FOOD QUALITY AND STANDARDS PERTAINING TO FISH

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Summary

The quality indices of seafood regarding sensory attributes, health safety aspects, nutritional value, functional properties, and conformation to product standards are treated in this chapter. Poisonous fish of several families and fish products containing biotoxins or visible parasites are not allowed for human consumption according to EEC requirements. Freshness is the primary attribute used when deciding the market value of an expensive variety of fish. It can be measured using sensory, biochemical, microbiological, and physical tests.

The sensory, nutritional, and functional properties of fish and shellfish are species-related, and affected by biological factors, and by handling and processing. Because of their high protein content, polyenoic fatty acids of the n-3 family content, and vitamin content, most seafood products have high nutritional value. The contamination of the catch and fishery products by microorganisms, marine toxins, parasites, and insects is controlled by regulations and standards regarding fishing, handling, and processing on board a vessel and onshore. Chemical contamination is generally within allowable limits and, being no higher than that of other foods on the market, generally affords no risk to the consumer.

1. Introduction

There is a large variety of fish and shellfish, belonging to hundreds of species fished commercially and produced in aquaculture, that are offered for human food. They are used in many different ways, as fresh or frozen, served at home or in restaurants after culinary preparation; as raw dishes such as sashimi, fried, grilled, broiled, baked, barbecued, marinated, or boiled in seasoned liquids, or further processed industrially into salted, dried, smoked, marinated, or canned products.

The suitability of the catch for these various end uses, judged by the particular customers, is reflected in the quality of seafood. The meaning of the term seafood quality is different for well-to-do connoisseurs, who select rare, expensive fish, crustaceans, and esoteric mollusks for their cuisine, and for the people in need, who eat cooked, dried, salted, or fermented fish as a supplement to the staple cereals in their daily diet.

The quality attributes of seafood comprise those that pertain to the species, sensory expectations of consumers, health and safety aspects, nutritional value, functional properties, and conformation to product standards regarding composition, proportions of components, appearance, ingredients, packaging, labeling, and shelf-life. These attributes can be quantitatively determined and the measured values used for assessing the quality grade.

The initial values of the different quality attributes of just-harvested seafood depend on the species' characteristics, seasonal biological changes in the fish organisms, and parasite infestation, and on the conditions applied in aquaculture and in fishing. The species-related properties regard size, appearance, and shape, yield of edible parts, content and distribution of dark muscles, flavor and texture of the meat, contents of valuable components (predominantly proteins, lipids, and vitamins), the activity of enzymes, and the presence of toxins. The size of the fish affects the vulnerability of the catch to damage during handling and processing. Appearance and shape influence the appeal of the fish to the buyer, while the yield of edible parts has an impact on the economy of processing.

The color, flavor, and texture of the meat are important factors affecting the suitability of the fish for different methods of culinary preparation and use in the food industry. The contents of proteins, lipids, vitamins, and mineral components affect the sensory properties of the products and the nutritional value. The activity of various enzymes influences the susceptibility of the catch to storage changes, such as rapid postmortem softening of the flesh of fish and squid rich in active proteolytic enzymes, or freezing denaturation in proteins of frozen stored fish of the *Gadidae* family, abundant in trimethylamine oxide (TMAO) demethylase. Enzyme activity also has an impact on the suitability of raw material for producing different kinds of products, such as mild salted maatjes herrings or marinades.

Various nonprotein nitrogenous compounds affect the sensory properties, safety, and suitability of the fish for different end uses; TMAO is involved in undesirable greening of canned albacore, and biogenic amines may cause health hazards. Endogenous toxins make the meat of the fish of several species unfit for human consumption. The seasonal biological changes are responsible for fluctuations in the contents of proteins and lipids in fish muscles, and for the activity of endogenous proteases.

The biological condition of the fish also affects the gel-forming ability of the muscle proteins. In migratory salmonid fishes during spawning, the flesh may have a paste-like appearance because of enzymatic degradation of the muscle fiber integrity. Infestation with parasites may decrease the technological value of the catch, or constitute severe health hazards for the consumers of raw fish and aquatic invertebrates of various species. Aquaculture and fishing operations affect the technological suitability of the catch.

The quality attributes of seafood change on the way to the consumer because of time and the impact of post-harvest treatment, sanitary conditions during handling, storage, and processing, and the procedures and materials used for preservation.

2. Species Identity

The flavor, color, and texture of the meat of fish and shellfish are important quality attributes. They are characteristic for each species and have a high impact on the market price of seafood. Many characteristic features affecting the suitability of fish for manufacturing various products or preparing certain dishes are shared by fish of a group of species. Examples are whitefish, such as cod and other gadoids; herring and several other similar species of fatty, pelagic fish; mackerel and tuna; or salmon and trout.

