APPENDIX
THE CHEMICAL COMPOSITION OF FISH

A knowledge of the chemical composition of fish is important in determining their nutritional properties, uses, and storage stabilities, as well as in the development of new fisheries technologies. Chemical analysis reveals that the actual composition varies widely in response to environmental and genetic factors, and, indeed, even within the body of a single fish. However, the general makeup is comparable between the species and it presents some unique and interesting considerations.

The chemical nature, significance, and critical factors for the following components of fish will be discussed: protein, lipid, non-protein nitrogenous compounds, pigments, and vitamins.

PROTEIN

The protein content of fish varies from 15 - 24%. Shellfish usually have less muscle protein than finfish; they range from 22% for crustaceans to about 9% for gastropods. In all cases, this is a high value protein. Eighty-seven to 98% of the protein utilized, the protein efficiency ratio (PER), is greater than that of eggs or casein. The relative ease of digestion may be due to the low connective tissue content or to the relative shortness of the muscle fiber.

The amino acid composition of fish protein is similar to that of other animal proteins. All of the essential amino acids are present. The lysine content is high, making fish a good supplement to cereal protein. The lysine content may be about 30% greater than that found in beef and about eight times that in bread. The histidine level is also high, especially in the red meat fish. Bacterial decarboxylation of histidine and the subsequent formation of histamine in scombroid fishes may create food poisoning problems.

Tryptophan and methionine are characteristically low, with methionine (or cysteine) being the limiting amino acid. However, cysteine is still
four times more abundant in fish protein than in casein.

The three general classes of proteins found in fish are the sarcoplasmic proteins, the myofibrillar proteins, and the connective tissue proteins. Sarcoplasmic protein or myogen makes up 20 to 30% of the total protein content. This fraction is composed chiefly of enzymes, most of which resemble those found in mammalian sarcoplasm. Two enzymes which are unique to fish are thiaminase and anserinase. The remaining sarcoplasmic fraction, about 0.5%, consists of the colored hemocyanin proteins and cytochrome c. These are usually present in low concentrations, especially in the white-fleshed fish. In some seafoods, however, the oxygen-carrying pigments create discoloration problems, especially during processing. Oxidative changes in myoglobin are responsible for such defects as the greening of tuna. Chemical changes in the copper hemocyanin of crab may cause the canned product to have a blue or blue-black discoloration.

Myofibrillar proteins comprise 65 to 75% of the protein content. They control the fibrousness, plasticity, and gel-forming ability of the flesh. Components of the myofibrillar proteins are actin, myosin, tropomyosin, and troponin. Myosins may be used to distinguish between different species on the basis of oligomer appearance in the ultracentrifuge.

The connective tissue (3 to 5% of the total protein) contains collagen and elastin. It is found in the skin of the fish and in the myocommata, which are thin connective tissue layers separating compartments or myostomes of fish flesh. The connective tissue denatures and dissolves at a relatively low temperature, 30°C, thus explaining the formation of flakes of flesh when fish are cooked. The small amount of connective tissue actually present also contributes to the tenderness of fish flesh. The scales of fish are scleroproteins of the keratin group.

The protein content of fish flesh is influenced by several factors. Chief among these are the fat and water content. There is an inverse relationship between the amount of fat and the amount of water. The sum of these two components is always constant in a given species. With some species (e.g., herring), the sum is so reliable that a determination of the water content alone is sufficient in deriving the fat content.

Protein content also varies inversely with water content. An
extreme of this relationship is seen in "jellied" fish such as plaice. Jellied fish suffer protein emancipation in the flesh because the gonads, which have priority over muscle, have an increased need for protein. The reverse situation is "chalkiness" in halibut, resulting from higher-than-normal protein content. The degree of hydration influences the dollar value, so protein content is usually expressed on a dry weight basis.

Differences in protein content and composition of red meat and white meat are minor but consistent and are identical in all species studied so far. The amino acid content of red meat protein is closer to that of land animals. Glycine, leucine, phenylalanine, and arginine are higher in red meat, while lysine, aspartic acid, and glutamic acid dominate in white meat. White flesh has a higher protein content, because it contains less oil than dark flesh.

