Seafood thawing

February 2008

Research & Development Department

SR598

ISBN - 0 903941 99 6

From Sea to plate, Seafish delivers expert knowledge, skills and support which help the UK Seafood Industry secure a sustainable and profitable future.

Seafish Research & Development

Author(s): Michaela Archer
Mark Edmonds
Martin George (Campden & Chorleywood Food Research Association)
Date: February 2008

Thawing seafood

Summary:

The UK seafood industry uses a large quantity of frozen fish and shellfish every year. Much of this product requires thawing before further processing or use.

Companies typically thaw seafood in-house using a range of different methods. These vary from using water, air or steam through to microwave and radio frequency systems.

Currently there is a lack of up to date information on seafood thawing, making it difficult for processors to understand the process, the relative merits of each type of available system and how and where the process can go wrong.

This document is a compilation of available information on the thawing of seafood. It includes;

- A summary of the key scientific principles of seafood thawing
- An overview of relevant UK and EU legislation
- A description of current UK thawing practice, highlighting good manufacturing practice and problem areas.
- Information on different seafood thawing systems,
- A review of new technologies, and
- Sources of further information and advice.

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Summary

1. Introduction

The UK seafood processing industry and the fish frying sector use a large quantity of frozen fish and shellfish every year. Much of this product requires thawing before further processing or use.

Companies typically thaw seafood in-house using a range of different methods. These vary from using water, air or steam through to microwave and radio frequency systems. The type of thawing method used is dependent on many factors including cost, throughput, timescale, size, efficiency and effect on quality amongst other things.

Currently there is a lack of up to date information on seafood thawing, making it difficult for processors to understand the process, the relative merits of each type of available system and how and where the process can go wrong.

Seafish contracted Campden and Chorleywood Food Research Association to undertake a review of information on thawing practices to collate and provide advice for businesses. This was undertaken during early 2007. Seafish completed the review and report in early 2008.

This document is a compilation of available information on the thawing of seafood. It includes;

- A summary of the key scientific principles of seafood thawing
- An overview of relevant UK and EU legislation
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- Information on different seafood thawing systems,
- A review of new technologies, and
- Sources of further information and advice.

2. Background information

With the use of frozen supplies, particularly frozen imports, controlled thawing of seafood is an important process undertaken by many seafood processors in the UK. Other sectors, notably fish friers, also thaw seafood but on a smaller scale

The benefits to using frozen seafood include that the eating quality can be excellent, it enables variability in the supply chain to be resolved, and frozen seafood has a longer shelf-life than fresh/chilled products. Some of these benefits can be lost if the freezing, cold storage or thawing processes are poorly managed.

In order to produce the best quality thawed product, it is important for businesses and seafood operatives to understand the thawing process and ensure their systems are as effective as possible. This section provides a summary of relevant information on thawing.

2.1. Why freeze seafood

The process of commercial freezing as a means of preserving seafood has been established since the early 1900's. The main reasons for freezing seafood are:

- As a means of long term preservation and storage, it greatly extends the shelf-life of seafood products.
- With a longer shelf-life seafood products can be distributed throughout the world.
- It enables a seafood processor to retain a supply of seafood that can be used throughout the year, reducing the seasonal fluctuations that exist in the fresh-chilled (never frozen) sector.
- In some cases, it is used as an aid to processing, particularly in shelling prawns or *Nephrops norvegicus* tails.
- It enables consumers to have greater choice of seafood throughout the year.

Seafood processors, retailers and caterers use frozen fish in a range of different forms. The majority of these frozen products require thawing before further processing, before being fried in a fish and chip shop or prior to final sale to the retailer. As such thawing is an integral part of the seafood trade.

2.2. What is thawing

Thawing is the process of changing a product from frozen to unfrozen. It involves transferring heat to a frozen product to melt the ice that was formed within the flesh during the freezing process. The point at which ice crystals are converted back to water occurs completely when the temperature throughout the seafood reaches -1°C. The time required to melt all the ice in the frozen seafood is the thawing time.

2.3. Temperature changes during thawing

Figure 1 shows the typical temperature changes that occur in foods during freezing and thawing.

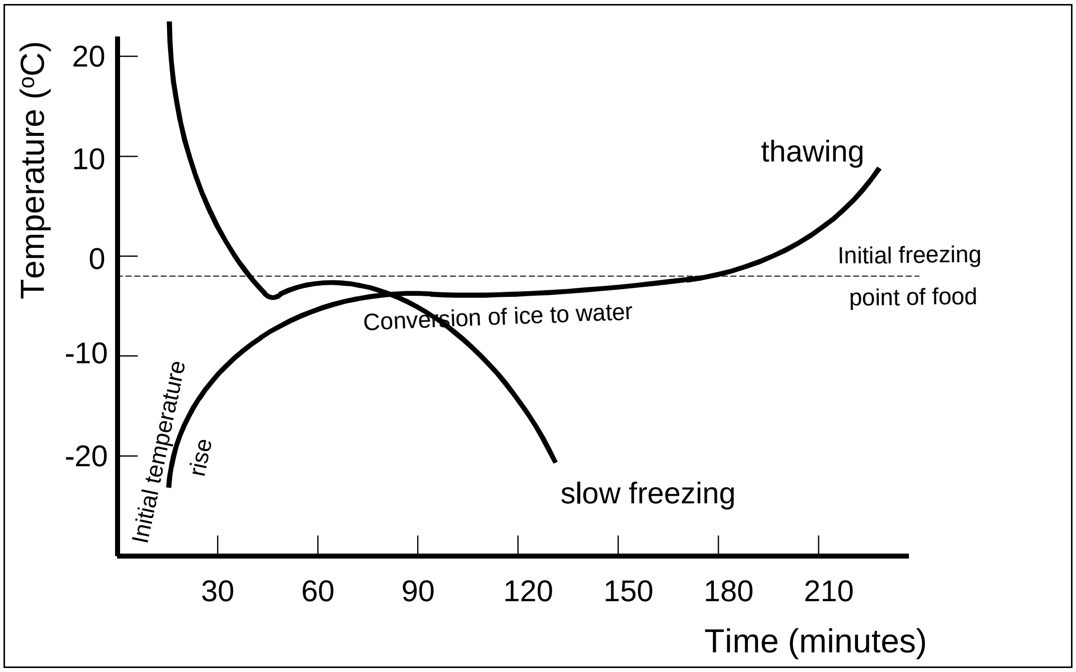


Figure 1 - Temperature changes during thawing

The initial rapid temperature rise during thawing is due to the presence of a layer of ice around the food material which forms a protective glaze. This ice glaze layer has a higher thermal conductivity than water and thaws quickly during the early stages.

As the surface ice (glaze) melts, the thawing rate slows down and there follows a long period when the temperature of the food is close to that of melting ice. At this time, the energy to overcome the latent heat (i.e. to change the solid ice to liquid water) needs to be overcome. It is also the period where any cellular damage caused by, for example, poor handling before freezing, excessively slow freezing or poor temperature controls, result in the release of cell constituents to form ‘drip losses’.

Commercially, foods can be thawed to just below the freezing point to retain a firm texture for subsequent processing. This process is known as tempering.

2.4. Thawing rates and temperature control

Thawing is often a lengthy process, much longer than that for the freezing process, for two reasons. Firstly, the temperature difference between the food and the thawing medium is likely to be smaller and, secondly, as the surface of the food thaws the rate of heat transfer to the food decreases. This is because the thermal conductivity of the unfrozen food is lower than that for the frozen food.

There are no definitive thawing rates as they depend on many factors including the type of thawing method used, the type and thickness of the product and the time taken for heat to transfer to the frozen product core. Like freezing, thawing should be carried out as quickly as possible to maintain product quality, however, it should not be so quick that it adversely affects the product. Thawing is complete when there is no ice remaining in the flesh of the product.

During the thawing process, the rate of thawing progressively slows down over time because the heat has to travel from the surface through a layer of thawed flesh which becomes increasingly thick over time. Throughout thawing, the highest temperatures in the seafood are always found at the surface. It is very important that the product surface does not get too warm during thawing, as this can accelerate spoilage. Once thawed, seafood must be kept chilled or processed immediately.

Temperature control during thawing is critical, however there is no definitive recommended maximum temperature. Table 1 provides a list of recommended maximum temperatures.

Table 1 – recommended product, air and water temperatures

Source	Maximum Air or Water Temperature	Maximum product temperature
CODEX standard for air thawing frozen fish blocks	25°C	7°C
CODEX standard for water thawing frozen fish blocks	21°C +/-1.5°C	7°C
Torry Research Station	20°C (air blast) 15°C (still air) 18°C (water)	0 to 4°C
International Institute of Refrigeration (IIR)	20°C (air) 18 to 20°C (water)	4 to 5°C
New Zealand Training manual	16 to 18°C (water) 12 to 15°C (air)	4°C

Thawing a given weight of seafood requires a specific quantity of heat. For example, white fish from a cold store at –30°C will require some 300 kJ of heat to thaw completely. Other fish types will have different properties, e.g. herring has a high fat content and because of the lower heat capacity of fat compared to water, will need less heat energy, in this case about 240 kJ of energy.

