NTNU Sustainable Energy in Food Production MSTU

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Superchilling Technology - Implementation

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Global food trends

- **Health**
  - Life style disease, diets
- **Availability/convenience**
  - Distribution, new products
- **Quality/enjoyment**
  - Food safety, traceability, taste, freshness

Market for fresh and chilled foods

- In Europe about 63% of mass products need refrigeration.
- 60-70% - chilled and fresh
- Technological and market development are one of the crucial factors for the survival of economical units.
- The technologist is trying to increase productivity and marketer is trying to expand revenue.

Chilled foods

The Institute of Food Science and Technology (UK) defines:

- chilled foods as perishable foods which, to extend the time during which they remain healthy, are kept within controlled ranges of temperature above -1 and below 8°C.
- -1 to +1 (e.g. fresh fish, meat, minced meat).
- 0 to +5 (e.g. milk, cream, prepared salads, sandwiches)
- 0 to +8 (e.g. fully cooked meat and fish pies, fruit juices, soft fruits)

Norwegian Seafood

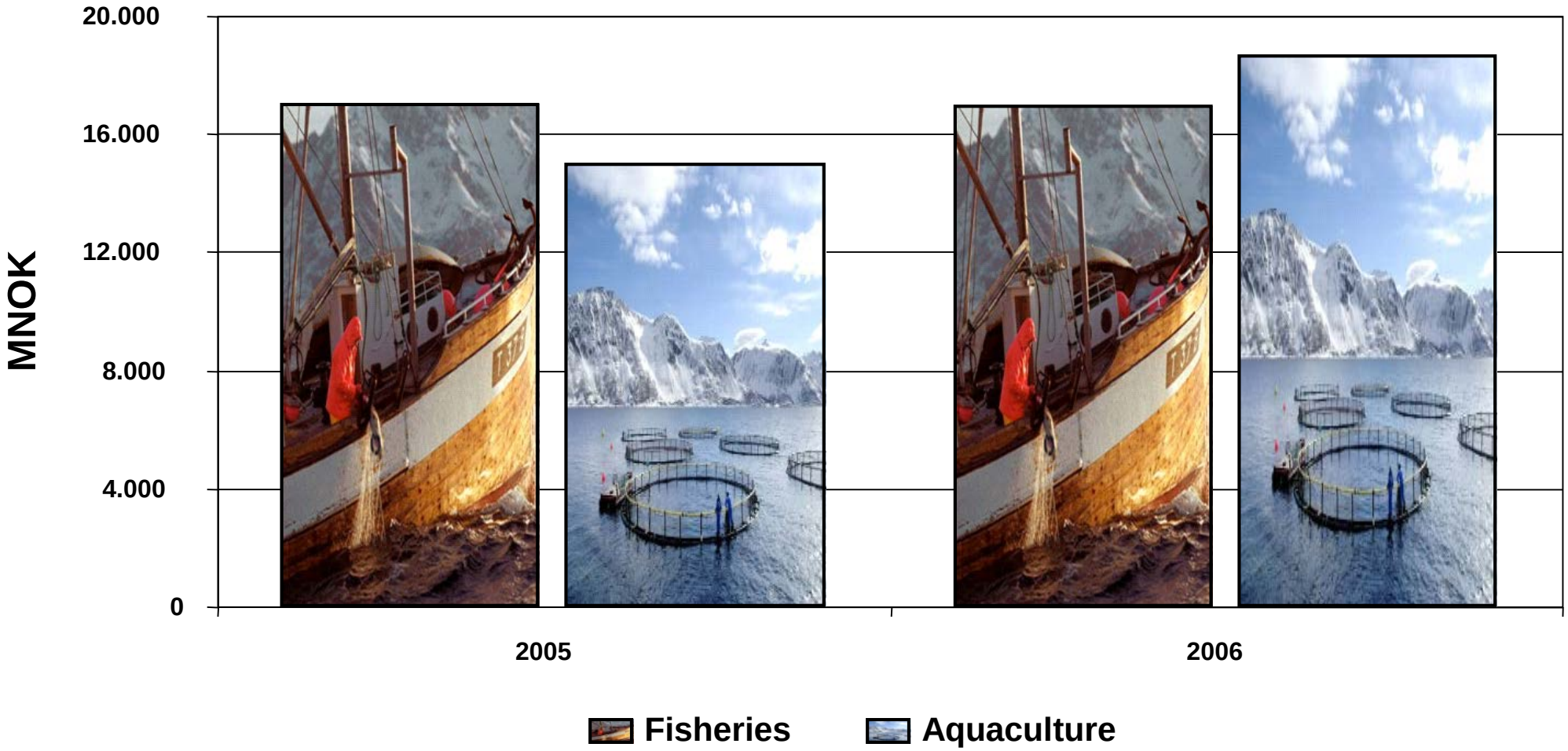
Natural conditions

People and the ocean

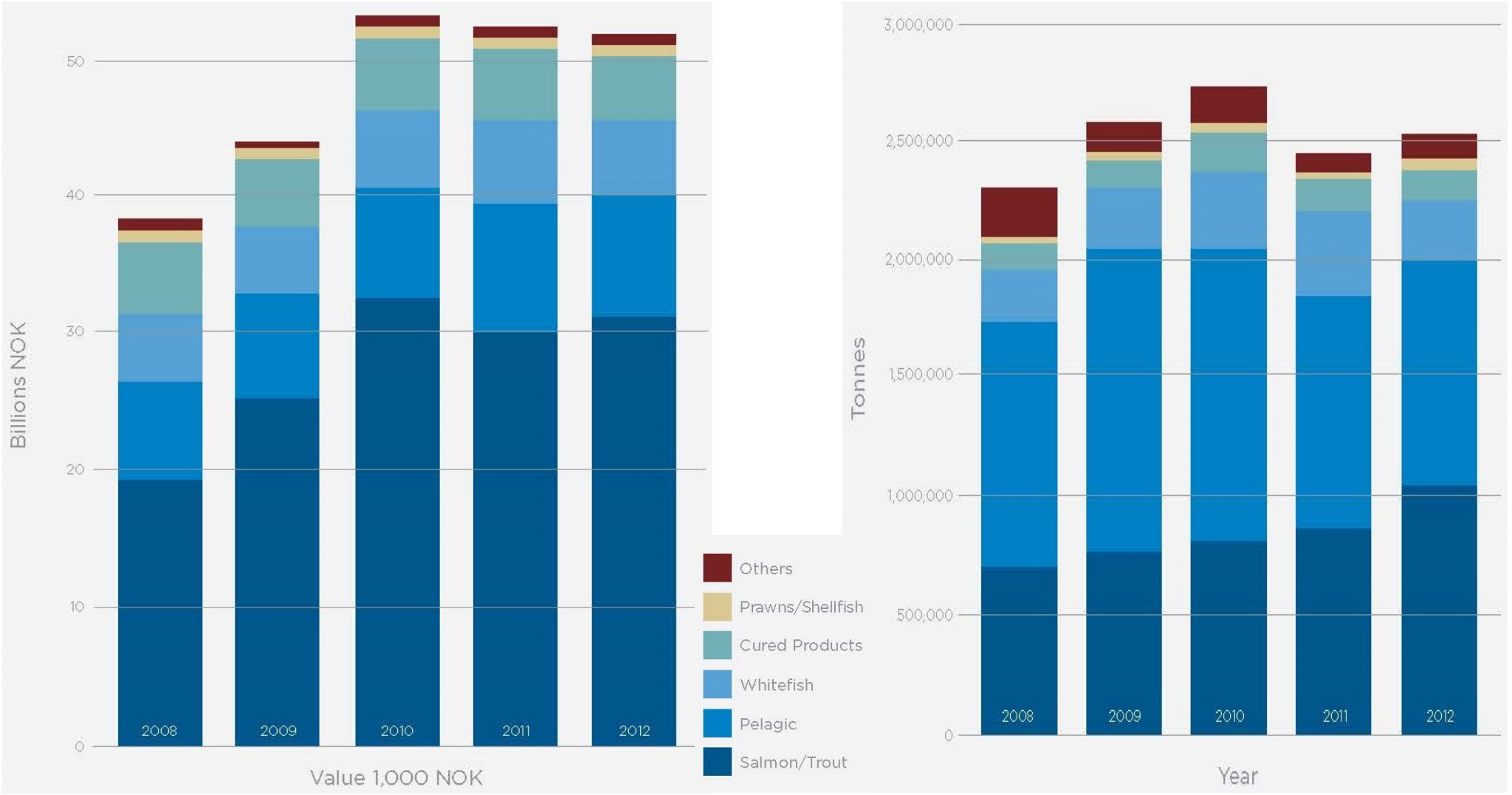
Sustainability

Norwegian export of seafood

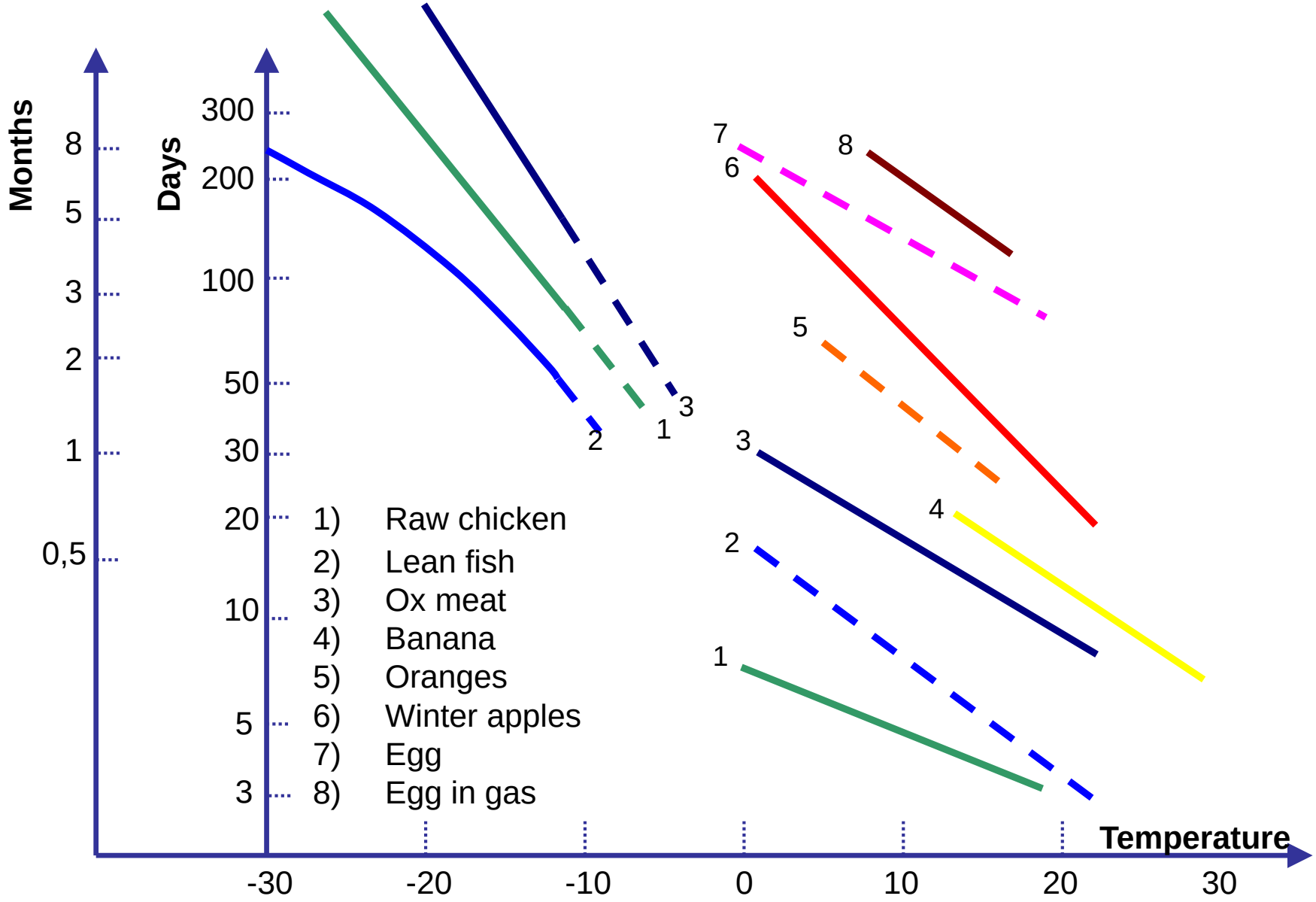
2005 – 2006



Trends in Norwegian fish export



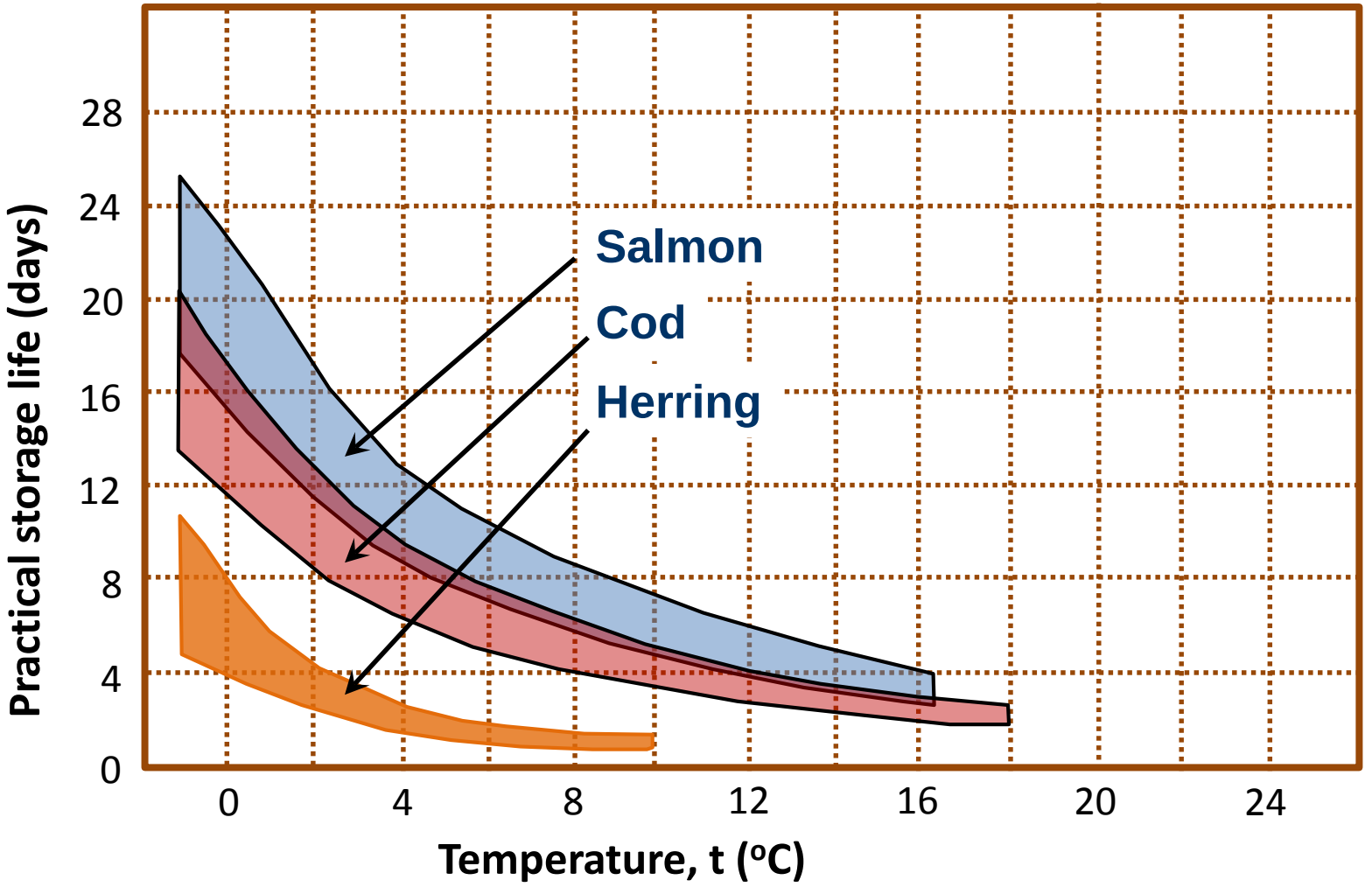
Shelf life dependent of temperature



Fresh fish distribution

Focus on fresh fish distribution require:

Long shelf life for valuable fish species



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Termodynamiske data for næringsmidler

Type mat	Fukt innhold % xwo	Protein % xp	Fett % xf	Karbohydrater Totalt % xc	Karbohydrater Fiber % xfb	Aske % xa	Initialt fryse punkt °C	Spesifik varme over frysepunkt kJ/(kg*K)	Spesifik varme under frysepunkt kJ/(kg*K)	Latent frysevarme kJ/kg	Porøsitet Kompakt ε = 0	Kontroll Vekt-andel %
Cod	81,22	17,81	0,67	0	0	1,16	-2,2	3,78	2,14	271	0	100,9
								3,75	2,37	212		

