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FACT SHEET

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SEAFOOD SPOILAGE

Purpose:

To review the processes contributing to the spoilage of seafood products

Target Audience:

Anyone, directly or indirectly, associated with production and sale of seafood products, and seafood consumers.

Seafood Composition

The composition of various seafood species is summarized below in Table 1.

Table 1. The macromolecule contents of various seafood products (Murray and Burt, 2001)

		Proportion (%)		
Species	**Scientific name**	**Water**	**Fat**	**Protein**
Cod	*Gadus morhua*	78 - 83	0.1 – 0.9	15.0 – 19.0
Haddock	*Melanogrammus aeglefinus*	79 - 84	0.1 – 0.6	14.6 – 20.3
Hake	*Merluccius merluccius*	80	0.4 – 1.0	17.8 – 18.6
Halibut	*Hippoglossus hippoglossus*	75 - 79	0.5 – 9.6	18.0 - 18.8
Herring	*Clupea harengus*	60 - 80	0.4 – 22.0	16.0 – 19.0
Mackerel	*Scomber scombrus*	60 - 74	1.0 - 23.5	16 - 20
Redfish	*Sebastes sp.*	73 - 79	3.2 – 8.1	16.8 – 19.7
Pollack	*Pollachius virens*	81	0.3 – 0.6	16.4 – 20.3
Atlantic Salmon	*Salmo salar*	65	13.4	20
Tuna	*Thunnus sp.*	71	4.1	25.2
Mussel	*Mytilus edulis*	80 - 84	0.8 – 2.3	8.9 - 11.7
Scallop	*Pecten maximus*	73 - 79	0.5 – 1.0	19.5
Lobster	*Homarus americanus*	75 - 81	0.3 – 0.7	16 - 19
Snow Crab	*Chionocetes opilio*	75	2	23

Seafood products are composed primarily of water, protein, and fat. Fresh seafoods have moisture contents ranging from 60 – 84 %, and protein contents from 10 - 25 %. Fatty fish, such as herring, mackerel, and salmon store substantial amounts of fats within their tissues, whereas lean fish such as cod and haddock store fat within their livers. Fatty fish have comparable protein contents to lean fish, but possess lower moisture contents.

Mechanisms of Seafood Spoilage

Seafood spoilage is a deteriorative process mediated by 1) enzymatic activity, 2) microbial growth, and 3) lipid (fat) oxidation. Indicators of spoilage include slime formation, gas production, off-odours and off-flavours, discolouration, and changes in texture (Table 2)

Table 2. The impact of spoilage processes on changes to product attributes (Huss, 1993).

	Causes of fish spoilage			
Product Attributes	**Microbiological**	**Oxidation**	**Enzymatic**	**Handling**
Off odours/ off flavours	+	+	+	-
Slime formation	+	-	-	-
Gas formation	+	-	-	-
Discolouration	+	+	+	+
Change of texture	+	-	+	+

Enzymatic Activity

All muscle tissues contain chemical compounds called enzymes. Enzymes in muscle tissues that act to recycle proteins are called proteases and break apart intact proteins into their component amino acids. Enzymes in seafood products harvested from temperate climates are cold-adapted, meaning that chilling of seafoods to 0 °C is not sufficient to completely arrest their activity. When fish die, enzymes continue to function uninhibited, leading to self-deterioration, or autolysis, of its own tissues. The enzymes active in these processes are termed autolytic enzymes.

Autolytic enzymes first contribute to the termination of rigor, then the development of distinct flavours and odours, followed by textural softening. Enzymes are also produced and expressed by bacteria that grow on and within the tissues of the fish that contribute to the development of off-flavour, off-odour, and exacerbate textural softening.

In the Gadidae family of fish (cod, hake, haddock, pollock), autolytic enzymes continue to act under frozen storage. Trimethylamine-oxide (TMAO) is reduced to trimethylamine (TMA) and again further to dimethylamine and formic acid. Formic acid causes the denaturation of proteins, leading to their cross-linking and the toughening of these tissues, even under frozen storage.