2.5. Seafood spoilage

It is important to understand seafood spoilage in terms of how it relates to thawing.

Just after capture, seafood is considered absolutely fresh but post-mortem changes result in loss of freshness, with the fish becoming progressively more spoiled and unpleasant to eat over time. Ultimately the seafood becomes unfit for consumption. Figure 2 shows the relationship between time and flavour deterioration in whitefish (e.g. cod, haddock).

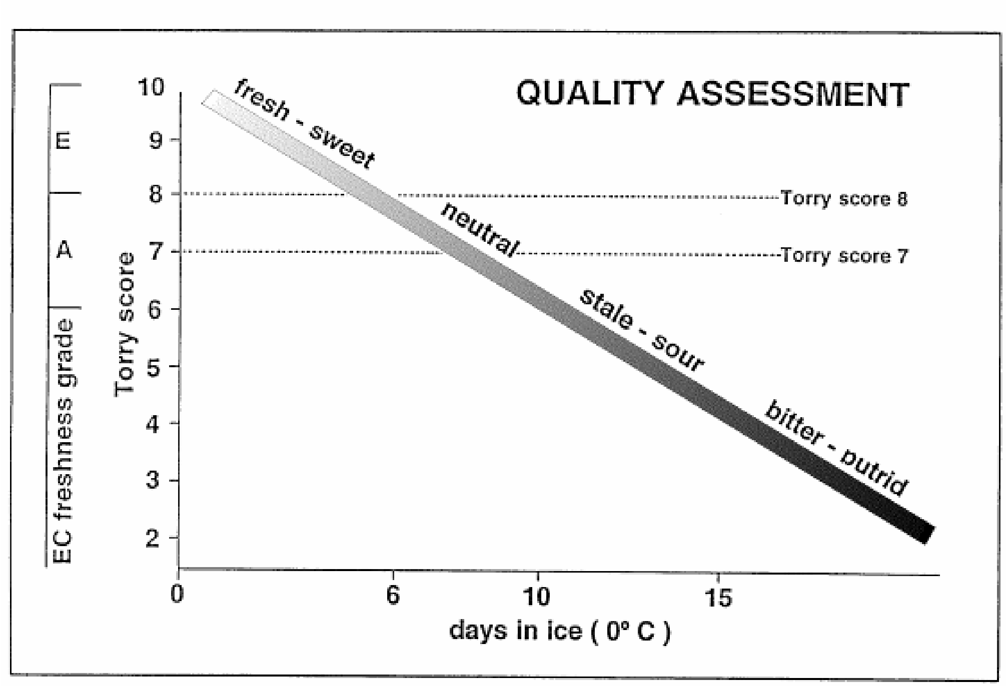


Figure 2 – Relationship between time and flavour deterioration in whitefish

Live seafood tissue is sterile even though the skin, gills and gut are not. These areas can contain bacterial levels of 10^4 to 10^8 per cm^2.

In the first couple of days after death, changes in seafood are mainly due to chemical processes. However, after a few days bacteria penetrate the flesh where they degrade tissue components, producing the unpleasant odours and flavours associated with spoilage. These unpleasant odours and flavours increase and change over time rendering the seafood inedible after a period of time. However, seafood typically becomes inedible long before the bacterial levels have increased to the extent where they would be injurious to health. At low temperatures, bacterial levels increase slowly but at higher temperatures the bacteria grow rapidly, accelerating the spoilage rate. The relationship between time, temperature and the spoilage rate of cod is shown in Figure 3. Time and temperature are the most critical factors to control to ensure seafood retains high freshness quality for as long as possible.

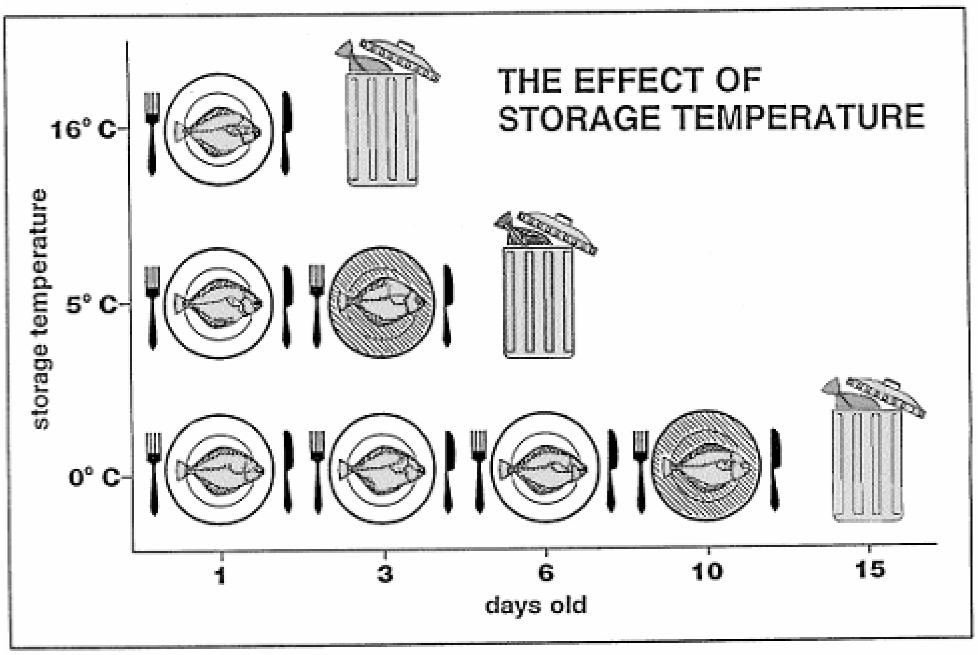


Figure 3 – relationship between time, temperature and spoilage rate of cod

Freezing the seafood at any stage can effectively stop bacterial growth, though some chemical or enzymic processes can slowly continue during frozen storage. When the seafood is thawed, it will spoil as quickly as chilled/never frozen seafood, so it must be kept chilled, as close to the temperature of melting ice as possible. Maintaining a low temperature (i.e. as close to 0^{o}C as possible) is perhaps the single most important factor in slowing down the deterioration of seafood.

With some exceptions, seafood is rarely incriminated with food poisoning outbreaks because:

- Most seafood is not infected by, or carries, food poisoning bacteria
- The cold temperatures at which it is stored means that most food poisoning bacteria grow poorly
- Seafood is traditionally eaten cooked so bacteria present are destroyed

There are safety issues with some species, for example the development of histamine in certain Scombroid species such as mackerel and tuna. These types of fish are associated with scombroid fish poisoning because their flesh contains higher levels of histidine. Histidine is converted to histamine by bacteria and if the seafood is eaten it can cause illness. Temperature abuse is the main cause of high histamine levels; growth is more rapid at high abuse temperatures (>21^{o}C) compared to moderate abuse temperatures (e.g. 7^{o}C). In general histamine production ceases at 4^{o}C. Once produced, it is heat stable so thermal processing will not remove it from the flesh. As such it is vital to more carefully control the storage temperature of affected species.

2.6. The microbiology of thawing and thawed foods

It has been suggested that micro-organisms die during the thawing process rather than during freezing or frozen storage. However, this has not been proven and cannot easily be demonstrated. When foods begin to thaw, ice crystals grow and exert the same stresses on microbial cells as that observed during the freezing process. In addition, as the frozen liquid in the food melts, the medium surrounding the microbial cells is diluted and the cells can be exposed to osmotic shock, which can inhibit their microbial viability.

In general, there is poor understanding on whether the rate of thawing has a significant effect on the survival of micro-organisms during thawing. However, it is appreciated that repeated freezing and thawing cycles do lead to a greater loss of microbiological viability than a single freeze-thaw cycle. However, for seafood products where structural integrity has a strong bearing on the textural properties and other consumer acceptability criteria, the use of repeated freeze-thaw cycles is not an acceptable process.

The temperature during thawing is extremely important to microbiology. During the thawing process, the surfaces of large frozen products will reach higher temperatures sooner and will be exposed to temperatures that can promote microbial growth for a longer time than the interior parts of the product. For partially thawed products, this can result in the growth of micro-organisms at the product surface. Thawing of foods at high temperatures can increase the risks of microbial spoilage. Although it is recommended that thawing at refrigerated temperatures would be prudent for food safety, prolonged exposure at low temperatures can still lead to the growth of spoilage organisms albeit at a slower rate. However it is important to note that seafood typically becomes inedible long before the bacterial levels have increased to the extent they would be injurious to health.