Beregnede verdier
Tall i gult felt er hentet fra ASHRAE

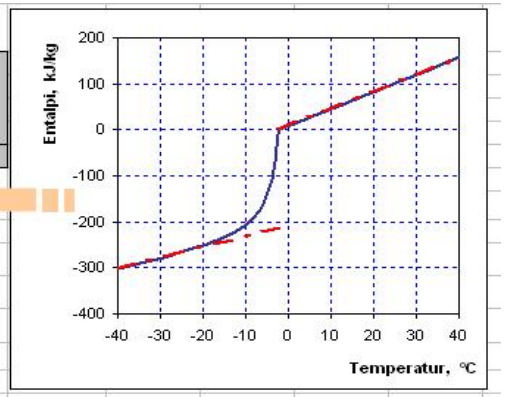
Velg her blant næringsmidler

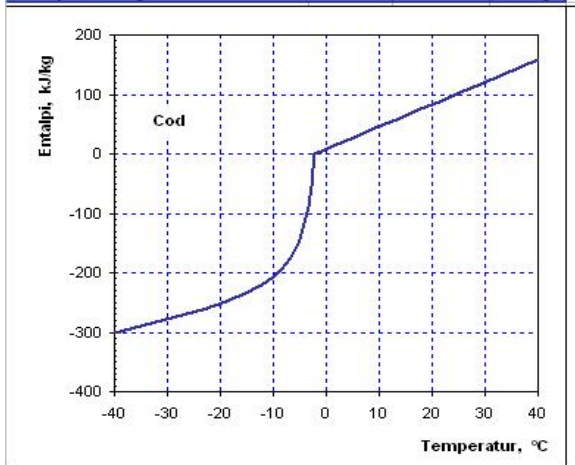
Oppdater data

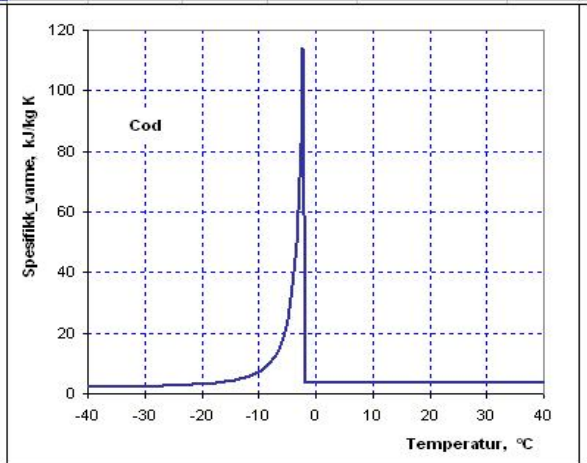
Cod

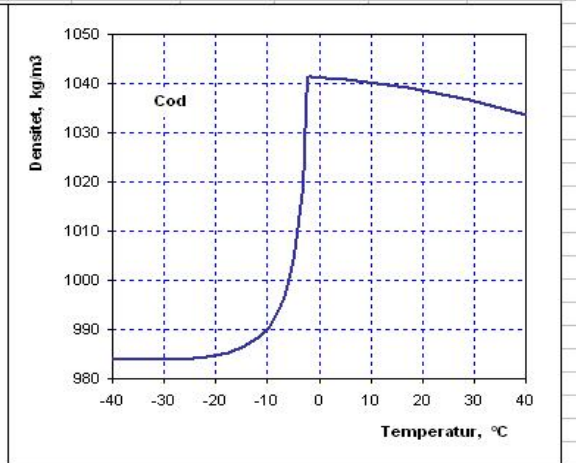
OBS!! Hvis navnet til Næringsmiddelet starter med 0- da mangler data for initialt frysepunkt og alle plott blir feil

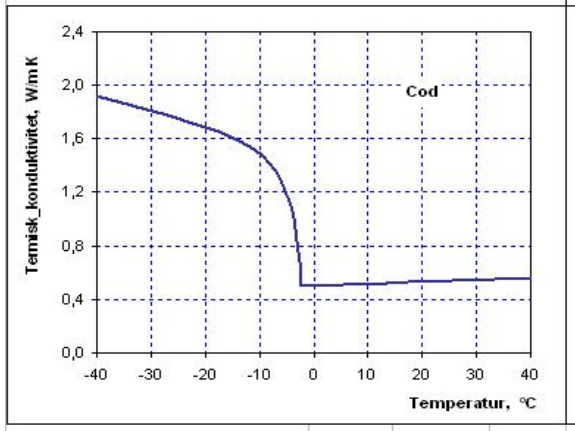
	°C	Entalpi	
Start-temperatur	7,0	34,39	kJ/kg
Slutt-temperatur	-20,0	-251,80	kjJ/kg
Entalpiendring		**286,19**	**kJ/kg**

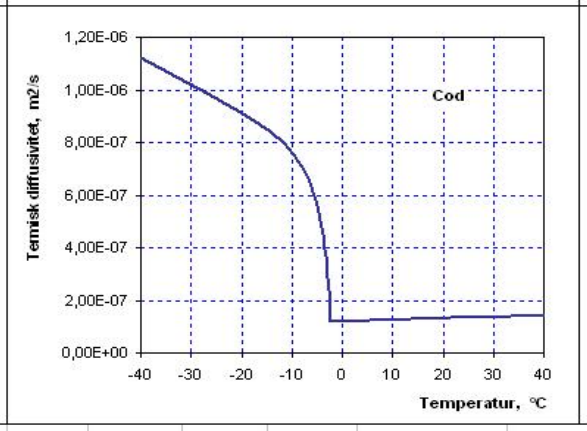


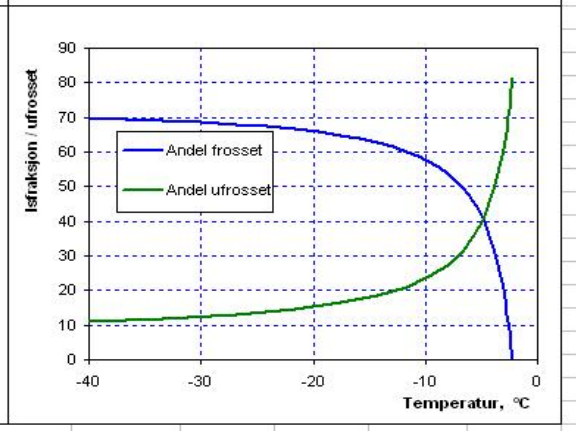












Data from
ASHRAE
Handbook of Refrigeration
Chapter 19

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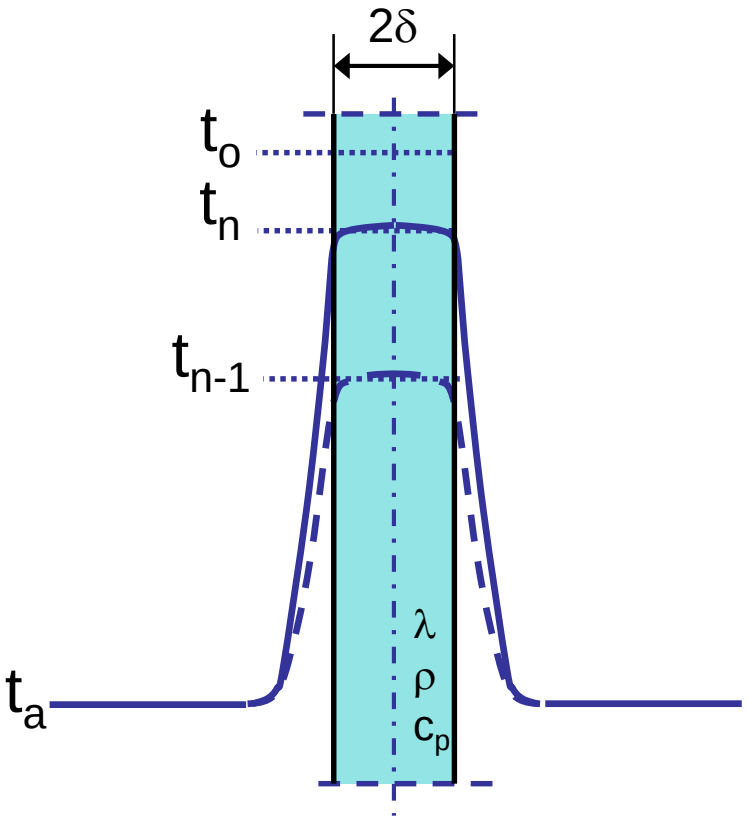
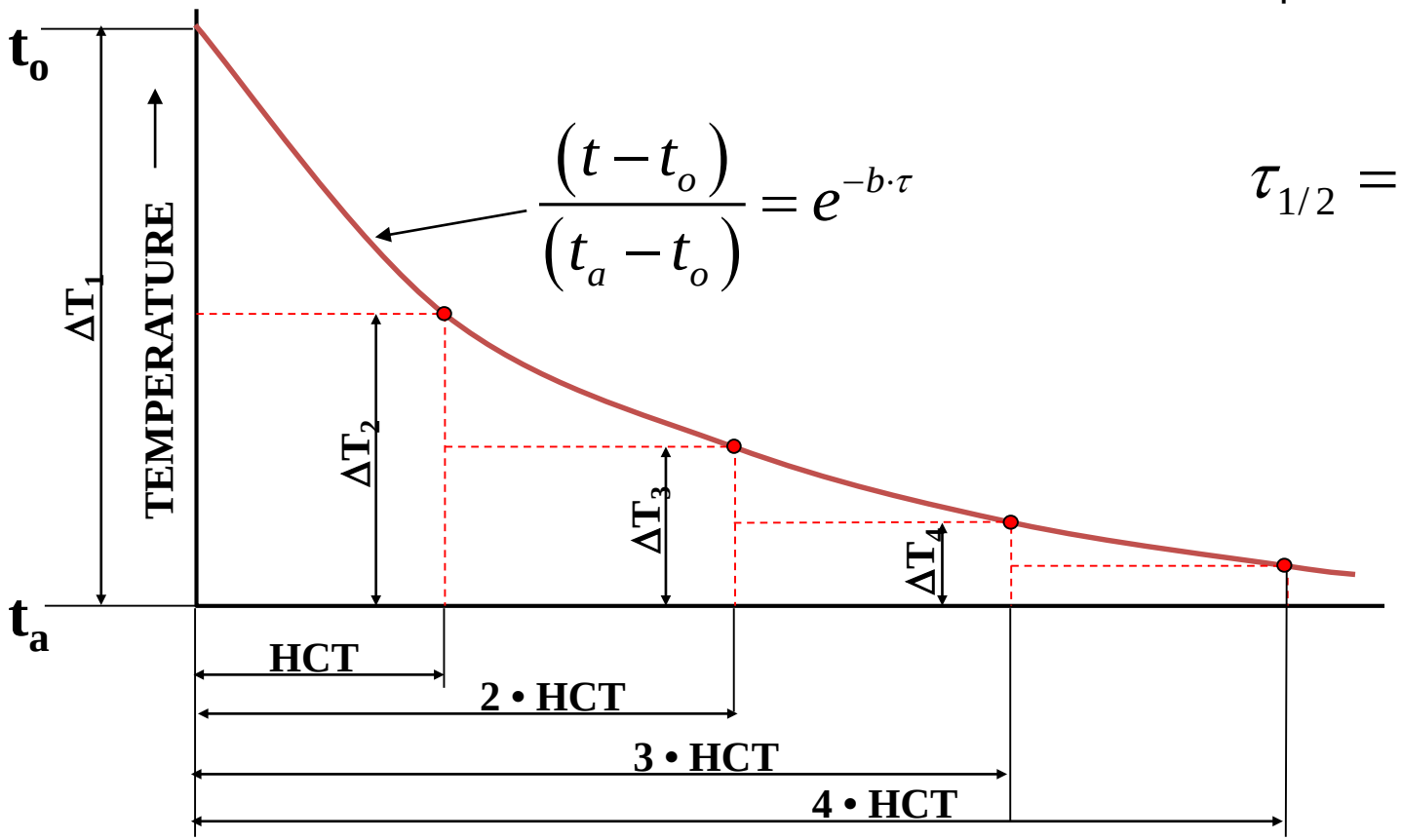
Cooling of products with neglectable internal resistance
Curve for a thin or small product