The sexual stage influences protein makeup. During depletion, catheptic enzymes preferentially destroy the protein for a food source and to supply building materials to gonads and eggs or sperm. The albumins are destroyed first, then α and β globulins, but never the σ fraction. Muscle protein may actually increase in the early stages of depletion while the liver glycogen is being utilized for energy. Contractile tissue breaks down more easily than collagens, so the actual collagen content appears to increase, along with a relative increase in the concentration of hydroxyproline and hydroxylysine. There is actually an increase in the absolute quantity of collagen during spawning. It is necessary to give increased strength to the body walls, so they can hold the accumulated eggs or sperm.

Amino acid content shows a response to environmental temperature. The hydroxyproline content increases as the water temperature increases. The denaturation temperature of protein is higher in fish from warmer waters.

Even within the same species or genus, variation in protein content will exist. For example, chum salmon always have more protein (21.5%) than pink salmon (19%). It was once believed that female fish contained a higher percentage of protein than males, but now differences due to sex appear to be minor and coincidental at best.

Shellfish protein varies greatly with season, especially during
spawning time. Fat and protein contents both build up just before spawning, then drop off afterwards. Protein also increases in spring and summer, when more food becomes available, then drops in late fall.

Crustacean protein is often bound to carbohydrate, thus existing as a glycoprotein. Crustacean protein suits human requirements for essential amino acids, but contains less tyrosine, arginine, and methionine than mammalian protein.

During processing, fish protein undergoes changes that are both detrimental and beneficial. The most obvious beneficial effect of heat processing is an increased digestibility, resulting from the cleavage of peptide bonds and the destruction of connective tissue. The deteriorative changes are more complex.

Freezing is a common preservation method. No change in texture will occur if the product is frozen and thawed out in less than 24 hours. Under less ideal conditions, deterioration will occur. With a loss of selective permeability on freezing, the myofibrillar protein gel loses its capacity to hold moisture. The resultant drip loss makes a dry product. Freezerburn can cause a tough, chewy, or rubbery product.

The temperature of freezing is an important consideration. Maximum ice crystal formation is between 0.8° and -5°C. A slow freezing rate causes the most damage to the actomyosin system because of the longer time taken to pass through this zone of maximum crystallization. Below -5°C, the rate at which fish toughens and becomes inextractable declines as the temperature drops. Below -30°C, changes take about one year to become apparent. Fluctuations in storage temperature have a more severe deteriorative effect than the actual temperature.

Several theories have been proposed to explain the nature of these reactions. The most widely accepted is that the toughness and water loss are due to an increased number and strength of actin-myosin bonds between the myofibrillar proteins. The cause of these altered binding characteristics is a concentration of solutes, especially hygroscopic salts like trimethylamine oxide and lactate, in the remaining unfrozen portion. This facilitates a pH change, protein dehydration, and crystallization of the solutes. No real benefit has been proven to freezing either post or prerigor.

Canning is a carefully controlled process that doesn't affect the
amino acid composition of fish. However, the protein may be less available for absorption due to Maillard type reactions or the formation of other indigestible bonds. The presence of copper in crab blood and iron in crab meat will accelerate such browning.

Drying may also decrease the physiological availability of amino acids due to the formation of enzyme-resistant linkages. The loss in nutritive value is primarily due to unavailability of lysine.

Lipids

Fish contain a great variety of unique lipids. They are present in the liver and viscera as fat deposits, and in the muscle tissue, skin, and roe to a smaller extent. Lipids make up from 0.1 to 22% of the fish.

Fish lipids differ from other naturally occurring fats and oils in having a greater proportion of unsaturated fatty acids; having large quantities of fatty acids with chain lengths greater than 18 carbon atoms; having polyunsaturates, mostly at the ω3 rather than the ω6 position; and in general possessing a greater variety of lipid compounds.

The origin of oil in fish is marine plant life, crustacea, and plankton that are able to convert ingested dienoic acids to tetra, penta, and hexaenoic forms. The odd number fatty acid chains in marine lipids come from phytoplankton, while the branched chain fatty acids are supplied by zooplankton. The degree of unsaturation varies with the diet. Diatoms provide an abundant supply of hexa-, penta-, and tetraenoic acids, while plankton have mostly hexa- and pentaenoic acids.