The microbiological quality of thawed foods

The number of micro-organisms is often reduced during freezing and frozen storage. Micro-organisms can also remain in their 'lag phase' for some time after thawing, before the minimum microbial growth temperatures are achieved and exponential microbial growth begins. Provided adequate temperature control, hygiene and handling are exercised, freezing provides an excellent long term preservation method. However, food manufacture is often under less than ideal conditions and microbiological problems can arise. For relatively sensitive foods such as seafood, freezing may affect the structural integrity of the product, making it more susceptible to microbial attack. Thawed seafood is also likely to have a moist surface, perhaps amplified by drip losses or condensation, making them a good substrate for bacterial growth. In addition, some bacteria in frozen foods may become more virulent after thawing and lag phase.

The conclusion of most studies on thawed foods is that there is very little difference in the shelf-life and microbial growth between never frozen and pre-frozen / thawed foods. In some cases, freezing may increase the storage life of the thawed product. In experiments with frozen cod, it was demonstrated that the storage of cod for eight weeks at –20^{o}C extended its shelf life, when thawed, by several days, i.e. longer than both fresh cod or cod stored at –30^{o}C, -60^{o}C or –80^{o}C. The reason was that the two most important spoilage bacteria in cod (*Shewanella putrefaciens* and *Photobacterium phosphoreum*) died after eight weeks at –20^{o}C, but survived eight weeks at –30^{o}C or colder.

From a microbiological view, the thawing process must be carefully controlled with respect to avoiding both contamination and poor temperature control.

In catering establishments and households, air thawing is the most conventional method and thawing of foods in the refrigerator is often recommended. From a food safety perspective, this is acceptable, as it ensures that no parts of the product become warmer than the temperature of the refrigerator. However, this process is relatively slow and does not always result in the best sensory quality. In experiments with whole trout, it was shown that faster thawing (water thawing) resulted in better quality than slow thawing in a refrigerator. If more rapid thawing is necessary, then thawing at room temperature for short periods of time is acceptable, but care should be taken to avoid high surface temperatures for too long.

(Bogh-Sorensen, 2000)

2.7. Consequences of inadequate thawing

If the thawing process is carried out correctly there should be few detrimental effects on the product. However, the final quality of thawed seafood will depend not only on the thawing process but also on other factors such as frozen storage conditions, packaging, and product form and type.

Frozen seafood should be thawed in a way that maintains the characteristic properties of the product. There are a number of problems that can become apparent during thawing that will affect the intrinsic quality of the product, as indicated in Table 2.

Table 2 – Consequences of inadequate thawing

Consequences of over thawing	• Flesh may soften affecting the texture of the seafood. • Flesh can become discoloured. • Loss of flavour. • Economic losses through reduced processing yield and drip loss. • Possible growth of bacteria that may accelerate spoilage, reducing the product shelf-life • Possible increase in enzymic spoilage • Waste of resources e.g. water if using water thaw method
Consequences of under thawing	• Fish may be difficult or dangerous to fillet • Poor filleting will result in a lower yield

Other significant factors affecting the properties of thawed seafood include:

Moisture migration – this is the principal physical change that occurs in frozen foods and has major effects on the physical, chemical and biochemical properties of the final product. It is manifested in several ways; moisture loss by surface evaporation, moisture absorption and redistribution in foods, recrystallisation of ice and drip loss during thawing. Having taken great care to freeze foods rapidly and store the frozen products under cold and well-controlled frozen storage conditions, the process of thawing takes precedent in dictating the likely final quality of frozen seafood. The role of water (frozen or unfrozen) in foods is an important consideration. Moisture loss from frozen seafood has important economic consequences and is a major factor in determining the shelf life. Moisture loss during frozen storage can lead to freezer burn and desiccation of the surface layers, making the product unappealing to the manufacturer or consumer. Moisture migration has a significant effect in the form of weight loss; the water that is lost has the same economic value as the product.

Drip loss – this is a form of moisture migration. It is known that fish usually lose weight on thawing. This drip loss may be up to 5% of the original product weight for properly frozen and cold stored whitefish, though it can be more if the thawing process is uncontrolled.

The factors that influence thawing drip loss are many and complex. It is determined by a number of factors intrinsic to the food product, the conditions of freezing and the thawing process and conditions. Thawing drip loss is visually unattractive, soluble nutrients are lost from the food and it represents a significant economic loss to the processor.

Drip loss is caused because during freezing, water is removed from its original location in the product and collected elsewhere in the form of ice crystals. During thawing, this water may or may not be reabsorbed into its original location within the food's microstructure. If it is not reabsorbed it leaches out of the product in the form of drip loss. The factors that determine the extent and severity of thawing drip loss include the size and location of ice crystals (which is related to the freezing operation), the physiological and biochemical status of the food prior to freezing (which is related to the quality of the raw materials prior to freezing), the intrinsic water binding capacity of the food material (which is related to the suitability of the product/species for freezing), and the rate of thawing.

In seafood, significant reabsorption of water lost via drip can take place. Drip loss is considered to be most associated with the occurrence of large intracellular ice crystals, which cause maximum damage to the walls of individual cells. The formation of large ice crystals is itself associated with slow freezing rates, high and fluctuating temperatures during frozen storage and long frozen storage times. The role of thawing in minimising drip loss is that very rapid thawing has generally been found to increase drip loss, possibly because of the reduced time for reabsorption of drip. Reabsorption of water is a slow process and can take several hours, particularly for seafood whose muscle structure has less capacity for reabsorption. However, it is unlikely that long thawing times will be practically beneficial for the majority of fish species. Consequently, the use of rapid freezing methods, well-controlled frozen storage conditions and good temperature control throughout all stages of handling and processing is undoubtedly the best way of minimising thawing drip loss in fish and seafood (Pham and Mawson, 1997).

Thaw rigor - when muscle is frozen pre-rigor and kept for a short time in cold storage, it is still able to contract and go into rigor after thawing. This is known as thaw rigor and, when the thawing is undertaken rapidly at a high temperature, the muscle can then suffer from the defects associated with high temperature rigor. Thaw rigor is rarely a problem in thawed whole fish. However, when pre-rigor fillets are thawed, the muscle can shrink as soon as the ice within the flesh has melted. The fillets become shrunken and corrugated and lose a large amount of drip. The effects are most severe when the pre-rigor muscle is cooked from the frozen state as the texture will be tough and stringy and drip loss will be high.

The simplest way to avoid thaw rigor is to extend the cold storage time of the stock of pre-rigor fish. Provided they are kept for at least eight weeks at a temperature of -28^{o}C or lower, the flesh has time to pass through rigor in the frozen state. If the fish have to be taken out of store in less than eight weeks, they should be thawed slowly at room temperature. In this way rigor is completed while the fish are in a semi-frozen state, thus preventing severe contraction of the muscle.

Seafood frozen pre-rigor enters a very strong rigor mortis when thawed at high temperatures, resulting in gaping (breaking of connective tissue between the muscle segments) and loss of drip. Therefore, a controlled slow thawing is recommended. For seafood frozen post-rigor the thawing time should be as rapid as possible (Archer and Kennedy, 1998).

3. Legislation relevant to thawing seafood

The main legislation relevant to seafood processing are

- Regulation 852/2004/EC (Hygiene of foodstuffs) and
- Regulation 853/2004/EC (Laying down specific hygiene rules for food of animal origin).