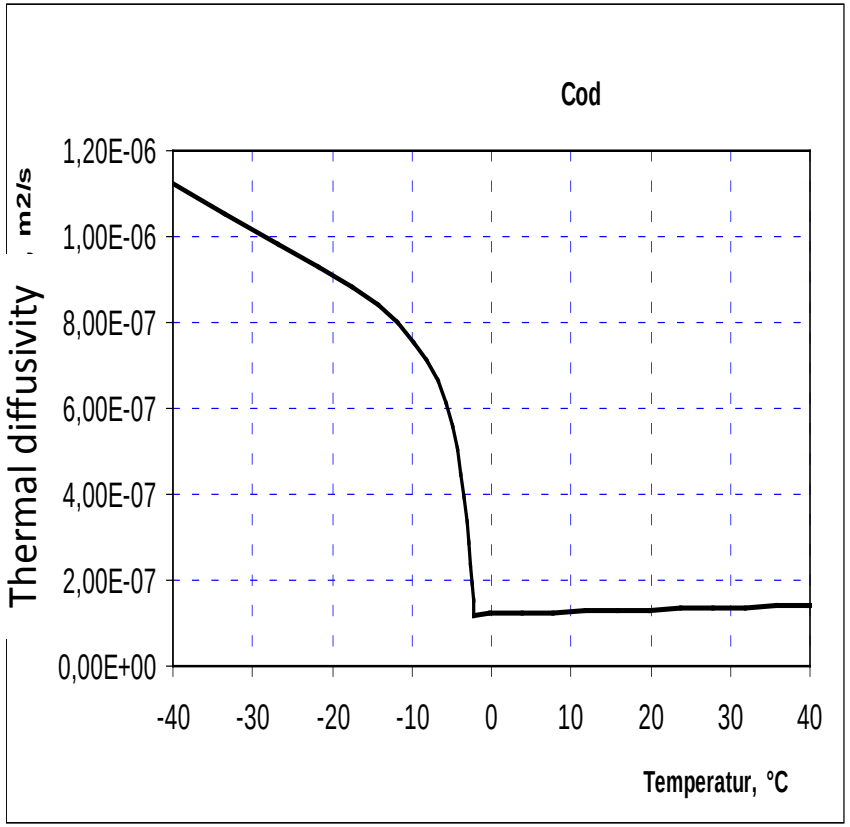
$$b = \alpha * A /(c_p * \rho * V)$$



$$\tau_{1/2} = \frac{\ln 2}{b}$$

Cooling of products with high internal thermal resistance

- Temperature laps can be described with models which uses dimension less numbers:
- **Fourier's number** $$F_o = \frac{a \cdot \tau}{D^2} = \frac{\lambda \cdot \tau}{\rho \cdot C_p \cdot D^2}$$
- **Biot number** $$B_i = \frac{R_{internal}}{R_{external}} = \frac{\frac{D}{\lambda}}{\frac{1}{\alpha}} = \frac{\alpha \cdot D}{\lambda}$$
- Physical the Fourier's number indicates the speed at chilling and heating of a material
- Biot's number gives the relation between heat transfer at the surface and the thermal resistance in the material. Low Biot's numbers, means the heat transmission internal in the material is the dominant factor and with high numbers the heat transfer at the surface is the dominant factor.



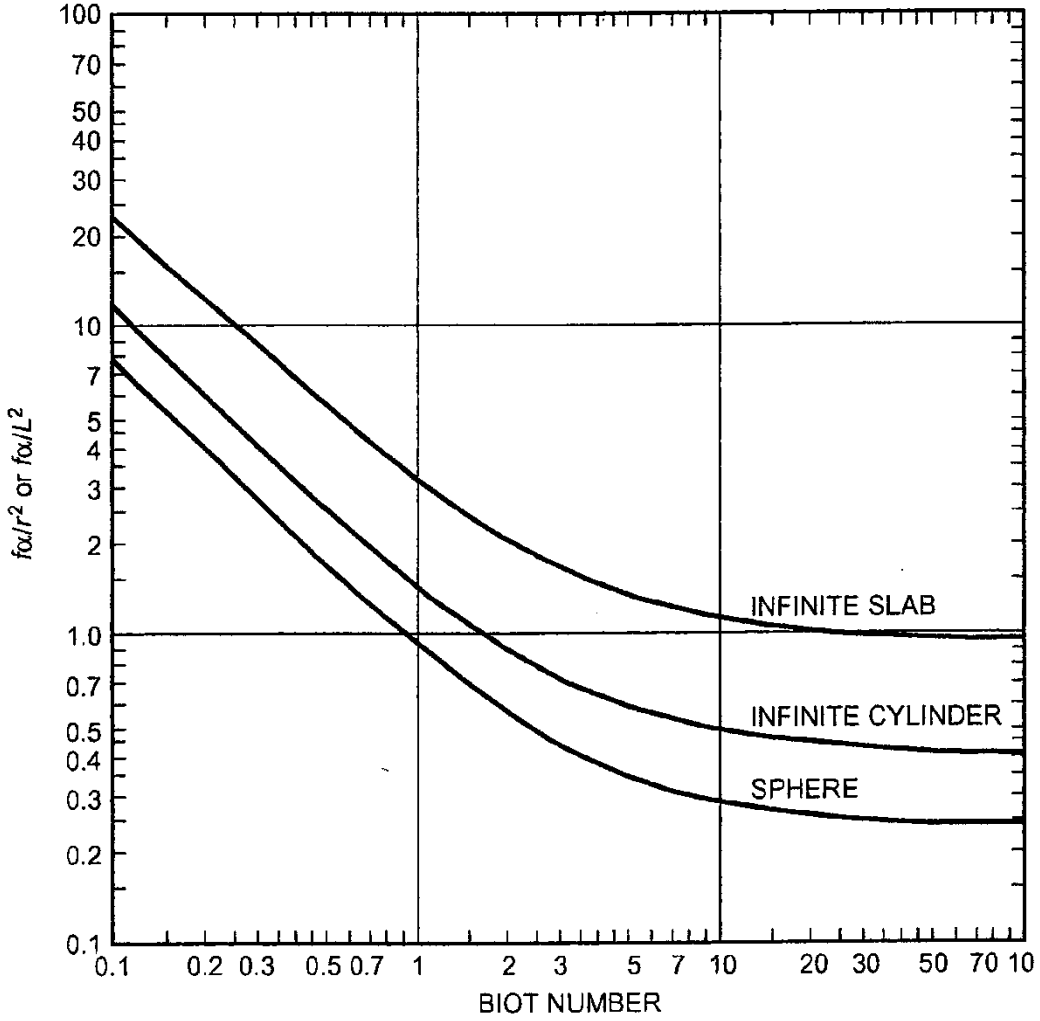
Thermal diffusivity $$a = \frac{\lambda}{\rho \cdot C_p}$$

