Industrial Refrigeration
For Food Preservation

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ASHRAE USA

Sawasdee Ka

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Outlines
- Product Lost
- Fruits & Vegetables
- Fishery

PRODUCT LOST
Product Lost

Causes:-
• Weight loss in storage and freezing
• Chilling injury
• Freezing injury
• Ammonia injury

Percentage of Weight (Moisture) Loss from Fruits and Vegetable that Affects Produce Quality after Harvest

<table>
<thead>
<tr>
<th>Product</th>
<th>Weight Loss (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans (broad, runner, snap)</td>
<td>6.0, 5.0, 4.0</td>
</tr>
<tr>
<td>Broccoli</td>
<td>6.0</td>
</tr>
<tr>
<td>Lettuce</td>
<td>3.7</td>
</tr>
<tr>
<td>Onion</td>
<td>10.0</td>
</tr>
<tr>
<td>Potatoes</td>
<td>7.0</td>
</tr>
<tr>
<td>Spinach</td>
<td>7.0</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>7.0</td>
</tr>
<tr>
<td>Tomatoes</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Weight loss during storage

Factors:-
• Room temperature & temperature fluctuation
• Humidity
• Air flow over the product
• Radiation effects of lighting
• Shape and size of the product
• Type of wrapper
Weight lost during freezing

Factors:
- Type of freezer
- Freezing time
- Type of product
- Air velocity
- Freezer operating conditions

<table>
<thead>
<tr>
<th>Product</th>
<th>Freezing Method</th>
<th>% weight loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>IQF shrimp</td>
<td>Air blast</td>
<td>2 to 2.5</td>
</tr>
<tr>
<td>IQF haddock</td>
<td>Air blast</td>
<td>1.2</td>
</tr>
<tr>
<td>IQF haddock</td>
<td>Cryogenic – CO2</td>
<td>0.6</td>
</tr>
<tr>
<td>IQF products</td>
<td>Cryogenic – N2</td>
<td>0.3 to 0.8</td>
</tr>
<tr>
<td>Tray of fillets</td>
<td>Air blast</td>
<td>1.0</td>
</tr>
<tr>
<td>Large fish or blocks</td>
<td>Air blast</td>
<td>0.5</td>
</tr>
<tr>
<td>Blocks of fish</td>
<td>Contact freezer metal to fish contact</td>
<td>0</td>
</tr>
</tbody>
</table>
FRUITS & VEGETABLES

Fruits & Vegetables
- Pre-cooling method
- Green Bean & Soya Bean
- Shallot (Red Onion)
- Banana Ripening
- Mango
- CA

Vegetables Postharvest General Flow
Fruits Postharvest General Flow at Packinghouse

- Load to Pre-cooler
- Pre-cooling @ desired condition
- Unload from Pre-cooler
- Packing

Load into wax m/c
Water spray cleaning
Inspection
Water spray brushing
Surface water removal
Wax emulsion coating with brush & spray
Drying with fan & heater
Grading by size
Packing
Cold storage
Transport