These contain requirements on the hygienic handling and storage of food and seafood products. The main requirements for thawing and thawed product include:

General requirements:	Interpretation:
Regulation 852/2004/EC Article 4 General and specific hygiene requirements *1. Food business operators carrying out primary production and those associated operations listed in Annex I shall comply with the general hygiene provisions laid down in part A of Annex I and any specific requirements provided for in Regulation (EC) No 853/2004.* *2. Food business operators carrying out any stage of production, processing and distribution of food after those stages to which paragraph 1 applies shall comply with the general hygiene requirements laid down in Annex II and any specific requirements provided for in Regulation (EC) No 853/2004.*	The 852/2004 Regulation refers to Regulation 853/2004 for specific requirements, including temperature requirements, applying to primary production.
Regulation 852/2004/EC Annex II Chapter IX Provisions applicable to foodstuffs *2. Raw materials and all ingredients stored in a food business are to be kept in appropriate conditions designed to prevent harmful deterioration and protect them from contamination.* *5. Raw materials, ingredients, intermediate products and finished products likely to support the reproduction of pathogenic micro-organisms or the formation of toxins are not to be kept at temperatures that might result in a risk to health. The cold chain is not to be interrupted. However, limited periods outside temperature control are permitted, to accommodate the practicalities of handling during preparation, transport, storage, display and service of food, provided that it does not result in a risk to health. Food businesses manufacturing, handling and wrapping processed foodstuffs are to have*	This is the general requirement, and it applies both to chill control and hot holding: 1) Any item likely to support the growth of pathogens or the formation of toxins must be kept at the appropriate temperature to reduce the risk; 2) The cold chain is not to be broken except briefly if required for practicality during handling; 3) Food businesses must have adequate refrigerated storage.

suitable rooms, large enough for the separate storage of raw materials from processed material and sufficient separate refrigerated storage. *6. Where foodstuffs are to be held or served at chilled temperatures they are to be cooled as quickly as possible following the heat-processing stage, or final preparation stage if no heat process is applied, to a temperature which does not result in a risk to health.* *7. The thawing of foodstuffs is to be undertaken in such a way as to minimise the risk of growth of pathogenic micro-organisms or the formation of toxins in the foods. During thawing, foods are to be subjected to temperatures that would not result in a risk to health. Where run-off liquid from the thawing process may present a risk to health it is to be adequately drained. Following thawing, food is to be handled in such a manner as to minimise the risk of growth of pathogenic micro-organisms or the formation of toxins.*	
Establishments handling fishery products	**Interpretation**
Regulation 853/2004/EC: Annex III Section VIII Chapter VII: Storage of fishery products *Food business operators storing fishery products must ensure compliance with the following requirements.* *1. Fresh fishery products, thawed unprocessed fishery products, and cooked and chilled products from crustaceans and molluscs, must be maintained at a temperature approaching that of melting ice.*	During storage, fresh product, thawed product, and cooked chilled crustacean and molluscan product must be kept a temperature approaching that of melting ice (close to 0^oC)
Transport	**Interpretation**
Regulation 853/2004/EC: *1. During transport, fishery products must be maintained at the required temperature. In particular:* *(a) fresh fishery products, thawed unprocessed fishery products, and cooked and chilled products from crustaceans and molluscs, must be maintained at a temperature approaching that of melting ice;* *(b) frozen fishery products, with the exception of frozen fish in brine intended for the manufacture of canned food, must be maintained during transport at an even temperature of not more than –18℃ in all parts of the product, possibly with short upward fluctuations of not more than 3℃.* *2. Food business operators need not comply with point 1(b) when frozen fishery products are*	During transport, fresh product, thawed product, and cooked chilled crustacean and molluscan product must be kept a temperature approaching that of melting ice. Frozen product may be transported at above -18℃ if: - the product is required to be thawed for immediate processing at its destination establishment; - the journey is short; and - the Environmental Health Officer is aware of the procedure and has permitted it.

transported from a cold store to an approved establishment to be thawed on arrival for the purposes of preparation and/or processing, if the journey is short and the competent authority so permits.	

More specific legislation or standards on thawing of fish and seafood is limited. A review of standards in other countries provided the following;

Denmark - the thawing of fish should be done hygienically, preferably in special containers (Danish Ministry of Food, Agriculture and Fishery, 1997). During thawing, the product temperature must not rise so much that the quality is reduced. Thawing equipment must be approved by the relevant authorities.

France - thawing should be carried out at a temperature between 0°C and 4°C, unless the company has an official approval to use another thawing method.

Codex standards - thawing procedure for quick frozen fish blocks
Air Thaw Method:
Frozen fish blocks are removed from the packaging. The frozen fish blocks are individually placed into snug fitting impermeable plastic bags or a humidity controlled environment with a relative humidity of at least 80%. Remove as much air as possible from the bags and seal. The frozen fish blocks sealed in plastic bags are placed on individual trays and thawed at air temperature of 25℃ (77℉) or lower. Thawing is completed when the product can be readily separated without tearing. Internal block temperature should not exceed 7℃ (44.6℉).

Water Immersion Method:
Frozen fish blocks are removed from the packaging. The frozen fish blocks are sealed in plastic bags. Remove as much air as possible from the bags and seal. The frozen fish blocks are placed into a circulating water bath with temperatures maintained at 21℃ ± 1.5℃ (70℉ ± 3℉). Thawing is completed when the product can be easily separated without tearing. Internal block temperature should not exceed 7℃ (44.6℉).

4. Current seafood thawing practice in the UK

The most common methods used in industry include water or air based systems. There are a range of systems available, with varying degrees of mechanisation and effectiveness. The system used seems to vary depending on the product, size of company and extent of use of frozen supplies. This section provides a summary of the main methods currently used.

4.1. Current water thawing techniques

Defrosting using water is one of the most common methods used. A range of systems using either immersion in tanks or spraying with water were identified.

Immersion in tanks is usually an ad-hoc method, involving putting frozen seafood into a tank of water, installing a hosepipe to distribute water into the tank and leaving the water supply running either overnight or until the seafood has thawed. This was found to be an ineffective and uncontrolled method of thawing seafood. Two examples of such immersion systems are shown below.

Figure 4 - Examples of two simple immersion water thawing systems

Spray systems use water from overhead sprays or a sprinkler system directed onto frozen blocks. Some companies have dedicated rooms where this is undertaken overnight in hygienic conditions whereas others use the production area and lay blocks of fish out on the floor or on fish boxes before using sprinklers to distribute water over the frozen blocks.

Figure 5 - An example of a simple spray water system for thawing fish blocks

4.2. Current still air thawing techniques

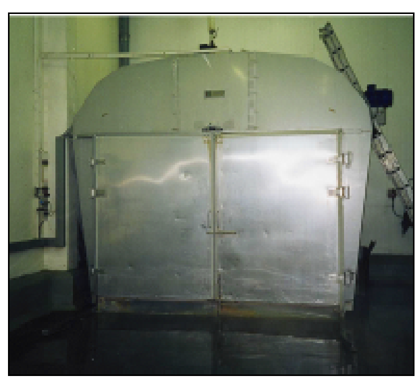
Thawing in still air involves placing frozen seafood at either ambient or chill temperatures (<4^{o}C) to facilitate a slow thawing rate. In practice, this is often undertaken overnight at ambient temperatures or can be undertaken in a chill store or refrigerator over a prolonged period of time.

4.3. Forced air thawing systems

Many companies are thawing significant quantities of seafood and require a greater degree of control over their process. As such many companies have invested in dedicated mechanised equipment for thawing seafood. Typically these incorporate the use of warm air or steam into a sealed unit that is programmed to run for a specific period of time. Typically, seafood is placed onto racks to facilitate the distribution of warm air. In the more sophisticated steam based systems, the seafood is loaded onto a conveyor in a single layer and steam is distributed over the product. Steam based systems are more typically used for shellfish or high value products.

Figure 6 - Example of a forced air thawing system

Fish on storage racks awaiting loading



A forced air thawing unit in operation

4.4. Problems with current thawing practices

The problems encountered with current thawing systems are numerous (Table 3). They are mainly evident in ad-hoc water or air based systems that companies had developed themselves.

Table 3 –main problems identified

Thawing system	Problems identified
Water	• Leaving the fish unprotected in the open air prior to thawing • Laying the frozen fish blocks out on the production area floor during thawing • Allowing seafood to fall to the floor as they separate • Leaving water running overnight, wasting resources. • Water left running for hours after the seafood has thawed • Use of unsuitable equipment including garden sprinklers, insulated tubs and fish boxes • Thawing fillets in water leaving them to become waterlogged • No control over water temperature which varies throughout the year. • No control or monitoring of product temperature • Generates a large volume of trade effluent • The need to provide product for the next day's production often is insufficient time, resulting in under thawed product and loss of yield, • Over thawed product with loss of texture and freshness quality
Still air (ambient)	• Leaving the fish unprotected in the open air • Laying frozen fish blocks out on the production area floor • Allowing seafood to fall to the floor as it separates • No control or monitoring of product temperature • No control over air temperature which varies during the year
Still air (chill or refrigerator)	• Product unprotected leading to surface dehydration, particularly on fillets • Can take a long time to thaw in a chill or refrigerator leading to quality losses
Forced air	• Inadequate maintenance of equipment • Uneven air distribution in the unit creating hot-spots, resulting in cooked products • Programme times too long or short resulting in under or over thawed product

The following pictures show examples of some of these ineffective practices.

Figure 7 - Examples of poor practices with water thawing systems

a) Frozen fish blocks set out on the floor and using a 'garden sprinkler' water spray

b) Allowing fish to fall onto floor during thawing

c) Use of ineffective equipment including water running into fish-boxes and insulated tubs

Figure 8 - Examples of poor practices in still / ambient air based systems

a) Unhygienic practices including product left outside

b) Unhygienic practices including product placed directly on the floor

4.5. Better thawing practices

Examples of good practice included setting out frozen fish blocks on racks, or bars, above fish boxes. This helped to improve air circulation around the blocks and enabled fish to fall into boxes, facilitating handling.