Cooling Time Estimation Methods Based on f and j Factors

$$Y = \frac{t_a - t}{t_a - t_o} = \frac{t - t_a}{t_o - t_a} = j\, e^{-2.202\tau/f}$$

$$\tau = \frac{-f}{2.202} \ln (Y/j)$$

Relationship between $f\alpha/r^2$ and Biot number



Relationship between J and Biot number for Various Shapes

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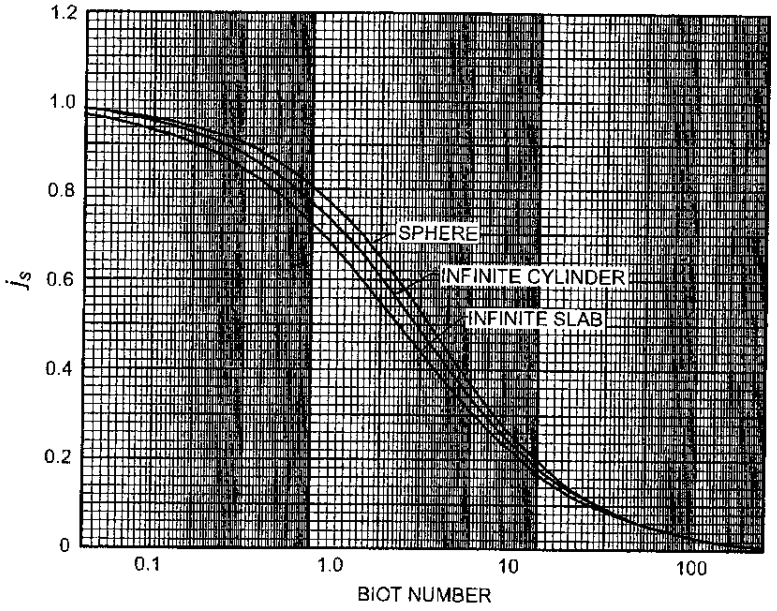
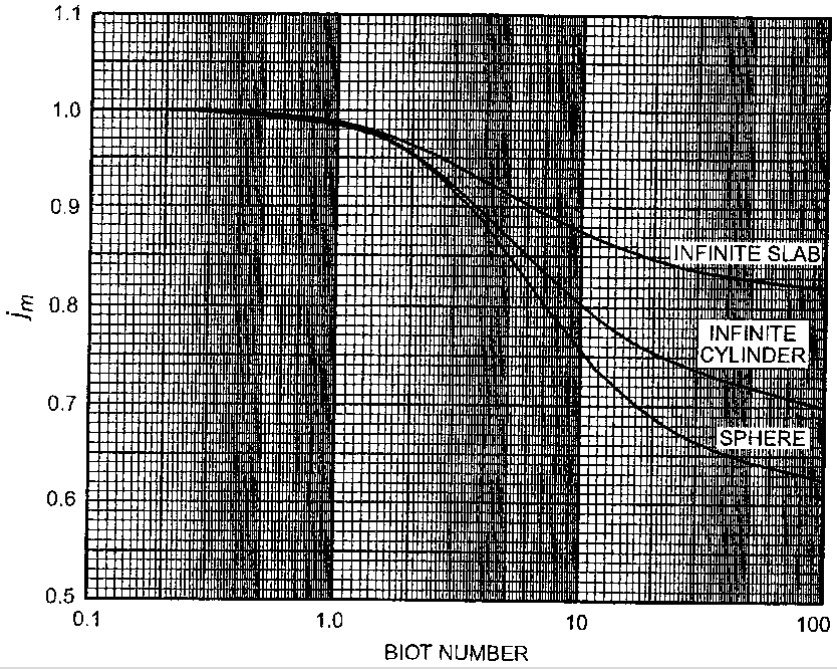
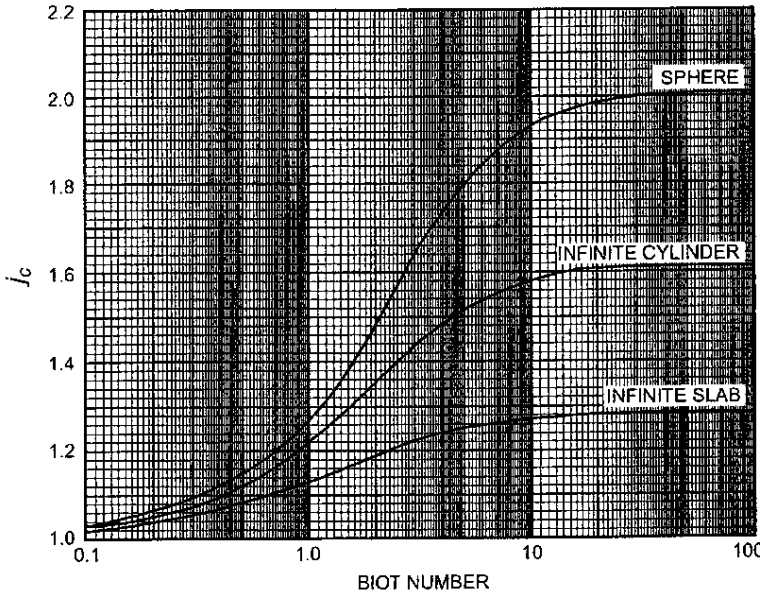


Surface Temperature



Average Temperature



Thermal Center Temperature

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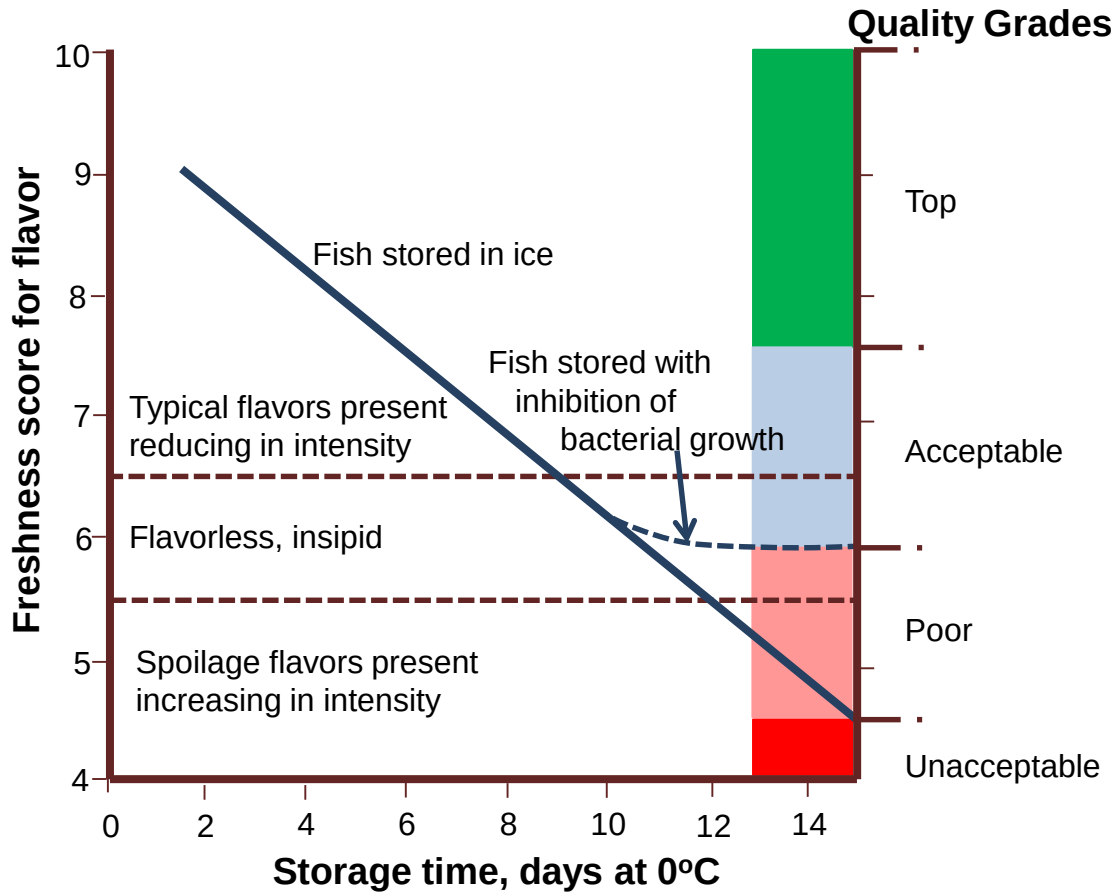
Freshness score with storage time