Fresh fruits

Ripening @ desired condition
Unload from ripening room
Packing

Fruits & Vegetables

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Max. transit &amp; shelf life (Days)</th>
<th>Opt. transit temp. (°C)</th>
<th>Highest freezing temp. (°C)</th>
<th>SRH</th>
<th>Air Change (cfm)</th>
<th>Ethylene Production Rate</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans, Green</td>
<td>10-14</td>
<td>7.2</td>
<td>5.0-7.2</td>
<td>90-95</td>
<td>45</td>
<td>Low</td>
<td>M</td>
</tr>
<tr>
<td>Broccoli</td>
<td>10-14</td>
<td>0</td>
<td>0.1-1.1</td>
<td>90-95</td>
<td>20</td>
<td>VL</td>
<td>High</td>
</tr>
<tr>
<td>Cabbage (White)</td>
<td>90-180</td>
<td>0</td>
<td>0.1-1.1</td>
<td>95-100</td>
<td>45</td>
<td>VL</td>
<td>High</td>
</tr>
<tr>
<td>Cucumber, Filled</td>
<td>30-140</td>
<td>0</td>
<td>0.1-1.1</td>
<td>95-100</td>
<td>45</td>
<td>VL</td>
<td>High</td>
</tr>
<tr>
<td>Lettuce</td>
<td>8-12</td>
<td>0</td>
<td>0.1-1.1</td>
<td>90-95</td>
<td>45</td>
<td>Low</td>
<td>M</td>
</tr>
<tr>
<td>Onions, Green</td>
<td>4-7</td>
<td>0</td>
<td>0.1-1.1</td>
<td>95-100</td>
<td>20</td>
<td>VL</td>
<td>Low</td>
</tr>
<tr>
<td>Onions, Dry</td>
<td>30-180</td>
<td>0</td>
<td>0.1-1.1</td>
<td>65-75</td>
<td>20</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Spinach</td>
<td>10-18</td>
<td>0</td>
<td>0.1-1.1</td>
<td>95-100</td>
<td>45</td>
<td>VL</td>
<td>High</td>
</tr>
<tr>
<td>Strawberries</td>
<td>3-7</td>
<td>85</td>
<td>0.1-1.1</td>
<td>90-95</td>
<td>20</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Sweet Corn</td>
<td>7-11</td>
<td>0</td>
<td>0.1-1.1</td>
<td>90-95</td>
<td>15</td>
<td>VL</td>
<td>Low</td>
</tr>
<tr>
<td>Tomatoes, breaker to light pink</td>
<td>7-14</td>
<td>100</td>
<td>0.1-1.1</td>
<td>90-95</td>
<td>15</td>
<td>M</td>
<td>High</td>
</tr>
</tbody>
</table>
Pre-cooling Methods for Fresh Produce

- Top Icing
- Hydro Cooling
- Hydair Cooling (air + cold water spray), Wet Air Cooling
- Air Cooling
  - Room Cooling
  - Force Air Cooling
- Vacuum cooling

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Top Icing

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Hydro Cooling
Hydro Cooling

Continuous Flow Shower Type Hydrocooler

Hydro Cooling

Batch Hydrocooler

Hydro Cooling

Continuous Flow Immersion Type Hydrocooler
**Hydro Cooling**

- Thermal Storage Immersion Hydrocooler

**Hydair Cooling System, Wet Air Cooling System**

- Wet Air Cooler
- Cold, Humid Air
- Produce
- Cold Room

**Hydair Cooling System, Wet Air Cooling System**

- Evaporative Condenser
- Compressor
- Ice Chiller & Water Tank
Hydro-Force Cooler (HAC)

Evaporator
Circulate Pump
Drift Eliminator
Air In
Water Spray
High Humidity Air Supply
Room Cooling
### Recommended Temperature (TD) for Four Classes of Foods (Forced Air Unit Coolers)

<table>
<thead>
<tr>
<th>Class</th>
<th>TD (°F)</th>
<th>RH</th>
<th>Suitable for</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7-9°F</td>
<td>90%</td>
<td>Fruits, vegetables, flowers, unpacked ice, chill room</td>
</tr>
<tr>
<td>2</td>
<td>10-12°F</td>
<td>80 - 85%</td>
<td>General cool room, packed products</td>
</tr>
<tr>
<td>3</td>
<td>12-16°F</td>
<td>65 - 80%</td>
<td>Beer, wine, pharmaceuticals, short term packaged products, tomatoes, onions, and tough skin fruits e.g. melons</td>
</tr>
<tr>
<td>4</td>
<td>17-22°F</td>
<td>50 - 65%</td>
<td>Processing rooms, cutting rooms, candies, loading docks</td>
</tr>
</tbody>
</table>

### Forced-Air Cooling

Tunnel type FAC using cold-wall system

### Force Air Cooling

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Vacuum Cooling

Some vegetables that can be vacuum cooled:
- All leafy vegetables
- Any type of lettuce
- Asparagus
- Bell pepper
- Bok choy
- Brussel sprouts
- Cabbage
- Carrots
- Cauliflower
- Celery
- Cucumbers
- Endive
- Escarole
- Green peas
- Leeks
- Mushrooms
- Oriental vegetables
- Parsley
- Prepack coleslaw
- Prepack spinach
- Radishes
- Romaine
- Snap beans
- Spinach
- Squash