Figure 9 - Fish placed on bars above boxes to improve air circulation and product handling

This system also has a uniform spray of water across all the blocks being thawed, so that rates of thawing are consistent. In this kind of spray system, 25kg fish blocks were thawed from –15^{o}C to 0^{o}C in 2 hours compared to 6 hours in a poorly designed system.

In winter months when water temperatures are low, the thawing process is assisted by the use of air heaters in the thawing room, or by slightly increasing the temperature of the spray water.

In air based thawing systems, improved practice included;

- Putting seafood onto racks to facilitate air circulation around all surfaces.
- Using fans to circulate air rather than relying on still air.
- Use of dedicated rooms or areas where the ambient temperature can be properly controlled.

5. Seafood thawing systems

This section of the report provides an overview of the range of thawing systems currently available and summarises the main properties of each, providing a basis for comparison.

There are a variety of different thawing methods currently available. These include;

- Water (immersion or spray)
- Forced air or air blast
- Still or ambient air
- Electric
    - Vacuum
    - Microwave
    - Radio frequency

Each main thawing method has different advantages and disadvantages, and no-one system suits all purposes. Within each of these main types of thawing are a number of different systems, again with their own relative merits. The type of thawing system used depends on a number of factors (Table 4).

Table 4 – factors affecting the type of thawing system used

Operational considerations	• whether batch or continuous operation • capital cost, including cost of housing the plant • labour requirements • availability of steam or hot water • fuel, maintenance and other running costs • hygiene • ease of cleaning • speed of operation
Input considerations	• species of seafood • type of product • whether or not seafood must be completely thawed • ability of plant to process variety of products
Output considerations	• output of plant • flexibility of output

5.1. Forced air or air blast systems

Air blast thawing involves surrounding frozen product with warm moving air. Frozen seafood is thawed more rapidly in moving air rather than still air. In this context it does not include thawing at ambient temperatures.

Typically it is a mechanical operation but there are different types available. The most common comprises a unit containing fans to circulate warm, moist air around a large chamber in which the seafood is placed. A water spray system is used to humidify the air. The unit is fully programmable to enable the thawing time to be controlled. The units are often modular enabling them to be extended when additional capacity is required.

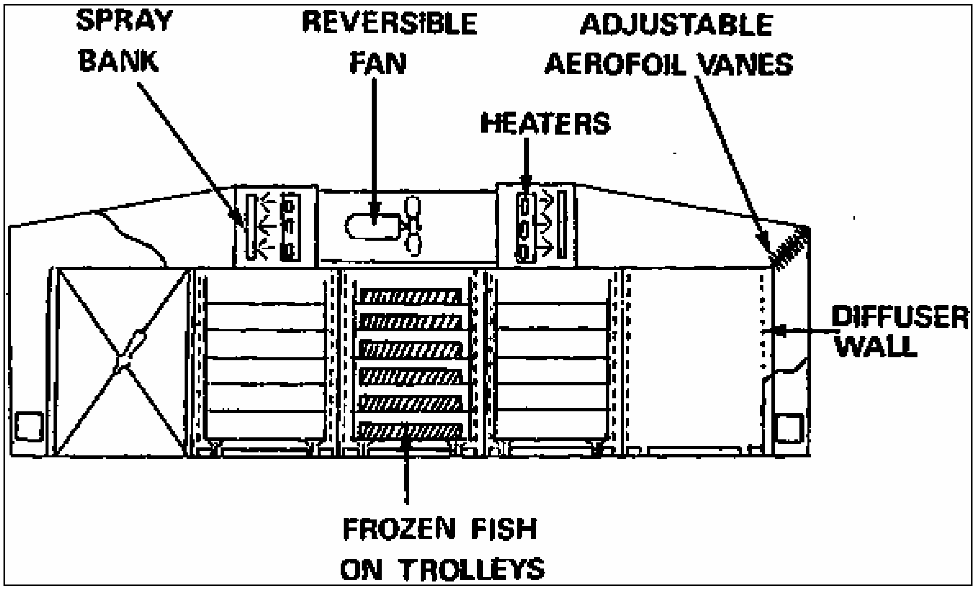


Figure 10 - Schematic of a type of air blast thawing system for fish

A typical crossflow batch thawing unit can hold several tonnes of seafood. The seafood is placed into the main chamber on racks. Air is made to flow along the length of the chamber by a powerful reversible fan situated in the recirculation duct above the chamber. Periodically the direction of air flow is reversed so that the seafood is heated more uniformly. The circulated air is humidified in the recirculation duct by water sprayed from a bank of nozzles.

Heat is provided by banks of finned hot water pipes placed in the air stream close to the fan and air temperature is regulated by thermostats. In simple systems the air flow is not reversible, so trays have to be rearranged during the process to ensure uniform thawing. In the first hour of thawing, when the fish is at its coldest, about half the total power is absorbed but after that power consumption falls.

In general, blocks of seafood are placed onto open shelving racks, which facilitate air circulation. These loaded racks are placed into the chamber and the pre-determined programme is selected. The seafood is left to complete the cycle, either until it is fully thawed or near to fully thawed.

Other types of air blast units available incorporate the same principles i.e. warm air blown over the product but these may be on a continuous basis, using conveyor belts to move product under the stream of air. These types of unit are mostly used for shellfish.

Air blast thawing units can incorporate additional controls including programme profiles, continuous monitoring, temperature recording etc. They may be constructed to thaw seafood either in batches or on a continuous basis. Because batch thawing units are simpler in construction they are cheaper to buy and easier to maintain than continuous systems.

In general it is difficult to completely air thaw all fish in a batch because larger sized fish will remain partly frozen whilst smaller fish can become overheated. It may therefore be necessary to store thawed seafood in ice in a chill or refrigerator after it has finished thawing, to allow temperatures to equilibrate for a period of time.

An air blast thawing unit provides accurate control of the environment and fish temperature by a combination of steam injection and a cool water spray, which together allow good control of the temperature immediately surrounding the fish blocks.

The steam injection and water misting system are able to maintain the temperature around the fish blocks at 30^{o}C for the first two hours, 25^{o}C for the next two hours and at around 20^{o}C for the subsequent two hours. The system then sets to a cooling mode, where the environment temperature is progressively lowered to help maintain the safety and quality of the fish as it thaws. Temperature probes within the fish blocks are used to ensure precise control. These times and temperatures would be modified to account for different fish blocks, different size of blocks, or partially defrosted blocks. A unit that is capable of thawing 4 tonnes of frozen fish blocks was found to consume 150 litres of water for misting purposes and 120 litres of water for generating the steam environment for each tonne of fish. Additionally, each of the six hour defrost cycles produced just over 1 m^3 of effluent. Such a system has been shown to be relatively cost effective, taking only about 4% of the water consumed by typical spray water defrosting systems. A comparison of defrost charges indicated that when taking into account electrical power, water and effluent costs, the steam thawing of one tonne of fish was more than 4 times more cost effective than costs of a typical inefficient spray water system (calculated in 1998).

5.2. Still or ambient air thawing

Still air thawing is the process of thawing seafood in air, either at ambient or chill temperatures (0-4^{o}C). It involves removing the seafood from outer packaging and setting out in a single layer. The seafood is then left for a period of time, usually overnight, until it is thawed. If the seafood is thawed in a chill or refrigerator it may take a longer period of time before it is fully thawed.

To air thaw seafood the following procedure can be used:

Step	Action	Important Points
1	Remove product from freezer & spread out on tables or benches.	Clean and sanitise surfaces where the product will be placed
2	Discard cardboard and cartons but leave product within plastic liners	Liners will allow thawing product to be broken apart without damaging the product surface
3	Leave product to thaw in cool temperatures	If environment is too cold, thawing will take time, but if too warm, spoilage may occur.
4	Remove outer layers of product as they thaw & place in chilled storage	Allows inner layers to thaw quicker and prevent the already thawed product from becoming too warm.
5	Once thawed, process product as quickly as possible.	If rapid processing is not possible store the product in the chill.

Slow thawing over several days should be avoided, as the outer surface will dehydrate and may begin to spoil before the centre has thawed. The total thawing time should not be longer than 15 to 20 hours.

A typical block of sea frozen whole cod (c. 100mm thickness) may take up to 20 hours to thaw in still air at cool temperatures, although by separating the single fish as soon as practicable, thawing times can be reduced to between 8-10 hours. Still air thawing is generally practicable only on a small scale, since considerable space and time is needed, although it needs little or no equipment.