Several classes of lipids are found in fish. Hydrocarbons may be present in quantities ranging from 0.1 to 90% of marine oils. These include a wide variety of saturated and unsaturated straight and branched chain hydrocarbons. Two common branched chains are squalene and pristane; paraffins are straight chain hydrocarbons. High percentages of hydrocarbons are found in elasmobranchs; shark oil may be 90% squalene.

Triglycerides (e.g., triolein, palmitodiolein) are the principal source of fatty acids in fish lipids. Of the fatty acids found on these triglycerides, only 15 to 40% are saturated. The chief one is palmitic. The remainder are polyenoic acids. They have a cis configuration with
no conjugated double bonds; most are straight chain and even-numbered. The polyenoic acids are preferentially bound at the two-position on the glycerol backbone. The C_{20-22} series is the most common. Common unsaturated fatty acids include palmitoleic, oleic, and linoleic.

Wax esters are also found in fish oils. They serve as an energy source and consist of a fatty acid and a fatty alcohol, usually with a low degree of unsaturation. They are found in sea anemone, crustaceans, and dolphins, as well as many species of fish.

Phospholipids make up the fat in body organs and cells, while most of the depot fats are triglycerides. Fish phospholipids are mainly lecithin and phosphatidyl ethanolamine. The polyunsaturated fatty acid is on the two-position of the glycerol backbone. Phospholipids are usually more unsaturated than triglycerides.

Differences are found in the content and composition of fish lipids, depending on many factors. Fish liver and egg oils differ from body oils in having a higher degree of unsaturation.

Large differences in oil content exist among species. Species are classified as fat when they contain 12 to 26% oil (e.g., salmon, tuna, herring), as semifat when they contain 2 to 10% oil (e.g., swordfish, halibut, mackerel), or as lean when they contain 0.1 to 1% oil (e.g., haddock, cod, sole, plaice).

The section of the fish sampled must be identified. For example, oil from the ventral area of Pacific herring has more than twice the amount of 20:1 and 22:1 acids than oil from the dorsal area of the same. The dark muscle of fish has a consistently higher oil content than the white muscle.

During sexual maturation and the following reproduction, extensive lipid depletion occurs as lipid is used for energy and for gonad growth. Selective mobilization, which influences the composition of the remaining fats and oils, is observed. Smaller lipid molecules are more readily utilized when depot fat is metabolized. The unsaturated oils are used preferentially. Phospholipids are not used because they have a structural function in cell walls. An increase is seen in free fatty acid concentration in the blood.

Environmental temperature plays a critical role in lipid composition. At lower temperatures, the lipids are more unsaturated. This is necessary
to keep the melting point below that of the water, so that the fish can maintain flexibility and motility. A reduction in chain length in response to a drop in environmental temperature also helps the fish adapt to surrounding conditions.

Marine fish oils have a more complex composition than freshwater fish oils. They have more C_{18}, C_{20}, and C_{22} series fatty acids and a higher bromine content. The freshwater fish fatty acids have more C_{18} and palmitic unsaturated acids. Elasmobranch lipids differ from teleost lipids. The liver oil has a higher content of saturated fatty acids and unsaturated fatty acids with 18 carbon atoms.

The high degree of unsaturation in fish oils causes many problems with rancidity. Two types of deteriorative changes are common: hydrolytic rancidity and oxidation rancidity. Hydrolytic rancidity yields free fatty acids from the breakdown of triglycerides. The reaction usually precedes only to a monoglyceride plus two free fatty acids, unless an enzyme or other catalyst is present. If an alkaline catalyst such as sodium hydroxide is used, soaps will be formed. The significance of free fatty acid formation is threefold. First, free fatty acids speed up oxidative deterioration. Second, they interfere with commercial processing by poisoning any catalysts used. Finally, the hydrolyzed fat probably has poor color, off-flavor, and low stability. All of these factors will lower the sales value of the oil.