Compare Cooling Methods for Fruits and Vegetables

<table>
<thead>
<tr>
<th></th>
<th>Room Cooling</th>
<th>Vacuum Cooling</th>
<th>FAC</th>
<th>Hydro Cooling</th>
<th>Top/Liquid icing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical cooling time (hr)</td>
<td>20 to 100</td>
<td>0.3 to 2.0</td>
<td>1 to 10</td>
<td>0.1 to 1.0</td>
<td>0.1 to 0.3</td>
</tr>
<tr>
<td>Product moisture loss (%)</td>
<td>0.1 to 2.0</td>
<td>2.0 to 4.0</td>
<td>0.1 to 2.0</td>
<td>0.1 to 0.5</td>
<td>No data</td>
</tr>
<tr>
<td>Water contact with product</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes, unless bagged</td>
</tr>
<tr>
<td>Potential for decay contamination</td>
<td>Low</td>
<td>none</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Capillarity</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Water-resistant packing needed</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Versatility</td>
<td>No</td>
<td>Common</td>
<td>Sometimes</td>
<td>Rarely done</td>
<td>Common</td>
</tr>
<tr>
<td>Feasibility of in-line cooling</td>
<td>No</td>
<td>No</td>
<td>Rarely done</td>
<td>Yes</td>
<td>Rarely done</td>
</tr>
</tbody>
</table>
# Recommended Cooling Methods for Fruits and Vegetables

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Vacuum Cooling</th>
<th>Room Cooling</th>
<th>Forced Air Cooling</th>
<th>Hydro Cooling</th>
<th>Top/liquid icing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans/snap</td>
<td>Y</td>
<td></td>
<td>Y</td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Broccoli</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cabbage</td>
<td>Y</td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Cantaloupe</td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Carrot</td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Celery</td>
<td>Y</td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Cucumbers</td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Egg Plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Onions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Vacuum Cooling</th>
<th>Room Cooling</th>
<th>Forced Air Cooling</th>
<th>Hydro Cooling</th>
<th>Top/liquid icing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lettuce</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potatoes</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spinach</td>
<td>Y</td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Strawberries</td>
<td></td>
<td>Y</td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Sweet corn</td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
<td></td>
</tr>
<tr>
<td>Sweet potatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tomatoes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Green Bean & Soya Bean**
Green Been & Soya Been

<table>
<thead>
<tr>
<th>Max. transit (Days)</th>
<th>Opt. transit temp. (°C)</th>
<th>Highest freezing temp. (°C)</th>
<th>Recommended container temp. accpeted (°C)</th>
<th>Shelf</th>
<th>Air change (cfm)</th>
<th>Ethylene Production Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beans, Green</td>
<td>~10-14</td>
<td>~7.2</td>
<td>~0.7</td>
<td>~5.0-7.2</td>
<td>~90-95</td>
<td>~45</td>
</tr>
</tbody>
</table>

Green Been & Soya Been

- Weighing
- Quality Control (Sampling)
- Bulk Store (Wet Air, FAC)
- Blowing Foreign Material
- Washing (Sand, Mud)
- Sorting, Size Grading
- Trimming (Tail, Head)
- Cleaning
- Blanching
- Quick Chilling (By Chilled Water)
- Fluidize Bed Freezing (IQF)
- Weighing & Packing
- Cold Store
- Export

Shallot (Red Onion) Processing
Fruits & Vegetables

<table>
<thead>
<tr>
<th></th>
<th>Max. transit &amp; shelf life (Days)</th>
<th>Opt. transit temp. (°C)</th>
<th>Highest freezing temp. (°C)</th>
<th>Opt. storage temp., setpoint (°C)</th>
<th>Rh.</th>
<th>Air Change (cfm)</th>
<th>Ethylene Production Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onions</td>
<td>7-14</td>
<td>0</td>
<td>-0.9</td>
<td>0-1.1</td>
<td>95-100</td>
<td>20</td>
<td>Very Low</td>
</tr>
<tr>
<td>Dry</td>
<td>30-360</td>
<td>0</td>
<td>-0.8</td>
<td>0-1.1</td>
<td>65-75</td>
<td>20</td>
<td>Medium</td>
</tr>
</tbody>
</table>

HARVEST

- Fully mature, well colored, and 1-2 inches in diameter.
- Cure in the sunlight, sacks, or bins, or under cover.
- Shallots are usually hand cleaned, topped and put into bags or bins for storage after the necks and bulbs are well cured.