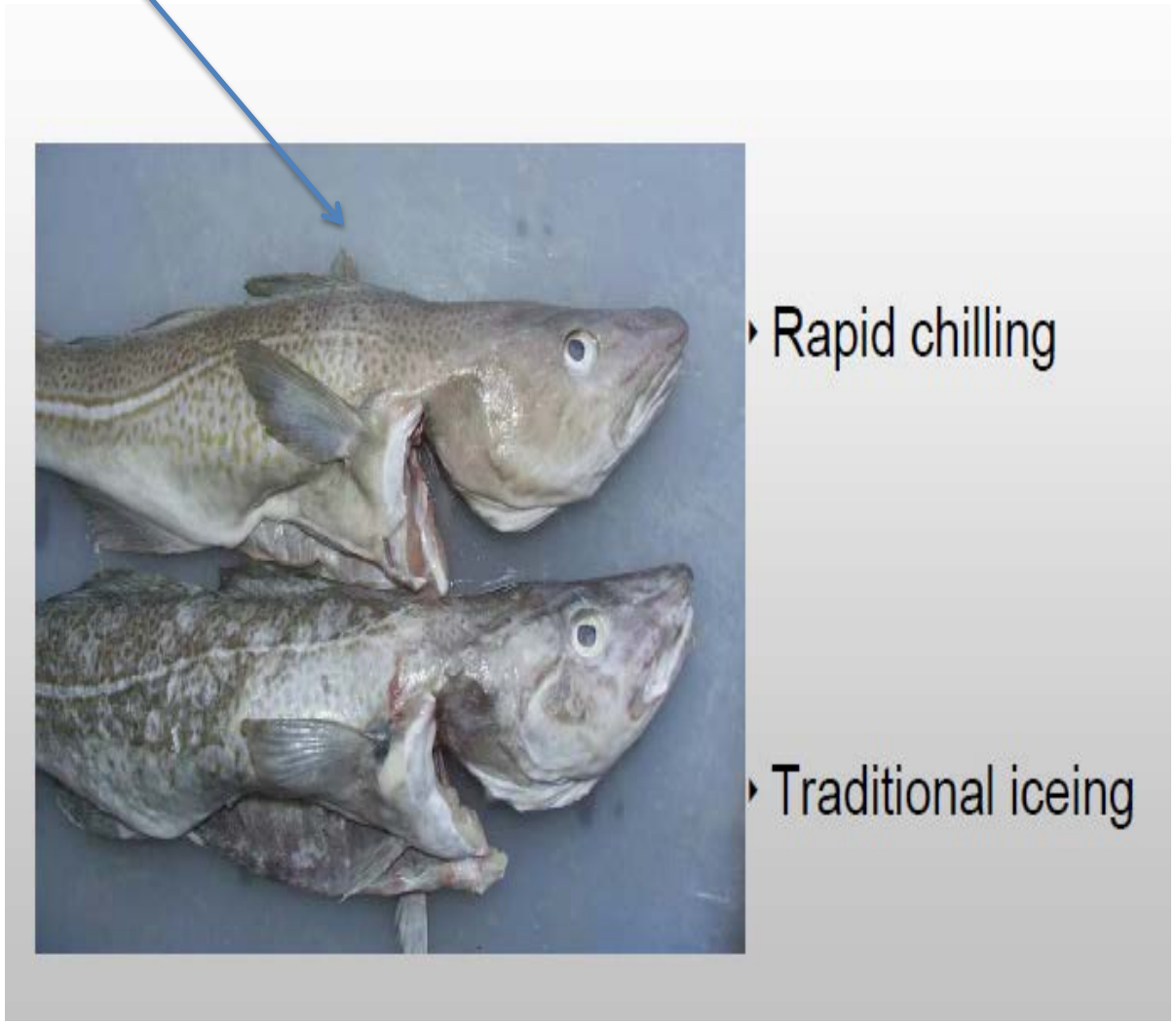
- Freshness, the extent of spoilage during storage under chilled conditions is key determine of the quality of food products.

- Based on the sensory evolution of eating quality, gutted cod, chilled in melting ice at 0 from time of capture, high quality 6 days, acceptable 10 days and unacceptable 15 days



Rapid chilling - Which cod would you buy?

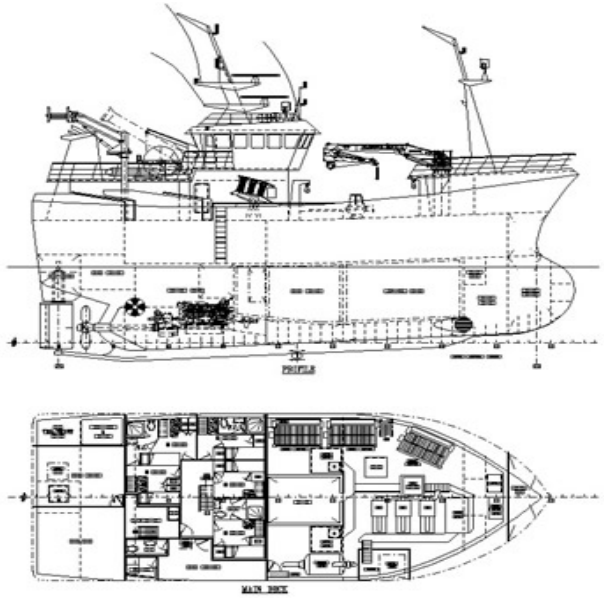
- Most foods are of high value and any increase in rate of product throughput will improve cash flow and utilise expensive plant more efficiently.
- Rapid reduction in surface temperature also retards microbial growth and consequently extends shelf life.
- Another important, advantage of rapid chilling is a reduction in weight loss which results in a higher yield of saleable material.



Refrigerated Sea Water

RSW

- Quick chilling (to -1°C)
- Efficient washing and bleeding
- Some spices absorbs water and salt
- Normally with several tanks on board



CSW (Cold Sea Water)

- Sea water chilled with ice

Treatment of fish onboard

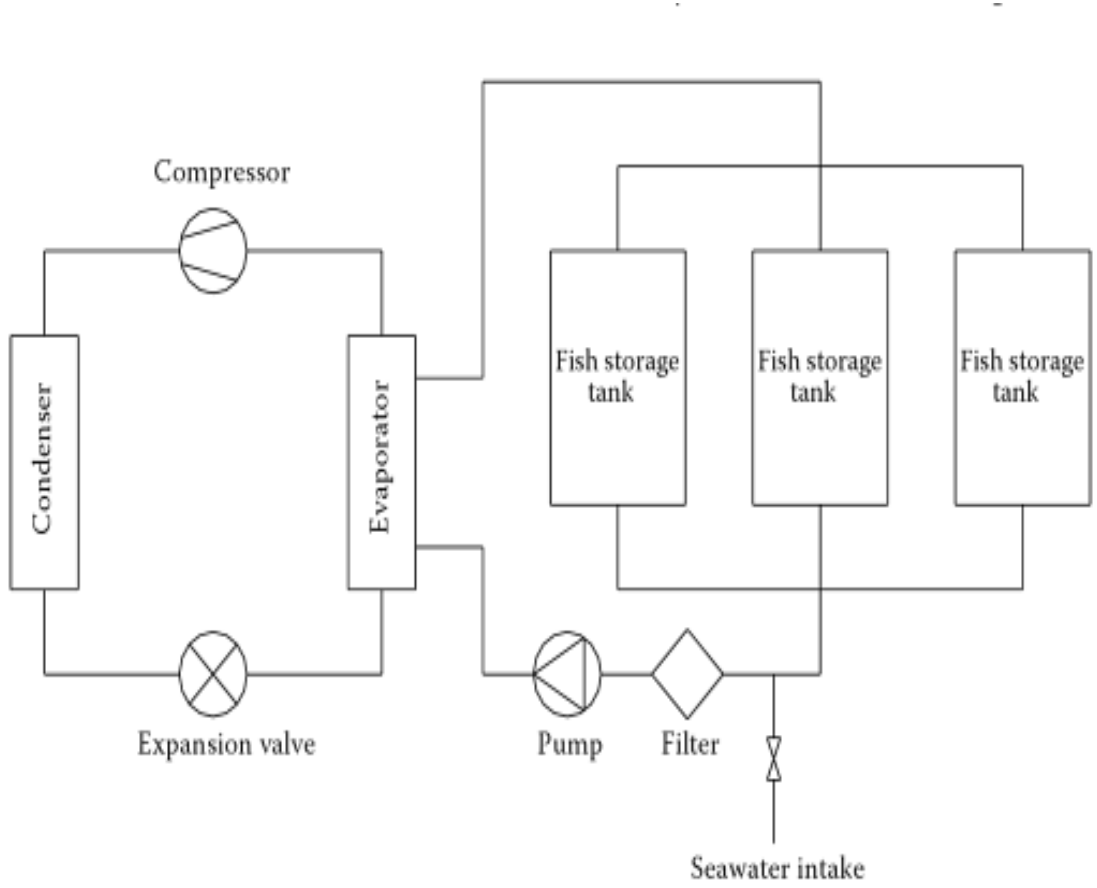
- Fish is perishable
- Living fish
  - To keep the fish alive is an old technique (alive catch and market based slaughtering)
  - Fish carrier technology combined with special net cage under developing
- Death fish
  - Temperature is vital

The effect of temperature of shelf life on fish.

Temperature	Shelf Life
-1° C	20 days
0° C	15 days
+6° C	6 days
+12° C	3 days
+18° C	11/2 days
+24° C	1/2 day