Oxidative rancidity is more detrimental than hydrolytic rancidity. The product may have a strong, disagreeable odor and flavor, due to the union of unsaturated compounds of the glycerides with oxygen to produce reactive molecules and rancid flavors. This type of rancidity gives highly unsaturated hydroperoxides which are very unstable and break down into flavorful compounds. Care must be taken to protect the unstable oil from catalysts like light, heat, and oxygen. Destruction of vitamins A, D, E, and K occurs with oxidative rancidity.

General characteristics of oxidized fish oil include increased specific gravity, index of refraction, viscosity, acid value, and saponification value. The iodine value and ether insoluble bromides are lower. A fishy flavor is prevalent and may be associated with the presence of rancidity products such as hydroperoxides, formaldehyde, and volatile bases including trimethylamine and trimethylamine oxide. The
fishy flavor may also be due to the breakdown of oxidized, highly unsaturated fatty acids. The color of the oil becomes brown or deep red, which may be due to interaction with protein, trimethylamine, or oxidized fatty acids. These reactions are accelerated by basic compounds.

The oxidative process occurs in two steps. During the induction period, oxygen is absorbed at a moderate rate. The main reaction is peroxide formation, but the chain reaction for oxidative rancidity is initiated. Oxygen is added at or near the double bond to give the highly reactive peroxides, which propagate the reaction by decomposing or reacting with one another. The products are acids, carboxyls, and condensation products, all of which produce off-odors and flavors.

The rate of these reactions increases with increased amounts of the following: degree of unsaturation, isolation of the double bond, temperature, light, and prooxidant metals such as copper and iron. This last factor necessitates the use of good quality stainless steel or tinplated metal when processing fish oils.

Practical measures must be taken during the harvesting of fish to prevent the initiation of rancidity reactions. Whole fish should be iced immediately; fillets should be ice-glazed to keep oxygen out. A carbon dioxide or nitrogen atmosphere may be helpful. A salt cure is sometimes applied to promote preservation, but the purity of the salt must be considered, since contaminants such as magnesium chloride are prooxidants. Refined oils should be stored below -30°C.

Antioxidants play an important role in preservation of fish and fish oils. They prevent or control rancidity through interference with the initiation or propagation steps by reacting with the initial free radical or one formed in the early stages. The intermediate formed is not capable of continuing the chain. The best antioxidants are aromatic phenols and amines. Those in common use include BHA, BHT, and TBHQ. Two natural antioxidants are lecithin and the tocopherols.

Synergists are often employed to enhance the effectiveness of the antioxidants. Their mode of action is to chelate metals which act as prooxidants. Phosphoric acid, citric acid, ascorbic acid, and ascorbyl palmitate function as synergists.
Nonprotein Nitrogenous Compounds

Nonprotein nitrogenous compounds are often volatile and malodorous, or have decomposition products which are. Thus they must be carefully controlled during fish storage. Nonprotein nitrogenous (NPN) compounds make up 9.2 to 18% of the total nitrogen in teleosts and 33 to 38% of the total nitrogen in elasmobranchs. The compounds include:

A. volatile bases; e.g., ammonium, mono-, di-, and trimethylamine
B. trimethylammonium bases; e.g., trimethylamine oxide, betaine
C. guanidine derivatives; e.g., creatine, arginine
D. imidazole derivatives; e.g., histidine
E. other miscellaneous compounds; e.g., urea, free amino acids, purines.

Nonprotein nitrogen compounds are important flavor components of fish. The free amino acids have the most significant impact on taste, with the most influential being glutamic acid, glycine, alanine, valine, and methionine. Their potency is greatest when they are combined with adenosine monophosphate (AMP), adenosine triphosphate (ATP), or inosine monophosphate (IMP). Other implicated compounds include trimethylamine oxide, histidine, and glycine betaine.

Some NPN compounds have osmoregulatory functions in the living fish. Specifically, these compounds are ammonia, urea, creatine, and trimethylamine oxide.

The most significant practical role NPN compounds play is that of a freshness indicator. The relative contents of fixed and volatile nitrogen bases are a good indication of the freshness of fish. In the living fish, equilibrium exists between trimethylamine oxide and trimethylamine. After death there is an increased content of di- and trimethylamine as a consequence of the reduction of the oxide to free base. The base is the principal compound responsible for the characteristic rotten fish odor.