Storage

- Store at 0–1 °C and 60-70% RH.
- Should not be placed into deep piles.
- Good air movement is critical.
- 8 to 10 months.
Postharvest Treatments

• Maleic hydrazide (Royal MH-30)
  • Two lb a.i. per acre when bulbs are
    • fully mature with soft necks and 5 to 8 green leaves
    • or approximately 50% of the tops have fallen, but are
      still green.
  • Applied at temperatures below 80 to 85° F.
  • Suggest to use a spray adjuvant in some arid
    regions.
  • Avoid early sprays before maturity.
  • Do not treat seed shallots.

Banana Ripening

Fruit Ripening

• What is Fruit Ripening?
  - Climacteric Fruits
  - Non-Climacteric Fruits
Climacteric Fruits

- Banana
- Apricot
- Papaya
- Kiwi
- Apple
- Guava
- Plum
- Figs
- Mango
- Pear
- Papaya

Non-Climacteric Fruits

- Pomegranate
- Raspberry
- Blackberry
- Strawberry
- Watermelon
- Litchi
- Grape
- Mousambi

Ripening Conditions for Some Kinds of Fruits

<table>
<thead>
<tr>
<th>Fruit</th>
<th>Exposure time (hours)</th>
<th>Range of ripening temperatures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avocado</td>
<td>8-48</td>
<td>59-68°F / 15-20°C</td>
</tr>
<tr>
<td>Banana</td>
<td>24-48</td>
<td>58-65°F / 14-18°C</td>
</tr>
<tr>
<td>Kiwifruit</td>
<td>12-24</td>
<td>54-72°F / 12-22°C</td>
</tr>
<tr>
<td>Mango</td>
<td>24-48</td>
<td>68-72°F / 20-22°C</td>
</tr>
<tr>
<td>Pear</td>
<td>24-48</td>
<td>68-72°F / 20-22°C</td>
</tr>
<tr>
<td>Tomato</td>
<td>24-72</td>
<td>65-68°F / 18-20°C</td>
</tr>
</tbody>
</table>

1 Shorter duration for more mature fruit
2 Faster ripening rate at higher temperatures
Banana Ripening

Four major factors:-
• Relative Humidity (RH) control
• Ethylene gas
• Temperature control (pulp temperature)
• Air circulation
Low relative humidity accelerates water loss and appearance of physical damage symptoms on banana.

Approx. daily pulp temperature desired for bananas scheduled to complete ripening in specified number of days

<table>
<thead>
<tr>
<th>Ripening schedule</th>
<th>Fruit temperature (°C) on day -</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day 1</td>
</tr>
<tr>
<td>4 days</td>
<td>18</td>
</tr>
<tr>
<td>5 days</td>
<td>17</td>
</tr>
<tr>
<td>6 days</td>
<td>17</td>
</tr>
<tr>
<td>7 days</td>
<td>16</td>
</tr>
</tbody>
</table>

Green bananas → Load into ripening room → Refrigerate for 12-16 hrs until pulp (core) temp. reaches 15-17°C, 90%RH

Close room and control atmosphere @15-17°C (3-4 days), 75%RH

Vent ethylene

Discharge Ethylene into room to 0.1% concentrate (1 day)
Mango

<table>
<thead>
<tr>
<th>Mango</th>
<th>Max. transit (Days)</th>
<th>Opt. transit temp. (°C)</th>
<th>Highest freezing temp. (°C)</th>
<th>Recommended container temp. (°C)</th>
<th>SAR</th>
<th>Air Change (cfm)</th>
<th>Ethylene Production Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mango</td>
<td>14-25</td>
<td>13.3</td>
<td>-0.9</td>
<td>12.2-13.3</td>
<td>85-90</td>
<td>20</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Export Fresh Mangos Process Flow