5.3. Water based thawing systems

Water thawing is commonly used in the seafood industry. It involves using water to remove heat from frozen product. It is carried out by immersion, by spraying the surface of the product with water or by a combination of both. Systems either work on a batch or continuous basis. Purpose designed equipment is available, with varying degrees of complexity and cost.

A simple immersion thawing unit consists only of a tank in which the seafood is placed. A water supply provides water to the unit whilst an outflow discharges waste-water from the unit. This can be a wasteful type of system that uses a large quantity of water with no control over the system or temperatures.

More sophisticated immersion systems include the use of water heaters, filters and pumps to enable water to be recirculated. These can also include water and product temperature monitoring and flow rate controls.

More complex water thawers work on a continuous basis. They convey seafood through a trough of water whilst being sprayed with water from overhead spray bars.

Ad-hoc systems, designed by processors, also exist (see section 4.1). These are either very simple immersion systems or spray systems using water from overhead sprays or a sprinkler system directed onto the frozen blocks. These systems may be left on overnight whilst the factory is closed, with no monitoring or control. Although typically of poor design, these types of system have been developed to suit the purposes of the respective business.

An example of a batch industrial water thawing system is shown below. The products are placed in water; whilst the tanks are stirred to ensure a consistent low temperature.

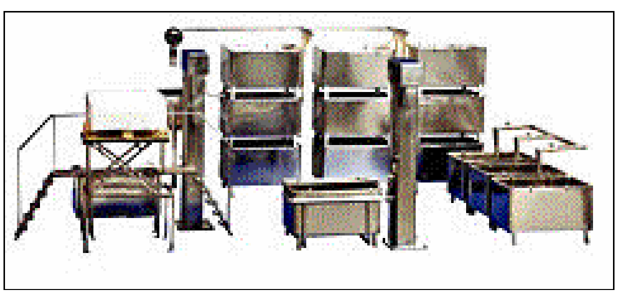


Figure 11 - Example of a batch thawing system (Carnitech)

An example of a continuous industrial fish thawing system is shown below. Cleaning continuous immersion thawers can be a problem as there are many places where scales and small pieces of fish can be trapped. It is essential to thoroughly clean the system after each batch of thawing.

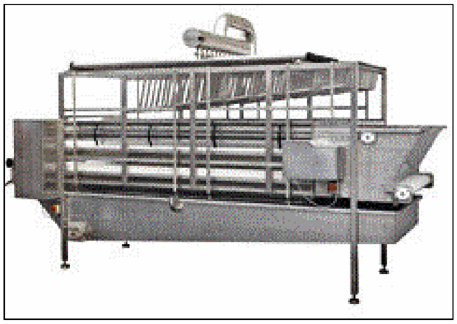


Figure 12 - Continuous industrial fish thawing equipment (Carnitech)

Mechanical continuous or batch spray thawers are available, although they are not routinely used because the process is difficult to control and can be wasteful of water unless recirculation and filtration are introduced.

Water thawing is used to thaw a variety of products such as whole, headed & gutted fish, fish blocks and shellfish. It is not recommended for fillets or processed products because they can become water logged with negative effects on texture and flavour.

For whole fish, water thawing can sometimes result in a slight loss of skin pigments. Some water thawing systems interpose a thin plastic film between the product and the water to avoid such losses but this can reduce the efficiency of the system. Sometimes, there is a slight gain in weight as water is absorbed, but this is usually lost during subsequent filleting or processing.

Water thawing times depend on many factors such as type of seafood, size of product or blocks, water temperature and flow rate, efficiency of equipment and temperature of the seafood when it was loaded into the system.

Recommended practice for thawing in tanks of water suggests the following;

- Control water inlet temperature to 16 to 18^{o}C
- Adjust the flow rate as close as possible to 3.3 litres/kg of fish per hour
- Product temperature should not exceed 7^{o}C
- Thawing process should be stopped when core fish temperature is close to 3^{o}C. Let the product equilibrate for 30 minutes.
- Process immediately

Thawing tanks should have even distribution and flow of water to facilitate an even thaw. Water flowing from the bottom of the tanks is more efficient. A constant water temperature is crucial for the effectiveness of the process and consequences in product quality and yield.

The ability of thawed fish to stand up to further processing partly depends on the temperature to which the fish is raised during thawing. Best results are obtained in fish barely thawed near the backbone, although too much frost in this area makes it difficult to fillet. The thawing process should be ended while some ice remains in the centre of the fish. The fish should be left for the temperature to equilibrate.

Fish thawed following these practices showed an 8 to 9% yield gain over fish that was completely thawed.

Additional advice suggests that the thawed fish is equilibrated to 4°C which can be achieved in 4 to 5 hours. Fish should then be iced and left for approximately 1 hour. This will increase the yield by 2 to 3%. Water methods only work well for headed and gutted (H&G) fish. Fillets require other thawing methods.

Ref: UC Davis HACCP discussion list – archives

5.4. Miscellaneous thawing systems

Other thawing systems available include vacuum, microwave, radio-frequency and electrical heating based systems.

5.4.1. Vacuum thawing systems

Vacuum thawing systems consist of airtight chambers into which the seafood is loaded on racks or trolleys. A vacuum is drawn in the chamber and water in a reservoir within the base of the chamber is heated to produce water vapour. This vapour condenses on the cold surface of the fish, allowing the heat released to be absorbed by the fish. After a period of time, the fish will thaw completely. The product and system temperature can be controlled by regulating the pressure within the chamber.

Vacuum thawing is a batch process and the capacity of the largest commercial system is of about 12 tonnes. Relatively thin products, with high surface area to thickness ratios, can be rapidly thawed in these conditions, but efficiency and thawing speed decreases as product thickness increases.

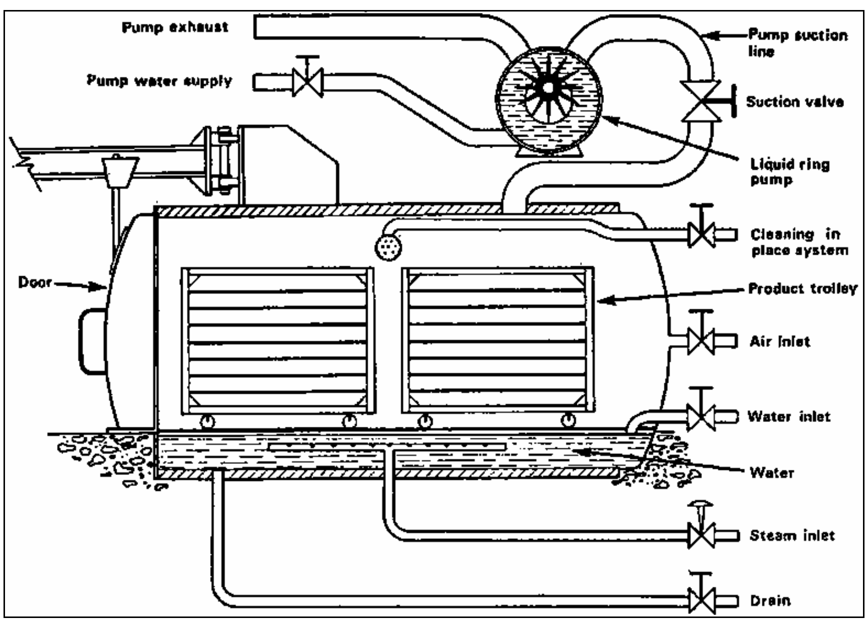


Figure 13 - Example of an industrial vacuum thawing system

5.4.2. Microwave thawing systems

Microwave thawing systems, although very rapid, are constrained to some extent by thermal instability. Parts of the food product can become overheated or cooked, while other parts remain frozen. For part-frozen products, there is also the possibility of runaway heating, where parts of the food which have thawed will absorb energy preferentially to those that are still frozen. This makes microwave thawing systems extremely difficult to control. Microwave systems are not ideally suited to the thawing of large frozen fish blocks, although microwave systems are widely used for tempering. Tempering raises the temperature of frozen blocks to just below the freezing point (between -5^oC and -10^oC) and is done to facilitate cutting and further handling of the product.

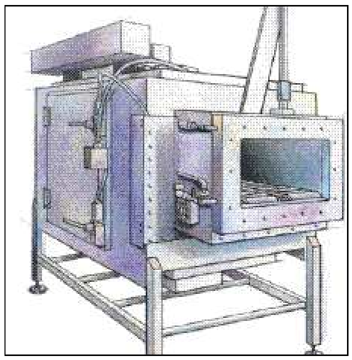


Figure 14 - Example of continuous microwave tempering equipment (Ferrite Inc)

5.4.3. Radio frequency systems

Radio-frequency thawing systems are also available, where the frozen product is placed between two parallel electrodes and alternating radio-frequency energy is applied to the electrodes. Temperature rise within the product is relatively uniform, the degree of uniformity being dependent on the size and composition of the product. It is suggested that 5cm blocks of fish can be thawed in 15 to 45 minutes. For final temperatures near the thawing point of seafood (typically -1^oC), the two frequencies offered by microwave processing (2450 MHz and 915 MHz) are no longer adequate as they can create uneven temperature distributions and result in poor quality products. However, radio frequency treatments have more promising attributes for processing seafood. At the lower frequencies of RF, penetration of the RF energy into foods is much greater and enables the temperature of blocks to increase from –20°C t o –2 or 0°C.