In dark-fleshed fish, about 21% of the total nitrogen exists in forms other than protein. The content of NPN is directly correlated with the degree of motility or, equivalently, the amount of red muscle. Red muscle contains the most free arginine and histidine. Seasonal changes are seen in the dark flesh. Monoamino nitrogen may drop in winter and increase in summer. Since the flavor is not usually as good
in summer, it may be related to diamine content or arginine and histidine content.

Histidine may be converted to histamine by bacterial decarboxylation and autolytic changes. Histamine has often been implicated as the causative agent in fish-related food poisonings.

The content of NPN in white-fleshed fish is markedly lower than in dark-fleshed fish. White-fleshed fish contain creatine, creatinine, trimethylamine oxide, anserine, and free amino acids. The amino acids detected include small amounts of arginine and histidine. Free cysteine is common in freshwater fish. These free amino acids, along with imidazole compounds, contribute to the sweet taste of white-fleshed fish. Among white-fleshed fish, trimethylamine oxide is found primarily in marine species.

In elasmobranchs, urea is the predominant nitrogenous compound. It is a muscle constituent and is also found in the blood where it acts as a freezing point depressant. The overall function of urea is its responsibility for osmotic regulation. Urea may be converted to ammonia during storage. The presence of ammonia is an indication of spoilage. Trimethylamine oxide is present in large amounts in elasmobranchs.

In invertebrates, free α-amino nitrogen accounts for 40% of the NPN. Crustaceans contain compounds similar to those present in dark-fleshed fish. The free amino acids include glycine, proline, arginine, glutamic acid, and alanine. In mollusks, amino acid nitrogen accounts for 52 to 63% of the NPN. Trimethylamine oxide is not present. In squid, scallops, and octopus, the main compounds are glycine, alanine, and hypoxanthine, respectively. All groups exhibit rapid ammonia formation.

Pigments

The colors of fish change in response to their background, during courtship, and in moments of excitement. Pigment-containing cells called chromatophores control these changes. Chromatophores are classified according to the pigment they contain:

A. melanophores - brown or black pigment
B. erythrophores - red pigment
C. xanthophores - yellow pigment
D. leucophores - white pigment
E. iridophores - iridescent or reflecting pigment.

Chromatophores may contain more than one pigment.

The brown and black pigments are produced by melanins, highly polymerized compounds derived from tyrosine. In some species, the intensity of the brown or black color is dependent on tyrosinase activity. For example, in some goldfish species, the tyrosinase activity will determine whether the fish is white, gray, or black. However, no generalization can be made for all species concerning tyrosinase level and color.

Carotenoids are the basis for the yellow and red pigments found in xanthophores and erythrophores. As members of the terpene group, they are highly unsaturated hydrocarbons consisting of a chain of carbon atoms with a ring structure at one or both ends. They are water insoluble, but are soluble in organic solvents.

Pteridines are present in both colored and uncolored forms in chromatophores. They have a variety of hues and may appear red, yellowish, blue, or violet fluorescent. Pteridines are related to purines and flavins; they have both a pyrimidine and associated pyrazine rings. They are water soluble.

Purines, especially guanine, are responsible for white or silvery colors. They are accumulated in leucophores and iridophores where they are stacked in reflecting layers or platelets of crystals.

Pigments from fish scales and skin have a number of industrial uses. Guanine crystals are purified from the skin and scales of herring and are manufactured into pearl essence. Products such as artificial pearl beads, buttons, jewelry, and ash trays are dipped into or sprayed with pearl essence to obtain an iridescent sheen.

Ground-up crustacean shells, which contain the astaxanthin pigment, are included in the diet of cultivated salmonids. The ingested pigment helps produce the desirable pink-colored flesh in these species when they are raised in captivity.

Vitamins

Fish oils are the richest known sources of vitamins A and D.
Soupfin shark liver may contain as much as 50,000 IU/g of vitamin A and swordfish liver can contain 25,000 IU/g of vitamin D. Fish flesh may also be a good source of some of the water soluble vitamins.

