The evolving story of fish shelf-life management

The keeping quality of most foodstuffs is dependent upon enzymatic or chemical and microbiological activity. When it comes to fish microbiological activity this is relatively much more important when the fish are held in the temperature range of 0-25°C as in this range temperature changes have a much greater impact on microbiological growth than they do on enzymatic activity.

Many bacteria have difficulty growing at temperatures <10°C and even psychotrophic bacteria grow very slowly at such temperatures. The growth rates for different types of bacteria at different temperatures is shown in Fig. 1.

In essence, microbiological activity is responsible for the spoilage of the majority of fish products and so the shelf-life of fish products is greatly extended when these products are stored at low temperatures. Shelf-life can be defined as the maximum length of time a given product is fit for human consumption.

Check core temperatures

Fresh fish stored at 10°C will spoil some five times faster than fish held at 0°C (remember, because of the chemical make up the actual freezing point of fish is a little below 0°C).

This being the case it is always prudent to check core temperatures of some fish in a batch being landed from a boat using a bi-metal thermometer and to check any temperature records if these are available.

The shelf-life of fish is significantly extended when products are stored at low temperatures and in Western countries fresh fish are often stored in ice at 0°C.

The shelf-life of product stored at higher temperatures is often expressed using relative rate of spoilage (RRS) and this can be defined by the relative rate concept equation:

$$\text{RRS at } x°C = \frac{\text{Keeping time at } 0°C}{\text{Keeping time at } x°C}$$

Table 1 shows the effects of storage at different temperatures on the shelf-lives and RRS of seafood products.

The relationship between temperature and shelf-life has been studied in depth with the outcome that this relationship can be expressed as an S-shaped general spoilage curve (Fig. 2). From this it can be seen that at temperatures <10°C there is a linear relationship between RRS and storage temperature.

The impact of storage temperature on chemical reactions can be explained by the Arrhenius equation, but this has been shown to lack accuracy when used over a wide range of temperatures, on bacterial growth and on food spoilage. As a consequence a 2-parameter square root model was suggested for the effect of sub-optimal temperature on the growth of micro-organisms:

$$\sqrt{\mu_{max}} = b(T - T_{min})$$

The combination of these two equations produced a preferred temperature spoilage model (see inset below).

0°C (in ice)	5°C	10°C	15°C
6.0	2.7	1.5	1.0
10.0	4.4	2.5	1.6
14.0	6.2	3.5	2.3
18.0	8.0	4.5	2.9

Table 2. Predicted shelf-life (days) of fish products stored at different temperatures.

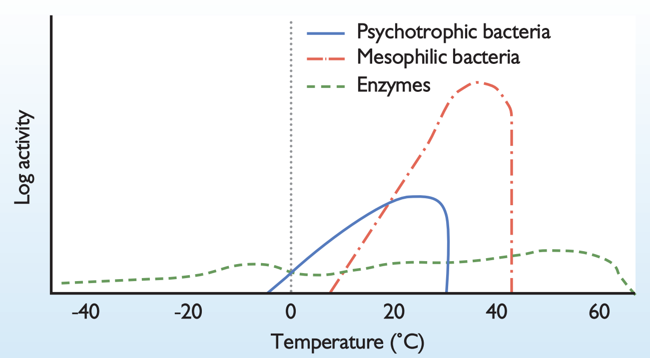

Fig. 1. Relative enzyme activity and growth rate of bacteria in relation to temperature (Andersen et al, 1965).

$$\sqrt{\text{Relative rate of spoilage}} = \frac{b(t°C - (-10°C))}{b(0°C - (-10°C))}$$

Table 2 shows the predicted shelf-life of fish products stored at different temperatures derived from this equation. The effect of time/temperature storage conditions on product shelf-life is cumulative and this allows spoilage models to be used for predictive purposes for the effect of temperature on shelf-life or a product's ability to keep.