It is not easy to identify fish species or even the family in many fishery products, if the original structure of the muscles cannot be recognized because of the cutting, breading, mincing, and forming applied in processing. Furthermore, compositions of several different raw materials, including vegetable protein and polysaccharides, with a selection of additives affecting the flavor and texture of the products, are made. The determination of the species identity of the fish contained in these products can be made by isoelectric focusing of sarcoplasmic proteins extracted from such commodities.

3. Freshness

3.1 Introduction

In the quality grading of seafood, strict attention is paid to the attributes characterizing the state of freshness. In countries with old traditions in fish consumption, such as Japan, freshness is, with respect to rare species, the fundamental and almighty determinant of acceptability and price on the market. Fish of valuable species and of prime freshness, suitable to be eaten raw, may have a price ten times higher than the same fish after several days of storage on ice, which is still fit for human consumption.

Just-caught fish and shellfish have a vivid, intensive hue, silver or any other color of the rainbow characteristic for the species, light-red gills, firm and elastic body, and delicate, typical, predominantly seaweed or shellfish aroma. The cooked fresh fish has a pleasant flavor, typical for the species, and springy texture; the myomeres of the fillets are held together by intact myosepta. Due to post-harvest biochemical changes in saccharides, nitrogenous compounds, and lipids, and because of chemical lipid oxidation, the freshness attributes deteriorate gradually, and signs of putrefaction appear. The initial loss of the attributes of prime freshness in fish and marine invertebrates is caused primarily by catabolic reactions in nucleotides and saccharides, which are soon followed by degradation of nitrogenous compounds, as well as by hydrolysis and peroxidation of lipids. At this stage, the reactions are catalyzed predominantly by endogenous enzymes. During further storage of the catch, the deteriorative processes result mainly from microbial activity. The rate of freshness loss and spoilage is controlled by endogenous factors related to species, condition, infestation with parasites, and initial bacterial contamination of the catch, and by handling and preservation of the fish on board the vessel and on shore.

The state of freshness can be determined by sensory assessment, and by using chemical assays of products of biochemical reactions, or by measuring physical properties of the fish muscles. There is no universal chemical or physical test applicable to assessment of the freshness of seafood of various species and at different stages of post mortem changes. The results of the tests have to be significantly correlated to those of sensory analysis.

3.2 Sensory Examination

The sensory grading of seafood freshness involves examination of the appearance, odor, and texture of the raw fish, and may additionally regard the odor and flavor of cooked fish, with reference to special ratings describing the attributes at different states of freshness for various types of products. In the European Community, freshness ratings have been established for five groups of products: A. whitefish, cod and sole; B. bluefish, albacore, and mackerel; C. selachii; D. cephalopods; and E. crustaceans (see

Table 1), whereby reference is made to appraisal criteria specific to each group. In computing total freshness ratings, the relative importance of different attributes is often taken into account; in fish of various species and intended uses, the weight of different attributes is not equal. Another type of grading is based on assessing the number and intensity of defects and subtracting demerit points from the highest quality score.

	Criteria			
	Freshness category			**Not admitted (1)**
	Extra	**A**	**B**	
Skin	Bright, iridescent pigment (save for redfish) or opalescent; no discoloration	Pigmentation bright but not lustrous	Pigmentation in the process of becoming discolored or dull	Dull pigmentation (2)
Skin mucus	Aqueous, transparent	Slightly cloudy	Milky	Yellowish gray, opaque mucus
Eye	Convex (bulging); black, bright pupil; transparent cornea	Convex and slightly sunken; black dull pupil; opalescent cornea	Flat; opalescent cornea; opaque pupil	Concave in the center; grey pupil; milky cornea (2)
Gills	Bright color; no mucus	Less colored; transparent mucus	Brown/gray becoming discolored; thick, opaque mucus	Yellowish; milky mucus (2)
Peritoneum (in gutted fish)	Smooth; bright; difficult to detach from flesh	Slightly dull; can be detached from flesh	Speckled; comes away easily from flesh	Does not stick (2)
Smell of gills and abdominal cavity				
• Whitefish other than plaice	Seaweedy	No smell of seaweed; neutral smell	Fermented; slightly sour	(2) Sour
• Plaice	Fresh oily; peppery; earthy smell	Oily; seaweedy or slightly sweetish	Oily; fermented; stale, slightly rancid	Sour
Flesh	Firm and elastic; smooth surface (3)	Less elastic	Slightly soft (flaccid), less elastic; waxy (velvety) and dull surface	Soft (flaccid) (2); scales easily detached from skin, surface rather

				wrinkled

([1]) This column will apply only until a Commission Decision is made establishing criteria for fish which is unfit for human consumption, pursuant to Council Directive 91/493/EEC