Vitamin A is present in fish oils predominantly as the xanthophyll form; the oils are almost devoid of β-carotene. Fish do not synthesize vitamin A. They may obtain it in several ways:

A. preformed vitamin A from ingested zooplankton
B. a noncarotenoid precursor of vitamin A ingested in copepods
C. astaxanthin precursor of vitamin A ingested from copepods and shrimp.

This fat soluble vitamin is found in the fat of viscera, muscles, membranes, and liver oils. The flesh of lean fish is almost devoid of vitamin A. For example, 100 grams of cod fillet contains only about 50 IU of vitamin A.

The amount of vitamin A found in the fish liver is dependent upon a number of factors. Large fish appear to store more of the vitamin than smaller fish. Some species show different levels of retention between the sexes. The sexual stage of the fish appears to be important. Immature fish have very little, if any, stored vitamin A but pregnant females have large stocks. Seasonal variation in food availability influences the amount of vitamin A being stored. As the summer season advances, the level will drop off because diatoms and copepods become scarce.

Dehydrocholesterol is metabolized into vitamin D₃, which is the most common form of vitamin D in fish. It is supplied by solar irradiation of plankton containing the provitamin. Liver oil or meat from fatty or semifatty fish is the richest source of vitamin D. It is not deposited in the visceral oils to as great an extent as vitamin A. Very little vitamin D can be found in the flesh of lean fish.

Vitamin E occurs in fish as an α-tocopherol. Shark liver oil contains about 100 µg/g which appears to be an excellent supply. However, the potency of this vitamin E is difficult to determine, since the liver oils contain vitamin E antagonists such as highly unsaturated fatty acids. There appears to be an inverse relationship between the rate of autoxidation of fish oils and their α-tocopherol content.

The presence of the antihemorrhagic factor, vitamin K, has been
reported in fish. Fish meal may be a good source, but little work has been done concerning this vitamin in fish.

Fish are a good source of thiamin. Thiaminase may be present, but since it is heat labile, it is destroyed upon cooking.

Fish also are an excellent source of niacin (especially in swordfish) and vitamin B_{12} (especially in clams and oysters).

Vitamin C is found only in very small amounts in fish.

REFERENCES


Glossary

Autolytic Enzyme: A bacterial enzyme located in the cell wall. It causes disintegration of the cell following injury or death.

Adductor muscle: A muscle that draws a part of the body toward the median axis. For example, the muscle that a clam uses to close its valves.

Biologically Available: Existing in a form that can be utilized by the body.

Bivalved: Having two valves, as the two "shells" of a clam.

Brackish: Water which is a combination of fresh water and salt water.

Buoy: A float moored in water as a warning of danger or as a marker.

Carapace: A hard outer covering such as the fused plates of a turtle.

Chlorination: The addition of chlorine to water to reduce contamination by microbes.

Coliform: Term used to describe a group of bacteria which have similar physical, growth, and biochemical characteristics. Used as an indicator of sanitary quality; however, due to a lack of specificity in characterizing and enumerating individual members within the group, its value as an indicator has been questioned.

Controlled Purification: The process of removing contamination from whole live shellfish acquired while growing in polluted areas.

Crustacean: A category of animals having jointed feet and mandibles, two pairs of antennae, and segmented bodies with a protective covering. Examples are crabs and lobsters.

Depuration: The process by which shellfish cleanse themselves of microbiological contaminants in a controlled process water environment.

Effluent: The outflow of a sewer.

Enzyme: An extremely complex protein molecule which is able to initiate or control the rate of certain biological processes. There are many different types of enzymes in the body, which control digestion, food uptake by cells, cell metabolism, muscle activity, and many other functions.
Estuary: An inlet or arm of the sea, especially the wide mouth of a river, where the tide of the sea meets the current of the river.

Exoskeleton: The external supportive covering of certain animals that lack backbones and internal skeletons.

Fatty acid: Long carbon chain molecules with an organic acid at one end and hydrogen atoms attached to the remaining carbon atoms. Three essential fatty acids (linoleic, linolenic, and arachidonic acid) are not synthesized by humans and must be obtained from diet.

Fecal: Of sediment or feces.

Fecal coliform: Coliform organism capable of growth at elevated temperature (44.5°C). More specific indicator of sanitary quality than coliform, as it is a more precise indicator of fecal contamination.