Chilling with Refrigerated seawater technology

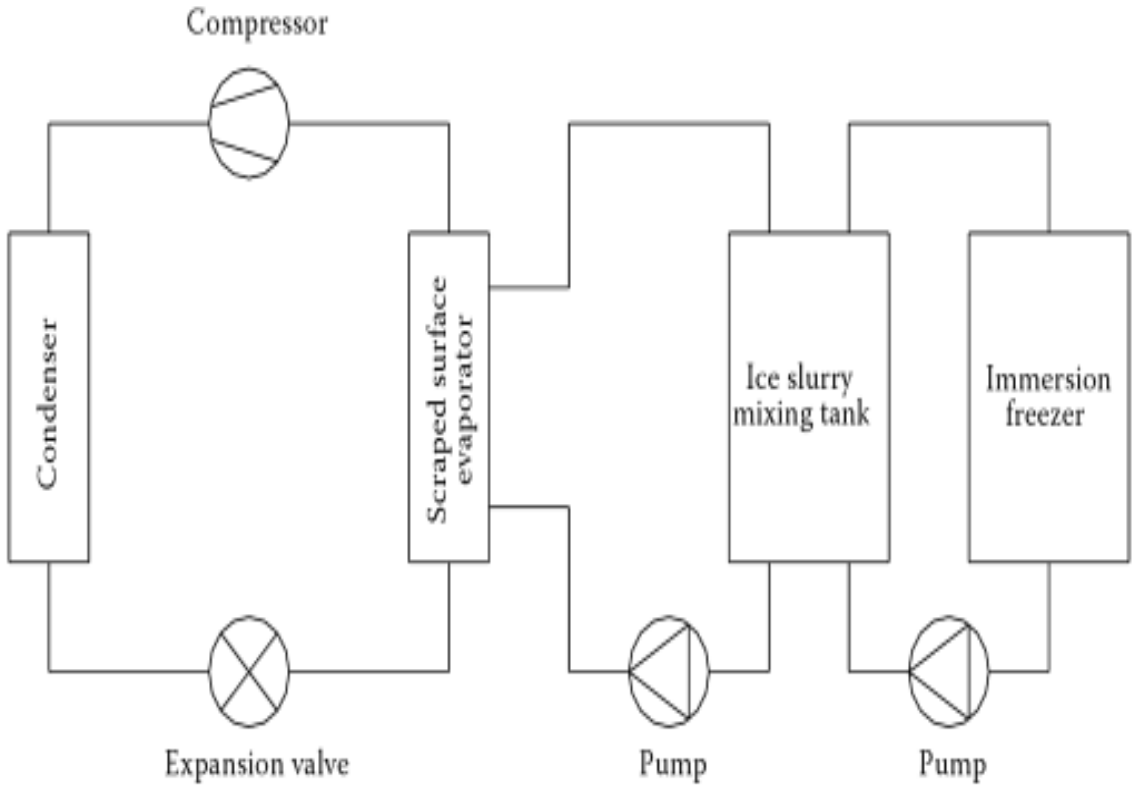
- An ice slurry consisting of seawater will typically have a temperature of -2.
- The water in each tank of fish is circulated to the refrigeration system and returned to the tank.
- This will promote rapid and uniform cooling of the fish.
- The water should be circulated continuously until the vessel is unloaded to avoid temperature stratification and formation of pockets of warm water within the holding tanks.



Schematic of refrigerated seawater (RSW) system

Ice slurries

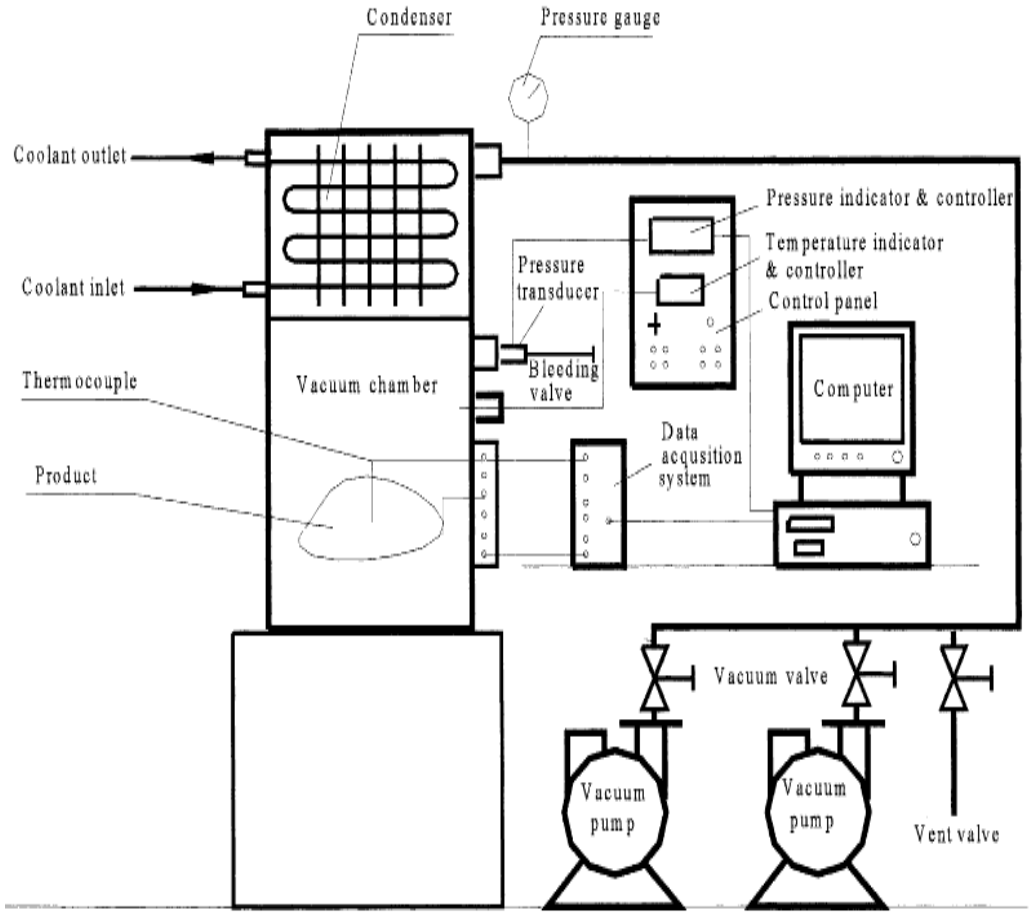
- Ice slurry consists of small ice crystals, typically 1 mm diameter or smaller.
- Ice in the mixture is between 5 and 30%.
- Very high HTCs can be obtained by directly immersing foods in ice slurry because slurry can observe both sensible and latent heat resulting from the melting of the ice.
- Thus, an ice slurry has even greater heat absorption capability than single-phase aqueous solutions.



A schematic of an ice slurry refrigeration system.

Vacuum chilling – evaporation of water

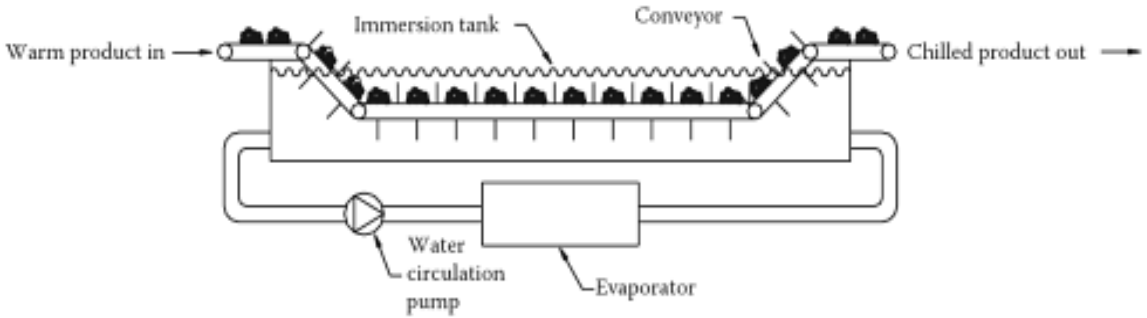
- In vacuum refrigeration, water as primary refrigerant, vaporizes in a flash chamber under low pressure.
- The product is loaded into the flash chamber, the system is put into operation, and the product is cooled by reducing the pressure to corresponding saturation temperature desired.
- Shorter processing times, consequent energy savings, improved product shelf life, quality and safety.



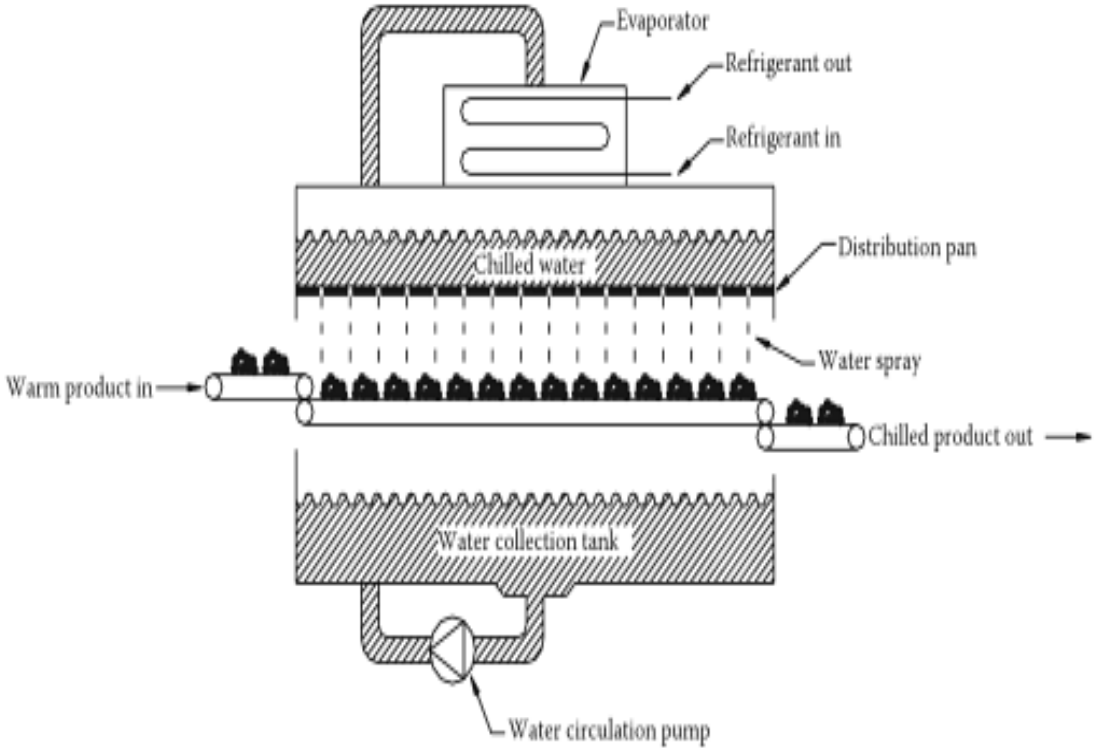
A schematic representation of a laboratory scale vacuum cooler