An electronic time/temperature function integrator for shelf-life prediction was developed in the early 1970s which predicted RRS accurately, but its practical use was limited by its then high cost.

Temperature logger

The historic temperature profile of a product through the system can be monitored by a temperature logger and the data obtained can be downloaded and analysed using a computer and a software program. With the data derived from a temperature logger we can obtain a temperature profile and then we can assess potential growth of undesirable bacteria from safety models.

The microflora associated with the spoilage of fresh fish changes as the storage temperature changes.

At low temperatures (0-5°C) Shewanella putrefaciens, Photobacterium, Pseudomonas Spp. and Aeromonas Spp. are involved, whereas at higher temperatures (15-30°C) bacteria like Vibrio Spp., Enterobacteriaceae and Gram positive assume the spoilage role.

However, the equation previously alluded to for relative spoilage rate does not take into account changes in bacterial type involved.

Even so, reasonable estimates of RRS can be obtained for whole fish, packed fresh fish and superchilled fish products but for many species of tropical fish stored at 25-30°C the

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Table 1. Effects of storage temperatures on the shelf-life (in days) and RRS of various seafood products stored at different temperatures.

	0°C		5°C		10°C	
	Shelf-life	RRS	Shelf-life	RRS	Shelf-life	RRS
Crab claw	10.1	1.0	5.5	1.8	2.6	3.9
Salmon	11.8	1.0	8.0	1.5	3.0	3.9
Sea bream	32.0	1.0	-	-	8.0	4.0
Packed cod	14.0	1.0	6.0	2.3	3.0	4.7

	Fillet yield (%) Iced 1.0 hour after catch	Iced 6.5 hours after catch
Yield of fillets	48.4	46.5
Yield after trimming	43.3	40.4

Table 3. Fillet yield of gutted cod.

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RRS is some 25 times higher than it is at 0°C. Thus, the RRS for tropical fish can be more than twice as high as the figures that are normally estimated for cooler water fish products.

Accordingly, a new model for tropical fish products stored at 0-30°C was developed in the 1990s.

Initial product qualities

The temperature models discussed so far ignore initial product quality and inaccurate shelf-life predictions can arise from products with a variable initial quality!

But, on the assumption that shelf-life at a given temperature and initial quality can be defined then shelf-life at other temperatures can be determined from a temperature spoilage model. Progressing on from here quality index methods were determined and these are useful for obtaining straight line relationships between quality scores and storage times.

Many facets of fresh fish spoilage still need to be fully elucidated but, despite this, the RRS concept has made it possible to quantify and mathematically describe the effect of temperature on the rate of spoilage on a variety of fish products.

Predicting shelf-life

These models can be used for the evaluation of production, storage and distribution conditions and, when combined with initial product quality data, they can be used to predict shelf-life.

As well as the actual storage temperature, the delay before chilling is important. For example, if white fleshed, lean fish enter rigor mortis at temperatures >17°C, muscle tissue can rupture resulting in flakes of meat separating from the fillet (known as 'gaping' in the trade). Such fish is difficult to fillet and its water binding capacity decreases (Table 3).

In addition, Table 4 contains Alaskan data that shows the effect of delayed chilling on subsequent shelf-life after holding fish at 10°C for the indicated times (4-48 hours).

For fatty fish such as herring, rapid chilling is essential if fish quality is to be maintained. Several studies have shown that the keeping qualities and storage lives of such fish are significantly reduced if they are exposed to sun and wind for four to six hours before chilling. This is because the lipids in these fish are rapidly oxidised resulting in off flavours of a rancid nature.

Storage of fish products between 0 and -4°C is known as partial freezing or superchilling and the shelf-life of various fish and shellfish can be increased by storage at subzero temperatures.

For a product that normally keeps for 14 days on ice its shelf-life is extended to 17, 22 and 29 days when stored at -1, -2 and -3°C.