Gills: The respiratory organs of water-breathing animals.

Lipid: Organic compounds often containing elements other than carbon, hydrogen, and oxygen -- particularly phosphorus and nitrogen. These compounds are insoluble in water. They include fats and waxes.

Mantle: An enveloping layer, such as the external body wall lining the shell of many invertebrates.

Mariculture: Artificial cultivation of marine (saltwater) organisms.

Metabolism: The physical and chemical processes by which foodstuffs are synthesized into complex elements, complex substances are transformed into simple ones, and energy is made available for use by the organism.

Milts: The secretions of the testis of fishes.

Mollusca: A category of animals that includes snails, slugs, octopuses, squids, clams, mussels and oysters. Mollusks are characterized by a shell-secreting organ, a mantle, and a radula (a food-rasping organ located in the forward area of the mouth).

Molting: Shedding an outer covering as part of a periodic process of growth.

Most Probable Number (MPN): A statistical estimate of the number of bacteria per unit volume.

Munsell value: A numerical representation of color based on a standardized color scale.

Oxidation: A chemical reaction that increases the oxygen content of a compound.
Pasteurization: A process of heat treatment of food to destroy all organisms dangerous to health. Pasteurized food is normally heated at between 70° and 100°C (160°-212°F).

Pathogenic: Capable of causing disease.

Plankton: Passively floating or weakly moving aquatic plants and animals, usually microscopic.

Polyunsaturates: Fats containing fatty acids having more than one unsaturated bond. An unsaturated bond is a chemical structure into which additional hydrogen can be incorporated. In general, polyunsaturated fats tend to be liquids of vegetative origin.

Radionuclide: Any element which has a radioactive emission.

Rancidity: An oxidative deterioration in food fat whereby a typical off-odor and/or flavor is produced.

Regeneration: The replacement by an organism of tissues or organs which have been lost or severely injured.

Relaying: The moving of commercial size shellfish from waters not classified as approved to waters classified as approved, conditionally approved, or restricted for the purpose of natural purification; by relaying shellfish they will purify themselves through depuration.

Retort: Any closed vessel or other equipment used for the thermal sterilization of foods.

Salinity: A salty quality or state.

Spawning: Producing or depositing eggs or discharging sperm. Applied to aquatic animals.

Teleost: A class of finfish, to which most of the world's fish belong.

Titration: A method of analyzing the composition of a solution by adding known amounts of a standardized solution until a given reaction (color change, precipitation, or conductivity change) is produced.

Transplanting: The moving of shellfish from one area to another area.

Turbidity: Muddy or cloudy state due to amount of free floating sediment in the water.

Viscera: The organs within the cavities of the body of an organism.

Weir: A fence placed in a stream to catch or retain fish.
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Teaching Aids

Sea Grant at Virginia Tech is developing a full range of teaching aids for teachers and lecturers in the field of seafood products. The following is a partial list of available items.

Films:
- Picking the Blue Crab
- Dressing the Pinfish

Videotapes:
- Picking the Blue Crab
- Dressing the Pinfish
- Blue Crab Industry of the Chesapeake Bay
- Hard-Shell Clam Industry

Slide Series (with script):
- Blue Crab Plant Sanitation
- The Blue Crab Industry
- Teaching Series to accompany Seafood Products Teacher Resource Guide

Seafood Transparency Masters with Text:
- For use in classrooms in conjunction with Seafood Products Teacher Resource Guide; illustrating many facets of seafood preparation (cleaning, filleting, harvesting, etc.).

Instructional Guides:
- Seafood Products: An Instrucional Guide for Home Economics Programs
- Seafood Products: Food Service Program Guide
- 101 Bulletin Board Ideas for Seafood Education
- Seafood Manual for School Food Service Personnel

The films and videotapes are available for sale or loan. For loan of films, write to Audiovisual Services, 2 Patton Hall, Virginia Tech, Blacksburg, Virginia 24061. For loan of videotapes, write to Instructional Television, 287 Whittemore Hall, Virginia Tech, Blacksburg, Virginia 24061.

For information on any of the above materials, write: Sea Grant Program, Department of Food Science and Technology, Virginia Tech, Blacksburg, Virginia 24061.