Radio-frequency systems are available in both batch and continuous formats. Batch RF systems operate from 40 to 350 kg/hour whilst continuous RF systems can operate from 900 to 3000 kg/hour.

Figure 15 - Example of a batch RF thawing/tempering system (6kW, 100 to 250 kg/hour) (Sairem S.A.)

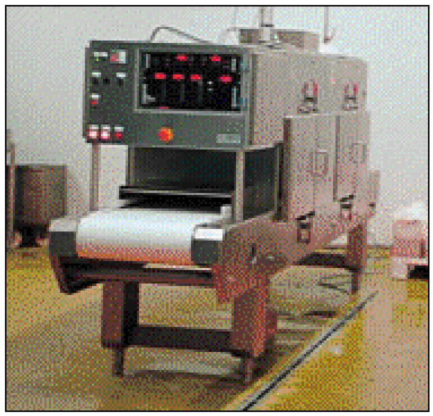


Figure 16 - Example of a continuous RF tunnel (50kW, 750 to 2000kg/hour) (Sairem S.A.)

In trials with frozen fish, Keam Holdem (2004), gave a comparative study on tempering and thawing times (Table 5)

Table 5 – Radio-frequency tempering and thawing times

Product	Trial starting temperature (°C)	Required final temperature (°C)	Tempering time (minutes)	Tempering time from an initial starting temperature of –18°C	Radio-frequency power level (W/kg)
Hoki fillets	-12.9	0.9	45	65	30
Barracuda fillets	-7.4	-0.5	76	110	22
Tuna fillets	-12.1	2.5	40	55	50
Whole sardines	-12	1.6	145	155	20

STALAM radio frequency equipment has been commercially tested to thaw some seafood products (Table 6). This information has been provided directly by the manufacturer / UK sales agent.

Table 6 – Radio frequency thawing rates

Product	Product size	RF time (minutes)	Initial product temperature (°C)	Final product temperature (°C)	Equilibration time
Raw shrimp and prawn	2kg block	2.5 2.25	-24 -24	-1.5 -0.1	2.5h in water 4h in water
IQF cooked and peeled *Pandalus borealis*	175-275 with 10% glaze	8	-28	-3	4h in chill
MAP seafood (IQF shrimp, scallop, mussels, calamari)	6 x 50g packs per carton	8	-25	-3.7	Unknown
Frozen mackerel	Blocks (unknown size)	9	-20	-2	unknown

5.4.4. Electrical heating

Blocks of frozen fish are placed between two parallel plates, across which a high frequency alternating voltage is applied. If the blocks are of uniform thickness, composition and temperature, and the voltage and frequency sufficiently high, heat is produced within the blocks. However in less than ideal conditions, such as if the blocks are irregularly shaped, localised overheating of the product can occur.

When thawing blocks of large whole fish, it is necessary to immerse the blocks in water and pass them through a sequence of separate thawing units. Immersing them enables the electrical conditions to be more uniform. Blocks of smaller fish do not require immersion.

Further information on this form of thawing is limited and it has not been included in the subsequent comparisons.

5.5. Comparison of the different thawing methods

5.5.1. Main properties of different thawing systems

Table 7 – Main properties of different thawing systems

	Air		**Water**		**Electric**		
	Air blast	**Still air**	**Ad-hoc**	**Purpose designed**	**Vacuum**	**Radio frequency**	**Microwave**
Seafood species (all or certain types)	all	all	all	all	all	all	all
Product type (processed, semi-processed, whole, all)	all	all	Whole & semi	Whole & semi	Whole & semi	all	all
Product quality	Variable	Consistent	variable	Consistent	Consistent	Variable	Variable
Space requirements (low, med, high)	Med – high	Low	High	High	Low	Low	Low
Complexity (simple, complex)	Complex	Simple	Simple	Simple	Complex	Complex	Complex
Scale / size (large, med, small)	All	Small	Medium	Medium to large	Medium	Medium	Medium
Operation type (batch / continuous)	Both	Batch	Batch	Both	Batch	Both	Both
Timescale (0-6, 6-12, 12+ hours)	0-6 hrs	>12hrs	6-12 hrs	0-6 hrs	0-6 hrs	0-6 hrs	0-6 hrs
Extent of product handling	Med	Low	High	High	High	High	High
Monitoring requirements	Low	Low	Low – med	High	Medium	High	High
Controllability	High	Low	Low	Med - high	Medium	Medium	Medium
In-built temperature monitoring	Yes	No	No	Yes	No	No	No

5.5.2. A basic comparison of costs associated with the different thawing systems

Table 8 – basic comparison of costs

	Air		Water		Vacuum	Di-electric	
	Air blast	**Still air**	**Ad-hoc**	**Purpose designed**		**Radio frequency**	**Microwave**
Capital costs (low, med, high)	High	Low	Low	Medium	High	High	High
What do the systems require (yes / no)							
Energy	Yes	No[1]	Yes	Yes	Yes	Yes	Yes
Water	Yes	No	Yes	Yes	Yes	No	No
Effluent	Yes	No	Yes	Yes	Yes	No	No
Maintenance	Yes	No[1]	Yes	Yes	Yes	Yes	Yes
What are the operational costs? (low, medium, high)							
Energy	Low	Low[1]	Medium	Medium	Medium	Medium	High
Water	Low	Low	High	Medium	Low	Low	Low
Effluent	Low	Low	High	Medium	Medium	Low	Low
Maintenance costs	Low	Low[1]	Medium	Medium	Medium	High	High

(1) – based on ambient temperature rather than chill / refrigeration temperature

5.5.3. Advantages and disadvantages of different thawing systems

A summary of the main advantages and disadvantages of each system is provided in Table 9.

Table 9 – advantages and disadvantages of different thawing systems

Thawing method	Advantages	Disadvantages
Air blast	• Modular so fit variety of uses • Controllable / programmable • Can control temperature • Hygienic • Less product handling • Suitable for all product types • Batch and continuous systems • Suitable for all products & species • Relatively quick • Range of systems available • Minimal loss of flavour / effect on product quality	• Capital costs can be expensive • Running costs can be high depending on energy consumption • Surface dehydration of product if not carried out properly • Require regular maintenance • Complex mechanical system • Can be difficult to thaw all seafood uniformly • Temperature of products should be equilibrated in a chill afterwards
Still or ambient air	• Cheap / cost-effective • Suitable for a range of products and species	• Slow • Only suitable for small quantities of product

		• Hygiene standards variable depending on where it is undertaken • Lack of temperature control or monitoring • Seasonal variations in ambient temperature • Space requirements • Can accelerate spoilage and reduce shelf life if lack of temperature control
Water -ad-hoc systems	• Cheap capital costs • Can be hygienic depending on design • Can be made to suit small or large scale requirements	• Running costs (water & effluent) can be high • Can be slow depending on water temperature and method used • Large amount of space required • Lack of monitoring • Lack of temperature control leading to either under or over thawing • Unsuitable for processed products / products with cut surfaces • Lack of control over variable water temperatures, particularly seasonal differences • Not always hygienic • Poorly designed systems in use • Leaching out of nutrients • Multiple product handling required • Handling of thawed product may be difficult
Water – purpose designed systems	• Batch & continuous systems available • Purpose designed units • Programmable • Controllable • Hygienic • Rapid thawing possible	• Running costs can be high (water, waste-water and energy) • Only suited for whole products • Few systems available
Vacuum	• Hygienic • Quick • Small footprint	• Has to be programmed for each type of product • Uneven rate of thawing • Difficult to control • Unsuitable for large quantities
Microwave	• Heat generated throughout the product • Quick • Minimal drip loss • Hygienic • Small footprint	• Capital costs are high • Uneven rate of thawing • Difficult to control • Unsuitable for large quantities • Specialist design and maintenance personnel needed
Radio-frequency	• Uniform • Quick • Hygienic • No effect on quality / texture • Small footprint • Minimal drip loss • Consistent temperatures • Proven with some seafood products	• Capital costs are high • Heating can be uneven • Can be difficult to control • Specialist design and maintenance personnel needed.

6. New or emerging technologies for seafood thawing

Technology is always progressing and in the past couple of years new or improved thawing methods have become available.