Bacterial Growth

Fresh fish and seafood have water activities measuring ~0.99, indicating these products are highly susceptible to the growth of bacteria. Bacteria in fish products are derived from those naturally present in the marine environment, but are also introduced to the product post-harvest through handling. Initially, bacteria are diverse in number, but eventually specific spoilage organisms (SSO) proliferate over the post-harvest storage period. There are a limited number of species that contribute to the development of off-odours and off-flavours called spoilage bacteria. The growth of spoilage bacteria in seafood products is directly related to the storage temperature of the product (Figure 1). Spoilage bacteria are the primary drivers of spoilage in fresh seafood products.

Lipid (fat) Oxidation

Seafoods are high-quality sources of polyunsaturated fatty acids (i.e., omega-3s) that exhibit health-protective effects and are recommended by Health Canada to be consumed in amounts of at least 1.5 g per day. The exposure of unsaturated lipids to oxygen promotes oxidation. Oxidation is a process whereby lipids breakdown into smaller molecules that contribute both to discolouration and the development of off-odours and flavours. Unlike bacteria, the oxidation of lipids in seafoods can occur during both chilled and frozen storage. Oxidation cannot occur in the absence of oxygen, thus vacuum packaging of fatty seafood products is recommended to maximize their shelf life.

How to minimize spoilage?

Handling

Rough handling of seafood products can lead to the physical damage of tissues. This damage may cause the tearing of cell membranes that expose internal contents to the external environment. As a result, rough handling can promote unwanted enzymatic activity, as well as the invasion of bacteria into tissues that act to reduce shelf life.

Hygiene

Spoilage bacteria are found in the environments used to convey and process seafood products for distribution to market. The bacterial load in these environments directly impacts the shelf life of the products, due to the contribution of spoilage bacteria on the development of off-odours and off-flavours. Good sanitation practices and hygiene in these environments is essential to limit the transfer of spoilage organisms on to products.

Chilling

The transfer of spoilage bacteria onto seafood products is an inevitability. However, the extent that these bacteria can grow and proliferate in these products is directly dependent on the environmental temperature where these products are stored. Chilling, either through the application of ice or other mechanical means, is an effective way to slow the growth rate of spoilage bacteria.

The growth of spoilage bacteria is based on the following equation: $\sqrt{r} = 1 + 0.1 \times t$ and summarized below in Figure 1. The growth rate of spoilage bacteria at 4 °C 2-fold compared to the growth rate at 0 °C. Likewise, at -2 °C spoilage bacteria have a growth rate that is 64% of the rate at 0 °C.

For more information on chilling, refer to the Chilling and Icing fact sheet.

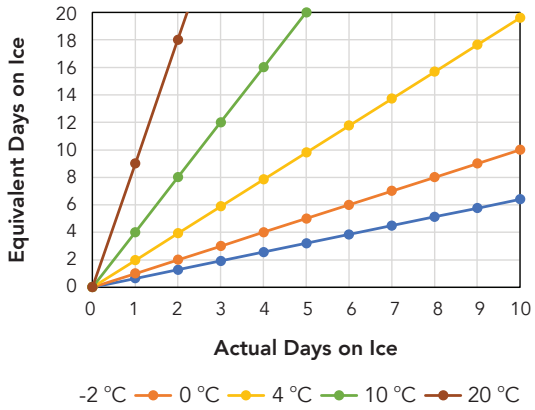

Figure 1. Growth rate of spoilage bacteria in seafood products at different storage temperatures.

Key Take Aways:

1. Spoilage is caused primarily by bacterial action in fresh seafood products, whereas in frozen seafood products, lipid oxidation and enzymatic activity are the primary causes of spoilage.
2. The growth of spoilage bacteria can reliably be controlled through effective post-harvest temperature management, whereby the lowest achievable temperatures for storage should be targeted.
3. Identification of spoilage in seafood products requires monitoring for the development of off-odours and off-flavours

References:

Doyle, J.P. 1989. Seafood Shelf Life as a Function of Temperature. Alaska Sea Grant Marine Advisory Program.

Huss, H.H. 1993. Chapter 3: Quality Aspects Associated with Seafood. In Assurance of seafood Quality. FAO Fisheries Technical Paper. No. 334. Rome, FAO

Murray, J., and Burt, J.R. 2001. The Composition of Fish. Torry Advisory Note No. 38. Torry Research Station.