1. Hand harvest into baskets, nets or buckets
2. Remove latex
3. Transfer to field lug boxes (shaded)
4. Hydrocooling
5. Rest 12-24 hrs at ambient temp.
6. Pre-rinse for hot water treatment, pre-wash defect
7. Portable water brush & rinse
8. Dump into chlorinated water
9. Move pallets to cold storage room prior to shipping
10. Forced Air cooling
11. Palletizing & strapping
12. Pack fruit into cartons by size
13. Grade according to buyer requirements
14. Transfer to packinghouse
15. Transfer to field lug boxes
16. Portable water brush & rinse
17. Dump into chlorinated water
18. Move pallets to cold storage room prior to shipping
19. Forced Air cooling
20. Palletizing & strapping
21. Pack fruit into cartons by size
22. Grade according to buyer requirements
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44. Dump into chlorinated water
45. Move pallets to cold storage room prior to shipping
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48. Pack fruit into cartons by size
49. Grade according to buyer requirements
50. Transfer to packinghouse
51. Transfer to field lug boxes
52. Portable water brush & rinse
53. Dump into chlorinated water
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Ripen Mangos Process Flow

Ripen Mangos
Clean & Rinse
Peel
Cut
Freeze (Air Blast, Tunnel)
Vacuum Pack
Cold Storage
Freeze Dry
Pack

CONTROL ATMOSPHERE (CA)

Control atmosphere (CA)
Control atmosphere (CA)

Membrane type
Nitrogen Generator

PSA type
Nitrogen Generator

Control atmosphere (CA)

VPSA type
Oxygen Absorbers

Carbon Dioxide
Absorbers

Control atmosphere (CA)

Ethylene Scrubber
Control atmosphere (CA)

CA Door

Control atmosphere (CA)

Analyzer

Control atmosphere (CA)

Air bags to equilibrate pressure in controlled atmosphere rooms
# FISHERY

Fishery
- Freezer Trawler
- Fish
- Surimi
- Shrimp
- Freezing Technology

## Frozen fish

<table>
<thead>
<tr>
<th>Species (fish, shellfish)</th>
<th>Min. Shelf life (days)</th>
<th>Opt. trans temp (°C)</th>
<th>Max. freezing temp (°C)</th>
<th>Vent setpoint temp (°C)</th>
<th>Reccomm. &amp; RH</th>
<th>Air Change (cfm)</th>
<th>Ethylene Production Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatty (carp, salmon, sardine, tuna)</td>
<td>120-140</td>
<td>-23.3 to -20.5</td>
<td>-23.3 to -20.5</td>
<td>Vents closed</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lean (cod, pollock, perch)</td>
<td>240-360</td>
<td>-23.3 to -20.5</td>
<td>-23.3 to -20.5</td>
<td>Vents closed</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shrimp, Scallops</td>
<td>120-360</td>
<td>-23.3 to -20.5</td>
<td>-23.3 to -20.5</td>
<td>Vents closed</td>
<td>None</td>
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<tr>
<td>Crab, lobster</td>
<td>120-360</td>
<td>-23.3 to -20.5</td>
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<td>Vents closed</td>
<td>None</td>
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</table>
Freezer Trawler

Ice Machine for trawler
• chip ice from freshwater
• chip ice from fresh or seawater
• liquid ice from seawater

Fish Processing
Fish Processing

Receiving (Fresh or Frozen Fish)

- Unpacking
- Thawing (in water)
- Washing & Grading
- Skinning
- Evisceration & removal of valuable by-products (liver, milt)
- Filleting
- Washing

Rejected fish
- Skin
- Guts, head
- Bones, off-cuts reject

By-product

- By-product material
- Fish meal & fish oil Process
- Dehydrating
- Packing

External Packing

- By-product material

Fish Processing

Fish Fillet

Fish Finger

Surimi

Raw Material
- Chilled and washed in ice water (6°C)
- Heading and Gutting
- washed in ice water (6°C)

Deboner
- Leaching
- Hydraulic press
- Pressed Meat

Strainer/Refiner
- Mixing
- Packing
- Contact freezing (-40°C)

Packing
- Cold storage (-18°C to -20°C)
Shrimp Processing

Harvest → Store → De-head → Grade → Peel → Cook → I.Q.F. → Glaze → Weigh → Pack → Store → Ship

Place in block tray → Block freeze → Knock out → Weigh → Trays pack → Freeze → Overwrap → Dust- Batter → Bread → Fry → I.Q.F.

Freezing Technology

- Brine Freezer
- Contact Plate Freezer
- Spiral Freezer
- Tunnel Freezer
- Fluidized Bed Freezer
- Cryogenic Freezer
Cryogenic Freezer

Industrial Refrigeration
For Food Preservation

**Q & A**

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Tel: +66-2-374-4640

**Thank You**
*For Your Attention.*

شكري
Khun Ka