6.1. Climatic thawing system

A climatic system a water based system that uses atomized water or steam which is injected into the thawing chamber. Temperature monitoring is carried out via sensors on the product surface and core. When products reach the required temperature, the equipment reduces the conditions inside the chamber to chill temperatures. Humidity can also be fully controlled.

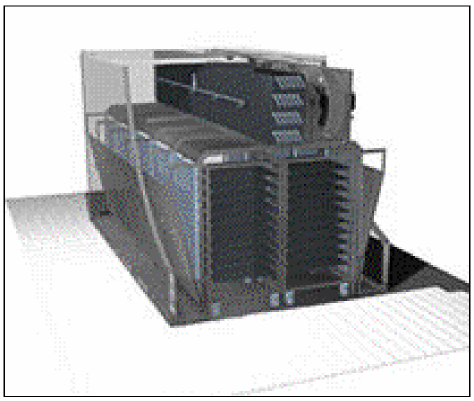


Figure 16 - Example of climatic fish thawing equipment (www.carnitech.com)

6.2. Ultra High Pressure thawing

A relatively novel process involves the use of high pressure processing to uniform freezing and thawing within food materials. The use of high pressures (up to 200MPa) has the effect of depressing the temperature of ice crystal formation. Freezing temperatures as low as $-21^{o}C$ can be achieved under high pressure before ice crystals are formed. When the high pressure is released, ice crystals form almost instantaneously and homogeneously throughout the food product. This results in virtually no cellular damage within the food as a result of the freezing process. Three potential applications are apparent for high pressure in this field, pressure-shift freezing, storage at sub-freezing temperatures and pressure-shift thawing.

Systems are highly mechanised, see Figure 17.

Figure 17 - Examples of two high pressure food processing systems (NC Hyperbaric)

Thawing of tuna under pressure has been investigated (Murakami et al, 1992). Frozen blocks were thawed between 0 and 20^{o}C at pressures between 50 and 150 Mpa for 30 and 60 minutes. An unfavourable colour change (red to pink) occurred in pressure thawed blocks but there was significant reduction in drip loss compared to blocks thawed at atmospheric pressure. Greatly increased rates of thawing have been reported in surimi, but protein denaturation and fish meat colour changes occur at higher pressures (Kalichevsky et al, 1995).

6.3. Updated water based thawing system

Variations in the design of water based systems are now available. The 3X thawing solution is based on a stainless steel screw-tank with temperature controlled water.

The thawing tank is adjustable for different block sizes, from 7 kg to 28 kg. The speed of the screw can be adjusted and the thawing process takes one to three hours depending on the product. Typical thawing throughputs with this system are 2 t/hr, with a water usage of 12m^3 per day. Electrical consumption is typically around 6kW and steam consumption 200kW maximum for this scale of operation.

By changing the parameters of the tank, the core temperature can be varied according to specification, from -2℃ to +2℃.

To minimise labour, the system comes with an electronic driven conveyor for feeding seafood into the system. The manufacturers suggest that in most cases, one operator can run the system at full capacity and that a processor thawing more than 10 tonnes of product per day will have a good payback on their investment.

Further information on this system is available from
http://www.3xtec.com/Solutions/ThawingSolutions/tabid/257/Default.aspx

Figure 18 - Example of modern design of water based thawing unit (GW Containers)

7. Key recommendations for GMP in seafood thawing

	Key recommendations
Temperature	• Ensure product temperature is monitored throughout thawing cycle. • Product temperature should be kept close to the temperature of melting ice i.e. as close to 0^oC as possible. • Ensure water and air temperatures are monitored and do not exceed recommended limits. • Allow seafood temperature to equilibrate after thawing as different parts of the product will be at different temperatures.
Timescale	• Ensure the timescale is appropriate for thawing the seafood. In general, seafood is best thawed quickly (0-6 hours) but not so quickly that product safety and quality is compromised.
Product	• If double freezing (i.e. re-freezing thawed seafood) ensure that thawing is done to the highest standards of GMP to reduce risks of changes in texture. • Thawed seafood will spoil as rapidly as chilled-never frozen seafood. Ensure thawed seafood remains at chill temperatures (as close to 0^oC as possible). • Do not process under-thawed product, unless it has been specifically tempered for use in another process.
Process & Equipment	• Ensure the process used is monitored and controlled throughout – do not leave the seafood thawing without any supervision as this can lead to under or over thawing. • Use most appropriate method & equipment for the product. • Thawing conditions should be clean and hygienic. • Do not use water to thaw cut or processed seafood – only use water to thaw whole or semi-processed product e.g. headed & gutted fish. • When purchasing thawing equipment ensure it has proven expertise with seafood products. Ask for demonstrations wherever possible.

7. Areas for further research

Areas for further research could include;

- Proper comparison of the different thawing methods from commercial perspective, using different products. Includes methods such as microwave, radio-frequency and ultra high pressure (UHP) thawing.

- Determination of the seafood quality issues arising from rapid thawing methods such as microwave, radio-frequency and UHP thawing.

- Development of an improved simple, ad-hoc water based thawing system to incorporate temperature and product controls, water shut off system etc. whilst remaining cost-effective.

- Better understanding of the indicators that dictate quality and safety of frozen-thawed seafood. Correlation between physical, chemical and biochemical indicators of seafood quality as a result of the freeze-thaw process. Also the effects of double freezing (freeze-thaw-freeze cycles) need further investigation, particularly effects on quality, texture, drip loss etc.

8. Further information

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8.2. Further reading / useful documents

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2. Torry Advisory Notes – contents list http://www.onefish.org/global/TorryNotesTableofContents.htm
3. Fish.gov.au website – summary on thawing http://www.fish.gov.au/manual/storage.php#thawing
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8.3. Seafood organisations (information on seafood industry, processing etc.)

Name	Country	Website
Ashtown Food Research Centre (Teagasc)	Ireland	www.ashtownfood.ie/preparedfoods
Codex Standards	International	www.codexalimentarius.net
Government of Newfoundland & Labrador, Department of Fisheries and Aquaculture	Canada	http://www.fishaq.gov.nl.ca/
International Association of Fish Inspectors	International	http://www.iafi.net/index.cfm
Irish Sea Fisheries Board	Ireland	http://www.bim.ie/templates/homepage.asp
Matis	Iceland	http://www.matis.is/english/about/
New Zealand Seafood Industry Council	New Zealand	http://www.seafood.co.nz
Norconserve	Norway	www.norconserve.no
Norwegian Institute for Fisheries and Aquaculture Research	Norway	www.fiskeriforskning.no
Onefish	worldwide	http://www.onefish.org/global/index.jsp
Research programme on seafood (Current Research)	Europe	www.seafoodplus.org
Sea Fish Industry Authority	UK	http://www.seafish.org
Seafood directory	UK	http://www.fishthenet.net
Seafood Network Information centre	USA	http://seafood.ucdavis.edu
Seagrant	USA	http://www.seagrant.noaa.gov/aboutsg/aboutsg.html
The Swedish Institute of Food & Biotechnology	Sweden	www.sik.se
West European Fish Technologists Association	EU	http://www.wefta.org/

8.4. Suppliers of thawing equipment for fish and seafood

This is not an exhaustive list. The inclusion of these companies and products is not a recommendation or endorsement.

Type of units	Company	Contact details
Quick Thaw units	Morep Limited	Tel 01422 885990 http://www.defrost.dk/
Defrosting techniques & installations	Cabinplant international	Tel +45 64732020 http://www.cabinplant.com/downloads/brochures/machinesprocess/thawing/
Automatic thawing equipment	AFOS Ltd	Tel 01482 352152 http://www.afosgroup.com/index.htm
Temperature & humidity controlled defrosting	Carnitech a/s	Tel +45 98373577 http://www.carnitech.com/Default.aspx?AreaID=88
Rapid air thaw	Foster Refrigerator Ltd	Tel 01553 61122 http://www.fridgeair.co.uk/pdf/bluepapers/blastchilling.pdf
Water thawing	G.W.Containers (3X systems)	Tel: 01543 491 870 www.gwcontainers.co.uk
Forced air thawing units	Dawson Rentals	Tel 01623 516666 www.dawsongroup.co.uk
Microwave/RF	Ferrite Inc.	http://www.ferriteinc.com
Microwave/RF	Sairem S.A.	http://www.sairem.com
Microwave/RF	Stalam c/o Chris Amos International	tel 01647 221544
Microwave/RF	Keam Holdem	http://www.keamholdem.com
Microwave/RF	NIS Ltd.	http://www.nisltd.com
Microwave/RF	Heat and Control	http://www.heatandcontrol.com
Microwave/RF	AWI Ltd.	http://www.awimicrowaves.com
Microwave/RF	AMT Microwave Systems	http://www.amtmicrowave.com