([2]) Or in a more advanced state of decay

([3]) Fresh fish prior to the onset of rigor mortis will not be firm and elastic but will still be graded in category Extra

Table 1. Freshness rating of whitefish established by the European Community (European Council Regulation EC No 2406/96)

3.3 Microbiological Tests

The advanced stages of undesirable post-harvest changes are related to the number of bacteria thriving on the fish. There is a direct relation between the number of bacteria present in the seafood and the quantity of products of their metabolism, regardless of the temperature of storage. Attempts have been made to correlate the state of freshness with the microbial contamination. Microbiological assays, however, are of little use for discrimination between prime freshness and a state corresponding to about three days' to four days' storage of the fish on ice. They can, however, be used to decide upon the fitness of the fish for human consumption.

3.4 Chemical and Biochemical Tests

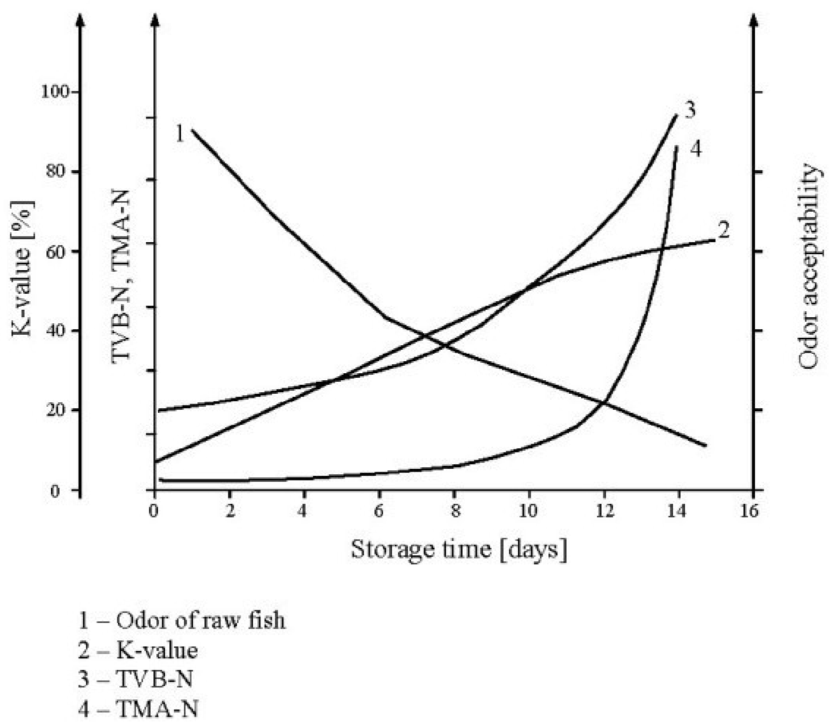

Figure 1. Typical values of freshness indicators in fish stored on ice

Soon after catch, post mortem degradation of nucleotides begins in fish muscles, catalyzed predominantly by endogenous enzymes. The activities of endogenous ATPase and lactic dehydrogenase decrease post mortem in the muscles of fish of several species. This loss in activity has been suggested as a test for differentiation between extremely fresh fish and those held for one or two days on ice. The concentrations of different catabolites of ATP are good indicators of freshness in the early mortem stages (see Figure 1).

The freshness index K-value is based on the determination of ATP and its degradation products—adenosine diphosphate (ADP), adenosine monophosphate (AMP), inosine monophosphate (IMP), inosine (Ino), and hypoxanthine (Hx):

$$K(\%) = \frac{[\mathrm{Ino}] + [\,\mathrm{Hx}]}{[\mathrm{ATP}] + [\mathrm{ADP}] + [\mathrm{AMP}] + [\mathrm{IMP}] + [\mathrm{Ino}] + [\mathrm{Hx}]} \times 100$$

The rate of increase in the K-value depends on the species and on handling during capture.

In most fish, the K-value just after catch does not exceed 10%, 20% is the limit of high freshness, and 60% indicates the rejection point. To be used for freshness grading, the K-value should be correlated with the results of sensory assessments for fish of different species. An approximation of the freshness index is the K_1 value:

$$K_1\,(\%) \frac{[\mathrm{Ino}] + [\mathrm{Hx}]}{[\mathrm{IMP}] + [\mathrm{Ino}] + [\mathrm{Hx}]} \times 100$$

which is easier to determine. Although a little less accurate, it can be used instead of the K-value, because in the catch of commercial fisheries, the enzymatic degradation of nucleotides is usually somewhat advanced, and the amounts of ATP, ADP, and AMP are low as compared with those of the further catabolites.

