vacuum-packed, and stored at -1.7°C ± 0.3°C with 90% ± 5% humidity for 28 days.
- **Measurements**: pH, sweetness, sensory evaluation (color, texture, aroma), and sous-vide cooking quality were assessed weekly.

7.2 Results

- **Day 1 (March 18)**:
  - Tail: pH 6.27, Sweetness 18.0.
  - Mid-section: pH 6.65.
- **Day 7 (March 25)**:
  - Tail (stored at -0.8°C): pH 6.44, Sweetness 10.8, Sensory Score 7. Bright color, firm texture, reduced elasticity. Sous-vide cooked salmon was fresh flavor.
  - Mid-section (stored at -1.7°C): pH 6.6, Sweetness 19.6, Sensory Score 9-10. Vibrant color, elastic texture, rich aroma. Sous-vide cooked salmon was juicy and aromatic.
- **Day 14 (April 1)**:
  - Salmon's mid-section flesh: preserved and stored at -1.7℃ degrees for 21 days, pH value 6.38, sweetness 18.4.
  - Sensory evaluation score 9 - 10
  - The color is bright, the muscle has a sheen, the fish meat has a rich aroma, the fish meat still has elasticity, and the texture is clear.
  - Sous-vide at 60°C for 2 hours - the fish has an enticing and rich aroma, is juicy and flavorful with a hint of sweetness.
- **Day 21 (April 8)**:
  - Mid-section (stored at -1.7°C): pH 6.38, Sweetness 18.4, Sensory Score 9-10. Bright color, shiny muscle, rich aroma, slightly declined elasticity, clear texture structure. Sous-vide cooked salmon was rich in aroma, juicy, and delicious, though sweetness was slightly declined.
- **Day 28 (April 15)**:

- Mid-section (stored at -1.7°C): pH 6.39, Sweetness 18.2, Sensory Score 9-10. Vibrant color, glossy flesh, no noticeable difference from day 21. Rich aroma, reduced elasticity, clear texture structure. Sensory evaluation of flavor and sweetness was slightly lower than the peak on day 21. Sous-vide cooked salmon had a sensory evaluation slightly below the day 21 peak.

7.3 Microbiological Safety

King Son Constancy IFP Chilling at -1.7°C inhibits microbial growth, particularly cold-tolerant bacteria and pathogens like *Vibrio parahaemolyticus* and *Salmonella*. The IFP Chilling technology maintains first-grade freshness for shrimp up to 8 days, compared to 4 days under refrigeration. At -1.7°C, microbial growth is slower than at 4°C, likely ensuring safety through 21-28 days with proper handling, reducing spoilage risks and enhancing consumer trust.

- **SGS Microbiological Tests**:
  - **Day 0**: Total Viable Count (TVC) of 6.4×10^3 CFU/g.
  - **Day 28**: TVC of 7.5×10^5 CFU/g, indicating acceptable microbial levels for extended storage.

7.4 Findings

The mid-section stored at -1.7°C exhibited superior quality retention compared to the tail at -0.8°C, which was insufficient for long-term shelf-life extension. IFP Chilling at -1.7°C preserved sensory attributes and extended shelf life effectively, with acceptable microbial levels after 28 days.

8. Industry Applications and Benefits

8.1 Supply Chain Flexibility

King Son Constancy IFP Chilling Technology enables longer storage and transport times, allowing seafood to reach distant markets without quality loss.

8.2 Economic Value

- **Reduced Waste**: By extending shelf life, IFP Chilling reduces spoilage losses, which account for 21.3% of fresh fish and 24.1% of shellfish at retail.
- **Premium Pricing**: Consumers pay a premium for fresh, high-quality seafood, and IFP Chilling supports “never frozen” claims.
- **Energy Efficiency**: Compared to freezing, IFP Chilling uses less energy, lowering operational costs.

8.3 Environmental Impact

IFP Chilling reduces food waste and energy consumption, aligning with sustainability goals. Unlike air-shipped fresh seafood, IFP-chilled products can be transported via sea or rail, lowering carbon emissions.

8.4 Culinary Applications

Chefs, particularly in French and Japanese cuisine, use IFP Chilling for dry aging sashimi and premium seafood, enhancing flavor while ensuring safety. The IFP Chilling technology's adoption in high-end restaurants underscores its ability to deliver superior quality.

9. Future Prospects

King Son IFP Chilling, endorsed by EU regulations (2023) and commended by the World Intellectual Property Organization (2020), is poised for broader adoption. Future developments could include:

- **Integration with IoT**: The A7 Intelligent Food-Tech Controller enables real-time monitoring, enhancing precision and scalability.
- **Expanded Applications**: Beyond seafood, IFP Chilling could preserve other perishables (e.g., meat, produce), as demonstrated with Korean sesame leaves.
- **Blockchain Integration**: Combining IFP Chilling with blockchain for traceability could enhance supply chain transparency.

11. Conclusion

King Son IFP Chilling Technology revolutionizes seafood preservation by extending shelf life, preserving sensory and nutritional quality, and enhancing microbial safety. Its precise temperature control, operating just above the initial freezing point, outperforms traditional chilling and freezing, offering a fresh-like experience without the drawbacks of ice crystal formation. The IFP Chilling technology's economic, environmental, and culinary benefits make it a game-changer for the seafood industry. While challenges like cost and implementation complexity exist, ongoing advancements and regulatory support position IFP Chilling as a cornerstone of modern food preservation.

12. Recommendations

- **Industry Adoption**: Seafood processors should invest in IFP Chilling systems, prioritizing species with high market value (e.g., salmon, shrimp).
- **Research**: Conduct species-specific studies to optimize IFP settings and quantify shelf-life extensions.
- **Consumer Awareness**: Launch marketing campaigns to educate consumers on the benefits of IFP-chilled seafood.
- **Policy Support**: Governments should incentivize adoption through subsidies for energy-efficient refrigeration technologies.