Species	Max shelf-life (days)	Remaining shelf-life (days) after storage at 10°C for indicated times (hours) 4	8	12	24	48
Halibut	18	17.3	16.6	16.0	14.0	10.0
Chum salmon	13	12.3	11.6	11.0	9.0	5.0
Sockeye salmon	12	11.3	10.6	10.0	8.0	4.0
Pacific cod	12	11.3	10.5	10.0	8.0	4.0
Silver salmon	12	11.3	10.6	10.0	8.0	4.0
King salmon	10	9.3	8.6	8.0	6.0	2.0
Sablefish	10	9.3	8.6	8.0	6.0	2.0
Pink salmon	6	5.3	4.6	4.0	2.0	0
Pollock	5	4.3	3.6	3.0	1.0	0

Assuming fish immediately chilled and handled gently under hygienic conditions at each step of harvesting, processing and display.

Table 4. The effect of delayed chilling on shelf-life.

However, not all fish types are ideal for superchilling. For example, haddock and cod can suffer adverse effects in terms of drip loss, appearance and texture due to formation of large ice crystals, protein denaturation and increased enzyme activity in partially frozen fish.

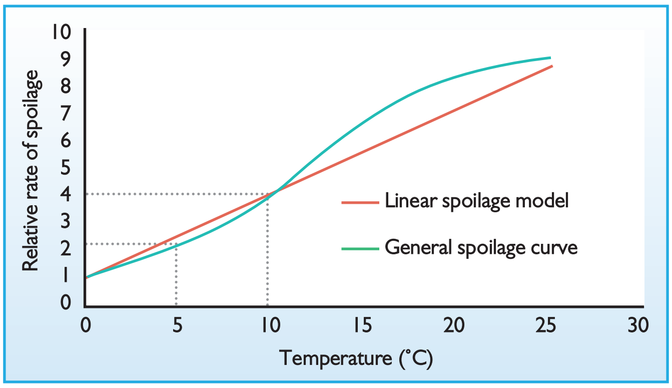


Fig. 2. Effect of temperature on the relative rate of spoilage of fresh fish products – the general spoilage curve and the linear spoilage model.

Superchilling has been used commercially with a few fish species and when it is used it can significantly improve shelf-life.

When it comes to shelf-life hygiene is important in relation to the handling of the fish from point of catching onwards.

Fig. 3 shows the impact of three standards of handling (normal, clean and aseptic) on the bacterial growth and organoleptic quality of plaice stored at 0°C with initial high, moderate and low bacterial counts.

Interestingly, when we look at the graph for bacterial counts in Fig. 3 the difference, and hence the importance of the differences in the fish handling procedures and the benefits derived from them is reduced. Therefore, the benefits of being very hygienic reduce with time.

However, there are merits in minimising the amount of melt water seeping down from the top boxes in a stack and contaminating lower boxes.

There are processes that will reduce naturally occurring microflora on fish but these are mainly of academic interest.

Interestingly, the benefits obtained in meat products from vacuum packing and modified atmosphere packing (MAP) with carbon dioxide levels of 25-100% could not be obtained for fish (Table 5).