The ratio of phosphocreatine to inorganic phosphate in the muscles has been proposed as a sensitive index of the early post-mortem changes in fish, more sensitive than the K-value.

Chemical measurements of products of bacterial decomposition of meat components reflect the level of bacterial development. These tests are usually not suitable for the determination of the early stages of freshness loss, because at low levels of bacteria the level of the metabolites is low. However, they are used for assessing the freshness of fish after several days of storage and are well suited for determining the limit of acceptability. Here belong the assays of ammonia, trimethylamine nitrogen (TMA-N), total volatile base nitrogen (TVB-N), volatile reducing substances, and sulphides. Ammonia is produced in seafood also~~,~~ because of the activity of endogenous enzymes in deamination of adenosine and AMP, whereas in sharks and rays it is a result of hydrolysis of urea. Because of the high concentration of urea in the muscles of sharks and rays, these fish have a distinct ammoniac odor, even early after catch. The accumulation of TMA-N is predominantly related to the population of *Pseudomonas putrefaciens,* and to bacteria of some other species capable of reducing TMAO. In the fish of many species, there is a linear correlation between the values for TMA-N and TVB-N. The TVB-N determination is widely employed for the freshness assessment of wet fish because of its simplicity.

The suitability of these tests is different for fish of various species and also depends on the conditions of preservation that may selectively affect the development of various microorganisms, the growth rate and metabolic capabilities, and thus influence the spoilage changes. Typical examples of such treatments are vacuum or modified atmosphere packaging, or application of ionizing radiation. For grading purposes, numerical values of the test results have been proposed. They are different for fish of various species.

The contents of TVB-N in canned fish can also inform us of the freshness grade of the raw material. Generally the values of TVB-N in canned products are higher than in fresh fish, above 250 mg/kg to 300 mg/kg, because thermal treatment leads to generation of volatile bases from TMAO and amino acids.

The quantity of thus produced volatile compounds depends upon the time and temperature of heating. However, for any specific product manufactured under given conditions of thermal processing, the TVB-N value can inform us of the initial freshness grade of the raw material. If the time-temperature regime is unknown, high values of TVB-N indicate either low initial freshness of the fish or overprocessing.

3.5 Physical Tests

Different freshness tests based on measurements of the physical properties of fish tissues have been proposed. Quality inspectors routinely examine the texture of the fish body or of the fillets during the sensory assessment of freshness.

For rapid estimations, especially on board the vessel and in the fish market, different electronic devices are available. The working principle of a portable instrument known as Fish Tester is based on measuring the capacitate component of the AC resistance of the fish tissues. The resistance decreases during storage of the fish due to degradative changes in the muscle cell structure.

The instrument scale is calibrated in degrees of freshness for different species, indicating the practical storage life of the fish on ice, in days. Another instrument, the Torrymeter, measures the dielectric properties of fish that change during gradual loss of freshness from degradative processes in the muscles. Significant linear correlation has been established between the Torrymeter readings obtained by placing an electrode probe on the skin of fish and the results of sensory freshness evaluation for fish of numerous species.

The state of freshness, or the remaining shelf life of fish of a given species at a given temperature, can be predicted on the basis of the time-temperature history of the batch of fish after catch, if the temperature effect on the rate of spoilage caused by endogenous enzymes, microorganisms, chemical reactions, and physical factors is known.

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Biographical Sketch

Zdzislaw E. Sikorski, a "Scorpio" born in Wilno, received his B.S., M.S., Ph.D., and D.Sc. Degrees from the Gdansk University of Technology (GUT), and Doctor honoris causa from the Agricultural University in Szczecin, Poland. He gained practical experience in fish processing in several plants in Poland and Germany and on a fishing trawler. He was organizer and head of the Department of Food Chemistry and Technology and served as Dean of the Faculty of Chemistry at GUT. He worked also several years as a visiting researcher/professor at Ohio State University, Columbus, Ohio; CSIRO, Fish Research Unit in Hobart, Australia; DSIR in Auckland, New Zealand; and National Taiwan Ocean University, Keelung, Republic of China.

He is professor at GUT and since 1996 chairman of the Committee of Food Technology and Chemistry of the Polish Academy of Sciences. He has published about 210 journal articles, 13 books (in Polish, English, Russian, and Spanish), 8 chapters on marine food science and food chemistry, and he holds 7 patents. His research deals mainly with food preservation, functional properties of food proteins, and interactions of food components.