Mechanical vapour-compression

- Hydrocooling is probably the least expencive method of achieving rapid cooling of small products
- The product to be cooled is immersed in or sparyed with cooled water, either at ambient or near 0oC



Schematic of an immersion hydrocooler



A schematic of a spray hydrocooler

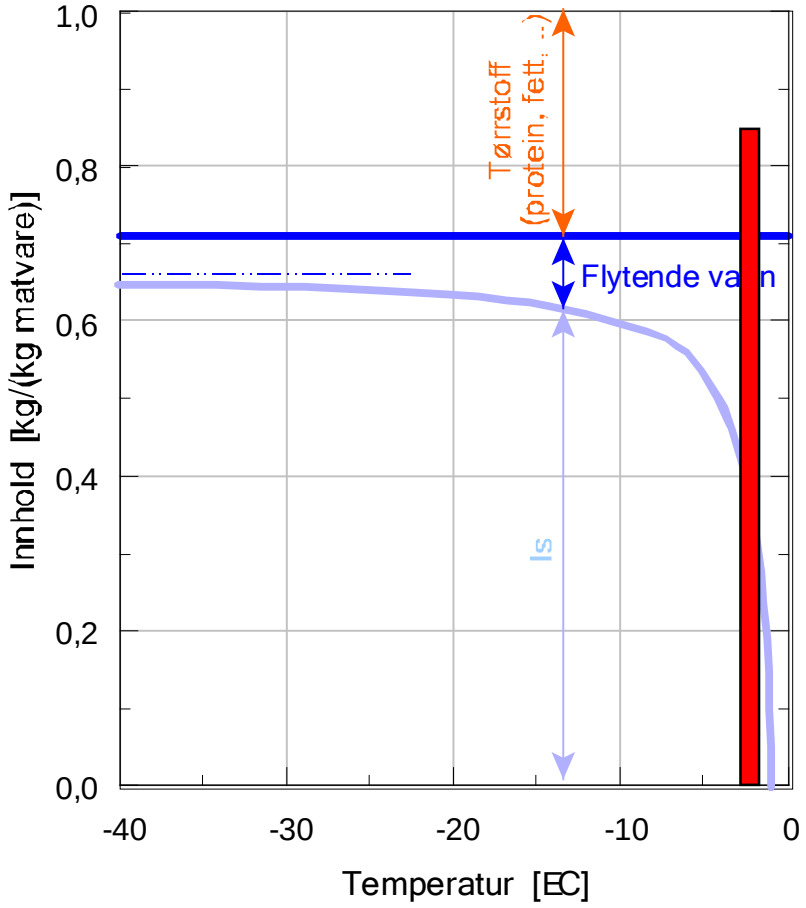
Preserving methods for fish

Icing for chilling and cleaning/gutting:

- 0°C
- Important with enough ice (experience at least 1:1 ice:fish)
- Both storage in packing case in bulk (more used earlier)
- Important with good design of the fish carrier and the cargo compartment

Super chilling:

- Chilling to temperature lower than the initial freezing point (example -2,5°C)
- The fish shall not freeze, but keep its quality as fresh
- Use the fish mass as thermal storage



Superchilling technology

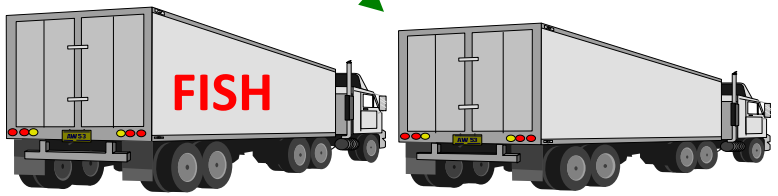
- Superchilling is a method of preserving freshness and maintaining high quality of foods by partial crystallization.
- The superchilled product is firmer and more resilient to processing, resulting in a more attractive product with greatly increased primary product ratio and shelf-life.
- Higher product value and price is therefore a key benefit of the system.
- A longer period of time, a longer shelf life also translates to increased sales, higher product quality and value, and greater customer satisfaction.

Capacity crisis on roads in Europe (salmon transport)

Normal week (2012)

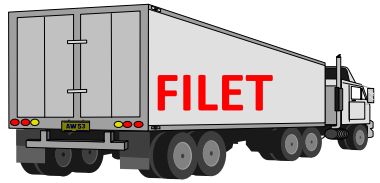
1000 trucks

300 trucks
with ice



700 trucks

280 trucks
with by products



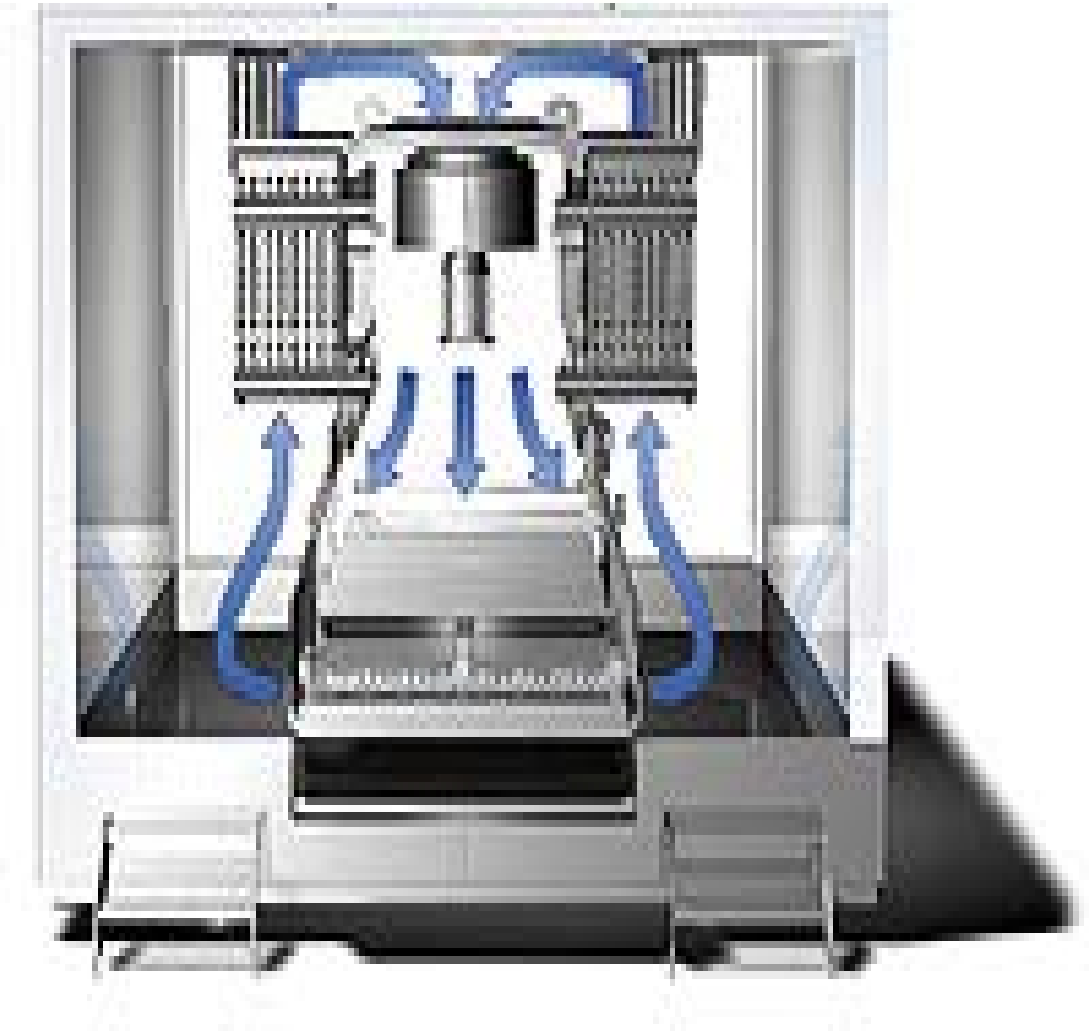
420 trucks
approx. 60%
reduction

SUPERCHILLING

(temperature 1-2°C below initial freezing point)

Superchilling with impingement freezer

- The surface of the product is exposed to very high air velocities at temperatures below -35˚C. This creates a thin, rapidly frozen crust of 2-5 mm thick depending upon the particular application.
- The shortened overall process is very cost-effective due to minimised handling, and the quality of the final product, which has a longer shelf life, is greatly improved.
- It can freeze thin products as fast as cryogenic at a fraction of the cost.



Transportation – World wide

- Developments in temperature control, packaging and controlled atmospheres have increased substantially the range of foods that can be transported around the world in a chilled condition
- Sea, road transportation, airfreighting
- Control of the oxygen and carbon dioxide levels in shipboard containers have allowed fruits and vegetables to be shipped (typically 40 days in the container) from Australia and New Zealand to markets in the USA, Europe, Middle East and Japan

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Thank you for your attention!

Спасибо за внимание!