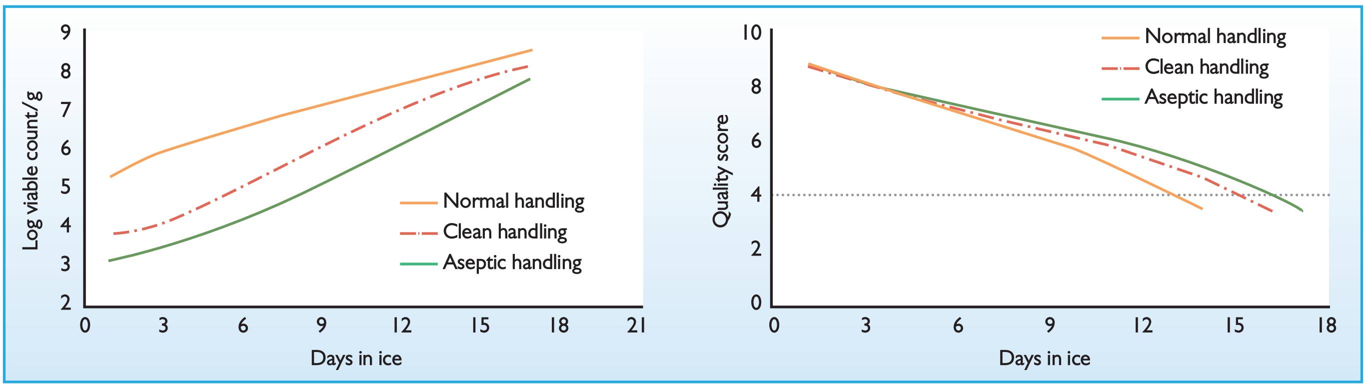
These differences are due to differences in spoilage bacteria and pH.

Shewanella putrefaciens

Fish stored under aerobic conditions are primarily spoiled by Shewanella putrefaciens, whereas the spoilage of meat products is caused by aerobes such Pseudomonas Spp. which are strongly inhibited by the anaerobic conditions of vacuum packing and by carbon dioxide in MAP.

For packed cod Photobacterium

Fig. 3. Bacterial growth and organoleptic quality of plaice stored at 0°C with initial high, medium and low bacterial counts (Huss et al, 1974).



Product	Storage temperature (°C)	Shelf-life (weeks) Air	Vacuum packed	MAP
Beef, pork, poultry	1-4	1-3	1-12	3-21
Pollock, cod, rockfish	0-4	1-2	1-2	1-2
Herring, salmon, trout	0-4	1-2	1-2	1-3
Crabs, scampi, scallops	0-4	0.5-2	–	0.5-3
Swordfish, tiapia, sheepshead	2-4	0.5-2	_	2-4

Table 5. Effect of different packaging protocols on shelf-life of different products.

phosphoreum is the organism of spoilage and its growth increases under anaerobic conditions!

This probably explains the importance of this organism in vacuum packed cod.

In carbon dioxide packed fish the growth of Shewanella putrefaciens is strongly inhibited, as is the growth of many other bacteria found on/in live fish.

Adverse effect on texture

High levels of carbon dioxide can adversely affect the texture of some fish and in red fleshed fish it can be associated with the formation of metmyoglobulin resulting in a darkening of the fish meat.

The use of MAP with fish products is limited because of the following factors:

- It is expensive.
- Prime fish quality is not improved.
- Only get a small extension to shelf-life.
- It can not replace good chilling and good hygiene.
- Toxin production of Clostridium botulinum might be increased when it grows under anaerobic conditions.

In some markets MAP and vacuum packed products are considered to be fresh products and can be useful for fresh fish products when only a few additional days shelf-life are required.

However, carbon dioxide can have a negative effect on the colour of whole fish and adverse effects can

be seen in terms of texture and drip loss with high concentrations of the gas.

Benefits of ozone

In recent times listeria has become a much bigger issue in relation to food safety and a variety of new products have appeared on the scene including sprays, ozonated water generators and dips that are aimed to increase sanitation while processing thereby, hopefully, increasing shelf-life.

However, if we use chemicals the issue of declaring them then arises.

For example, there are products based on acidified sodium chlorite which generate chlorine dioxide which will kill pathogens. Such products will probably increase shelf-life by 20% as an absolute maximum.

Another proprietary brand is based on ammonium sulphate, sulphuric acid and copper sulphate and it can be used by processors or fish retailers and in some circumstances it is claimed that this product can double shelf-life!

The use of ozone can increase shelf-life and decrease listeria and other bacteria.

So, high technology is having its impact on seafood products but their advent does not mean we can pay any less attention to the two basics of temperature and hygiene management. ■